Guidance on Managing the Risk of Hazardous Gases when Drilling or Piling Near Coal

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Acknowledgements

Working Group

Acknowledgement is made to the following members of the working group who are responsible for the co-authorship of this publication.

Keith Banton	The Coal Authority + Chairman & Editor
Steve Kershaw	The Coal Authority
Marcus O'Connor	Health & Safety Executive
David Allan	British Drilling Association & Raeburn Drilling & Geotechnical Ltd
Brian Stringer	British Drilling Association

Others who have collaborated in the compilation of this guidance are:

Jon Ball	Federation of Piling Specialists & Roger Bullivant Ltd
Neil Parry	The Association of Geotechnical and Geoenvironmental Specialists & Geotechnical Engineering Limited
Louise Clarke	The Coal Authority
Ian Smith	The Coal Authority
Bill Denton	Formerly The Coal Authority

Reviewers

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Wolverhampton Council & Black Country Geotechnical Association (Clive Roper et al.); BAM Ritchies (Rod Edser et al.); SYMAS (Paul James et al.); Highways Agency (Andrew Jukes et al.); Geotechnics (Keith Nicholls); Halcrow (Ray Kenny); Glasgow Council (Donald Linn); Forkers Ltd (Peter Watson); M & J Drilling Services Ltd (Steve Rule et al.); HM Specialist Inspector - Construction Engineering Specialist Team (Martyn Ostcliffe); NHBC (Ruth Easterbrook et al.); Coal Authority (Joe Dearden)

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Definitions

Act	An Act of Parliament, a statute (commonly called a law), primary legislation
ACoP	Approved Code of Practice. Code that provides practical guidance on how to comply with the legal requirement of an Act
Adit	Non vertical mine access roadway (usually walkable) driven from the surface and used for removal of mineral, ventilation, pumping water etc. See also Drift; Sough, Level; Day Level
Admixture	Something produced by incorporating an item into something else
Afterdamp	A mixture of gases primarily nitrogen, carbon monoxide and carbon dioxide, left in a mine after a fire or an explosion
Alkanes	Any gas in a group that contains only carbon and hydrogen atoms, with the carbon atoms joined together in a simple chain, such as butane and propane. Often very flammable. Methane is the simplest single carbon alkane
Asphyxiation	To deprive of oxygen often leading to unconsciousness or death
ATEX	From the French – Atmospheres Exposable. European directive for explosive atmospheres
Blackdamp	A mixture of gases formed when oxygen is removed from mine air and is replaced by carbon dioxide, also known as ‘stythe’ or ‘chokedamp’
Broken Ground	Area of disturbed ground usually associated with the collapse of overlying strata into former coal workings
Cap	A strong slab or block of concrete placed over a shaft and capable of supporting both overburden and, exceptionally, a structure
Carbonaceous	Consisting of, containing, relating to, or yielding carbon
Casing	Open tubes inserted into a borehole to prevent the hole from collapsing
CDM	The Construction (Design & Management) Regulations 2007
CFA Piling	Piles formed by drilling using a hollow stem continuous flight auger through which concrete is pumped as the auger is withdrawn
Coalfield	An area in which deposits of coal are found
Coal Measures	Coal-bearing part of the Upper Carboniferous System
Coal Workings	Areas of underground strata from which coal is being or has been mined. Coal workings can be open and void, partially collapsed

	and semi void, or totally collapsed with little void space. See also - Broken Ground
Comminuted	Powdered; pulverized, divided into small parts
Competent Authority	Person or organisation that has the legally delegated or invested authority, capacity, or power to perform a designated function.
CPCS	Construction Plant Competence Scheme
CSCS	Construction Skills Certification Scheme
Day Level	Non vertical mine access roadway driven from the surface. See also ‘Adit’
Desorption	The release of gas from coal where it has been stored on the surfaces of the internal structure
Dip	Angle at which a stratum or other planar body is inclined to the horizontal
Discontinuity	Fracture or break in soil or rock fabric in the form of bedding, faults, joints, cleavage or fissure
Dissociate	The breaking of a chemical (molecular) bond
Drift	See also ‘Adit’. Non vertical mine access roadway. Particularly known as a drift when driven as a major access
Drilling	The intrusive process by which ground is penetrated by percussive, rotary or rotary percussive or resonance techniques to obtain samples or data, provide access for installations and ground stabilisation etc
Drill Rig	A powered drilling machine for investigating sub surface ground conditions, stabilising ground, geothermal drilling and other such activities
Face	A surface exposed by excavation usually for mineral extraction
Fault	A fracture or fracture zone in rock along which there has been an observable displacement
Firedamp	Mining term used for methane and associated alkanes
Groundwater	Aqueous liquid present in the cavities and spaces in soils and rocks
Ground Investigation	Exploration and recording of the location and characteristics. Specialist intrusive investigation on a site with the associated monitoring, testing and reporting. This may comprise boreholes, trial pits, penetration tests, laboratory tests and geophysical methods

Grout	A mixture of cementatious material and aggregate to which sufficient water is added to produce pouring consistency without segregation of the constituents but will gain strength over time
Guidance	Technical information on a particular work arena provided by the HSE and others e.g. Trade Associations, based on good practice
Hydrocarbon	A chemical combination of hydrogen and carbon, e.g. oil or methane
Heating	Colloquial name for a spontaneous combustion fire in coal
Level	See also 'Adit'. Non vertical mine access roadway. Often known as a level when driven for mine drainage
LOLER	Lifting Operations and Lifting Equipment Regulations 1998, as amended
L.E.L	Lower Explosive Limit
L.T.E.L	Long Term Exposure Limit
NVQ	National Vocational Qualification (NVQ diploma)
Outcrop	The area over which a coal seam (or other rock type) occurs at bedrock level – whether exposed at ground surface, or buried beneath drift
Oxidation	To convert into an oxide; combine with oxygen
Pelistor	Gas sensor used to detect flammable gases
Permeable Ground	Rock or superficial deposits that will allow gas and/or water to pass through it with relative ease
Piling	Construction of deep foundations by driving a preformed pile (usually concrete or steel) into the ground or by casting concrete in a pre-bored shaft which may be cased or uncased
Piling Rig	Machine used for the installation of piles by drilling boreholes or driving or vibrating preformed piles
ppm	Parts per million
PUWER	Provision and Use of Work Equipment Regulations 1998, as amended
Pyrite or Iron Pyrite	An iron sulphide with the formula FeS_2. Nicknamed "fool's gold" due to its resemblance to gold. Often found in association with coal seams
Rockhead	Interface between soil (superficial deposits) and the underlying solid rock
Regulations	Legal duties made under the Health & Safety at Work etc Act

	1974 and any other enabling Act. Generally compulsory and are more specific than Acts
Shaft	Vertical or almost vertical opening used for access to the mine, removal of mineral, ventilation of a mine, or pumping water etc
Site	The bounds of an area of ground designated for a project
Site Investigation	The overall process of determination of the physical characteristics of sites as they affect design, construction and stability of neighbouring ground or structures
Sough or Slough	Non vertical mine access roadway. Particularly known as a sough when driven for mine drainage. See also 'Adit'
S.T.E.L	Short Term Exposure Limit
Stinkdamp	A mining term for hydrogen sulphide
Stythe	See blackdamp
Superficial deposits	Soil materials overlying rockhead. The most recent deposits, mostly unconsolidated (e.g. sand, silt, clay, mud, etc)
SVQ	Scottish Vocational Qualification
Toxic	Poisonous / deadly
Tremie Pipe	Device that carries materials, usually grout or concrete, to a designated depth in a borehole or void.
U.E.L	Upper Explosive Limit
Unworked Coal	In situ coal, of any thickness, which has not been mined
Whitedamp	A mining term for carbon monoxide
% v/v	Percentage by volume

Guidance on Managing the Risk of Hazardous Gases when Drilling or Piling Near Coal

1. Introduction

Serious incidents, which have occurred during geotechnical drilling operations to investigate and treat former coal mine workings, have highlighted the need for guidance to ensure the safety of operatives and the public whilst undertaking such work.

Of particular concern are incidents where carbon monoxide has been measured or inferred as entering houses contemporaneously with adjacent drilling operations, in one instance affecting the health of the residents and in another the loss of two lives. The source of the carbon monoxide in both cases was not clear, but possibilities are that the gas was either in the workings due to existing or previous spontaneous combustion or that the drilling operations themselves, which were air flush drilling into a spontaneous combustion prone seam, produced the gas.

Subsequent research carried out by the Coal Authority led to a group, comprising Health and Safety Executive, British Drilling Association, Association of Geotechnical and Geoenvironmental Specialists and the Coal Authority, being formed to produce guidance, in conjunction with the industry, on how coal mine workings and unworked coal can be drilled, treated and piled through, without creating or displacing hazardous gases.

Entering former coal mine workings, coal mine entries and unworked coal can present many hazards for both site operatives and properties adjacent and in close proximity to the site. Operations to investigate, treat or disturb such features should only be considered by suitably competent persons. Moreover physical (manned) entry to such environments can only be undertaken by persons qualified to do so under the Management and Administration of Safety and Health at Mines (Masham) Regulations 1993.

Where proposed works will intersect, enter or disturb the Coal Authority's property it is a pre-requisite that prior consent is obtained. In the case of an accident occurring, if it is established that a contractor has knowingly undertaken work which was advised against by a competent authority, or that he has knowingly circumvented authorised schemes designed to ensure safety, this may be seen as an aggravating factor in any potential prosecution of the company.

This document gives guidance on the general procedures to be adopted when drilling or piling into former coal mine workings (including shafts and adits) and unworked coal. If you follow this advice then the likelihood of an incident will be reduced.

However this guidance does not preclude the use of alternative strategies and arrangements which provide equivalent or higher standards of safety.

2. Scope

This document is designed and published in order to provide guidance with respect to hazardous gases for the safe drilling and piling through Coal Measures up to a maximum depth of 200m. These gases include the most common such as methane, hydrogen sulphide, carbon dioxide and carbon monoxide but also less common such as hydrogen. It also includes oxygen deficient air.

This guidance will only apply in the coalfield areas of Great Britain where the proposed activity will or is likely to intersect areas of unworked coal seams and former coal mine workings (including shafts and adits), henceforward referred to as just unworked coal and former coal workings, (which are in most instances the property of the Coal Authority).

Coalfield areas are identified by the Coal Authority Gazetteer which can be viewed at www.groundstability.com and where a coal mining report or ground stability report can also be obtained. Furthermore the Coal Authority has defined specific 'Coal Mining Development Referral Areas'. These are areas, based upon Coal Authority records, where the potential for instability and other safety risks associated with former coal mining activities are likely to be greatest. These areas can be viewed at http://coal.decc.gov.uk/en/coal/cms/services/planning/strategy/strategy.aspx

All drilling applications are included within the scope. Principally these are ground investigation, piling, drilling and grouting, geothermal, waterwell and processes which are geotechnical in nature. Driving precast piles is also included.

The scope of this document is limited to and includes all matters concerning health and safety in relation to hazardous gases associated with unworked coal and coal workings. These include identifying the hazards, evaluating the risks and taking protective measures both on and in close proximity to sites. The responsibilities and duties of Clients, Designers and Contractors are covered in this document.

Specialist advice is always recommended in providing a balance to the often conflicting demands of safety, economy and durability, particularly for sites with complex histories and geology. Such sites are often affected by contamination and expert specialist advice based on adequate site investigation data is therefore essential, preferably at a very early stage

Not included in the scope of this document are hazardous gases in landfills, hazardous gases in contaminated land, and naturally occurring gases as a result of non coal geology. These are covered by BDA (British Drilling Association), ESA (Environmental Services Association) and other authoritative publications. However the guidance within this document may be useful in other areas.

The document does not cover the activities involved in hydraulic fracturing (also called "fracking") or exploration drilling for oil and gas,

3. Disclaimer

The information contained in this guidance has been compiled by the British Drilling Association Ltd, the Coal Authority, the Health and Safety Executive, the Federation of Piling Specialists and the Association of Geotechnical and Geoenvironmental Specialists and reviewed by those listed under acknowledgements above and is supplied to the recipient on the following terms:-

1) The authors and compilers of this guidance are not responsible for the results of any actions taken on the basis of the information contained in this guidance, or for any errors or omissions from this guidance.

2) The authors and/or compilers of this guidance are not engaged in rendering professional services, except when acting on a personal consultancy basis.

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4) This guide is only intended for use in the stated context and should not be used otherwise. The guidance is compiled from the authorship team's knowledge of current good professional practice and standards. Any limitations are identified where possible but the guidance may require amendment should additional information become available.

In this document reference is made to various National Regulations, European, International and British Standards and other appropriate reference documents. Some of the major aspects of these have been summarised. This is done only to assist users of this guidance by drawing their attention to these regulations and standards.

It is the responsibility of those who use this guidance to make themselves thoroughly conversant with all the appropriate legislation and standards and not to rely on any reference or summary contained in this document that may be incomplete or incomprehensive. It is not intended that this document should replace any Acts, Codes of Practice, Regulations or other documents having legal or contractual standing.

Of necessity this document addresses the broad principles that should be adopted. Advice in respect of specific equipment or operations should be obtained from the appropriate body or technical reference source.

The recognition of the various and individual responsibilities are fundamental to the application of this guidance and the principle of "**Identify the Hazard, Assess the Risk and Take the Appropriate Control Measures"** should always be applied.

4. Legal Duties/ Competence Requirements for those Undertaking Drilling or Piling Work

General legal duties for those undertaking applicable construction works are defined under Construction (Design and Management) Regulations. This section deals with those specific areas that relate to the drilling process. For more general information refer to the CDM ACoP.

Competence is a combination of aptitude, training, experience and familiarisation of the work to be undertaken. As such, each task should be done only when the employer is confident that those performing the task are competent to do so. Below is an outline of minimum attributes necessary to undertake work involving the drilling or piling activities that may be affected by hazardous gases.

4.1 Client

A client is someone who is having construction or building work carried out. The Client has one of the biggest influences over the way a project is run and their approach may help to define the structure and safety culture of the work. Clients are not required or expected to plan or manage projects themselves, nor do they have to develop expertise in construction health and safety, unless it is central to their business. Clients must ensure that various things are done, but are not normally expected to do them themselves. There are two types of client - a domestic client and a commercial client.

4.1.1 Domestic Client

A domestic client is someone who lives, or will live, in the premises where the work is carried out. The premises must not relate to any trade, business or other undertaking. Although a domestic client does not have duties under CDM, those who work for them on construction projects will. A contractor engaged by a domestic client, takes on the responsibilities of the Client to make arrangements for the management of health, safety and welfare issues on the project.

4.1.2 Commercial Client

Client duties apply to any business that seeks or accepts the services of architects, builders, and workers etc. to carry out construction project work. This definition is very wide and includes companies, partnerships and sole traders. Client duties apply on all projects and there are additional requirements on notifiable projects. Client duties apply from project conception through to completion. Most Client duties require action well before work starts on site.

The Client is critical to securing project safety and achieving compliance with all other aspects of CDM

2007. The extent of Client duties will be affected by the scale and nature of the project. Clients must ensure that those appointed or engaged on the project are competent to comply with health and safety requirements.

In practical terms, this means the Client must implement procedures that check the CDM Competence of others. The Client must ensure that CDM co-ordinators, designers and contractors are promptly provided with pre-construction information (PCI).

The PCI consists of all the information which is relevant to the health and safety of those engaged in, affected by the work or using the structure as a future workplace. It will provide designers and contractors who may be bidding for the work (or who they intend to engage), with the project-specific health and safety information needed to identify hazards and risks associated with the design and construction work. This could include the information in any relevant existing health and safety file but where there are gaps in this information, the Client should ensure that these are filled by commissioning surveys or by making other reasonable enquiries (see section 8 – Desk Study). It is not acceptable for clients to make general reference to hazards which might exist. The PCI should be sufficient to ensure that significant risks during the work can be anticipated and planned for. It should concentrate on those issues that designers and contractors could not reasonably be expected to anticipate or identify.

For notifiable work the Client must appoint a project CDM Co-ordinator (CDM-C) at an early stage and subsequently appoint a Principal Contractor (PC). If others are not appointed the project client becomes both CDM-C and PC and takes on the duties of both roles.

The Client must also:

- Take steps to ensure that these arrangements are maintained and reviewed throughout the project.
- Allow sufficient time and resources for all stages of the work.
- Co-ordinate their own work with others involved with the project in order to ensure the safety of those carrying out the construction work, and others who may be affected by it.

4.2 Designer

Designers are defined under CDM as those who have a trade or business which involves them in:

"Preparing designs for construction work, including variations. This includes preparing drawings, design details, specifications, bills of quantities and the specification of articles or substances, as well as all the related analysis, calculations and preparatory work." (see CDM ACoP para's 115-118).

This definition includes contract engineers who have responsibility for analysis of the site, including the location of the coal workings and the calculations for the work. Designers have a general duty to eliminate risk within the work, where reasonably practicable by design. For example, if the design calls for a borehole to be drilled in an area which makes it impractical to use guards on a machine and it is possible to relocate the hole then a designer has a duty to do so. Similarly, if the drilling process presents a risk of gas migration and the process can be designed out, so far as is reasonably practicable, then this is a legal duty.

The Designer in providing advice and plans for drilling and piling works into coal measures should be able to demonstrate their familiarity and competence in the following areas;

- Health and Safety at Work Act and the accompanying relevant regulations.
- CDM requirements.
- Contractual matters.
- Coal Authority permissioning regime.

- Desk study principles and practice.
- Coal Measures geology and hydrogeology.
- Historical coal mining.
- Risks from hazardous gases.
- Migration of gases on and off site.
- Influence of atmospheric conditions.
- Monitoring for hazardous gases on and off site.
- Drilling and/or piling processes.
- Emergency procedure for coal seam fires, blow outs and evacuation.

4.3 CDM Co-ordinator

The CDM coordinator (CDM-C) is an enabling role. A CDM-C has to be appointed to advise the Client on projects that last more than 30 days or involve 500 person days of construction work. A Client engages a CDM-C to liaise and advise all parties before and during the construction phase. They may assess the competence of Principal Contractors on behalf of the Client, discuss design implications with designers and give advice on additional control measures for tasks. Their legal duties are to:

- Advise and assist the Client with its duties; and thus be up to date with safety issues surrounding specific work activity, such as the dangers of drilling into unworked coal and coal workings.

With this in mind the CDM-C's should have an intimate knowledge of the issues and hazards involved within the drilling and /or piling industry, including sufficient knowledge of potential difficulties and solutions to engage designers in a meaningful dialogue regarding these issues.

4.4 Contractor

The drilling or piling contractor shall be able to demonstrate its competence to undertake and manage the risk arising from the work. This may be shown by:

- Experience of similar work (References).
- Using only competent, assessed and authorised personnel.
- Having appropriate insurance cover.
- Using only suitable plant with:
    - Rig certification (LOLER).
    - Compliance with PUWER (Dangerous rotating parts).
- A Health & Safety Policy for their organisation.
- Having a Construction Phase (Health and Safety) Plan.
- Or additional documentation demonstrating expertise and experience.

4.5 Drilling and Piling Operatives

Drilling and Piling Operatives shall be able to demonstrate their competence.

For drilling this should be all of the following:

- NVQ/SVQ certificate in Land Drilling (or proof of an equivalent level of experience and continuous development).
- A current and valid Audit card as issued by the British Drilling Association or an equivalent body in a State of the European Union.
- CSCS Land Drilling card.
- Or have proof of an equivalent level of training and experience.

The certificates and cards for Lead Drillers shall be applicable to the work and specific boring / drilling operation on which they are engaged.

For Piling this should be:

- NVQ/SVQ certificate in Piling Operations (or proof of an equivalent level of experience and continuous development).

4.6 Plant Operatives

Operatives using plant covered by Construction Plant Competence Scheme (CPCS) e.g. piling rigs, excavators, dumpers etc employed on the contract should hold an appropriate card (or proof of equivalent training and experience of operating this category of machine).

4.7 Site Supervisors

Site Supervisors shall be able to demonstrate their competence.

This should be all of the following:

- NVQ/SVQ certificate or equivalent proof of experience and continuous development of knowledge and skills.
- Appropriate CSCS card.
- Safe site supervision training.
- Or have proof of an equivalent level of training and experience.

4.8 Site Engineers

Site Engineers shall be able to demonstrate their competence

This should be all of the following:

- Appropriate degree.
- Appropriate CSCS card.
- Safe site supervision training when acting in supervisory role.
- Or have proof of an equivalent level of training and experience.

4.9 Site Managers

Site Managers shall be able to demonstrate their competence.

This should be all of the following:

- Appropriate CSCS card (or proof of equivalent training/ experience).
- Site manager's safety training when acting in a managerial role.
- Or have proof of an equivalent level of training, experience and familiarisation of the processes to be undertaken on site.

5. Gases – Properties and Problems

5.1 Coal Mine Gases and their Principal Hazards

5.1.1 Atmospheric Air

Atmospheric air is often a component of gas emitted from mines. Most often mine gas is a mixture of atmospheric air and various pollutants, the pollutants in some cases completely displacing the air.

5.1.2 Oxygen (O_2)

Oxygen makes up 21% of air and is the dominant reactive gas in the atmosphere. The remaining 79% comprises of 78% nitrogen and 1% argon along with other trace gases.

Hazardous conditions can arise from excess levels of oxygen, but such conditions are extremely unlikely to be encountered. On the contrary, hazardous conditions due to reduced levels of oxygen, usually as a result of oxidation of carbonaceous material, are likely to be encountered. Operations should not be carried out where workers are consistently exposed to concentrations of oxygen below 19% v/v (percentage by volume). Once oxygen levels approach 17% v/v breathing can become laboured and judgement impaired. Once oxygen concentrations approach 10% v/v there is a high probability of unconsciousness and death.

Low oxygen levels are most often found in conjunction with elevated levels of carbon dioxide (see below), although high concentrations of methane can also produce oxygen deficiency.

Sometimes coal mine atmospheres contain excess levels of nitrogen, which are due to oxygen being removed, usually by conversion into carbon dioxide which is then dissolved in water.

5.1.3 Methane (CH_4)

Methane is present in mine workings due to desorption from the coal seams. Methane was produced during the conversion of organic matter to coal due to heat and pressure and some of the gas produced remains within the structure of coal. In general, the methane content of coals increases with depth. As a consequence, where only shallow seams have been mined or deeper seams have become flooded by rising mine waters, high methane concentrations are unlikely to be present. Conversely, where deep mined seams are connected either directly to the surface or through shallow workings, methane may be a significant constituent in mine gas.

The principal danger arising from methane is fire and explosion. The explosive range for methane in air is 5% to 15% methane by volume (v/v) (50,000-150,000 ppm). Sometimes gas concentrations are quoted in terms of percentages of the Lower Explosive Limit (%LEL), where 100% LEL is 5% v/v. So, for example, 1% methane by volume is equal to 20% LEL. Because of the wide disparity in values care must be taken when reading gas monitors as to which scale is being used. Although concentrations higher than 15% v/v (the Upper Explosive Limit or UEL) cannot be directly ignited they can dilute into the explosive range or represent a risk of ignition as they will burn at the interface of the gas and air.

Even small quantities of gas can produce significant damage and risk to people, especially if the gas volume is confined at the time of ignition. A particular aspect of gas ignitions is the fact that the size of the flame is much larger than the volume of the gas before ignition, due to the temperature of the flame. This means that the flame can impact on a much wider area than might be expected and may mean that an ignited flame might be hard to avoid. Ignitions within confined spaces can produce significant overpressures causing harm both to operators and structures. For these reasons it is especially important that monitoring is undertaken where methane might be encountered. If detected moving away from the source is also an important safety precaution.

Methane is ignited relatively easily by either naked lights or sparks from electrical equipment such as switches. Great care needs to be exercised in not allowing methane to come into contact with electrical equipment, or taking electrical equipment into atmospheres potentially containing methane. Any equipment which may come into contact with methane must be suitably ATEX compliant. This also applies to any equipment used to monitor for the presence of methane and other mine gases.

Methane has a density of about 0.7 kg/m^3, compared to the density of air of about 1.2 kg/m^3. Being lighter than air, mixtures of methane and air, especially at high methane concentrations, will tend to rise in air. Methane mixtures may also form layers when rising gas encounters horizontal barriers, such as ceilings, and especially where the gas is emitted close to such a horizontal barrier.

Methane is not toxic, but can act as an asphyxiant by displacing oxygen from the air. For a pure mixture of air and methane, every 10% of methane will produce a 2% reduction in oxygen.

5.1.4 Carbon Dioxide (CO_2)

Carbon dioxide in mines originates predominantly as a result of oxidation processes. These processes are generally as a result of oxidation of carbonaceous material, but biological processes could also be involved. In oxidation processes a unit volume of oxygen will produce an equal volume of carbon dioxide. Consequently, an increase in the concentration of carbon dioxide will be at the expense of an equal reduction in the concentration of oxygen. In many cases the sum of the concentrations of oxygen and the concentration of carbon dioxide will be close to 21% v/v - the atmospheric concentration of oxygen. However, solution of carbon dioxide in water can result in atmospheres which are predominantly nitrogen. In the mining industry, a mine air mixture rich in carbon dioxide and poor in oxygen is also known as blackdamp or stythe.

Carbon dioxide has a density close to 2 kg/m^3, which is significantly higher than air. As a result, blackdamp emissions have a tendency to layer at ground level, especially if the mine gas is cold, which enhances the density difference. Blackdamp is therefore particularly dangerous in cases such as cellars, trenches, cuttings and any other confined low lying ground. The gas can also flow downhill and collect in low lying ground at a distance from the point of emission.

Carbon dioxide is toxic, but the principal danger arising from emissions is asphyxiation due to the associated reductions in oxygen. The 8 hour long term exposure limit (LTEL) is 0.5% v/v or 5000ppm and the 15 minute short term exposure limit (STEL) is 1.5% v/v. (See 6.2). The STEL and LTEL figures included here and in the Table of Characteristics and Effects of Toxic Mine Gases (6.2), are set out in EH40 Occupational Exposure Limits published by the HSE.

5.1.5 Carbon Monoxide (CO)

Carbon monoxide is produced as a result of incomplete combustion of fuel. In domestic situations the main danger arises from problems with heating appliances and leaking flues. In mines the gas is generally associated with spontaneous combustion of the coal seams (see Section 6.2). Indeed, the presence of carbon monoxide has long been used as an indicator of the probable presence of an in-seam heating or combustion.

Carbon monoxide is normally found in low levels, at a few ppm, in abandoned mine workings which does not represent a risk to health. However, the Coal Authority has found carbon monoxide at one location, at a level of about 200ppm where historically there had been spontaneous combustion. This suggests that carbon monoxide could remain for substantial periods underground. In contrast, carbon monoxide has a lifetime of about four months in the general atmosphere.

Carbon monoxide is toxic at very low levels. The LTEL for CO is 30ppm and the STEL is 200ppm. For further details see the Table in 6.2, but severe effects will result from spending short times in concentrations as low as 0.1% v/v (1000ppm).

The density of carbon monoxide is 1.25 kg/m^3, but because it is generally found in low concentrations, it does not have any effect on the physical behaviour of the gas, such as layering.

5.1.6 Hydrogen Sulphide (H_2S)

The principal characteristic of hydrogen sulphide is its smell, which may be perceived at levels as low as 0.003 ppm. The short term exposure limit for H_2S is 10ppm and the long term exposure limit is 5ppm.

Hydrogen Sulphide is produced either as a by product of degradation of organic material or due to the action of acidic mine water on sulphide materials, such as pyrites. Hydrogen sulphide is highly soluble in water and dangerous conditions can arise from gas release due to disturbance of standing pools containing saturated solutions of the gas. It is heavier than air and although flammable, at between 4.3% – 46% v/v, its principal danger is its toxicity.

Although very pungent at first, it quickly deadens the sense of smell, so potential victims may be unaware of its presence until it is too late. The gas is toxic and is likely to result in unconsciousness at concentrations over 250 ppm and death at over 1000 ppm.

5.1.7 Hydrogen (H_2)

Hydrogen is not normally encountered within abandoned workings although it has sometimes been found where there have been signs of spontaneous combustion. Hydrogen can also be formed by concrete when aluminium is part of the admixture when, for example, incinerator bottom ash is used. Hydrogen may be produced from the dissociation of water (H_2 and O_2) if used in an attempt to put out a spontaneous combustion fire, resulting in an explosion.

The principal danger of Hydrogen is that it is explosive in the range 4% to 75% v/v in air.

5.1.8 Other Gases

- Although methane is the principal hydrocarbon gas found in mine workings there will also be lower levels of other **alkanes** especially **ethane** (C_2H_6). Because the concentration of ethane is usually about two orders of magnitude less than that of methane it does not represent a significant increase in risk. However, it affects infrared methane detectors disproportionately and so, where present, it can give misleading readings which are too high.
- **Radon** is an inert but radioactive gas which is derived from the decay of naturally radioactive elements in the strata. The problem from radon arises from its daughters which are other radioactive elements produced as a result of the decay chain and which can become deposited in the lungs. In operating mines the build up of radon is prevented by ventilation of the mine which dilutes and removes the gas from the mine. In closed workings, there is a potential to build up levels of radon although radon's half life is only 3.8 days. There is limited information on the general levels encountered within old workings and it will depend on the types and composition of rocks exposed by mining. However, some measurements from metal mines suggest that radon levels can be measured in the tens of thousands of becquerels per metre cubed (Bq/m^3).

  The principal risk from radon is lung cancer, usually as a result of prolonged exposure to elevated levels of the gas in homes or workplaces, caused by emissions from radioactive decay in the underlying rocks. The risk is a combination of the level of radioactivity with the exposure time. The Health Protection Agency recommends that radon levels should be reduced in homes where the average is more than 200 Bq/m^{-3} over a 12 month period. The target level of 100Bq/m^{-3} is the ideal outcome for remediation works in existing buildings and protective measures in new buildings. In a drilling context, prolonged exposure is unlikely, due to the limited times when drillers are likely to encounter undiluted airflows from mining voids and therefore the risk will be low. For example, continuous acceptable exposure (100 Bq/m^{-3}) in a building for one year would be about 50 million

Bq.minutes/m^{-3}, whereas 10 minutes exposure to say 50,000 Bq/m^{-3} would be 500,000 Bq.minutes/m^{-3} or 100 times less. Where these instances do occur it is likely that other mine gases, created in stagnant mine atmospheres, will also be present and detectable.

5.2 Table of Characteristics and Effects of Toxic Mine Gases

GAS	CHARACTERISTICS	CONCENTRATION		EFFECT
		% v/v	ppm	
Oxygen	Colourless and odourless	21	210,000	Normal Atmospheric Concentration
		17	170,000	Heavier and faster breathing and possible impaired judgement
		16	160,000	The first signs of hypoxia appear
		15	150,000	Dizziness, buzzing noise, headache and blurred vision may develop
		12 -16	120,000 - 160,000	Breathing and pulse rate increases; muscular coordination impaired
		10 -12	100,000 - 120,000	Emotional upset and abnormal fatigue on exertion are evident; a person may remain conscious
		6 -10	60,000 - 100,000	Nausea and vomiting may occur; victims may lose consciousness
Methane	Flammable, colourless and odourless	5	50,000	Lower Explosive Limit in air
		15	150,000	Upper Explosive Limit in air
Carbon Dioxide	Colourless, sharp odour, sour taste. Toxic.	0.5	5,000	LTEL
		1.5	15,000	STEL
		5.0	50,000	Breathing laboured
		7 - 10	70,000 - 100,000	Unconsciousness after a few minutes; a high concentration will eventually cause death
Carbon Monoxide	Colourless and odourless. Highly Toxic	0.003	30	LTEL
		0.02	200	STEL
		0.04	400	Headache and discomfort with possibility of collapse after 2 hours at rest or 45 minutes work
		0.12	1,200	Palpitations after 30 minutes at rest or 10 minutes work
		0.20	2,000	Unconsciousness after 30 minutes rest or 10 minutes work
Hydrogen Sulphide	Smell of rotten eggs. Highly Toxic	0.0005	5	LTEL
		0.001	10	STEL
		0.003	30	Eye irritation
		0.005 - 0.015	50 -150	Irritation of eyes and respiratory tract, leading to nausea, vomiting and headaches
		0.015	150	Olfactory (sense of smell) fatigue occurs
		0.1	1000	Immediate unconsciousness
Hydrogen	Flammable, colourless and odourless	4	40,000	Lower Explosive Limit in air
		75	750,000	Upper Explosive Limit in air
LTEL - Long Term Exposure Limit (8 hour) STEL - Short Term Exposure Limit (15 minute)			From EH40 Occupation Exposure limits, HSE	

5.3 Spontaneous Combustion ('Spon Com')

Spontaneous combustion of coal is the process where coal catches fire without an external heat source. Spontaneous combustion usually occurs in coal as a result of air flowing over it. Coal will oxidise in the presence of air releasing carbon dioxide and, importantly, heat. Where the flow of air is insufficient to carry away the generated heat the coal will warm and increase the rate of oxidation. In this way the coal's temperature can increase until it auto-ignites. However, where the airflow is very low there will be insufficient oxygen for oxidation and the process will be stopped. The process of spontaneous combustion therefore requires sufficient air to allow oxidation/combustion, but not so much as to cool the coal.

Spontaneous combustion of coal is most often associated with former coal workings. In operating mines it is usually found in collapsed ground, which contains coal, or in fractured coal around roadways. In these situations it is the replenishment of potentially oxidising gas conditions by ventilation air in the workings which allows continued heating. It is also found where coal outcrops at the surface especially where it has been disturbed by mining operations which allows air to come into close contact with the coal.

As the temperature of the coal increases, gases other than carbon dioxide are produced. These include hydrogen, higher hydrocarbons and carbon monoxide. Carbon monoxide is produced in conditions of incomplete combustion caused by a limited supply of oxygen. These gases are produced, albeit at lower concentrations, at temperatures well below those at which the coal actually catches fire.

There appears to be very little in the literature regarding spontaneous combustion of coal in air flush boreholes. Nevertheless, details of known examples of this happening, along with anecdotal evidence, suggest that there have been potentially many other cases where such events have not been reported.

The production of spontaneous combustion, or heating, of coal by air flush drilling is probably a combination of two factors. These are the production of heat by the mechanical action of the drill on the coal and the oxidation of the coal due to the injected air. The presence of broken coal and fines may also increase the rate of oxidation as it is a surface process and comminution of coal leads to an increase in its surface area.

Whatever the cause, ignition of a coal seam can have dangerous consequences. Where associated with underground workings there is a danger of the fire spreading through the workings and threatening the safety of any properties lying above them. There is also the potential to spread hazardous gases, including carbon monoxide, through the workings to locations where they might escape at the surface, especially up dip.

A list of seams which have had incidents of spontaneous combustion in the past is available on the Coal Authority website at http://coal.decc.gov.uk/en/coal/cms/services/permits/permits.aspx. However this list is by no means comprehensive and some of these incidents have occurred within deep mines where the condition of the coal may be materially different to its condition when near the surface. It should not be assumed that because a seam is not on the list it is not capable of spontaneous combustion.

5.4 Atmospheric Pressure

Atmospheric pressure is usually the most important factor controlling the movement of gases within abandoned mine workings. Where water levels are rising within an area of workings gas will be displaced and potential pressurisation can occur. Nevertheless, even in these circumstances changes in atmospheric pressure can still have an effect on the movement of gas and the concentrations of gas in the workings.

If the atmospheric pressure falls below that in an abandoned mine and there are connections between the mine and the surface then there will be a flow from the mine to the surface, until the pressure becomes equal. If the connection to the surface is good, which is most common for shallow workings, then the pressure in the mine is usually close to atmospheric pressure and the rate of emission from the mine is related to the rate of fall in atmospheric pressure, The time of greatest risk of surface emissions of mine gas is therefore when deep depressions are moving across the country where pressure fall rates of 4mb/hr are possible.

Rising atmospheric pressure, by the same argument, will tend to push air into the workings. In this case, the air will either dilute the pollutants or completely displace them in a zone close to the point of ingress. On falling pressure, gas from deeper in the mine will displace any fresh air drawn into the mine, but may still contain atmospheric air as part of its composition.

If the connection to the surface is poor, which is the usual case with deeper workings, the rate of flow will be related to the difference between atmospheric pressure and the pressure in the mine. Such differences can be substantial, especially where pressurisation due to rising mine water is present.

5.5 Migration and Pathways

5.5.1 Migration

The concept of migration of gases due to pressure differences and the existence of connections between workings and the surface were raised in the previous section. Pressure differences may be produced by:

- Rising water levels.
- Atmospheric pressure.
- Differences in gas density.
- Injection of fluids and gases.

The first two have been discussed already. The movement of gas due to differences in density is sometimes referred to as natural ventilation. Where there are two points of access to a mine void and the density of the gas in the void is higher than that of the atmosphere then, due to gravity, the denser air will flow from the lower connection and draw fresh air into the higher connection. If, alternatively, the density of the gas in the void is lighter than that of the atmosphere, then, by gravity, the atmospheric air will displace the lighter air by entering by the lower connection and forcing the lighter mine gas out of the higher connection.

The density of the gas will be a function of its temperature and composition. The density of a gas will decrease as its temperature increases, which means that warmer air tends to rise. The density of a gas mixture is made up of that of its constituents, so if it contains gases of a lower molecular weight its density will tend to be lower. For example, mine atmospheres with high levels of carbon dioxide are likely to be more dense than the surrounding atmosphere. Nevertheless the effect of temperature can be important. Because the mine atmosphere is less prone to temperature change, but the outside temperature can change substantially, especially overnight, the flow of gas from the mine can vary over a 24 hour period or even reverse.

The most likely case where fluids are injected into workings is during drilling or piling operations where air or water flush drilling are utilised. The extent to which injection of fluids, such as air and water, into workings will influence the movement of the mine atmosphere will be a function of the flow of the fluids, the void volume and the resistance to the flow.

Where there is a very large open interconnected void the induced pressures are likely to be small and this has been borne out by experiment. However, if the connected void is small it is possible that it could become pressurised. In the case of air flush, the maximum pressure will be the back pressure exerted by the resistance of the air returning up the annulus between the drill string and the side of the drilled hole. In the case of water flush, higher pressures could be exerted if void volumes were very small and the volume of water injected was to fill a significant portion of it.

In comparison the low pressure and relatively low flow methods employed in open or closed bore piling techniques do not lend themselves to ground pressurisation.

Areas of broken ground, although offering greater resistance to flow, will also allow better transmission of pressure over short distances as the pressures can less easily dissipate.

Beyond pressurising the workings the injection of air or other materials will also displace gas within the workings, potentially moving dangerous gases into places they did not previously occupy. In general, air flush, as it uses much larger volumes, has a greater potential to displace mine gases over larger distances. Measurements to date have shown that normal air flush drilling is capable of having an effect on the gases in voided mine workings at distances up to 60m although flows were low (see Case Study 4)

5.5.2 Pathways

Pathways between mine workings and the surface can be of a number of forms although they are all weaknesses within the intervening ground which present a lower resistance to movement of gases. The mine workings themselves also represent a pathway through which gas can move considerable distances.

Examples of pathways are:

- Mine entries (shafts and adits).
- Shallow mine workings.
- Previous boreholes.
- Water wells.
- Service ducts and trenches.
- Faults / break lines.
- Permeable strata.

The most obvious form of pathway is a shaft or an adit constructed to access the workings. Although such mine entrances are usually filled to some degree, they may still represent a weak point through the strata due to containing permeable fill. Gas is also able to move along the interface between the strata and the lining of the mine entry.

Collapses of ground over coal workings are also a potential route for gas migration. In some cases the movement of the developing void to the surface may not be complete, but the weakening of the strata may be sufficient to allow movement of gas. In general, fracturing of the strata, either mining induced or natural, such as faults, are potential lines of weakness which can provide pathways.

It should be noted that, where it is unknown whether pathways exist, the risk assessment must err on the side of caution and assume that they might be present. As such a layer of clay in the superficial deposits cannot be classed as impermeable if it is not known whether pathways exist.

Where mine gas gets close to the surface it has the potential to run through ground which might have a higher permeability than the natural ground surrounding or underlying it. Examples are made ground and service runs.

Colliery spoil as placed is frequently high in sulphides. Upon exposure to air and moisture these have the potential to generate significant sulphate and low pH conditions which are aggressive to concrete. Over time the corrosion of piles formed using concrete may, in addition to detrimentally affecting load bearing characteristics, lead to the formation of a new pathway. It is therefore important to design the concrete to resist such attack.

5.6 Monitoring and Testing

Refer also to Section 10.5

5.6.1 General

If carrying out works or investigations in areas which may be affected by mine gas, then suitable safeguards must be in place to ensure a safe working environment. The risk assessment for the drilling operations should identify any significant risks from gas and should make sure that a suitable drilling method is being used along with adequate testing and monitoring procedures and that the appropriate equipment is in place before commencement of operations.

Monitors are readily available which will detect the gases described in Section 6.1 and alarm if trigger gas levels are exceeded. The most likely gases to be encountered are methane and carbon dioxide (usually associated with low oxygen). An ability to measure carbon monoxide can also be of great benefit in identifying potential spontaneous combustion. **This guide recommends that monitors / alarms should routinely sample for carbon dioxide, carbon monoxide, methane and oxygen.** The presence of hydrogen sulphide is very rare and is apparent by its smell even at very low levels.

All gas monitors being used need to be calibrated and tested with copies of supporting certificates available on site. Provision needs to be made to ensure that monitors are operational at all times whilst in use on site.

When using gas monitors, it is important to remember that monitors measure gas properties and not the gases directly. Because of the nature of the gas detection cells, some gases can affect cells other than those for which they were designed. This cross sensitivity effect can cause monitors to provide false readings. Some examples of this are:

- Infrared methane cells will also record ethane, and other hydrocarbons, at an enhanced level. This means that small levels of ethane mixed in with methane will show methane levels potentially well in excess of actual levels.

- Electrochemical cells used to detect gases such as oxygen, carbon monoxide, hydrogen and hydrogen sulphide often show cross sensitivity to the other gases. Known examples include both hydrogen and an unsaturated hydrocarbon (e.g. ethyne/acetylene) registering as carbon monoxide and resulting in a misdiagnosis of the particular problems encountered.

- Pelistors, sometimes used to detect methane, are also cross sensitive to other flammable gases, so that hydrogen will register as methane.

When unusual readings are being detected during operations and cross sensitivity is suspected another instrument using a different type of cell may help, but laboratory analysis of a gas sample will be required to provide certainty.

5.6.2 On Site monitoring

Gas monitors may be carried by individuals or a single monitor placed in a suitable position, where appropriate. The key guideline for siting monitors and alarms is that they must be located close to those who might be affected. For example, on a drilling rig the monitors should be sited close to the drill string and the operators, to ensure that the atmosphere being tested is the same as that to which the workers are exposed.

A monitoring regime needs to be designed to address the works being undertaken. The following are suggested criteria:

a) When drilling in confined spaces where pathways exist or potentially exist into underground workings (e.g. mine entries and boreholes), continuous monitoring in the working area close to the source is recommended. Additionally, further tests should be carried out to check for layering of cold gas or blackdamp at ground level or methane in the roof of an enclosed area or at any open boreholes within the confined space. Exit routes from the confined space should be well defined, clear of obstruction and identified to those working in the confined space. Evacuation should take place in these circumstances, in the first instance, at gas concentrations at the trigger level rather than the action level due to the enhanced risk in these situations.

b) When drilling boreholes into shafts or mine workings, for the purposes of investigation, grouting etc, the following points should be considered:-

- Continuous monitoring at the drilling rig location (with appropriate alarm) at 1.2m height near the drill string.

- If steel casings are being inserted and welded, then prior to each section of casing being attached, the contractor needs to monitor for gas within the mouth of the casing. The main risk is an explosion of flammable gas caused by contact with a flame. It is suggested monitoring 0.5m down the casing to obtain a meaningful reading. It is also suggested that any other adjacent boreholes should be monitored for flammable gas to indicate whether there is any in the immediate vicinity before drilling commences.

c) Boreholes which are left open temporarily for operational reasons (see **d** below) and which are in contact with workings, represent a potential route for gas and so should be checked periodically for potentially hazardous conditions. The interval for inspections should be based on the findings of the initial and ongoing risk assessment. It should be remembered that gas composition can change with time due to atmospheric pressure effects.

d) When a series of holes are being drilled such as when mine workings are being grouted or on a piling scheme prior to cast then pathways (boreholes) can be left open for short periods until the grout is injected or the concrete is poured. However the time between drilling and sealing should be kept to a minimum and where these two operations cannot be achieved concurrently temporary caps or bungs should be inserted into the hole.

e) Air flush drilling is the technique most likely to displace gases which may emit from adjacent pre drilled holes, or other pathways to the surface.

Monitoring of specific perimeter holes is unlikely to protect properties adjacent to the site. Whilst these holes may intersect mineworkings, other unconnected mineworkings and pathways may exist elsewhere.

All parties involved in the works need to be aware of atmospheric conditions and realise that under falling or low atmospheric pressure, gas more readily emits from the ground (usually during adverse weather conditions).

The following table suggests trigger levels of gases, measured within the general working area, at which the drilling supervisor should be informed and he/she should make an assessment of the situation and determine suitable actions to take. The table also includes suggested action levels where drilling should cease and all personnel withdrawn from the affected working area. If withdrawal takes place there should be no return to the affected area until a competent person has investigated and assessed that it is safe to do so. Methane has a low suggested trigger level, because it is rarely contacted and is a particular danger due to its explosivity. Oxygen has a suggested trigger level of 19% v/v as the effects are unlikely to be felt, but it is very close to 17% v/v at which effects are likely to be felt. The action level has therefore been set at 18%. The carbon monoxide Action level has been suggested as 100ppm rather than the STEL to take some account of the cumulative effects of the gas. The trigger level for hydrogen sulphide has been suggested as 1ppm which, although only 20% v/v of the LTEL, would represent a very strong unpleasant smell.

Gas	Trigger Level	Action Level
Methane	≥0.1% v/v	≥1% v/v (20% LEL)
Carbon Dioxide	≥0.5% v/v (LTEL)	≥1.5% v/v (STEL)
Oxygen	≤19% v/v	≤18% v/v
Carbon Monoxide	≥30 ppm (LTEL)	≥100ppm (50% STEL)
Hydrogen Sulphide	≥1ppm (20% LTEL)	≥5ppm (50%STEL)

5.6.3 Off Site Monitoring

There will necessarily be less control over off site locations, because they will be in land owned by others. A risk assessment should be carried out, based on a ***source – pathway – receptor*** model (see section 9.2), to determine whether there is a medium to high risk of gas migrating off site which might cause harm. If so the working method should be reviewed to determine whether the risk can be reduced. If not, then the contractor should arrange for monitors to be installed in adjacent, off site, occupied buildings which are assessed as being at risk.

Off site monitoring will normally be in the form of alarms to provide immediate warning to those potentially affected. All those provided with alarms should be provided with clear instructions on what to do in the event of an alarm sounding. The precise actions will vary with the type of risk, but the instructions should set out:

- What they should do to make themselves safe in the first instance.
- Who they should contact for further assistance. During operations this should be the site supervisor, but there should also be an out of hours contact in case of problems after work has stopped on site. The out of hours contact should be able to arrange for someone to quickly attend the site to investigate the problem.

Alarms could be backed up with monitoring by staff visiting properties at intervals during the day and/or by continuously monitoring and logging results using a suitable instrument to provide a full picture of conditions during the full period of working including out of hours.

Depending on the particular risks, suitable alarms will be flammable gas alarms, carbon monoxide alarms and carbon dioxide alarms. The first two are available through retail outlets, but carbon dioxide alarms are usually more expensive and need to be obtained through specialist suppliers. In all cases the alarms should be calibrated where appropriate and within their approved lifetime.

6. The Influence of Flush and Injected Materials

6.1 Introduction

Any material that is injected into mineworkings will have the effect of displacing any gas that is already present within the workings. The amount of gas displaced will depend upon the volume of the displacing agent being injected.

The selection of a particular drilling fluid is normally based on the formations to be drilled, required fluid functions for the selected drilling process and method, fluid efficiency and cost (including disposal) and its contribution to productivity. Part of the selection process shall also include whether it will have harmful effects on persons, property or the environment – either directly or indirectly.

Before final selection of a particular drilling fluid, the project risk assessment shall consider whether hazardous gases are likely to be present; could be created, or could be mobilised to cause harm by any of the preferred drilling fluids. A selected drilling fluid shall eliminate or minimise the risk of harm.

The flushing mediums most generally used are air and water. Beyond the potential oxidisation of the coal, using large air volumes also has the capability of displacing large volumes of gas, as large pressures are required to flush out the spoil from the hole. Nevertheless, air can be more practical where water supplies are limited.

Conversely, water will have a cooling action and displace much smaller volumes of hazardous gases. It does have the disadvantages that a water supply needs to be available and in weak strata can cause erosion of the borehole. Although rare, the use of water has also been known to precipitate mine working collapses in nearby ground due to the washing out of supporting material.

Whilst the highest degree of displacement during drilling will come from the injection of compressed air, the effect of inserting large volumes of non compressible materials, such as grout, should also be considered.

6.2 Drilling Fluid

Drilling Fluid is a fluid circulated through the in-hole drilling assembly. Its basic constituent may be air, water or oil or a combination of these. Main functions include carrying the cuttings from the drill bit to surface; cooling and cleaning the drill bit; suspending the cuttings; reducing friction between the drill rods and the sides of the borehole; stabilising the borehole, and preventing fluid loss to the formation. The drilling fluid may also have the function of transmitting power to a bottom hole drilling tool e.g. DTH hammer, mud motor etc.

Many types of drilling fluid are used but they generally fall into a few broad classifications and variations.

6.2.1 Air Flush

Compressed air is often chosen as the drilling fluid for rotary and rotary percussive drilling methods. It is supplied generally by mobile compressors, either owned or hired in by the drilling contractor. Some rigs have compressors mounted on board e.g. quarry and large waterwell rigs. It is efficient in cleaning the hole due to its self expanding property but has a low specific gravity of close to zero.

To effectively flush the borehole the compressor must supply a sufficient volume of compressed air at an adequate pressure. The compressor capacity that is necessary is a function of the uphole velocity required to lift the cuttings to surface. An optimum uphole velocity is approximately 1200 metres / minute but will vary depending upon cutting size and density. If the drill bit produces large, high density cuttings then either the uphole capacity has to increase i.e. larger compressor required or the cuttings will be reground by the bit to a smaller size for uplifting.

Uphole velocity is calculated with reference to cutting size and density; annular space between rod outside diameter and hole diameter, and compressor free air discharge (FAD).

Note: Discharge volumes of compressed air i.e. compressor volume rating are always given as FAD which means that the air will occupy equivalent volume when the air pressure drops to that of standard atmospheric air.

Air Flush - hazardous gas risk assessment - Factors to be considered are:

- Fire needs an ignition source. Will the drill bit generate heat and / or sparks to cause ignition of coal? Air is not particularly effective as a substantial coolant.
- Will the introduction of compressed air (which contains oxygen) fuel a fire e.g. coals already smouldering or liable to spontaneous combustion thus having the potential for creating hazardous gases?
- Air heats up when compressed. Compressors cool the air before discharge and normally have a discharge temperature gauge. Is the air delivered to the drill bit of sufficiently low temperature to cool the bit i.e. is the compressor working correctly?

- High volumes of compressed air will expand into voids e.g. old workings, broken ground etc. and may displace / drive existing hazardous gases in those voids. Where and how far will those gases be displaced to?
- Is the compressor of a greater capacity than required to achieve sufficient uphole velocity? If so more air than necessary may be being introduced into the formation. This may be achieving greater drilling productivity at the expense of driving hazardous gases further away from the borehole.
- Does the Coal Authority normally allow the use of this drilling flush for the type of project and the strata that is to be drilled?

6.2.2 Air Mist Flush

This is a variant of air flush. The principal constituent of the drilling fluid is still compressed air but water is added to increase the fluid viscosity, provide more cooling, assist in dust suppression, and provide a little more lubrication. A water injection pump injects small amounts of water into the compressed air delivery hose thus raising the specific gravity of the drilling fluid to about 0.2.

Because the air mist drilling fluid has higher viscosity than air it is more capable of “lifting” cuttings than compressed air. Cuttings of similar size and weight will not require the same uphole velocity as that required for air flush given that everything else is equal. Compressor capacity to generate the lower uphole velocity will therefore be less. One reason that air mist is selected for coring, for example, is that with the decrease in velocity at the bit face there is less erosion of the core.

Air Mist Flush - hazardous gas risk assessment - Factors to be considered are:

Those in 8.2.1 Air Flush as above plus the following:

- What safeguards are to be employed if the water injection pump fails or the water supply is cut off?

6.2.3 Foam Flush

This is a variant of air flush in that the principal constituent is compressed air. However it can be considered to be a significant improvement in safety terms in that a significantly smaller capacity compressor is employed. Foam flush has the benefit of reducing the uphole velocity to as little as 15 metres / minute due to its great cutting carrying capacity.

Air is combined with a foam fluid. The latter comprises a small quantity of water and foaming agent which is prior mixed and then injected into the compressed air delivery hose by an injection pump. The ratio of foam fluid to air is about 1:150, and foam fluid usually consists of about 1% by volume of foaming agent mixed with water. The foaming agent may incorporate high molecular weight polymers which increase the foam bubble strength. The consistency of the foam flush is much like shaving foam when it emerges from the top of the borehole. It has an interlocking bubble structure of encapsulated air that provides its high lifting capacity. Some skill is necessary to adjust the consistency – too little foam fluid injection will result in the bubble structure not being formed and thereby loss of cutting carrying capacity.

One major disadvantage is the volume of foam that emerges at surface. This takes time to settle and drop its cuttings unless sprayed with water. Handling of the foam / cuttings waste is a major exercise which may explain why it is not more generally used especially in high production open holing.

Foam Flush - hazardous gas risk assessment - Factors to be considered are:

- In general, foam flush when done correctly does not comprise the risks associated with air flush or air mist flushing with regard to hazardous gases.
- However there is the possibility that incorrect operation will effectively convert the flushing into air mist or air flush. This may happen if the mixing of the foam fluid is done incorrectly e.g. foam fluid is omitted or insufficient. It could also occur if the injection pump fails. Incorrect operation will

usually be detected fairly quickly as no foam will emerge at the surface.

- Environmental considerations and COSHH assessments.

6.2.4 Water Flush

Water by itself is often used in drilling. Being far more viscous than air it can lift cuttings at an optimum uphole velocity of 30 metres / minute, some 40 times less than air. A water flush pump is employed with capacity suitable to obtain this velocity for the specific drilling application. The capacity will vary between 45 litres / minute up to approximately 220 litres / minute. The water flush pump will also be able to generally provide up to 50 bar pressure.

While water is readily available in developed locations and relatively cheap, it does have the disadvantage of being expensive to provide in locations at relatively short distances from the water network. Unlike air flush and air mist it also has greater problems of control, containment and waste management on emergence from the borehole. It can be re-circulated in that the borehole returns are taken to cutting settling pits or tanks and the water (less cuttings) is then pumped back into the drill rods.

Water Flush - hazardous gas risk assessment - Factors to be considered are:

- Water flush is a major coolant and therefore the drilling bit will remain relatively cold during drilling. It will also have the effect of damping any sparks.
- Water flush will not contribute to the creation of hazardous gases as air is not being introduced into the unworked coal or coal workings.
- Water flush is non compressible and will therefore only displace a volume, equivalent to its own, of gases that may be present within any voids or broken ground.

6.2.5 Mud Flush

Mud flush for the purpose of this guidance is the combination of adding any substance, other than foaming agent, to water to improve the latter's capabilities during the drilling process. The substances may be naturally occurring e.g. bentonite, and / or naturally occurring polymers e.g. starches, guar gum etc., and / or synthetic polymers. There may be other chemicals e.g. potassium formate introduced into mud flush to achieve various effects. This guidance does not consider oil-based mud or synthetic-based mud, both of which are employed mainly in off-shore oil and gas operations.

Mud flush involves the mixing of substances with water and should be performed in accordance with the manufacturer's / supplier's recommendations. This will often include mixing plant. The mud drill fluid is then supplied to a mud pump which pumps the fluid into the drill rods (or borehole annulus on occasions). Mud flush is mainly selected because it has a high density which permits a low uphole velocity, and obviates the need for casing because it prevents hole collapse; prevents fluid loss to the formation, and is economical in use with re-circulation.

Mud Flush - Hazardous Gas risk assessment - Factors to be considered are:

- Mud flush is a major coolant and therefore the drilling bit will remain relatively cold during drilling. It will also have the effect of damping any sparks.
- Mud flush will not contribute to the creation of hazardous gases as air is not being introduced into the unworked coal or coal workings.
- Mud flush is non compressible and will therefore only displace a volume, equivalent to its own, of gases that may be present within any voids or broken ground.
- Environmental considerations and COSHH assessments.

6.2.6 Summary - Drilling Fluid Influence

In conclusion, the selection of any drilling fluid with regard to hazardous gases is of prime importance. The "lighter" drilling fluid of air flush has the greatest potential to provide conditions for the ignition and

/ or support of an underground fire creating hazardous gases and / or the displacement / mobilisation of existing underground hazardous gases. Air mist shares some of the same potential but if well controlled is not considered to be a major risk. Foam flush contains a very slight risk if not controlled but is unlikely to create a hazard. Water and mud flush will have a negligible effect and can therefore be classed as having minimal risk.

6.2.7 Table of Risks for Different Drilling Scenarios

Situation	Air flush	Mist flush	Foam flush	Water flush	Mud flush	Additional controls
• Unworked coal or coal workings • High or unknown risk of hazardous gases being present / created • Occupied property within risk area	**HIGH**	**HIGH / MED'M**	**HIGH / MED'M**	**LOW**	**LOW**	• Monitoring at rig and other open holes. • Seal boreholes as soon as possible.
• Unworked coal or coal workings • High or unknown risk of hazardous gases being created or displaced • NO occupied property within risk area	**MEDIUM**	**MED'M/ LOW**	**MED'M/ LOW**	**LOW**	**LOW**	• Monitoring at rig and other boreholes. • Ensure materials are on site to extinguish any heating • Seal boreholes as soon as possible.
• Unworked coal or coal workings • Defined low risk of hazardous gases being present / created • Occupied property within risk area	**MEDIUM**	**LOW**	**LOW**	**LOW**	**LOW**	• Monitoring at rig and other open holes. • Seal boreholes as soon as possible.
• Unworked coal or coal workings • Defined low risk of hazardous gases being present / created • No occupied property within risk area	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	• Monitoring at rig and other open holes. • Seal boreholes as soon as possible.
• Key / Notes						
High / High Medium drilling operations should not be undertaken if there is a safer, practicable, alternative. Stringent control measures, such as monitoring inside occupied properties within the risk area, would be required to mitigate this level of risk to an acceptable level.						
Medium / Medium Low drilling operations can be undertaken but only with sufficient control measures to ensure that the work can undertaken without endangering the public or the workforce.						
Low risk drilling operations can be undertaken with standard control measures i.e. monitoring for hazardous gases at the drill rig						
This table provides general guidance and does not and cannot represent every circumstance. Each drilling operation must have a unique, robust and appropriate risk assessment and this table should not be used as a substitute for this.						

6.3 Grout and Other Filling Materials

Most bulk infilling of mine working voids and broken ground is undertaken with grout. However, expanding foams are becoming more prevalent for smaller voids. Most grouts are essentially non-compressible and will therefore displace and move volumes of gases that are equal to the amount of fluid injected. Where grout is being used as bulk filler the volumes injected can be quite considerable.

With grout introduced through a gravity feed it is possible that any displaced gas will eventually migrate back to the surface through weaknesses or boreholes and as the process of infilling is gradual the effects are likely to be negligible. However if gases become trapped by the grout they could become pressurised and force a route to the surface. Grouting is usually carried out from the 'down dip' side of the site in an up dip direction which will displace any gases in an 'up dip' direction. Properties on the 'up dip' side of the site could therefore face an increased risk at this time and this should be accounted for in the risk assessment. The creation of a grouted perimeter curtain around the site could limit the 'off site' movement of any gas and allow for controlled 'on site' venting of any displaced gas.

Pressure grouting could also have the effect of pressurising and mobilising any gases within the voids, driving them to the surface, should a suitable pathway exist. Grout injected into the workings via a tremie with an open annulus between it and the casing could provide a preferential pathway back up the injection hole for any displaced gases.

Foaming agents are designed to expand as they are injected and will initially displace gases in a similar way to pressure grouting. However its use within former coal mine workings is generally limited to surface based collapses at the moment.

It should be noted that sand or aggregate may need to be strategically placed in mine workings as a barrier prior to the injection of grout. It is unlikely that the placing of these materials will have any substantial displacing effect on the mine atmosphere.

The potential hazards involved with the injection of any bulk filling material should always be considered as part of the risk assessment.

6.4 Piling

It would be good practice for any mine working stabilisation work, using grout injection, to take place in advance of any piling technique. Piling can be split into three global groups, open bore, closed bore and driven methods. Where the method involves the introduction of uncured concrete to the bore it should be remembered that this operation is carried out at relatively low pressures when compared with grouting; analogous to gravity feed methods. Secondly the concrete consistency used is relatively low in comparison. It should be noted that piling methods will only have the potential to act as a pathway when they come into contact with existing closed or open pathways. Should the technique remain within a zone unaffected by pathways, for example where a significant thickness of impermeable strata exists between the piling works and any mine workings, then no potential for ingress of gas exists.

6.4.1 Open bore piling

Sometimes known as bored or segmental flight auger, the boring and concreting are two distinct parts of the operation, As such in the time between boring or augering of the void and concrete placement there may be a period where the pile is left open and the possibility of a temporary pathway dependant upon conditions, especially if temporary or permanent casing is used.. Where pile holes are in contact with unworked coal or mine workings they should be temporarily plugged or sealed at the earliest practicable opportunity pending permanent sealing when the concrete is introduced,

Open bore piling - hazardous gas risk assessment - factors to be considered are:

- Will the introduction of atmospheric conditions containing oxygen during the open bore phase fuel a fire?

- Are the gases likely to vent through the open bore?
- Once concrete has been introduced the pathway will close.

6.4.2 Closed bore piling

Continuous Flight Auger and auger displacement piling form part of this category. The operation differs from the above in that once at the required depth, concrete is introduced to the base of the bore under pressure and the tool only withdrawn when sufficient head of concrete has developed around the tool which effectively protects the pile from the ingress of gases. This operation continues until the pile is fully cast to final level. It is not anticipated that a significant pathway exists during this operation provided that sufficient head of concrete is present to outweigh any gas influx.

Closed bore piling - hazardous gas risk assessment - factors to be considered are:

- Closed bore piling will not contribute to the creation of hazardous gases as air is not being introduced into the unworked coal or coal workings.
- The method will only displace a volume equivalent to its own of gases that may be present within any voids or broken ground.
- As the concrete or grout is introduced at low pressure there a lesser risk of gas migration.

6.4.3 Driven piling

This method usually takes the form of using a piling hammer to install preformed elements of either concrete or steel. In the same way casing can allow a pathway to develop so a driven steel tube has an increased potential for gas migration. Precast concrete units do not have this disadvantage. Where the pile driving is protracted due to the slow progress of the pile there is potential for a limited pathway to arise due to the small lateral movement of the pile, known as pile whip.

Driven piling - hazardous gas risk assessment - factors to be considered are:

- Will prolonged pile driving lead to pile whip increasing the potential for a pathway to develop?
- Will prolonged driving of steel tubular sections result in heating of the element sufficiently to aid combustion?
- Will the introduction of the hollow tube allow contact between the mine gases and the atmosphere fuelling a fire e.g. coals already smouldering or liable to spontaneous combustion?
- The method will only displace a volume, equivalent to its own, of gases that may be present within any voids or broken ground.
- Are the gases likely to vent through the hollow section?

7. Coal Authority Permission

7.1 Introduction

During privatisation of the coal industry in 1994 the Coal Industry Act transferred ownership of unworked coal and coal workings, including shafts and adits, (previously vested in the NCB & British Coal) to the Coal Authority. In the interests of public safety and to ensure the proper exchange of relevant information, the Coal Authority, as owners, requires that any activity which intersects, disturbs or enters any of its property interests requires its prior written authorisation.

This authorisation can take the form of a Licence, an Agreement, or a Permit, depending upon the nature of the activity to be carried out.

The following activities may require a Permit and are dealt with by the Authority's Licensing and

Permissions department:

- Site investigation boreholes.
- Treatment of abandoned coal mine workings for ground stability purposes.
- Investigation and treatment of coal mine entries (shafts and adits).
- Piling.
- Geothermal boreholes.
- Water wells.
- Ground anchors.
- Trial pits and other activities which intrude into unworked coal or coal workings.

Incidental digging of coal and commercial coal mining are dealt with by Licenses and Agreements.

7.2 Application Process

Applicants requiring the Authority's permission are required to complete a pro-forma which sets out who is involved, what intrusive activity is being proposed and how any risks are being mitigated. The process also requires that a set of terms and conditions are agreed to which effectively makes the applicant responsible for any adverse consequences which occur to Authority property as a result of their actions for a period of 12 years. As an agreement is being entered into it is expected that applicants should have some interest in the surface property, e.g. owner or developer.

Application forms supported by notes of guidance can be viewed and downloaded at the Authority's web site: http://coal.decc.gov.uk/en/coal/cms/services/permits/permits.aspx. Submissions should include the appropriate application fee (see Coal Authority website for current fees. Fees are levied on a cost recovery basis for the running of the service as per Treasury guidelines).

7.3 Requirements

The MHSWR require a suitable and sufficient assessment to be made of the risks to health and safety of their employees to which they are exposed at work. This includes looking at appropriate sources of information, such as relevant legislation, appropriate guidance and seeking advice from competence sources.

HSE consider that it is a reasonably practicable step for companies planning to undertake work in the vicinity of mineworkings to have undertaken a desk study prior to the proposed works. This study should consider the mining circumstances of the site and the immediate surrounding area, based upon, amongst other things, the information contained within a Mining Report available from the Coal Authority and other reputable coal mining information suppliers.

Applicants should reduce risks to public safety arising from their proposed works by considering the layout of proposed works in relation to potential receptors, method of work, inherent hazards of the site, the sequencing of the work and any additional risk mitigation measures.

When considering applications, the Coal Authority will review the coal mining information available and carry out a risk assessment of the proposed works based upon the Source, Pathway, Receptor principle and any proposals deemed to be high risk will be referred back to the applicant for further consideration. Only where the residual risk has been determined to be low or medium will the Authority consider allowing access to its mining estate.

Under no circumstance should any intrusive activities take place which knowingly enter or disturb the Authority's property without its permission. Undertaking works without permission will result in trespass, the potential for court action and could adversely affect property sales. Furthermore home warranty and household insurances could be affected and planning permission may be prejudiced. In the case of an accident occurring, if it is established that a contractor has knowingly undertaken work which was advised against by a competent authority, or that he has knowingly circumvented authorised schemes designed to ensure safety, this may be seen as an aggravating factor in any potential prosecution of the company.

Upon completion of the proposed works, applicants are required to submit details of the actual site works carried out, in the form of a recommendation, completion or validation report, to the Coal Authority in order that its records can be updated, where required, and the information referred to in its Mining Reports. Site works are considered to be ongoing until this report is received by the Coal Authority.

8. Desk Study

8.1 Elements to be Considered

A desk study should be carried out before any drilling or piling operations take place and should form part of the pre-construction information (PCI). Beyond the normal requirements to establish the location of services, identify any environmental issues etc, the drilling location needs to be assessed for potential risks from unworked coal and coal workings, especially mine gas.

The desk study needs to identify, amongst other things:

- The depth and position of any known or possible unrecorded mine workings.
- Whether the seams are prone to spontaneous combustion. A list of seams that are known to have had spontaneous combustion incidents in the past is available on the Coal Authority's website at: http://coal.decc.gov.uk/en/coal/cms/services/permits/coal_seams/coal_seams.aspx.
- Whether there is a history of mining related gas problems in the area.
- The nature of the strata above the workings including layers of clay and any made or permeable ground.
- Zones of geological disturbance.
- The location of any mine entries.
- The location of any existing properties close to operations.
- Other underground features e.g. ground water levels and mine water levels.
- Are the mine workings dry, flooded or partially flooded with water?

Further information on what is required from a desk study is available through the AGS publication 'A Client's Guide to Desk Studies': http://www.ags.org.uk/site/clientguides/clientguides.cfm.

The information gathered from the desk study should be used to formulate a conceptual site model to gain an holistic view of both the surface and the underground environment.

8.2 Sources of Coal Mining Information

The Coal Authority holds an archive of approximately 118,000 old mining plans and a register of approximately 170,000 former mine entries. This information is disseminated to the public via its mining reports service. The information provided by these reports is a fundamental building block for the start of any desk top or other feasibility studies and any risk assessments necessary when planning proposed works.

Furthermore the Coal Authority has defined specific 'Coal Mining Development Referral Areas'. These are areas, based upon Coal Authority records, where the potential for land instability and other safety risks associated with former coal mining activities are likely to be greatest. They include, for example, areas of known or suspected shallow coal mining, recorded mine entries, past surface hazards and areas affected by mine gas. Further information is available at http://coal.decc.gov.uk/en/coal/cms/services/planning/strategy/strategy.aspx

The Coal Authority's abandoned mine plans and other mining records can also be viewed, by prior appointment, at its Mansfield offices. Further information is available at http://coal.decc.gov.uk/en/coal/cms/services/records/records.aspx

It should be noted however that a significant proportion of shallow mineworkings have no plan record of their existence. There was no obligation on mine owners to make plans and deposit them with the Mines Records Office until 1872 by which time many millions of tonnes of coal had been mined. Furthermore many of the early mine plans are of variable accuracy and standards and their interpretation can require considerable expertise.

As a general rule it should be assumed that if coal of a workable thickness exists then there is a good chance that it may have been mined at some time in the past.

As part of the process of obtaining the Coal Authority's permission to enter or disturb its coal and mining interests, known mining hazards, which may influence the site, will be brought to the attention of the applicant.

Other important sources of information include:

- Ordnance Survey plans.
- Geological plans.
- British Geological Survey.
- Local Authority plans / records.
- Aerial photo's.
- Network Rail / British Waterways.
- Private / Local companies: Mining Reports / Ground Investigations / Geotechnical Consultants / Mining Engineers and Surveyors.
- Public libraries.
- Local History groups.
- Public Records Office.
- Mining and Speleological societies.
- Internet sites.
- Local publications.
- Deputy Gaveller (Forest of Dean).

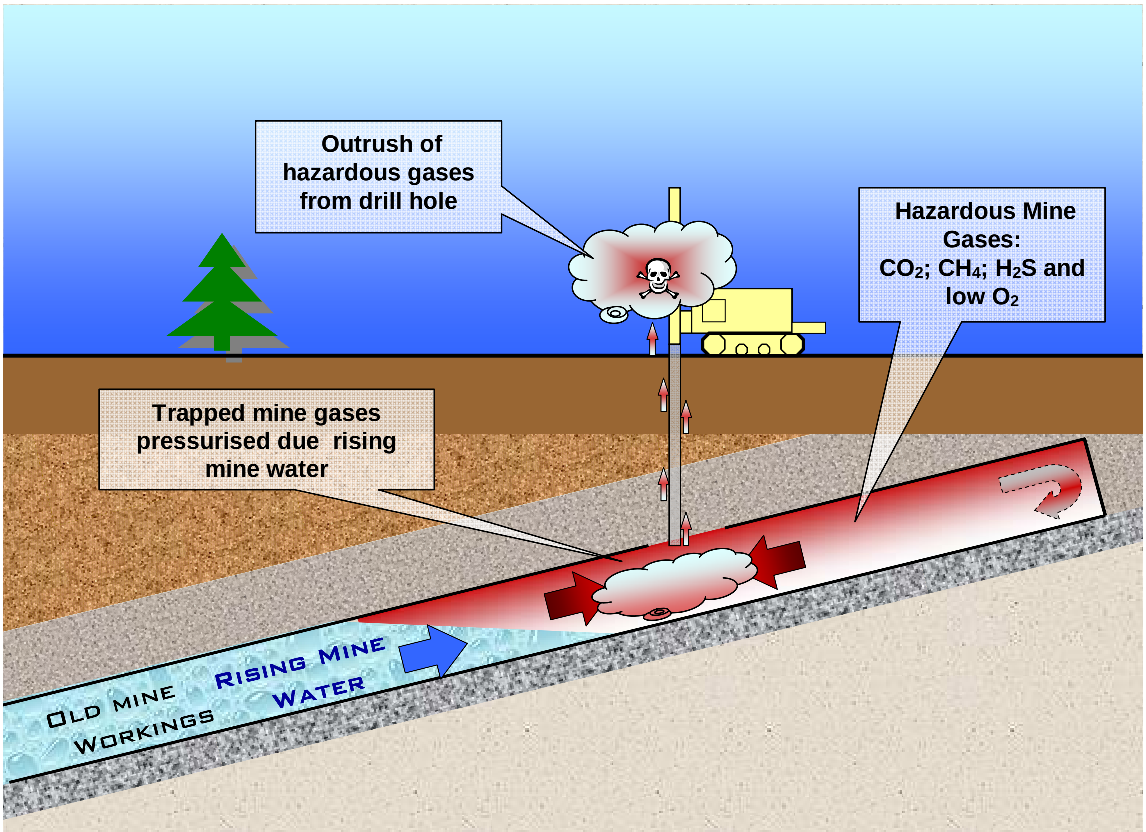
9. Risk Assessment

9.1 On Site Risks

There are three principal hazardous gas risks associated with drilling and piling works. These are:

- Emissions at the rig during or immediately after drilling or piling operations.
- Emissions from previously drilled boreholes and other pathways between the unworked coal and coal workings and the surface.
- Spontaneous combustion of coal (not a gas risk as such, but does present the risk of the creation of carbon monoxide) – See section 5.3.

9.1.1 Emissions at the Rig



Whilst drilling or using open bore or some driven piling techniques, the greatest risk comes from entering a void or permeable ground containing a volume of gas at pressure. In this case there could be an outrush of gas into the working area. The possibility of this is difficult to exclude unless it is known that there are open connections to the workings which are being drilled into. The risk is likely to be higher in areas where mine water levels are known to be rising. The risk is also likely to increase with depth as the likelihood of a connection to the surface is likely to decrease with depth. Clearly working within a confined area will greatly increase the risk and suitable arrangements would be required to provide protection in these circumstances.

Where blackdamp is contacted, this can give rise to the risk of asphyxiation. In low oxygen atmospheres unconsciousness can occur very rapidly and it is important that people are removed from such an atmosphere as soon as possible. This is particularly the case where the working area is a confined space, such as within a building. In these circumstances a dangerous atmosphere would remain in place for a long time rather than being dispersed as it would be in an outside environment. Care should be taken to ensure that routes of egress are clear and short. In certain circumstances where the risks merit it, breathing sets may be appropriate. The risks in these types of situations should be controlled by a Permit to Work procedure.

The risk from flammable gas, of which methane is the most likely to be contacted, is an ignition or explosion. Where high concentrations are found above the Upper Explosive Limit of 15% v/v it should not be assumed that the gas is safe. The gas will still burn at the interface and can be diluted into the explosive mixture due to mixture with air. The effects of such an event can be very sudden and it is therefore very important that people move to a point of safety at the first sign of flammable gas. It should also be borne in mind that the volume of the flame produced by an ignition is many times that of the volume of flammable gas that produced it. Again the risks are increased where working within a confined area as egress may be more difficult and the effects of an ignition in a confined area more damaging. Beyond the risk of the direct effect of an ignition on those within range there is the potential to cause secondary burning of the operatives clothing or other equipment and property. There has been a recorded instance where a rig and operative was set on fire when a smoker ignited methane near an open hole which had just been drilled. Where flammable gases are possible no naked lights, smoking, or storage of flammable liquids should be permitted within a minimum of 15m of the borehole (see also section 10.4)

9.1.2 Emissions from Previously Drilled Boreholes and Other Pathways

Previously drilled open boreholes are a potential contact to dangerous atmospheres below ground. While drilling using air flush the mine atmosphere is likely to be displaced and diluted in the vicinity of the hole once air is introduced into the workings. Nevertheless, after a period of time gas can migrate to the surface through these holes due to naturally induced pressures or through convection of the gas in the holes. Alternatively, if the holes contact workings, drilling of another hole in the vicinity can displace gas up the holes through injection of water or more especially air. For this reason it is important to monitor any open holes during drilling operations that could pose a risk to the Public or operatives. It should not be assumed that holes are safe because they have been safe at some time previously. Again this is particularly the case in a confined environment if there are open holes within a building for example. Where holes need to be left open, temporary caps or seals should be considered to reduce the risk.

Where other possible pathways are likely to exist on site, between the mine workings being drilled and the surface e.g. mine shafts, the risk of gases being displaced via these pathways should be considered and monitoring undertaken as required. However it is likely that in many cases the location of such pathways will be unknown or uncertain and in such cases monitoring may not be practicable.

9.1.3 Spontaneous Combustion

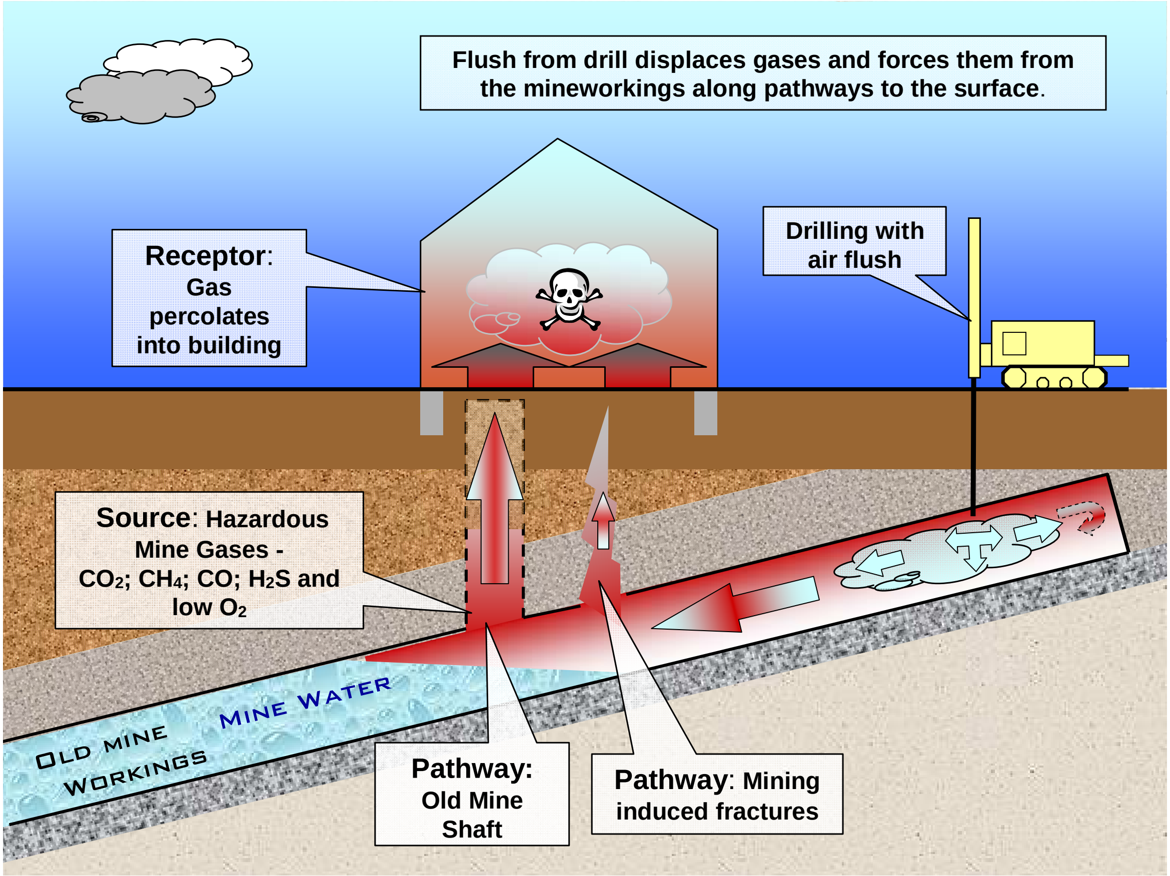
Before any drilling operations commence which may contact an unworked or remnant coal, efforts should be made to establish whether a particular seam is known to be prone to spontaneous combustion. The Coal Authority website contains a list of those known in the mining industry and those which recent laboratory tests have been shown to represent a medium to high risk. See section 5.3 for more details.

9.2 Off Site Risks

Off site risks arise principally from the movement of dangerous mine gases onto adjacent land and into properties. Such gases can move through the atmosphere, but this is only likely to represent a problem where there are very large flows of gas. The more relevant risk is produced by the movement of gas through coal workings and other pathways and its subsequent displacement into adjacent properties

The risk of off site gas emission as a result of drilling operations arises primarily as a result of displacing the mine atmosphere by use of the flushing medium used in drilling.

Although carbon monoxide has been identified as a real and significant hazard, other mine gases could migrate in a similar fashion and provide the risk of methane, carbon dioxide or low oxygen atmospheres entering property. It should not be assumed that the use of air as a flushing medium will clear away other gas and therefore provide a clean environment. Tests have shown that even over short distances injecting air into a borehole moves existing mine atmospheres rather than replacing them.



The aim of the risk assessment is to identify whether there is an increased risk of gas entering adjacent properties due to operations: If there is a source, a potential pathway and a potential receptor then the necessary preconditions are in place. In these circumstances gas could potentially migrate naturally. However, the risk assessment should identify any increased risk due to the presence of additional motive force created by drilling operations. In the case of piling it is unlikely that this will have significant influence due to the relatively low flow and high stiffness of the grout or concrete.

A motive force can be produced by injection of fluids such as air, water and grout into permeable ground and mine workings. The injection of these fluids has the potential to displace volumes of gas and increase pressure to allow the flow of gas through pathways.

Areas of ground which are at highest risk of mine gas are those which lie:

- On or in close proximity to a mine entry.
- On fractured or broken ground connected to mine workings.
- On a collapse which results in connection to mine workings or ground which is prone to such a collapse.
- On opencast backfill.
- On made ground and permeable strata directly above mine workings.

Lower risks will be associated with an absence of these factors. Also if it is known that potential pathways, such as mine workings, are totally flooded it would have a large mitigating effect on the risk. However in reality it is very difficult to definitively prove that mine workings are totally flooded and that no pockets of dry roadways exist without detailed knowledge of the workings and a thorough understanding of the hydrogeology in the area. It should be noted that ground water levels will not, in many cases, correspond with the water levels in the mine workings.

The risk assessment should estimate the likelihood of:

- Whether there is a risk of mine gases being present in any unworked coal or coal workings contacted during operations.
- Whether carbon monoxide might be created.
- The existence of pathways from source to surface which might allow the passage of gas.
- Gas entering properties if it were to reach the surface.

It should be based on a ***source – pathway – receptor*** model and needs to identify if the necessary conditions are in place and whether the proposed operation might enable the gas to enter properties at concentrations which will cause harm.

Where it is not possible to define whether there is a likelihood of any of the above conditions then it must be assumed that there is a potential for them to exist.

9.3 Residual Risks

Although we have so far considered the risks associated with the processes of drilling, there is also potential for the drilling operations to leave the area at a higher risk once those operations have ceased.

The process of drilling into mine workings creates a pathway between those workings and the surface through which gases can escape to the surface and air can enter the workings. The area covered by the drilling is therefore at an enhanced risk of gas emissions to the surface unless an absolute seal against the workings can be established. For example, a close pattern of holes may be drilled over an area to be stabilised by grout in order to allow construction of buildings over it. Although grout placed in the workings will provide increased stability, it is not likely to provide a good seal against the movement of gas. The process of drilling can therefore provide a route for mine gas to enter beneath such properties and put the occupiers at risk.

Boreholes provided with an inadequate seal could also produce risks from spontaneous combustion, especially where contacted seams are prone to this phenomenon. Air drawn into abandoned workings during periods of rising atmospheric pressure could potentially lead to a heating especially where the flow is restricted to low velocities.

For these reasons it is imperative that where drilling contacts unworked coal and coal workings the boreholes should be properly sealed (see section 10.8). If buildings are constructed over such boreholes they should have suitable gas protection installed in case of failure of the seals. Gas protection is usually afforded by means of ventilation and sealing. Ventilation beneath properties can help dissipate and dilute any gases, reducing the risk from any gases that enter the property. Sealing is usually carried out by placing a gas proof membrane across the whole footprint of the building and creating a seal around any service entries.

Another potential risk caused by grouting operations is where they restrict the normal flow of gas (or water) through the workings, leading to uncontrolled emissions at another location. Although grouting will not provide a perfect seal against gas (and thereby allow gas to leak to the surface) it is capable of restricting flow. Placing a barrier of grout, therefore, between gas filled mine workings and a normal point of contact with the surface could place the land above those workings at increased risk, especially if any points of weakness are present. If the Coal Authority has specific knowledge regarding relevant gas or water problems at the site of operations or in the surrounding area, this will be provided as part of their permission granting procedures.

10. Practical Measures

10.1 Introduction

If it is anticipated that a drilling operation will encounter unworked coal or former coal mine workings, including shafts and adits, particular risks to site personnel and members of the public must be considered. Precautions to protect those working on the site and any others who may be affected by the works will need to be evaluated before work commences.

Dangers from inhalation of hazardous gases, collapsing ground, ignition of coal seams and migration of gases both within and beyond the site need particular consideration. Practical measures to alleviate or control risk should be taken by the Client, Designer and Contractor.

These measures are intended to focus attention on planning and management of the drilling or piling works from design concept onwards. The aim is to ensure the safety of operatives, the Public and property from hazardous gases.

10.2 Pre-Tender Stage

This is the stage prior to inviting drilling or piling contractors to bid for the work. The Client (see section 4) or their appointed agent has a duty, under CDM Regulations, to provide pre-construction information (PCI) to be supplied with any invitation to tender for drilling or piling works. The PCI should include, but not be limited to, “actual and potential health and safety hazards”. In particular details of anticipated ground conditions, underground structures or watercourses that may affect the safe use of drilling machines and site personnel should be listed. This also includes safety hazards which have the potential to affect adjacent land or occupants of adjacent properties. Other hazards such as buried services should also be identified.

It is recommended that a desk study is carried out to determine;

- Underlying geology of the site.
- Whether coal seams are present.
- Whether the coal seams are known to be susceptible to spontaneous combustion.
- Presence of shafts or workings.
- Dip and strike of the strata.
- Potential gas migration pathways.
- Potential gases that may be encountered or produced.
- Proximity of properties and occupancy potential beyond the site boundaries.
- Site classification (Green, Yellow or Red according to BDA/SISG guidelines).

From the desk study (see Section 8) the principal safety hazards will be identified and forwarded in the pre-construction information pack for potential contractors to consider. Please note that information on the coal seams underlying the site should be compared to the named seams on the Coal Authority’s web site under spontaneous combustion http://coal.decc.gov.uk/en/coal/cms/services/permits/coal_seams/coal_seams.aspx.

It is the Client’s responsibility to apply for the Coal Authority’s permission and this is best done at either pre or post tender stage. Only those who have a long term interest in the drilling or piling works should apply for permission as the applicant must take responsibility for the works and indemnify the Coal Authority for a period of 12 years.

In the urban environment the risk assessment will usually dictate that water flush drilling techniques are required for exploratory or remedial drilling. However it is recommended that Clients obtain the Designer’s advice on drilling methods before applying for permission.

The Coal Authority in considering any application for permission will only grant when it is satisfied that the applicant has applied suitable safeguards to mitigate the potential hazards from its unworked coal and coal workings and it is not uncommon for proposed methodologies to require alteration before permission can be given.

It is important that sufficient time is allocated for permission to be granted and for the agreed methodology to be incorporated into the pre-construction information to be provided to contractors at tender stage. If the bidding contractors are unaware of the agreed methodology then bids submitted may vary and may not be directly comparable. This could result in a bid being incorrectly awarded which could in turn carry financial and contractual issues.

Refer to Section 7 for further details on procedures for applications to The Coal Authority.

The Contractor should ensure that permission has been obtained before commencing site works.

All drilling or piling works which require Coal Authority permission should be formally contracted between the Client, the Contractor and the Subcontractor. Such contracts should be in writing and clearly identify the responsibilities of each party with regard to hazardous gases either on-site or off-site. There should be clear agreement within the contract(s) as to the course of action and by whom in the event of hazardous gases posing a risk to site operatives, the Public or property.

10.3 Planning of Works Prior to Site Operations

This is the stage after contract award when the Contractor will plan for the works using the pre-construction information supplied at tender stage.

The successful Contractor will review the supplied information to determine the coal hazards that could be present, as part of their risk assessment and method statement preparation. The Contractor will provide the Client with its risk assessments and method statements.

The risk assessment shall include a review of both the on-site and off-site conditions and those who may be affected by the site works.

If acting as the Designer the Drilling or Piling Contractor will assess the coal mining circumstance and determine whether there is a potential for any hazardous gases to be either present or created, the potential for pathways to the surface (e.g. presence of adits or mine shafts within or adjacent to the site) and the distance to the nearest on and off site properties, including their type of occupancy. From this the Contractor shall determine whether there is a potential for hazardous gases to emanate at the surface, either on site or beyond the boundaries of the site, which may endanger the operatives or the public.

If there is a risk of gas entering properties, controls need to be put in place. Controls available include:

- The method of drilling – consider whether techniques other than using a flush medium are suitable.
- The flushing medium – water flush will displace smaller volumes of gas.
- Monitoring holes will not prevent gas migration, but monitoring might indicate whether dangerous gases are present.

Where the risk of mobilising and displacing mine gases cannot be eliminated, mitigation measures must be put in place. The principal mitigation method is to install gas alarms in properties which are potentially at risk. Monitoring of gas levels may also be considered to identify any gas ingress below alarm threshold levels. Where there is a significant risk of harm or where the occupants are vulnerable, evacuation should be considered as an alternative.

The Contractor should prepare a Construction Phase Health and Safety Plan, whether the project is notifiable or not under CDM Regulations, as there are elevated risks associated with drilling or piling into coal and former coal workings. The Construction Phase Plan sets out how health and safety is to be managed. The Construction Phase Plan should list all known or significant hazards present on the site. The risks should have been identified from the desk study or other preliminary investigations. Measures to control the risks to health and safety of those working on the site and, where identified, off site, must be included in the Construction Phase Plan.

Measures to be planned for could include but not be limited to;

- Appropriate Personal Protective Equipment (PPE) for site workers.
- Appropriate Respiratory Protective Equipment (RPE) for site workers.
- Gas monitoring equipment and procedures (see Section 6.6).
- Gas alarms.
- Suitable and sufficient material on site to seal boreholes in an emergency.
- Evacuation procedures.
- Fire control measures e.g. no naked lights, smoking, flammable liquid storage.
- Shutdown procedures.
- Blow out preventer.
- First aid.
- Training.

The Contractor should use the drilling flush method stipulated in the application for the Coal Authority's permission. If the Contractor considers from the risk assessment that a different drilling flush could be used safely, an application for an amendment to the Coal Authority permission shall be made and agreed prior to changing the flush method.

If off site gas monitoring is identified by the risk assessment then monitoring and early warning systems should be implemented where practicable and permitted. In all circumstances where monitoring equipment or alarms have been installed the Contractor shall ensure that the occupant has been briefed on their operation and has understood the requirement for them.

If an occupier refuses to allow gas monitors then the Contractor must reassess the risks and if required adopt other suitable mitigation measures. If the risks cannot be effectively mitigated and significant danger to the public remains then work must not proceed.

It should be noted that monitoring of specific perimeter holes is unlikely to protect properties adjacent to the site. Whilst these holes may intersect mineworkings, other unconnected mineworkings and pathways may exist elsewhere.

It is recommended that where requests to install gas monitors have been refused then the reasons for permission not being granted are recorded.

The Contractor following all the above processes will have established site specific safe systems of work for the contract which will include a contingency emergency plan.

10.4 Management of On-Site Works.

This is the stage when the Contractor should ensure that the planned safe systems of work are strictly followed during site operations. The Contractor should not commence work until emergency contingency plans are in place both on and off site as required.

Where flammable gases are possible no naked lights, smoking, or storage of flammable liquids should be permitted within a minimum of 15m of the borehole. This zone can be extended should the risk assessment or prevailing conditions dictate. Consideration should be given to the direction of the wind. Suitable warning notices should be posted warning of the restrictions and dangers.

If the safe system of work includes gas monitoring equipment then the equipment should be available on site and used by trained personnel to monitor the works. Refer to Section 6.5 for details. Gas monitoring must be undertaken at the top of the borehole prior to starting the rig or other plant to ensure the absence of flammable gases.

Where the borehole position has to be fenced off then escape routes must be set up and kept clear while drilling or piling operations are continuing.

Emergency control measures should be ready to be implemented if required.

10.5 Monitoring

Refer also to Section 5.6.

This is the stage when the Contractor should ensure that the planned gas monitoring is strictly followed during site operations and from the start of drilling operations into permeable strata.

Prior to any gas monitoring the Contractor should ensure that the monitor is calibrated with inspection certificates available for inspection and that the appropriate drill crew are trained to operate the gas monitoring equipment. It is recommended that a reading is taken in fresh air to check that the sensors are reading correctly. When drilling into any unworked coal or coal workings **this guide recommends that monitors / alarms should routinely sample for carbon dioxide, carbon monoxide, methane and oxygen**. Carbon dioxide readings can be inferred from low oxygen readings which usually have a direct correspondence, but this is not always the case and slight changes in displayed oxygen concentrations are not uncommon in monitors. The presence of hydrogen sulphide is very rare and is apparent by its smell even at very low levels. Hydrogen is also very rare within mineworkings and can be monitored indirectly by a combustible gas meter if this gas is suspected. Should a flammable gas be recorded by this means and there is little or no methane then hydrogen may be present. Laboratory tests would be required to confirm the identity of the combustible gas.

If hazardous gases are expected to be encountered and the boreholes are close to the site boundary or adjacent properties then monitoring boreholes around the perimeter may be beneficial, in addition to the monitoring of the properties, when using air or air/mist and these should be monitored when coals or workings (broken ground) are encountered in the “production” borehole.

If hazardous gases are detected at either the top of the borehole or at any of the monitoring points then awareness of a potential gas problem will be heightened. If gases are detected in the general working area, in concentrations above the trigger levels (see Section 5.6.2), or if any of the gas alarms are activated then the drilling supervisor should be informed and he should make an assessment of the situation and determine suitable actions to take. Where the concentrations detected in the general working area exceed suggested action levels, drilling should cease and all personnel be withdrawn from the affected area. If withdrawal takes place there should be no return to the affected area until a competent person has investigated and assessed that it is safe to do so.

Where gas monitors/alarms are fitted inside buildings, on or off site, these should, where practicable, be inspected by the Contractor’s site management at the time of any hazardous gas levels being detected on or off site. Those inspecting the gas monitors/alarms should carry personal gas monitors and test the atmosphere before entering any building, basement or room. If gas monitors within buildings cannot be inspected at this time e.g. locked residential housing, then this should be noted and provision made to alert occupants, before they enter these properties, to immediately check for elevated gas readings.

Hazardous gases are sometimes encountered under pressure when drilling and piling and it may be necessary to allow a hole to vent for a while until the pressure in the mineworkings drops and the emanating gas reaches safe levels. In circumstances where high levels continue a decision may have to be made to seal the borehole.

Gas monitoring equipment installed inside buildings should have suitable alarms to warn the occupants to take action and this may include the provision of special alarms for occupants with hearing difficulties. All such equipment must be calibrated, in good working order and if battery operated should be installed with new cells. The Contractor must provide additional batteries in a timely manner so that monitors/alarms are never non–operational.

Building occupants must be briefed on the dangers from hazardous gases and what actions to be taken if gases are detected entering the building. Where gas monitors/alarms are fitted inside buildings these could also be monitored by the Contractor at suitable intervals as required.

Spontaneous combustion sometimes only becomes apparent when smoke starts appearing out of the open hole. Monitoring of drilled holes should provide an early indication of a problem if high levels of carbon monoxide are detected.

10.6 Rig Operations

This is the stage when the Contractor should start work after implementing all identified safe systems. Before commencing work all site personnel should have a site induction. The induction should include, but not be limited to, the hazardous gas information and instructions contained in the Construction Phase Health & Safety Plan. If required by the Construction Phase Health & Safety Plan, persons off site who may be affected by the works should be informed of precautions prior to operations commencing. Where warning alarms and monitoring is required then it should be in position and operable prior to operations commencing. All drilling crew should have basic hazardous gas training and should be aware of the recommended trigger levels. All on site personnel should have appropriate PPE and RPE (as identified by the risk assessment).

When drilling into coal seams where the depth of coal is definitively known the Contractor may choose to employ a different flush prior to encountering the coal, former workings or overlying broken ground and permeable deposits (e.g. air flush through superficial deposits and water flush through rock). The switch to the agreed flushing medium, as specified during the obtaining of the Coal Authority permit, must be made in a timely manner to ensure a suitable standoff distance is maintained between any potentially hazardous areas and the drill bit.

10.7 Spontaneous Combustion

If a seam is likely to be contacted which could be prone to spontaneous combustion then a non air based flush should be the primary method used to drill the holes. In practice this will usually be water flush. Depending on the other drilling risks, there may be occasions when air flush drilling cannot be avoided, but in such circumstances there must be strict monitoring of the holes (along with any other precautions which the risk assessment determines) to determine if any signs of combustion are apparent. If any such signs are noted then the holes must be sealed and to this end grout and suitable equipment must be available on site to enable this to take place without delay.

Where conditions of a possible heating are detected management should be informed immediately. If still drilling, the drill flush should be switched off, and where it is safe to do so CO should be continuously monitored, the drill string should be removed and the rig moved off the borehole position. Open holes and any coal workings encountered should be grouted without delay to seal the fire from the air/oxygen. Consideration should be given to the inclusion of down hole temperature sensors to monitor the situation and ensure that the heating has been confined.

DO NOT INSTINCTIVELY INJECT WATER INTO A COAL SEAM WHICH IS ON FIRE. Water added to burning coals can dissociate, releasing oxygen and hydrogen leading to an uncontrolled and unpredictable explosion. No further drilling should be undertaken other than for controlling the fire/heating and this should only be undertaken following a specialist risk assessment.

The Site Manager/Engineer should arrange for a site meeting to inform all interested parties of the situation and co-ordinate an action plan to control the heating and assess the implications on properties adjacent the site, including hazardous gas migration, especially up dip from the incident. The Site Manager/Engineer should also ensure that the Fire Brigade has been notified and informed that water is unlikely to be an appropriate medium for extinguishing a coal seam fire.

Long term, monitoring will also be required to ascertain whether the heating has been controlled, which could involve the drilling of monitoring holes nearby.

The Site Manager/Engineer should inform the Coal Authority of any incident at the earliest practicable opportunity.

10.8 Borehole Backfilling

Open boreholes, which intersect unworked coal and former coal workings, are a pathway which can allow potentially hazardous mine gases to emanate at the surface, and furthermore can allow the ingress of air which could trigger a spontaneous combustion event.

On completion of each borehole it should be temporarily plugged or sealed pending permanent sealing at the earliest practicable opportunity, having regard to the proposals for operational needs and site stabilisation. Boreholes left open for monitoring purposes must be provided with a cap or seal pending permanent sealing upon abandonment. Where indications of a spontaneous event are detected the hole and any workings encountered should be grouted immediately, having regard to the fact that monitoring equipment may need to be installed down hole, to assess whether the incident has been contained.

All temporary plugs, caps and seals must be robust, effective in preventing the movement of gases in or out of the borehole and tamper proof if being left on an unsecured site.

For site investigation and other non treatment holes permanent sealing should be affected with a suitable cementatious based material and should have the following properties:

- Be throughout the full depth of the borehole.
- Be injected through a grout pipe / tremie from the bottom of the hole upwards.
- Contain suitable and sufficient swelling material, such as bentonite, to inhibit shrinkage and ensure a good seal with the sides of the borehole.
- Once set, should be chemically inert.

For boreholes drilled for the treatment of mine workings, permanent sealing should be affected with the specified infill grout. This should be injected until the grout overflows at the surface and then the casing should be pressurised to ensure the hole is completely full.

If any grouting materials contain blast furnace cement or fly ash they should meet the waste quality protocols as detailed on the Environment Agency's website http://www.environment-agency.gov.uk/business/topics/waste/32154.aspx.

10.9 Off Site Considerations

The Contractor must consider the risks from hazardous gases being present in and around coal seams and former mineworkings and also from the operation spontaneously combusting (heating) the coal. This will also produce hazardous gases, which, dependent upon the flush being used, can move gases over considerable distances and possibly off site.

Due to this potential for hazardous gases to be forced out beyond the site boundaries the Designer and Contractor must also consider the risks to those beyond the site boundaries before work commences.

Different types of occupiers will have different risks. Those in commercial properties may be less at risk than residential occupants. Commercial building occupiers may accept hazardous gas monitoring and be suitably trained to respond to any alarms. Doors and windows may be opened providing some ventilation. Residential property occupiers may not be willing to have hazardous gas monitoring installed in their homes and may have their doors and windows closed for long periods during the day. Alarms installed in residential properties may have to alert sleeping occupants or those with hearing and mobility issues.

Given the unacceptably high risks to members of the Public, the prevention of the production of hazardous gases and the forcing of hazardous gases off site into adjacent occupied residential buildings should be prevented.

The distance gases can be forced along coal seams or workings is not able to be calculated with any reasonable degree of certainty. On very limited tests, at one site, indications were that under certain specific conditions the flow from the air flush drilling was not detected in test holes much beyond 50m. It has to be emphasised that the results were specific to the ground conditions at the particular site and cannot be considered representative of other sites.

Air flush drilling will create the furthest flow of gases through fractured coals than open worked seams due to size of voids. Considerable quantities of flush blows out of the top of the borehole with cuttings until a void is encountered at which point the “flush is lost”. The air flush down the borehole will take time to pressurise the voids before the flush flows back out of the top of the borehole. However the flush may not return depending on the size of void and the degree of rock/coal fracturing which can allow flow of flush through fractures and even out of other boreholes. There is also the potential for the flush to follow the fractures in seams which can outcrop beneath property, excavations, sewer systems, culverts or other sub-surface structures, presenting risks to personnel who may be working or living in the structures. Other structures that could be at risk from hazardous gases, particularly flammable gases, are lighting columns.

The examples given are not exhaustive and an assessment of the risks to any structures adjacent to the site needs to be considered.

10.10 Emergencies

An emergency plan must be in place which should take into account the risks of spontaneous combustion, and hazardous gases emanating off site where property exists.

The Emergency Plan must be suitable for dealing with the risks identified in the site risk assessment and be able to be implemented immediately.

The Site Manager/Engineer or Drilling/Piling Supervisor should have access to a list of emergency contact names and telephone numbers from where they can obtain advice and report abnormal situations.

Consideration must be given to the evacuation of properties at risk and the possible requirement to house residents in temporary accommodation.

If methane or coals ignite, the Drilling/Piling Supervisor should immediately notify their Manager.

Injured personnel should be treated by their First Aider. A BDA Audited Lead Driller is qualified in first aid; however, if they are injured or the injured person has suffered significant injuries the Ambulance Service should be called immediately.

In the event of an underground heating, the Site Manager/Engineer or Drilling/Piling Supervisor shall contact the Fire Brigade stipulating that water is unlikely to be an appropriate medium for extinguishing a coal seam fire.

If any flames at the surface are perceived to be moderate to low then attempts to extinguish the flame using carbon dioxide or powder fire extinguishers may be attempted, but it should be recognised that the source of the flames may be many metres down the hole and as such this may have little effect on the fire.

Where the borehole site needs to be evacuated other site personnel should be informed of the incident and the need to clear the borehole site. Where necessary, especially if boreholes are to be left to vent overnight, the borehole site should be fenced, with suitable warning signs posted, to prevent unauthorised personnel accessing the area where they would be at risk.

The Site Manager/Engineer should inform the Coal Authority of any incident at the earliest practicable opportunity, using the Coal Authority's emergency call-out number **01623 646333**.

10.11 Reporting and Recording

The method and date of boring, water strikes, flush and prevailing strata found during boring operations will be recorded by the Drilling/Piling Supervisor in their company's record sheet. The subsequent method of backfilling should also be recorded in the borehole logs (see Section 10.8)

The Drilling/Piling Supervisor or Site Engineer will monitor the gases from the hole and record the results. Additionally the atmospheric pressure and flow of gases at the borehole head should be noted.

The following gases are to be recorded; methane, carbon dioxide, oxygen and carbon monoxide. Where there is reason to suspect other gases these should also be determined e.g. hydrogen sulphide, ethane, propane and hydrogen. If a flammable gas monitor is used and detects gases and there is little or no methane found by the other method then hydrogen may be present. Minor gases generally require a sample to be submitted to an Analytical Laboratory for chromatographic analysis.

The person carrying out the monitoring should be suitably trained and familiar with the specific instrument being used and what procedures are to be carried out should gas concentrations increase to levels of concern. Modern instruments can have alarm values set to warn operatives of approaching concentrations of hazardous gas levels.

Significant incidents such as emissions of hazardous gases into property or spontaneous combustion should be reported to the Coal Authority at the earliest practicable opportunity, using the Coal Authority's emergency call-out number **01623 646333**. Furthermore such incidents along with gas monitoring results should be included within the validation/completion report which is required to be sent to the Coal Authority under the terms and conditions of a Permit. Site works are considered by the Coal Authority to be ongoing until a completion report is received.

Appendices

Appendix A - Case Studies

Case 1

Following reports of subsidence below a large pharmaceutical works in the north east of England the Coal Authority was called upon to investigate and subsequently carry out remedial stabilisation grouting under the occupied control building of the plant. As the building was clearly unstable it was decided that water flush drilling could not be used as this could worsen the underground conditions resulting in further damage to the structure. The works were undertaken as part of a CDM project and during the design stage and at pre start meetings the potential for mine gases within unrecorded workings had been considered along with possible unrecorded gas migration pathways. As well as monitoring for gases adjacent to the drill string the risk control measures called for the installation of a series of gas monitoring meters at strategic places within the control building along with emergency evacuation procedures should the alarms have sounded. Furthermore lone working procedures were established for certain areas of the building involving personal gas alarms and 2 way radios.

The work involved drilling down to 25 metres into unrecorded shallow coal mine workings which were thought to contain voids of up to 5m. A series of holes had been established around the perimeter of the building when carbon dioxide was recorded at 2% v/v blowing out of one of the last holes to be drilled. At this stage the drill string was pulled out and the gas was allowed to vent into the atmosphere discharging the pressurised void of gas (approximately 5 hours duration). None of the monitors in the buildings recorded any carbon dioxide and it decided that there was no reason to evacuate the buildings.

Carbon dioxide emissions at these levels could have had very serious consequences, especially within a confined space, however the risk assessment and control measures employed ensured that the works were undertaken safely and no one was injured.

Case 2

At 3 am a father of three was awakened by the noise of a carbon monoxide detector downstairs. He struggled for over half an hour to wake up his family who were in a very deep sleep like state. Although the detectors had been installed many years ago by a former owner of the property, this was the first time they had gone off.

Three days before this incident a drilling company had begun to work at a site which bordered the house. This was the preliminary phase of a house building project and they had been contracted by a developer to remediate the site, by drilling to locate the underground mine workings and then grout the voids.

The site was located over a coal seam which the Coal Authority had identified as a seam which had a high risk of spontaneous combustion. The drilling company had not consulted the Authority prior to the work commencing and thus did not have the appropriate amount of information on which to make an adequate assessment of the risks of drilling in this area. They were drilling using air flush and left several boreholes open in order to establish the gas levels rising from the holes. However, this only made the situation worse.

The following morning, HSE inspectors arrived on the site and suggested additional measures to be taken by the drilling contractor before the drilling could recommence. This included re-housing the family in a hotel, venting the house using fans and negative pressure units, creating a trench on the perimeter to trace the pathways and adopting a better testing regime for CO movement. This placed a huge additional cost upon the drilling company which could have been avoided by a desk study and use of the Coal Authority's expertise of the location of high risk sites.

HSE hadn't encountered this problem before but has helped with this guidance which represents reasonably practicable precautions to address the issue. Whilst this guidance is not compulsory, assessing and controlling risk is, and those who fail to do so may expect formal enforcement action to be considered.

Case 3

A Drilling Contractor was commissioned to drill into coal measures strata to determine the engineering properties of the ground prior to the construction of a new building.

A desk study had been undertaken and being in coal mining area this included an assessment of the mining risk. The coal mining report had indicated that shallow coal was likely to be present below the site and further investigation had narrowed this down to a zone of between 10m to 20m below the surface. The properties closest to the site were about 50m from the nearest borehole and the seam which was anticipated was not known to be susceptible to spontaneous combustion. The risk of hazardous gases being present in the workings and the potential for pathways to be present was considered but was not able to be quantified and as such it was assumed that they could be present.

The Coal Authority's Permissions team had been contacted and the agreed methodology had been that the contractor would use air mist flush through the overburden into rock before changing to coring techniques employing air mist flush within the rock. After encountering rock the contractor would check for hazardous gases each time rods were added. The overburden was typically 0.9m of loose fill material over 6.8m of boulder clay, with a sandstone rockhead.

At 11.6m, within the sandstone a 0.3m deep void was encountered, the flush return was lost and drilling stopped. The borehole was checked for the presence of hazardous gases. Elevated concentrations of carbon dioxide, 9.9% v/v, and low levels of oxygen, 6.4% v/v were found.

The Lead Driller stopped drilling and informed the Site Engineer who contacted the organisations Contracts Manager for instruction. The Contracts Manager called a meeting with the Client, their Safety and Geotechnical Managers to discuss the situation.

It was considered that the likely source of the gas was from coal workings below through broken ground created by the collapsing of the workings.

As the gas encountered was at dangerous concentrations it was decided to carry out a gas spike survey adjacent to the residential premises nearby. No hazardous gases were detected. Coring was allowed to proceed but it was decided to utilise water flush, along with gas monitoring, to ensure that the gases could not be mobilised and displaced.

The first coal workings were encountered at 15.8m and the flush was stopped and gases within the borehole checked. Again elevated carbon dioxide, 3.3% v/v, was found with low levels of oxygen, 17.5% v/v. No other gases were detected.

Coring proceeded with gas monitoring each time a drill rod was added. A further set of coal workings were encountered at 20.6m and again a check for gases undertaken. No hazardous gases were detected.

Coring stopped at the required depth and a gas monitoring installation was inserted into the borehole with post site monitoring carried out by the Consultant Engineer for a period of 6 months, over differing barometric conditions.

Case 4

A series of drilling tests were carried out at the location of a planned opencast site where exploratory drilling operations had been ongoing. A line of six boreholes using air flush was drilled extending over a distance of 60m with the shortest separation of the holes 5m and the longest 20m. The seams in this location were prone to spontaneous combustion. The drilling encountered mining voids at different seam levels. The degree of voiding suggested that the mine workings were still substantially open rather than collapsed. Continuous monitoring on the second drilled hole during the drilling operations indicated peak levels of about 5% v/v carbon dioxide. However these peaks were also associated with peaks of carbon monoxide in excess of 30ppm and hydrogen in excess of 100ppm.Pressures at the drilled holes were monitored during drilling of the next hole when it contacted void or broken ground. Recorded pressures due to the air flush did not exceed 5Pa, which was of the same order as the pressures potentially induced by wind moving over the site. However, flows were detected at the drilled holes out to 60m where they reached a level indistinguishable from wind induced flow, Nevertheless, on drilling the final hole it was found that at the first three holes, at distances between 50m and 60m away, the carbon dioxide concentration rose from about 5% v/v to between 8.7% and 10%. This final result appears to indicate that another body of mine gas had been contacted and was being displaced into a location over 50m away.

Appendix B - Legislation, Standards and Industry Guidance

The following is some of the principal legislation applicable to drilling within coal and former mine workings at the time of publication. This list is by no means comprehensive and users of this guidance are advised to make themselves aware of all the current legislation which may be applicable to their particular work activity.

Acts

The Health & Safety at Work etc Act, 1974 (HSWA)

Applies to most work activities and places a variety of duties on employers, the self-employed, and employees. The Act lays down the general principles for managing health and safety for all work activities. It places a duty to ensure, so far as is reasonably practicable, the health, safety and welfare of those employed and others who may be affected by the work activity, including the general public. HSWA also places similar duties on those who own premises, to the extent of their control, to ensure that work taking place there is carried out safely.

Regulations

Construction, Design and Management Regulations 2007 (CDM)

CDM applies to all construction work. This is defined within the regulations and includes most of the work described in this guidance. It provides a description of persons involved in construction work and assigns specific duties to them. This includes client, principal contractor, designer and contractor. These duties are explored in greater detail in Section 4 of this document.

Management of Health and Safety at Work Regulations 1999 as amended (MHSWR)

Imposes a duty upon an employer to assess the entire health and safety operational arrangements of their organisation. The duty applies to most types of work activity and includes the following requirements:

- Assess the risk to health and safety of employees and other persons who could be affected by the work activity. Where there are more than five employees this should be written down.
- Implement measures shown by the risk assessment to be necessary to adequately manage these risks.
- Ensure that only trained persons carry out these activities.
- Set up emergency procedures for foreseeable risks.
- Supply employees with adequate information with regard to health and safety.

Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)

Dangerous substances can put people's safety at risk from fire and explosion. DSEAR puts duties on employers and the self-employed to protect people from risks to their safety from fires, explosions and similar events in the workplace. This includes members of the public who may be put at risk by work activity.

Dangerous substances are any substances used or present at work that could, if not properly controlled, cause harm to people as a result of a fire or explosion. They are especially relevant to the drilling industry as they include such things as flammable gases and explosible dusts.

What does DSEAR require?

Employers must:

- Find out what potentially explosible substances are in their workplace and what the level of risk is.
- Put control measures in place to either remove those risks or, where this is not possible, control them.
- Put controls in place to reduce the effects of any incidents involving dangerous substances.
- Prepare plans and procedures to deal with accidents, incidents and emergencies involving dangerous substances.
- Make sure employees are properly informed about and trained to control or deal with the risks from the dangerous substances.
- Identify and classify areas of the workplace where explosive atmospheres may occur and avoid ignition sources (from unprotected equipment, for example) in those areas.

The Building (Approved Inspectors etc.) Regulations 2010

The Building Regulations are made under powers provided in the Building Act 1984 and the majority of building projects are required to comply with them. They exist to ensure the health and safety of people in and around all types of buildings (i.e. domestic, commercial and industrial).

The Building Regulations contain various sections dealing with definitions, procedures, and what is expected in terms of the technical performance of building work and set out the ‘requirements’ with which the individual aspects of building design and construction must comply in the interests of health and safety .

Practical guidance on ways to comply with the functional requirements in the Building Regulations is contained in a series of Approved Documents. The document which will be of particular interest with regard to the drilling and piling industry is “Approved Document C - Site preparation and resistance to contaminants and moisture”.

For the purposes of this document gases associated with coal mining are classed as contaminants.

From 31 December 2011 the power to make Building Regulations for Wales has been transferred to Welsh Ministers. The Building Regulations 2010 and related guidance, including Approved Documents as at that date will continue to apply in Wales until Welsh Ministers make changes to them.

More information is available on the following web site:
http://www.communities.gov.uk/planningandbuilding/buildingregulations/brlegislation/

The Building (Scotland) Amendment Regulations 2010

The Building Regulations are made under powers provided in the Building (Scotland) Act 2003 and came into force on October 1, 2010. This has resulted in changes to mandatory standards and associated guidance, and the publication of new documents.

More information is available on the following web site:
http://www.legislation.gov.uk/ssi/2010/32/contents/made

Confined Spaces Regulations 1997

A confined space is a place which is substantially enclosed (though not always entirely), and where serious injury can occur from hazardous substances or conditions within the space or nearby.

Employers must carry out a suitable and sufficient risk assessment for all work to be undertaken and put in place appropriate control measures to ensure safety.

It should be noted that whilst some risks may be a feature of the confined space itself, others, as could be the case for drilling, may be caused by particular work activities carried out there.

For example, if gases were to emanate from unworked coal or mine workings whilst drilling in or near a substantially enclosed space there would be a serious risk of asphyxiation or explosion and as such the area should be defined as a confined space.

The Control of Substances Hazardous to Health Regulations 2002 as amended (COSHH)

Provide a framework for the control of substances at work that may be hazardous to health, for example, substances that are toxic, cause irritation or are corrosive. Organisations must make an assessment of the risks from the hazardous substance and decide on control measures to prevent harmful exposure. A hierarchy of control is established: elimination; substitution; reduction; control.

Provision and use of Work Equipment Regulations 1998 as amended (PUWER)

These regulations place a duty on employers to ensure that they:

- Select the right equipment to perform the task.
- Ensure this equipment is inherently safe to use, in good working order and inspected and maintained in line with manufacturers recommendations.
- Ensure that equipment is operated by persons trained in its use and familiar with its specific control systems.
- Prevent access to dangerous moving parts of machinery.

The Lifting Operations and Lifting Equipment Regulations 1998 as amended (LOLER)

The Regulations require that lifting equipment provided for use at work is:

- Strong and stable enough for the particular use and marked to indicate safe working loads.
- Positioned and installed to minimise any risks.
- Used safely, i.e. the work is planned, organised and performed by competent people.
- Subject to ongoing thorough examination and, where appropriate, inspection by competent people.

What equipment is covered by the Regulations?

Lifting equipment includes any equipment used at work for lifting or lowering loads, including attachments used for anchoring, fixing or supporting it. The Regulations cover a wide range of equipment including cranes, fork-lift trucks, lifts, hoists, mobile elevating work platforms, and drill rigs. The definition also includes lifting accessories such as chains, slings, eyebolts etc.

If you allow employees to provide their own lifting equipment, then this too is covered by the Regulations.

British Standards

The following are some British Standards which may be useful for both background reading on related activities and for further information on some of the issues raised in this guidance. This list is by no means comprehensive and users of this guidance are encouraged to make themselves aware of all Standards which may be applicable to their particular work activity.

BS EN 791:1996 + AMD2: 2008 - Drill rigs. Safety (currently under review and will be superseded by

BS EN 16228: Drilling and foundation equipment - Safety)

BS 8485:2007 Code of practice for the characterisation and remediation from ground gas in affected developments. (currently under review)

BS EN 1127-1:2007 - Explosive atmospheres. Explosion prevention and protection. Basic concepts and methodology.

BS EN 1997-1:2007 - Eurocode 7 Geotechnical design. General Rules.

BS EN 1997-2:2007 - Eurocode 7. Geotechnical design. Ground investigation and testing.

BS 5930:1999+A2:2010 - Code of practice for site investigations. (currently under review)

BS EN 1127-2:2002+A1:2008 - Explosive atmospheres. Explosion prevention and protection. Basic concepts and methodology for mining.

BS EN 1536:2010 - Execution of special geotechnical work: Bored piles.

BS 10175:2011 - Investigation of potentially contaminated sites. Code of practice.

BS EN 12699:2001 - Execution of special geotechnical work: Displacement piles.

BS EN 14199:2005 - Execution of special geotechnical work: Micropiles.

BS EN ISO 22475-1:2006 - Geotechnical investigation and testing. Sampling methods and groundwater measurements. Technical principles for execution.

BS EN 50104:2002 - Electrical apparatus for the detection and measurement of oxygen. Performance requirements and test methods.

BS EN 60079-29-2:2007 - Explosive atmospheres. Gas detectors. Selection, installation, use and maintenance of detectors for flammable gases and oxygen.

BS EN 61779-1:2000 - Electrical apparatus for the detection and measurement of flammable gases. General requirements and test methods.

BS EN 61779-2:2000 - Electrical apparatus for the detection and measurement of flammable gases. Performance requirements for group I apparatus indicating a volume fraction up to 5% methane in the air.

BS EN 61779-3:2000 - Electrical apparatus for the detection and measurement of flammable gases. Performance requirements for group I apparatus indicating a volume fraction up to 100% methane in air.

BS EN 61779-4:2000 - Electrical apparatus for the detection and measurement of flammable gases. Performance requirements for group II apparatus indicating a volume fraction up to 100% lower explosive limit.

BS EN 61779-5:2000 - Electrical apparatus for the detection and measurement of flammable gases. Performance requirements for group II apparatus indicating a volume fraction up to 100% gas.

Industry Guidance

The following are published by various industry bodies and may be useful for both background reading on related activities and for further information on some of the issues raised in this guidance. This list is by no means comprehensive and users of this guidance are encouraged to make themselves aware of all industry guidance which may be applicable to their particular work activity.

AGS : 2006 : A Client's Guide to Desk Studies. Association of Geotechnical and Geoenvironmental Specialists.

BDA : 2000 : Guidance Notes for the Protection of Persons from Rotating Parts and Ejected or Falling Material Involved in the Drilling Process. British Drilling Association.

BDA: 2002 : Health and Safety Manual for Land Drilling – A Code of Safe Drilling Practice. British Drilling Association.

BDA : 2005 : Guidance for the Safe Operation of Cable Percussion Rigs and Equipment. British Drilling Association.

BDA : 2007 : Guidance for the Safe Operation of Dynamic Sampling Rigs and Equipment. British Drilling Association.

BDA : 2008 : Guidance for Safe Intrusive Activities on Contaminated or Potentially Contaminated Land. British Drilling Association.

BRE : 1990 : Site Investigation for Low Rise Building: Desk Studies. Digest 318. Building Research Establishment.

BRE : 2003 : Building on Brownfield Sites: Identifying Hazards. Digest GBG 59 Part 1. Building Research Establishment.

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CIRIA : 1996 : A Guidance for Safe Working on Contaminated Sites. Report 132. Construction Industry Research and Information Association. ISBN 0 86017 451 4.

CIRIA : 1999 : Environmental Issues in Construction – A Desk Study. Project Report 73. Construction Industry Research and Information Association.

CIRIA : 2007 : C665 - Assessing risks posed by hazardous ground gases to buildings (revised) Construction Industry Research and Information Association.

CIRIA : 2010 : C692 - Environmental good practice on site (third edition). Construction Industry Research and Information Association.

EA : 2002 : Piling into Contaminated Sites. Environment Agency.

ESA : 2005 : ICoP 1, DSEAR for the Waste Management Industry. Industry Code of Practice. Environmental Services Association.

ESA : 2007 : ICoP 4, Drilling into Landfill Waste. Industry Code of Practice. Environmental Services Association.

FPS: 2010 : Notes for Guidance on PUWER (Regulations 11 & 12) in Relation to Guarding and Cleaning of Augers on Piling Operations.

GSHPA: 2011 : Closed Loop Vertical Borehole Design, Installation & Materials Standards. Ground Source Heat Pump Association.

HSE : 1981 : The Health & Safety (First-Aid) Regulations. Approved Code of Practice and Guidance, L74. Health & Safety Executive. ISBN 0 7176 1050 0.

HSE : 1991 : HSG 66 Protection of Workers and the General Public During the Development of Contaminated Land. Health & Safety Executive. ISBN 0 11 885657 X.

HSE : 1993 : Health Surveillance under COSHH. Guidance for Employers. Health & Safety Executive. ISBN 0 7176 0491 8.

HSE: 1997 : Safe Work in Confined Spaces. Approved Code of Practice, Regulations and Guidance: Health & Safety Executive. ISBN 0 1106 4643 6.

HSE : 1998 : L22 Safe Use of Work Equipment. The Provision and Use of Work Equipment Regulations. Approved Code of Practice and Guidance. Health & Safety Executive. ISBN 0 7176 1626 6.

HSE : 1998 : L113 Safe Use of Lifting Equipment. The Lifting Operations and Lifting Equipment Regulations. Approved Code of practice and guidance. Health & Safety Executive. ISBN 0 7176 1628 2.

HSE : 1998 : HSG 53 The Selection, Use and Maintenance of Respiratory Protective Equipment. A

Practical Guide. Health & Safety Executive. ISBN 0 7176 1537 5.

HSE : 1999 : HSG 61 Health Surveillance at Work (revised). Health & Safety Executive. ISBN 0 7176 1705 X.

HSE : 2005 : EH 40 - Occupational Exposure Limits: Health & Safety Executive.

HSE : 2007 : Managing Health and Safety in Construction: Construction (Design and Management) Regulations. Approved code of practice and guidance. Health and Safety Executive.

NHBC: 2007 : Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present. National House Building Council.

NHBC/Environment Agency/CIEH: 2008 : R & D 66 : Guidance for the Safe Development of Housing on Land Affected by Contamination.

SISG : 1993 : Guidelines for the Safe Drilling of Landfills and Contaminated Land. Institution of Civil Engineers, Site Investigation Steering Group – Thomas Telford.

SISG: 2011 : UK Specification for Ground Investigation. Second Edition. Institution of Civil Engineers, Site Investigation Steering Group – ICE Publishing.

Appendix C - Regulatory Agencies and Trade Bodies

Health & Safety Executive (HSE)

The Health and Safety at Work etc Act 1974 established the enduring principle that those who create risk are best placed to manage it. The Act led to the formation of the Executive (HSE). HSE is responsible for regulation of health and safety within specific industries, these include factories, construction sites, agriculture, mining, nuclear sites and chemical industries. HSE provides strategic direction for health and safety. It does this by inspection, investigation and enforcement, and other key activities including research, creating regulations and codes of practice, alerting duty holders to new and emerging risks and providing information and advice.

The Coal Authority (CA)

The Coal Authority is a Non-Departmental Public Body sponsored by the Department of Energy and Climate Change and established by the Coal Industry Act 1994. Its duties include the holding and managing of the rights and interests in unworked coal and former mines of coal, licensing of coal mining operations, the provision of coal mining information and certain functions in respect to coal mining subsidence.

Environment Agency (EA)

The Environment Agency is an Executive Non-Departmental Public Body responsible to the Secretary of State for Environment, Food and Rural Affairs and an Assembly Sponsored Public Body responsible to the National Assembly for Wales.

Its principal aims are to protect and improve the environment, and to promote sustainable development. It plays a central role in delivering the environmental priorities of central government and the Welsh Assembly Government through its functions and roles.

Scottish Environmental Protection Agency (SEPA)

The Scottish Environmental Protection Agency is a Non-Departmental Public Body, accountable through Scottish Ministers to the Scottish Parliament. Its main role is to protect and improve the environment by regulating activities that can cause harmful pollution and by monitoring the quality of Scotland's air, land and water. The regulations it enforces also cover the keeping, use and the accumulation and disposal of radioactive substances.

Local Government

Local government is the collective term for local councils, sometimes referred to as local authorities. Local authorities work within the powers laid down under various acts of parliament. Their functions are far-reaching. Some functions are mandatory, others are discretionary.

Councils can either provide services directly to the public or arrange for others to do so e.g. approved inspectors in the case of Building Regulations. The local authority has a general duty to enforce the Building Regulations in its area and will seek to do so by informal means wherever possible. This duty extends to and forms a part of its function when it is carrying out the Building Control Service. Local authorities have enforcement powers to require you to alter work, which does not comply with Building Regulations, if they consider it necessary.

The British Drilling Association (BDA)

The British Drilling Association (BDA) was founded in 1976 and is the trade association for those associated with ground drilling activities. Comprising some 115 company members, it includes contractors, manufacturers and suppliers amongst others.

The range of member activity incorporates ground investigation, geotechnical processes & ground stabilisation (grouting, anchoring etc.), waterwell, mineral exploration, geothermal, landfill and other ground drilling. The BDA's mission statement is "Committed to Excellence in Health & Safety, Quality of Workmanship and Technical Standards for the Benefit of the Drilling Industry and its Clients".

The Association of Geotechnical & Geoenvironmental Specialists (AGS)

The Association of Geotechnical & Geoenvironmental Specialists (AGS) is a trade association established to improve the profile and quality of geotechnical and geoenvironmental engineering. The membership comprises organisations and individuals having a common interest in site investigation, geotechnics, geoenvironmental engineering, engineering geology, geochemistry, hydrogeology and other related disciplines.

The Federation of Piling Specialists (FPS)

The Federation of Piling Specialists (FPS) represents piling and foundation contractors. FPS's principal objectives are to maintain and improve standards and seek technical excellence in all of members' activities in carrying out piling, embedded walling and other specialist foundation techniques. All Members are audited by an independent auditor on a regular basis to ensure that high standards are maintained in technical ability, quality management, safety, training and environmental practice.

Ground Source Heat Pump Association (GSHPA)

The Ground Source Heat Pump Association (GSHPA) is a trade association which encourages the growth and development of the ground source heat pump industry by promoting the efficient and sustainable use of ground source heat pumps; raising awareness of the benefits of ground source heat pumps; developing ground source installation standards, and encouraging high standards of training for the industry.

Appendix D - Useful Contacts & Addresses

The Coal Authority

- **web:** http://coal.decc.gov.uk/
- **e-mail:** thecoalauthority@coal.gov.uk
- **mail:** 200, Lichfield Lane, Mansfield, Notts. NG18 4RG
- **tel:** Permissions: 01623 637 339

  Mining Reports: 0845 762 6848

  Mining Records: 01623 637 235

  Surface Hazards Emergency: 01623 646 333
- **fax:** 01623 620 363

Health and Safety Executive (HSE)

- **web:** www.hse.gov.uk

British Drilling Association (BDA)

- **web:** www.britishdrillingassociation.co.uk
- **e-mail:** Office@britishdrillingassociation.co.uk
- **mail:** Wayside, London End, Upper Boddington, Daventry, Northamptonshire, NN11 6DP
- **tel:** 01327 264622
- **fax:** 01327 264623

Association of Geotechnical & Geoenvironmental Specialists (AGS)

- **web:** www.ags.org.uk
- **e-mail:** ags@ags.org.uk
- **mail:** Forum Court, 83 Copers Cope Road, Beckenham, Kent. BR3 1NR
- **tel:** 020 8658 8212
- **fax:** 020 8663 0949

Federation of Piling Specialists (FPS)

- **web:** www.fps.org.uk
- **e-mail:** fps@fps.org.uk
- **mail:** Forum Court, 83 Copers Cope Road, Beckenham, Kent. BR3 1NR
- **tel:** 020 8663 0947
- **fax:** 020 8663 0949