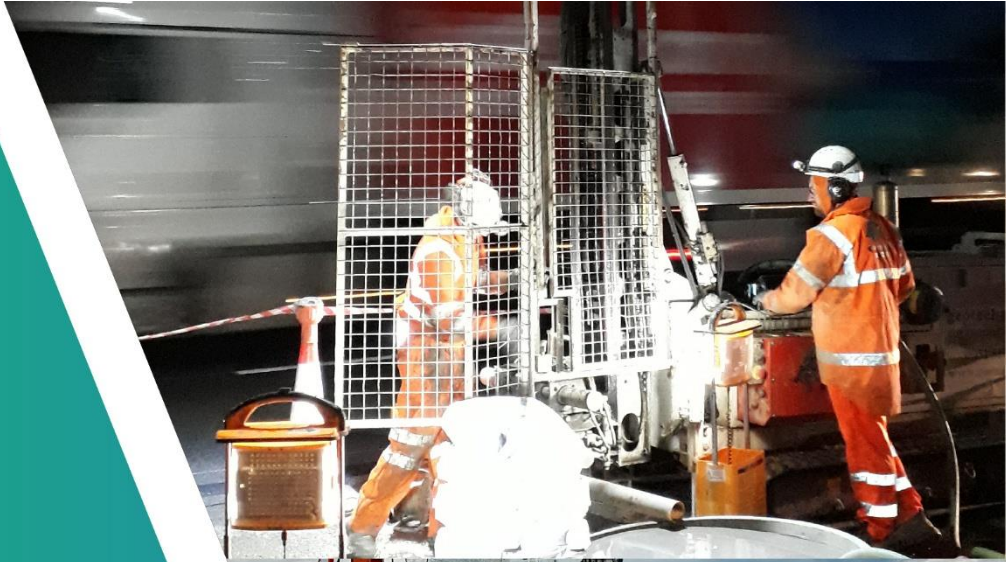

AGS

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MANAGING PRESSURISED GASES DURING DRILLING

JOINT INDUSTRY GUIDANCE

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Executive Summary

The occurrence of ground gas is well documented within all drilling sectors, however, the potential for encountering a pressurised gas pocket within the land drilling sector whilst not common or well documented is not an unknown hazard. The geographical locations, geological setting and likely sources of pressurised gas are reasonably foreseeable as long as the works involve a competent ground engineering specialist with the relevant experience to assess the risk.

Managing the risk of encountering pressurised gas during drilling must form part of a robust risk assessment process for all sites and where the hazard is identified, suitable and sufficient control measures and emergency response must be implemented and all site staff briefed and trained.

This guidance provides information to aid ground engineering specialists in the risk assessment process.

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1. Introduction

A pressurised gas show occurs when gas under pressure is encountered and flows up the borehole which can result in catastrophic consequences. Whilst gas shows are a known hazard when carrying out deep oil and gas exploration due to the potential generation of natural gases from the hydrocarbon sources rocks they are drilling towards, they are not common in boreholes drilled in other sectors. However, there have been incidents where gas shows have occurred when drilling boreholes for ground investigation, ground source heat and piling in the UK but in general these have been poorly documented. Such gas emissions have however resulted in explosions in buildings and fatalities. The earliest recorded encounter of pressurised methane in Jurassic strata below Buckinghamshire was around 1904 and it was still venting in 1913[1]. The gas was present below the Lias Group at a depth of around 115m and was at a pressure of about 4 bar.

All oil and gas exploration and production wells incorporate continuous gas detectors and a blow-out preventer at the head of the well. As drilling progresses the instrumentation monitors for combustible gases (methane, ethane, butane and others) and will warn if dangerous conditions start to develop. If a surge of gas (kick) is detected the blow-out preventer is used to control the gas and seal the borehole. A procedure will then be followed to manage the risk.

The gas shows that have occurred in boreholes, other than those drilled in the oil and gas sector, are in effect mini blow outs and, whilst not normally catastrophic in the same way as a well blow out, they do pose a health and safety hazard and must be managed in an appropriate way both in the short and long term.

This guidance relates to the types of boreholes that may be drilled by either BDA or AGS members and provides information which can be used whilst assessing the risk of encountering pressurised gases during land drilling activities. This excludes piped and stored natural gases for energy.

2. Legislation and Guidance

As with all current approaches to health, safety and the environment in the UK, management of a potential gas hazard starts with a suitable and sufficient risk assessment before any drilling works start. The risk assessment should follow the principles set out in the Management of Health and Safety at Work Regulations (HSE 1999). When preparing the risk assessment and developing safe systems of work the following should be consulted:

- Health and Safety at Work etc Act. (HSE 1974)[2]
- Construction (Design) and Management (CDM) Regulations. (HSE 2015)[3]
- Borehole Sites and Operations (BSO) Regulations. (HSE 1995)[4]
- Guidance on managing the risk of hazardous gases when drilling or piling near coal. (Coal Authority, 2019)
- Dangerous Substances and Explosive Atmospheres Regulations (DSEAR). (HSE, 2002)

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[1] Davies AM and Pringle J (1913) On Two Deep Borings at Calvert Station (North Buckinghamshire) and on the Palæozoic Floor north of the Thames. Quarterly Journal of the Geological Society, Volume 69, June 1913.
[2] Health and Safety at Work Act 1974
[3] Construction (Design and Management) Regulations 2015
[4] The Borehole Sites and Operations Regulations 1995

- Safe Intrusive Activities on Land Potentially Impacted by Contamination. (British Drilling Association, 2024)

In addition to the above documents, the AGS, CL:AIRE and CIRIA have numerous publications which discuss various aspects of ground gas and provide additional information and guidance.

3. Sources of gas hazard during drilling

Before any drilling work is undertaken for deep boreholes a robust geological assessment is required to assess the potential for strata to be a gas source or reservoir. This must be carried out by a ground engineering specialist with relevant experience.

Appendix A provides a table of potential sources of pressurised gas which will assist the assessment. The assessment should also use published geological information (e.g. BGS 1:10,000 scale geological maps, geological memoirs, published papers and reports[5], etc) and local knowledge and information. This should involve little additional work because it is good practice to complete a thorough desk study to understand the ground prior to drilling on any ground investigation, water well, ground source, geothermal or similar borehole.

4. Risk Assessment

The risk assessment must be carried out by a ground engineering specialist with an understanding of the circumstances where gas can be created and the geological situation or structures which can lead to that gas becoming trapped and potentially building up and becoming pressurised. This risk assessment must assess the risk of ground gas being present including likelihood and consequence. Even though a rare occurrence, when pressurised gas shows do occur, they should not come as a surprise and procedures should be in place to deal with them quickly and safely.

As well as identifying the source of the gas there must be a reservoir e.g. permeable stratum, salt dome; a suitable pathway e.g. permeable strata, discontinuities (faulting, fracturing or fissuring) and a capping medium e.g. an impermeable stratum, water. Pathways could also be utility ducts, backfilled trenches or tunnels.

With respect to permeable gas bearing strata, incidents with respect to flammable gas (methane) have occurred within the following strata and formations; Lower Carboniferous, Old Red Sandstone, Bridport Sand, Great Oolite, Sherwood Sandstone, Silesian sandstones, fractured Dinantian Carboniferous limestones, Upper Magnesian Limestone and Collyhurst Sandstone Formation, Coal Measures, Alluvium and landfill waste (or other Made Ground containing a significant proportion of organic material).

The risk assessment process should consider:

- Geological sequence and potential sources of gases

[5] An example of a BGS report is Open Report OR/16/020, Summary of potential oil and gas formations in England for use in groundwater vulnerability assessments, Groundwater Programme.
[6]The Unconventional Hydrocarbon Resources of Britain's Onshore Basins – Coalbed Methane (CBM). (Department of Energy and Climate Change, 2014)

- Stratigraphy and structure - confining low permeability layers or structures which could trap gas above a potential gas source
- Potential gas sources from previous or existing land-use
- Possible presence of mine workings, voids or cavities. Worked coal often has a lower potential for pressurised than in undisturbed geological settings, but it can be present if groundwater has risen and trapped gas from workings below a cap rock.
- The potential for increased risk with increasing depth of the borehole
- The potential for increased risk with increased depth below water table
- If gas is considered reasonably foreseeable additional information required:
    - Likely volume
    - Potential pressure
    - Type of gas and significance of the hazard posed to people or property
    - Gas monitoring, trigger levels and training
- Understanding of DSEAR zoning in the event of a kick / blow-out.
- Surrounding land users and developments i.e. distance to residential properties

5. Control Measures

The control measures should be commensurate with the level of risk identified.

Most shallow boreholes will have a low or even negligible likelihood of encountering ground gas under pressure and no specific control measures will be required.

A number of boreholes may be identified where gas may be present but the likelihood of encountering a pressurised pocket and a gas kick is low. The risk assessment in these circumstances should consider:

Area gas monitoring during drilling

1. Procedure should gas be encountered
2. Emergency procedures
3. Respiratory Protective Equipment (RPE)

Where pressurised gas is reasonably foreseeable the risk assessment should also consider:

1. Cementing in a top section of permanent casing
2. Casing to be used to full depth of the borehole
3. Management of drilling mud weight to control potential gas flows
4. DSEAR precautions where there is a risk of a gas kick– gas diverter (vent) capable of being operated remotely from the borehole* and not require a person to enter the danger zone, spark arrestors, Chalwyn valves on drill rigs – all determined based on risk assessment.
5. Gas monitoring to be undertaken at the top of the open borehole

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6. Personal gas monitoring during drilling
7. Gas monitoring in adjacent properties and buildings
8. Stop work and allow to vent - if suitable for the hazard identified and location. This must consider the stability of the borehole and potential in ground gas migration pathways if the hole bridges (becomes blocked due to collapse)
9. Method to seal the borehole – weighted grout/sacrificial packer/blow-out preventer
10. Enhanced emergency procedures – raising the alarm, notifications, making the area safe
11. Evacuation procedure including exclusion zones
12. Ongoing monitoring.
13. Training and competence of personnel for dealing with kicks / well control – or arrangements in place to access those skills.

*Note: Gas diverters or blow out preventers (BOPs) specifically designed for controlling pressurised gas are typically oil and gas technology which is rarely used in the land drilling sector. Where risk assessment identifies these as a potential control measure, clients should allow for additional time and resources to implement them.

6. Operating Procedures

Where the risk from encountering pressurised gas during drilling has been identified, the risk assessment must be accompanied by a robust procedure to deal with controlling and managing the gas show.

6.1 Low Risk

Low risk may include an unlikely event, low pressure gas flow, instant gas exhaustion or short duration gas shows. There is no pathway for gas migration to the surrounding area.

Low risk circumstances are likely to require no specific measures. If a gas show is encountered the risk should be re-assessed and additional control measures implemented as necessary. Short duration venting and ongoing gas monitoring may be suitable for low risk events.

6.2 Medium Risk

Medium risk may include low pressure gas flow, unsustained gas emission, significant gas shows where there is no pathway for gas migration into the surrounding ground or no nearby receptors (e.g. in rural areas away from buildings), non-toxic or non-flammable or non-explosive gas shows or gas shows in unconfined locations.

In these instances, the procedure should include the availability of gas monitoring equipment and well control. The well control may vary from immediate sealing of the borehole or venting prior to continuation of the borehole. Upon completion the borehole may require sealing, or a gas monitoring well may be installed.

6.2 High Risk

High risk may include high pressure gas flows, sustained gas emission, boreholes in urban areas or where gas can migrate to receptors, toxic, flammable or explosive gas, boreholes in confined spaces.

Where the risk has been identified as high, suitable plant and equipment should be used to safely manage any gas show that occurs. This may include gas monitoring, gas diverter (vent), or even blow out preventers, spark arrestors and Chalwyn valves on drill rigs. Equipment to manage the borehole should also be immediately available and may include grouting equipment, grout additives such as barites and sealing equipment such as packers.

Emergency procedures for high-risk incidents may be quite variable but, in all situations, drilling should cease immediately, all plant and equipment turned off and the area made safe. Depending upon the actual pressure, type of gas and the environment making the area safe will vary from fencing off the borehole to evacuation of premises and the vicinity around the borehole. The procedure must also include how to make the borehole safe and whether immediate sealing is required.

6.3 Sealing of Boreholes

Where gas shows have been encountered the borehole should either be sealed or a gas monitoring well installed (this is likely to be temporary situation to allow the long term risk to be assessed and on completion of any monitoring will require decommissioning and the borehole sealing). The hole must not be allowed to collapse. High and most medium risk situations are likely to require prompt sealing, and the borehole must be sealed along its entire depth by tremieing cement slurry into the base of the hole. It is oil / gas borehole practice to leave the drill string in the hole to allow well control / abandonment muds / cement to be pumped without difficulties. To do this and provide diverter arrangements should be part of the consideration for the installation at the well head.

High pressure gas shows may require sealing using weighted grout, but a packer installed directly above the depth of the gas show is often a more controlled solution as it will reduce the pressure during subsequent grouting. Practical and safety difficulties such as "getting back in the hole" to install packers or general operation of the machine in a potentially hazardous environment should be considered. The most appropriate solution should be based upon a robust risk assessment which considers all factors including the working environment, well integrity and well casing.

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Appendix A. Potential sources for pressurised gas

Gas Hazard	Geological Formation	Geographical Location	Cause	Consequence
De-oxygenated Air (< 18% oxygen but as low as 1%) Pressurised gas. Rapid ejection of material from boreholes commonly sand and gravel.	Upnor Formation of the Lambeth Group Woburn Sands	London Basin Milton Keynes	Chemical reaction of 'green rust' with air often within glauconite rich strata. Rise in groundwater trapping gas below a confining layer (often very low permeable clay).	Confined space hypoxia. Injury. Death. Injury. Damage to buildings and property from ejectiles.
Geogenic Gases Toxic, flammable or explosive gases Methane, Carbon Dioxide, Carbon Monoxide, Hydrogen Sulphide	Coal Measures Oil Shales	South Wales, Midlands, Northern England and Central Scotland Central Scotland	Gases emanating from coal measures strata often trapped within mine workings or other geological structures by water level rising.[6] Gas migration from coal measures.	Gases driven into buildings or dwellings through drilling. Confined space hypoxia. Explosion. Death.
Combustion Gases	Coal Measures Oil Shales	South Wales, Midlands, Northern England and Central Scotland Central Scotland	Gases trapped below impermeable layer e.g. till	Fire. Explosion. Damage to structures Injury. Illness. Death.
Pressurised Natural Gas – flammable and potentially explosive	Hydrocarbon source rock i.e. Kimmeridge Clay	Dorset, Midlands, Northern England, Southern and Central Scotland	Gas generated from hydrocarbon source rocks with low permeable cap rock or capping structure	Fire. Explosion. Severe damage to structures. Injury. Illness. Death.
Pressurised Natural Gas – flammable and potentially explosive	Lower Carboniferous or Old Red Sandstone below the base of the Lias Group	Bedfordshire and Buckinghamshire	Predominantly biogenic gas production	Fire. Explosion. Severe damage to structures. Injury. Illness. Death.
Biogenic Gases Methane, Carbon Dioxide, Hydrogen Sulphide and Carbon Monoxide	Organic rich estuarine, alluvial and tidal flat sediments	Major river systems and tidal flats throughout the UK e.g. River Clyde, River Thames, Newport, Cardiff etc	Build-up of deoxygenated, toxic or flammable gases due to the chemical reaction within anaerobic conditions.	Confined space hypoxia. Explosion. Illness. Death.
Contaminated Land Gases Methane, Hydrocarbons, Carbon Dioxide, Hydrogen Sulphide, Hydrogen Cyanide	Made Ground and Fill	Landfill, Post Industrial Sites, other Brownfield Sites	Direct sources. Decomposition of substances. Combustion.	Fire. Explosion. Illness. Death.

Note: The above table is not an exhaustive list of potential sources for pressurised gas. A ground engineering specialist must be engaged to assess the risk.

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