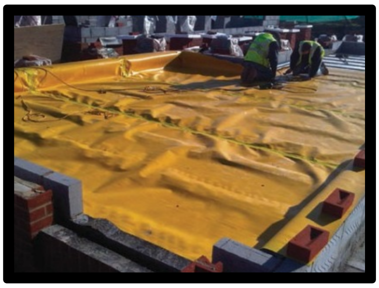
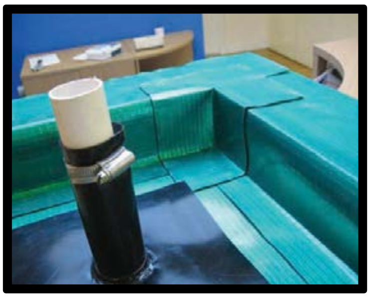




VERIFICATION REQUIREMENTS FOR GAS PROTECTION SYSTEMS

Technical Guidance for Developers, Landowners and Consultants

Yorkshire and Lincolnshire
Pollution Advisory Group

Version 1.1 – December 2016

The purpose of this guidance is to promote consistency and good practice for development on land affected by contamination. The Local Planning Authorities in Yorkshire, Lincolnshire and the North East of England who have adopted this guidance are shown below:

Contents Page

Disclaimer

This guidance is intended to serve as an informative and helpful source of advice. It is intended to review this guidance annually, but readers must note that legislation, guidance and practical methods are inevitably subject to change and therefore should be aware of current UK policy and best practice. This note should be read in conjunction with prevailing legislation and guidance, as amended, whether mentioned here or not. Where legislation and documents are summarised this is for general advice and convenience, and must not be relied upon as a comprehensive or authoritative interpretation. Ultimately it is the responsibility of the person/company involved in the verification of land contamination to apply up-to-date working practices and requirements.

Acknowledgments

The authors and YALPAG would like to specifically acknowledge and thank CIRIA for the permission to use sections, including tables and photographs, of the CIRIA C735 document. Mallett, H, Cox (nee Taffel-Andureau), L, Wilson, S, Corban, M (2014) *Good practice on the testing and verification of protection systems for buildings against hazardous ground gases*, CIRIA, C735, London (ISBN: 978-0-86017-739-5). Go to: www.ciria.org

The author, Leeds City Council (Brad Hall, Julia Reynolds), would like to acknowledge the assistance provided by the following people and organisations: East Riding of Yorkshire Council, Doncaster Metropolitan Borough Council, Wakefield Council, Hugh Mallett of BuroHappold, Neil Salvage of PAGeotechnical and John Naylor of Ground-Gas Solutions.

Consultation

The YALPAG Local Planning Authorities were consulted over a four week period in 2015 during the production of this guidance. Consultation comments were considered by the review panel and a number of revisions were made to the guidance to reflect these comments.

Introduction

This guidance has been produced to help developers ensure that they can demonstrate that gas protection systems are appropriate for the development and level of risk associated with a site and that they have been installed correctly and can be relied upon to provide the required level of protection and ultimately demonstrate that, in terms of gas risk, the development is suitable for use. It is intended to improve the quality of reports submitted to Local Planning Authorities on this matter and to give contractors/consultants a point of reference to obtain approval for such work from their client.

The verification of gas protection systems should be an integral part of remediation and agreed between developers and Local Planning Authorities at an early stage in the development.

Failure to comply with this guidance may result in delays to the development. Relevant planning conditions cannot be discharged until the Local Planning Authority is satisfied appropriate verification has been undertaken to confirm that the development is safe.

Available UK guidance regarding gas risk assessment includes:

- CIRIA C665 Assessing risks posed by hazardous ground gases to buildings;
- NHBC Report Edition No: 4 Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present;
- BS 8485:2015 Code of practice for the design of proactive measures for methane and carbon dioxide ground gases for new buildings.

In particular, readers of this document should refer to the detailed guidance on verification published by CIRIA (CIRIA C735 Good Practice on the testing and verification of protection systems for buildings against hazardous ground gases, 2014). This guidance note should be considered as supplementary advice to be used in conjunction with these documents.

This document does not cover risks associated with radon. Please contact individual Local Planning Authority for further information.

The following YALPAG technical guidance documents for developers, landowners and consultants are also available;

- Verification Requirements for Cover Systems.
- Development on Land Affected by Contamination.

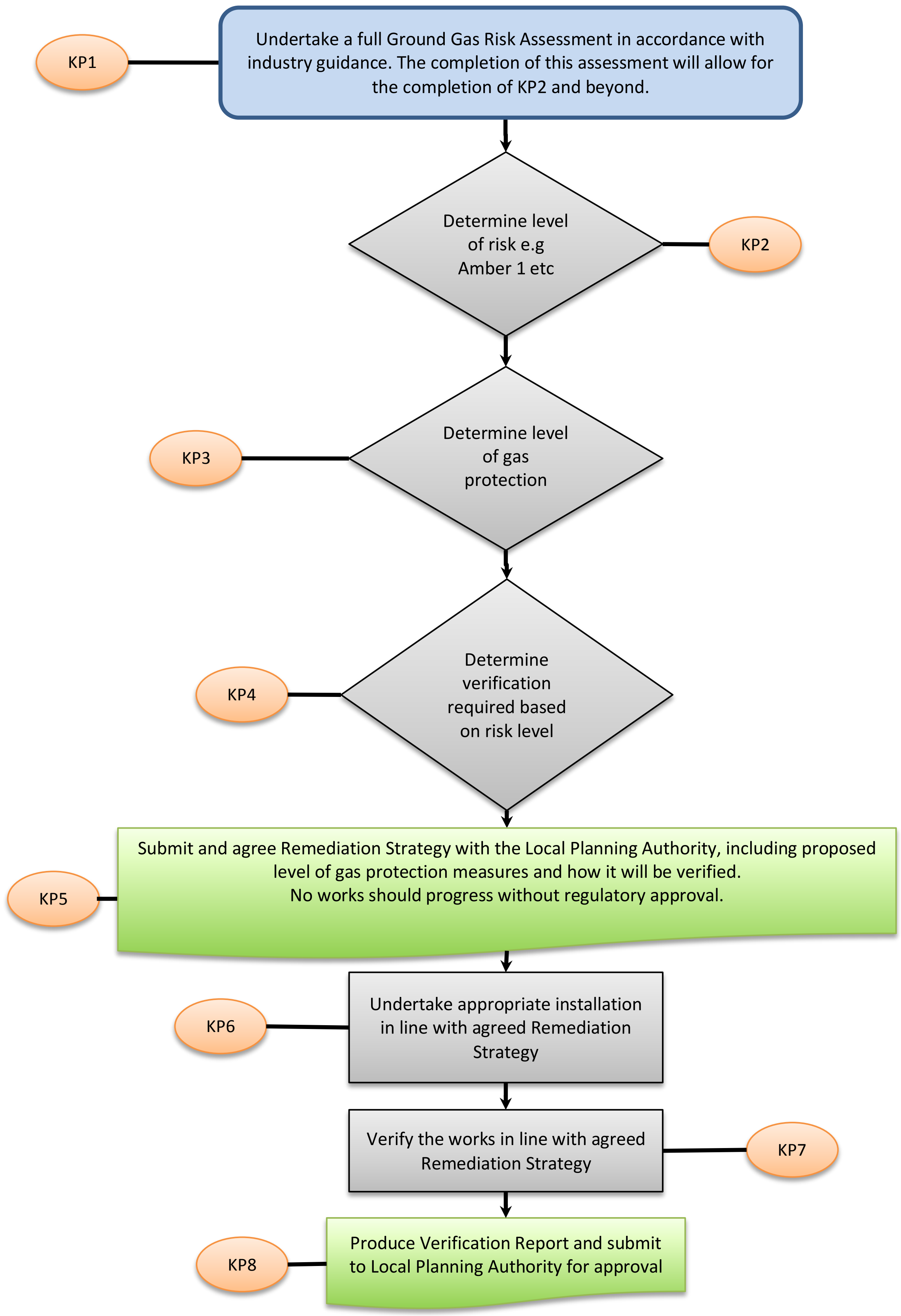
The Process of Verification

Implementation and verification plans for gas protection systems should always be site specific and based on the gas risk assessment and conceptual site model (CSM) for the site in question.

For gas protection systems, acceptable verification will normally comprise the provision of clear evidence that the level of protection is appropriate to the established risk and has been installed by suitably experienced personnel in line with the manufacturer’s instructions and appropriate guidance. Critical factors to be considered are:

- What should be installed?
- How should it be installed?
- Who should install it?
- How will correct installation be demonstrated?

Overview Flowchart



Key Points

KP1 Ground Gas Risk Assessment	Undertake an appropriate gas risk assessment for the site in accordance with industry guidance*. On completion of the risk assessment and the generation of the appropriate Gas Screening Value (where required) and on a full understanding of the gas regime/ CSM, move to KP2 to determine the level of risk for the site. **Where the desk study has identified the need for gas monitoring to be carried out it would always be **expected** that site specific gas monitoring data would be used in the gas risk assessment.*
KP2 Level of Risk	The level of gas risk needs to be determined by using the appropriate gas guidance document/s relative to the development (e.g. low rise housing, residential apartment blocks with areas of public open space, commercial or public buildings etc). For example Amber 1 (Low rise housing) equates to Low Risk in Table A1 CIRIA 735. Once the level of risk has been determined move to KP3 and determine the appropriate level of gas protection.
KP3 Level of Gas Protection	The level of gas protection should be based on the level of risk established by the gas risk assessment and CSM. It should provide the appropriate gas protection for the ***lifetime of the development***. Detailed specification of gas protection measures in accordance with appropriate guidance to include (but not be limited to): • Submission of appropriate drawings (site specific plans and details to clearly show where the measures will be installed and how they fit into the design of the building and foundations). • Full written description of the protection measures to be included. • Detailed justification of the protection measures being used along with reference to the guidance document(s) being used.
KP4 Level of Verification Required	The level of qualification and experience of the installer will determine the level of verification required. Verification should always be carried out by an appropriate independent person such as an experienced and suitably trained verification consultant or third party qualified **and** experienced installer (see KP6). **See Appendix 1 for full details of verification requirements for installation of gas protection measures and the associated verification requirements.**

KP5 Submission and Agreement of Remediation Strategy	No installation of gas protection measures should be carried out at the site until the full details (KP1 to KP4) have been approved by the Local Planning Authority and formalised in an agreed Remediation Strategy (including Verification Plan). The Remediation Strategy, incorporating the detailed Verification Plan, should include (but not be limited to): • A summary of the ground gas risk assessment. • The gas protection measures proposed. • Who will undertake the installation including levels of experience and/ or qualifications. • How the works will be verified/ tested and by who. • How the works will be reported to the Local Planning Authority. **See Appendix 2 for details of Remediation Strategy requirements.**
KP6 Installation of Gas Protection	Installation should only be done once the Remediation Strategy has been agreed with the Local Planning Authority and should be carried out in line with the agreed Remediation Strategy. Any deviation away from the agreed Remediation Strategy should be agreed in writing with the Local Planning Authority prior to commencement of installation. **See Appendix 4 for examples of good and poor gas protection installation.**
KP7 Verification of Gas Protection	The verification of the gas protection measures should be undertaken in accordance with the Verification Plan set out in the agreed Remediation Strategy. Any deviation to works away from the agreed Remediation Strategy should be agreed in writing with the Local Planning Authority prior to installation. **See Appendix 5 for an example Verification proforma.**
KP8 Submission of Verification Report	The Verification Report must be produced in line with the agreed Remediation Strategy and Verification Plan. All aspects of the Remediation Strategy must be addressed in the Verification Report along with full details and justification of any deviation. **See Appendix 3 for details of the required contents of the Verification Report. Please note, the required contents should be agreed within the submitted and approved Remediation Strategy at KP 5.**

Appendix 1 – Requirement for Installation and Verification

Copied directly from Annex 1 CIRIA C735

Mallett, H, Cox (nee Taffel-Andureau), L, Wilson, S, Corban, M (2014) Good practice on the testing and verification of protection systems for buildings against hazardous ground gases, CIRIA, C735, London (ISBN: 978-0-86017-739-5). Go to: www.ciria.org

The tables in this appendix should be used for guidance only and are not intended to be used in lieu of sound professional judgment, which should take into account the risk factors affecting the development (the gas regime, the number of buildings, the complexity of design, and the expertise of the installation workforce) on a site-specific basis. The tables should not be used independent of, and without reference to, the accompanying text in the main guide C735.

Situation A – all development types except situation B – non reinforced slabs (from Wilson et al, 2007)

Gas regime/risk	Slab type	Installer experience	Suggested levels of verification and integrity testing
Low risk CS2 (*with venting) Basic radon protection area	Non reinforced All slabs	General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours. Contractor to supply sign off sheets (verification evidence) including photographs to independent verifier.
		Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer) to conduct a thorough verification (visual) inspection prior to 25 to 50 per cent of concrete pours (min one visit). Installer to supply sign off sheets (verification evidence) including photographs to independent verifier for all other pours.
Intermediate risk CS2 (no venting) or CS3 (*with venting) Full radon protection area		General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours. All joints, pipe penetrations etc independently air lanced to ASTM D4437. Contractor to supply sign off sheets (verification evidence) including photographs to verifier. Consideration given to need for/scope of integrity testing (eg initially on say 25 to 50 per cent of pours then falling to 10 to 25 per cent if acceptable results obtained and no concerns raised by visual inspections).
Gas regime/risk	**Slab type**	**Installer experience**	**Suggested levels of verification and integrity testing**
Intermediate risk CS2 (no venting) or CS3 (*with venting) Full radon protection area	Non reinforced All slabs	Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to 25 to 50 per cent of concrete pours (min two visits). 25 per cent all joints, pipe penetrations etc independently air lanced to ASTM D 4437. Remaining 75 per cent joints, pipe penetrations etc tested to recognised standard by installer (as detailed in method statement/CQA plan). Installer to supply sign off sheets (verification evidence) to verifier for all other pours. Consideration given to need for/scope of integrity testing (eg initially on 10 to 25 per cent of pours then falling to 0 to 10 per cent if acceptable results obtained and no concerns raised by visual inspections).
High risk VOCs etc CS3 (no venting) or CS4 and above (*with venting)		Qualified[1] and experienced installer (50 per cent of operatives to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours. All joints, pipe penetrations independently air lanced to ASTM D 4437. Installer to supply sign off sheets (verification evidence) to verifier for all pours. Consideration given to need for scope of integrity testing (eg initially on 25 to 50 per cent of pours then falling to 10 to 25 per cent if acceptable results obtained and no concerns raised by visual inspections).

Notes

* Assumes venting designed to keep steady state concentration of CH_4 below one per cent in void, sites designed with higher levels of gas in the void should adjust the frequency of inspection and testing as appropriate

1 Relevant qualification is NVQ Level 2 in gas protection installation (see Section 3.3).

2 Before works start the contractor should produce a detailed installation plan including method statement, CQA procedures and qualifications, on receipt of these the verification protocol could be increased or reduced.

3 Consideration should be given to carrying out leak detection (ie smoke, tracer gas or dielectric testing) on the first plots on higher end sites CS3 and above. If an unacceptable amount of holes are found during these tests then the verification consultant should discuss with the relevant personnel, strategies to prevent this occurring, these could include changing material, improving subgrade preparation, putting up warning signs to reduce the amount of trafficking etc.

4 Verification consultant should be competent, experienced and suitably trained (see Section 3.2). A statement detailing their qualifications and relevant experience should be included in the verification plan.

5 Air lancing is the only integrity test that has an independently recognised international standard that is suitable for testing taped and welded seams.

Situation A – all development types except situation B – reinforced slabs (from Wilson et al, 2007)

Gas regime/risk	Slab type	Installer experience	Suggested levels of verification and integrity testing
Low risk CS2 (*with venting) Basic radon protection area	Reinforced All slabs	General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours. Contractor to supply sign off sheets (verification evidence) including sub grade acceptance forms and photographs to independent verifier.
		Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to 25 per cent concrete pours (min two visits), including vented void, subgrade etc. Installer to supply sign off sheets (verification evidence) including, sub grade acceptance forms, photographs to independent verifier for all other pours.
Intermediate risk CS2 (no venting) or CS3 (*with venting) Full radon protection area		General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours including vented void, subgrade etc. All joints, pipe penetrations etc independently air lanced to ASTM D4437. Consideration given to the need for and scope of integrity testing (eg initially on say 50 to 25 per cent of pours then falling to 25 to 10 per cent if acceptable results obtained and no concerns raised by visual inspections.
		Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to 50 per cent of concrete pours, including vented void, subgrade etc 25 per cent of joints, pipe penetrations etc independently air lanced to ASTM D4437. Remaining joints, pipe penetrations, corners etc tested to a recognised standard by installer (as detailed in method statement and CQA plan). Installer to supply sign off sheets (verification evidence) including, sub grade acceptance forms, photographs etc to independent verifier for all other pours. Consideration given to need for/scope of integrity testing (eg initially on 10 to 25 per cent of pours then falling to 0 to 10 per cent if acceptable results and no concerns raised by visual inspections).
High risk VOC and hydrocarbons CS3 (no venting) or CS4 and above (*with venting)		Qualified[1] and experienced installer (50 per cent of operatives to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct a thorough verification (visual) inspection prior to all concrete pours including vented void, subgrade etc. All joints, pipe penetrations etc independently air lanced to ASTM D4437. 100 per cent leak detection considered on VOC/ hydrocarbon contaminated sites.. Consideration given to need for/scope of integrity testing (eg initially on 50 to 25 per cent of pours then falling to 25 to 10 per cent if acceptable results obtained and no concerns raised by visual inspections).

Notes

* Assumes venting designed to keep steady state concentration of CH_4 below one per cent in void, sites designed with higher levels of gas in the void should adjust the frequency of inspection and testing as appropriate.

1 Relevant qualification is NVQ Level 2 in gas protection installation (see Section 3.3).

2 Before works start the contractor should produce a detailed installation plan including method statement, CQA procedures and qualifications, on receipt of these the verification protocol could be increased or reduced.

3 Consideration should be given to carrying out leak detection (ie smoke, tracer gas or dielectric testing) on the first plots on higher end sites CS3 and above. If an unacceptable amount of holes are found during these tests then the verifier should discuss with the relevant personnel, strategies to prevent this occurring, these could include changing material, improving subgrade preparation, putting up warning signs to reduce the amount of trafficking etc.

4 Verification consultant should be competent, experienced and suitably trained (see Section 3.2). A statement detailing their qualifications and relevant experience should be included in the verification plan.

5 Air lancing is the only integrity test that has an independently recognised international standard that is suitable for testing taped and welded seams.

6 Where a sufficiently robust protection layer (protection fleece, protection boards or insulation) are laid directly on the membrane, inspection after placement of the reinforcement should not be necessary.

Situation B – low rise housing with ventilated void (from NHBC and Wilson et al, 2007)

Gas regime/risk	Slab type	Installer experience	Suggested levels of verification and integrity testing
Low risk Amber 1	All slabs with min 150 mm ventilated sub floor void	General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct thorough verification (visual) inspection of first plot and after placement of reinforcement if no protection provided. Subsequent inspections carried out at approx. frequency of 1 in 10 plots (minimum 5). Contractor to supply sign off sheets (verification evidence) including photographs for all other plots. Consideration given to need for/scope of integrity testing if concerns identified by visual inspections[3].
		Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct thorough verification (visual) inspection of first plot and after placement of reinforcement if no protection provided. Subsequent inspections carried out at approx. frequency of 1 in 20 plots. Contractor to supply sign off sheets (verification evidence) including photographs for all other plots. Consideration given to need for/scope of integrity testing if concerns identified by visual inspections[3].
Intermediate risk Amber 2		General builder/ groundworker/ landfill operative (no relevant qualification[1])	Verifier (consultant[4] or qualified and experienced installer[1]) to conduct thorough verification (visual) inspection of first 10 plots and after placement of reinforcement if no protection provided. All joints, pipe penetrations etc air lanced to ASTM D4437. Subsequent inspections (including air lancing) carried out at approx. frequency of 1 in 20 plots Contractor to supply sign off sheets (verification evidence) including photographs for all other plots. Consideration given to need for/scope of integrity testing (eg initially on 30 to 50 per cent of plots then falling to 0 to 10 per cent of plots if acceptable results obtained and no concerns raised by visual inspections).
		Qualified[1] and experienced installer (minimum one operative to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct thorough verification (visual) inspection of the first 5 plots and after placement of reinforcement if no protection provided. All joints, pipe penetrations etc air lanced to ASTM D4437. Subsequent inspections (including air lancing) carried out at a frequency of about 1 in 20 plots. Contractor to supply sign off sheets (verification evidence) including photographs for all other plots. Consideration given to need for/ scope of integrity testing (eg initially on 10 to 25 per cent of plots then falling to 0 5 per cent of plots if acceptable results obtained and no concerns raised by visual inspections)[3].
High risk Red VOC and hydrocarbons		Qualified[1] and experienced installer (all operatives to hold qualification)	Verifier (consultant[4] or third party qualified and experienced installer[1]) to conduct thorough verification (visual) inspection of all plots, and after placement of reinforcement if no protection provided. All joints, pipe penetrations etc air lanced to ASTM D4437. Consideration given to need for/scope of integrity testing (eg initially on 30 to 50 per cent of plots then falling to 0 to 10 per cent of plots if acceptable results obtained and no concerns raised by visual inspections)[3].

Notes

* Gas regime defined by characteristic situation as set out by Wilson *et al* (2007), and all other recent good practice guidance and British Standards.

** Assumes venting designed to keep steady state concentration of CH_4 below one per cent in void, sites designed with higher levels of gas in the void should adjust the frequency of inspection and testing as appropriate.

1 Relevant qualification is NVQ Level 2 in gas protection installation (see Section 3.3).

2 Before the works start the contractor should produce a detailed installation plan including method statement, CQA procedures and qualifications, on receipt of these the verification protocol could be increased or reduced.

3 Consideration should be given to carrying out integrity testing/leak detection (ie smoke, tracer gas or dielectric testing) on the above basis and/or if an unacceptable amount of damage/loss of integrity is found during visual inspections. In this instance the consultant should discuss with the relevant personnel, strategies to prevent this recurring. This could include changing material, improving subgrade preparation, putting up warning signs to reduce the amount of trafficking etc.

4 Verification consultant should be competent, experienced and suitably trained (see Section 3.2). A statement detailing their qualifications and relevant experience should be included in the verification plan.

5 Air lancing is the only integrity test that has an independently recognised international standard suitable for testing taped and welded seams and should be used at the frequency suggested in the table.

Appendix 2 – Remediation Strategy and Verification Plan for Gas Protection Systems

The Remediation Strategy should include a detailed verification method statement. This should address how the gas protection measures will be installed and what verification information will be provided to demonstrate the installation has been carried out in accordance with the appropriate guidance.

As a minimum the report should include (but not be limited to):

- A summary of the gas risk assessment.
- The gas protection measures proposed (including reference to the appropriate guidance documents) and confirmation they will meet the gas protection requirements for the lifetime of the development.
- Technical drawings showing how the gas protection measures will be incorporated.
- Formal qualifications/experience/training of the person carrying out the installation.
- Formal qualifications/experience/training of the person carrying out the verification.
- Clear demonstration of the independence of the person carrying out the verification.
- The manufacturer's specification of the gas protection membrane to be used.
- Full details of what the verification process will comprise and at what stage verification will be carried out.
- Details of how any non-conformance will be dealt with.
- Details of the number of plots to be validated. (Deviation from verification of every plot will need to be justified and agreed with the Local Planning Authority in line with Appendix 1 of this document).
- Timeline of when during the build, each of the gas protection measures will be installed.
- Details of management measures proposed to ensure how damage to the membrane will be prevented prior to the floor being installed, post installation.
- Details of how **all** site personnel (including follow on trades) will be made aware of the presence of the membrane and that damage to the membrane must be prevented.
- Details of the extent of overlap and method of sealing (these must be in line with manufacturer's instructions and evidence provided).
- Confirmation that a signed (plot specific unless agreed otherwise) statement confirming that the gas protection measures were installed as agreed and that the membrane was free from tears and punctures and was lapped and sealed as agreed at joins and around services and sub floor voids were clear and free from debris will be included in the Verification Report.
- Confirmation that plot specific photographs showing the installed membrane will be included in the Verification Report.

Appendix 3 – Checklist for Gas Verification Reports

The Verification Report should include a summary of all the works undertaken, relating to gas protection measures including all elements detailed within the Remediation Strategy.

As a minimum the report should include (but not be limited to):

- Site details.
- Planning Application details.
- Summary of Gas Risk Assessment (including original CSM).
- Details of who carried out installation (qualifications/experience/training).
- Details of who carried out verification (qualifications/experience/training).
- Description of protection measures installed with reference to method statements and drawings and manufacturers specification of the materials used.
- Details of the verification inspection regime.
- Supporting information, plans, air vent installation, photographs, as built drawings.
- Summary of verification data (completed proformas, test results)
- Details of non-conformances and how they were rectified.
- Clear statement saying remedial objectives been achieved supported by lines of evidence including reference to CSM.
- Where necessary further works and/ or long term management.

Mallett, H, Cox (nee Taffel-Andureau), L, Wilson, S, Corban, M (2014) Good practice on the testing and verification of protection systems for buildings against hazardous ground gases, CIRIA, C735, London (ISBN: 978-0-86017-739-5). Go to: www.ciria.org

GOOD PRACTICE PHOTOGRAPHS

Figure A4.7 *Geovent protruding out of the frontage of the unit. Gas membrane along the sides of the slab preventing lateral gas ingress (courtesy Alderburgh Group)*

Figure A4.8 *Geovent beneath the 2000g taped gas membrane lined up with collector pipes (courtesy Alderburgh Group)*

Figure A4.9 *On site schematics to aid construction workers build the gas protection system (courtesy Alderburgh Group)*

Figure A4.10 *Almost complete coverage available for inspection, minimal jointing, service entries suitable distance from walls, light traffic (courtesy Smith Grant)*

Figure A4.11 *Gas membrane continued through cavity wall and above air bricks (courtesy Hydrock)*

Figure A4.12 *Good edge detail across cavity (courtesy PAGeotechnical Ltd)*

Figure A4.13 Gas proof DPC adhered on top of gas membrane using butyl strips across cavity space (courtesy NHBC)

Figure A4.14 Good perimeter seal (courtesy PAGeotechnical Ltd)

Figure A4.15 LDPE type gas membrane overlap and double sided tape. Sand blinding to protect underside of gas membrane (courtesy A Proctor Group)

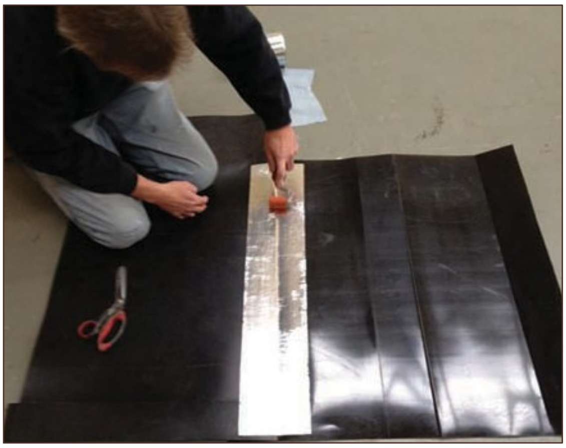


Figure A4.16 Example HDPE type gas membrane and steam roller used to ensure self-adhesive tape is correctly installed (courtesy A Proctor Group)

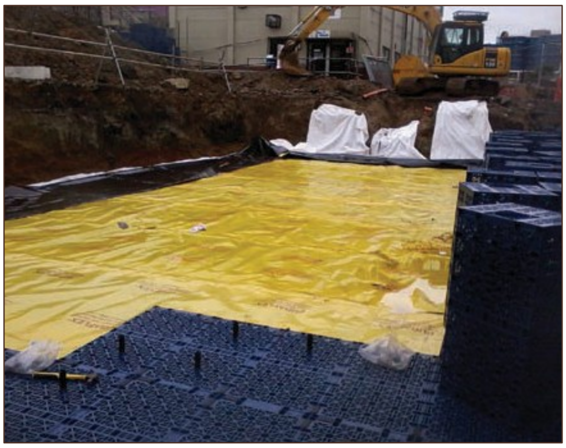


Figure A4.17 Gas membrane installed in attenuation tank (courtesy Industrial Textiles & Plastics Ltd)

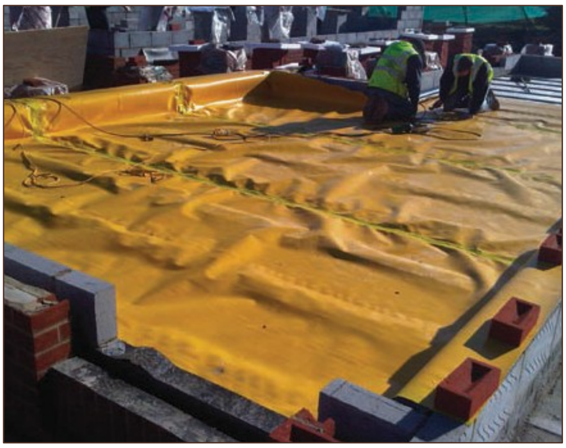


Figure A4.18 Gas membrane installed as part of foundation barrier (courtesy Industrial Textiles & Plastics Ltd)

Figure A4.19 Well-constructed joints with gas resistant DPC, lap and double sided butyl joints visible beneath semi-transparent gas membrane, secondary seal with proprietary single sided tape (courtesy Smith Grant)

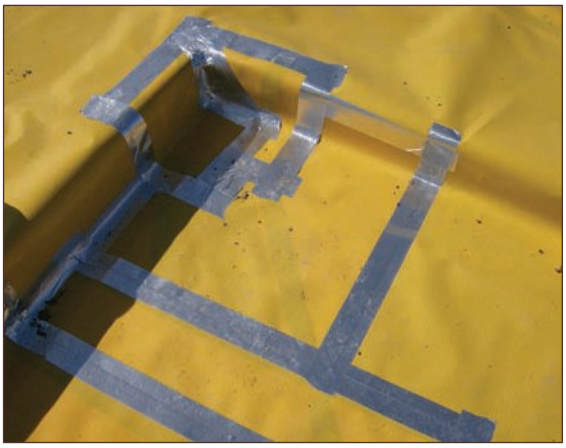


Figure A4.20 A pre-formed corner unit would have been preferable as fewer joints would have been formed, however the installer has achieved a good level of workmanship in this corner detail (courtesy Smith Grant)

Figure A4.21 Good prefabricated corner detail (courtesy MEC Environmental Ltd)

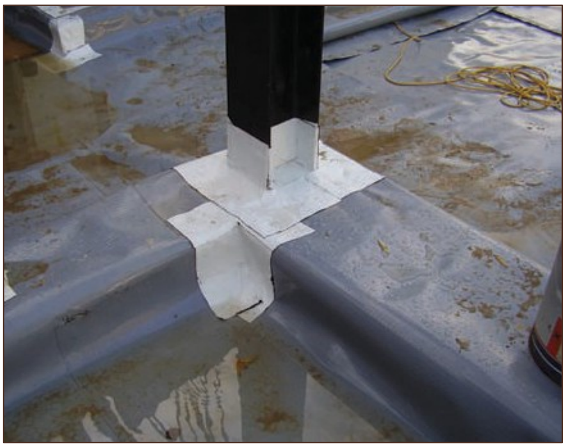


Figure A4.22 Good detail around stanchion and corner (courtesy PAGeotechnical Ltd)

Figure A4.23 Complex column seal (courtesy PAGeotechnical Ltd)

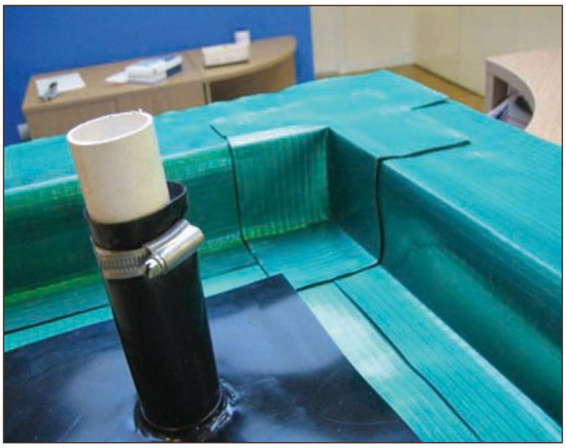


Figure A4.24 Prefabricated corner detail and top hat (courtesy A Proctor Group)

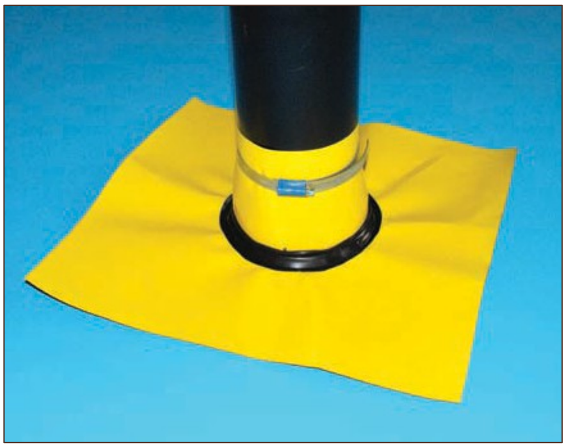


Figure A4.25 Top hat around service entry (courtesy Industrial Textiles & Plastics Ltd)

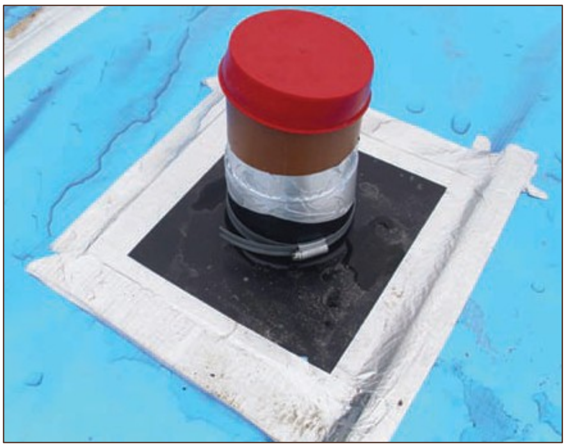


Figure A4.26 Well-constructed service entry: top hat fits well with service pipe and taped down to gas membrane, secondary seal with proprietary single sided tape (courtesy Smith Grant)

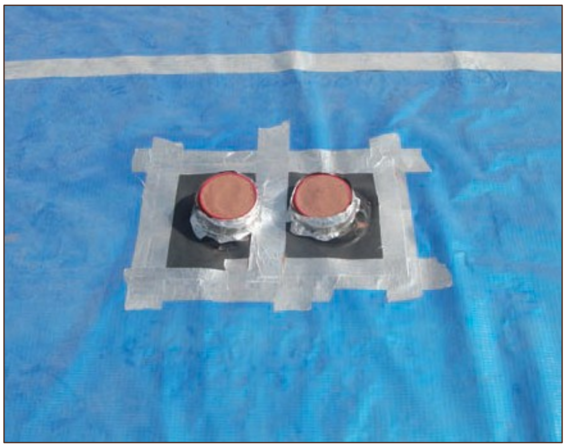


Figure A4.27 Top hats placed around service entries secured with jubilee clip seals. Top hats secured to gas membrane with double sided butyl tape (courtesy Hydrock)

Figure A4.28 Bead of double sided butyl tape provided between interfaces of ID top hat and OD service pipe. When compressed with jubilee clip, forms an effective seal (courtesy Smith Grant)

Figure A4.29 Extrusion welding technique (courtesy Industrial Textiles & Plastics Ltd)

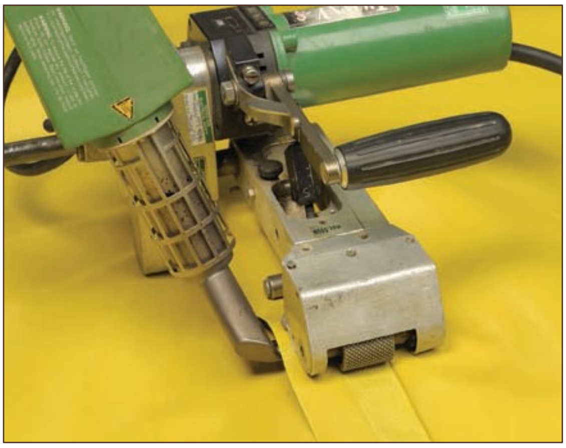


Figure A4.30 Thermal welding technique (courtesy Industrial Textiles & Plastics Ltd)

Figure A4.31 Extrusion welding (courtesy PAGeotechnical Ltd)

Figure A4.32 High quality installation of liquid gas membrane to lift pits, including resin gas protection on all screw penetrations (courtesy Card Geotechnics Limited)

A4.2.2 Good practice – passive venting systems

Figure A4.33 Good ventilation in internal sleeper walls, cast into prefabricated beams (courtesy Smith Grant)

Figure A4.34 Open void >300mm deep, good ventilation through internal sleeper walls (courtesy Smith Grant)

Figure A4.35 Good installation of passive gas venting trenches and 'egg-crate' (courtesy Card Geotechnics Limited)

Figure A4.36 Raised air bricks are preferable due to the reduced potential for blockade but the vent trench specified is provided with clean single sized stone (courtesy Smith Grant)

A4.2.3 Good practice – integrity testing

Figure A4.37 Tracer gas testing, whereby gas or smoke is applied under pressure beneath the installed gas membrane and detectors are used to screen for leaks above (courtesy NHBC)

Figure A4.38 Tracer gas testing (courtesy PAGeotechnical Ltd)

Figure A4.39 Scanning for leaks (courtesy PAGeotechnical Ltd)

Figure A4.40 CO_2 injection integrity testing (courtesy Landline Ltd)

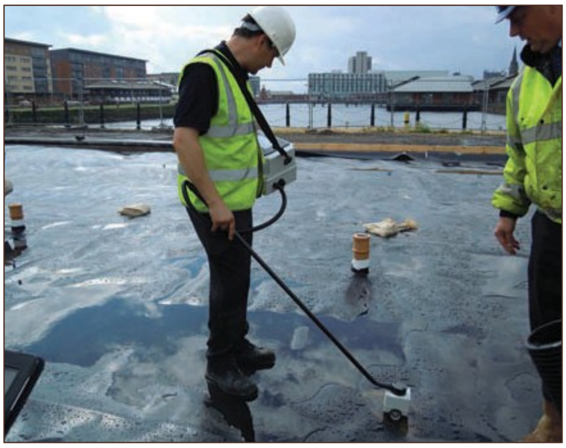


Figure A4.41 Small sand bags are marking holes made in the gas membrane used to check whether injected CO2 has worked its way beneath whole area (courtesy Landline Ltd)

Figure A4.42 Air pressure testing (courtesy GSE Environmental)

Figure A4.43 *Dielectric porosity testing for housing scheme (courtesy NHBC)*

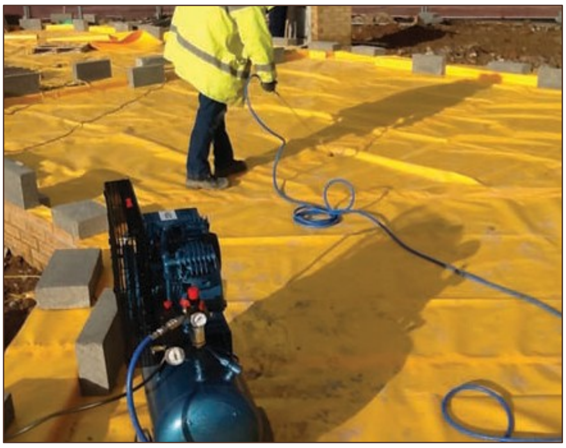


Figure A4.44 *Air lance test, used to test the quality of welded seams along gas membrane joints (courtesy MEC Environmental Ltd)*

Figure A4.45 *Spark testing (courtesy GSE Environmental)*

Figure A4.46 *Testing a weld with 'dog bone' grips (courtesy MEC Environmental Ltd)*

BAD PRACTICE PHOTOGRAPHS

Figure A4.47 *Follow-on works purposefully penetrating gas membrane (courtesy Card Geotechnics Limited)*

Figure A4.48 *Loose nails and over construction debris likely to be left in place beneath gas membrane – poor preparation of gas membrane prior to sealing service penetration (courtesy Card Geotechnics Limited)*

Figure A4.49 Lifted gas membrane at corner position. Light penetrating through confirms damage to aluminium internal core layer (courtesy NHBC)

Figure A4.50 Large/heavy/sharp objects being moved over unprotected gas membrane (courtesy Card Geotechnics Limited)

Figure A4.51 Gas membrane torn by reinforcement (courtesy MEC Environmental Ltd)

Figure A4.52 Gas membrane cut by scaffolders and bricklayers after installation (courtesy MEC Environmental Ltd)

Figure A4.53 Gas membrane left exposed for long period of time, shows significant fraying at cavity edge (courtesy NHBC)

Figure A4.54 Gas membrane damage/tearing at edge of ground floor slab screed layer where it was left exposed to elements for period of time (courtesy NHBC)

Figure A4.55 *Gas membrane at stepped junction of slab to integral garage, appears to be susceptible to tearing when screed is poured. Screed may also weigh down on gas membrane if fitted too tight (courtesy NHBC)*

Figure A4.56 *Gas membrane at edge of concrete screed. Screed has been grinded to achieve desired levels, gas membrane shows extreme wear and damage as a result (courtesy NHBC)*

Figure A4.57 *Unprotected gas membrane damaged by heavy traffic (courtesy MEC Environmental Ltd)*

Figure A4.58 *Damage caused to gas membrane by follow-on trade who cut/shaped the dry lining board directly on the unprotected installed gas membrane (courtesy NHBC)*

Figure A4.59 *Gas membrane slit at the bottom of a cavity tray to enable water to drain away (courtesy Smith Grant)*

Figure A4.60 *Some stones could penetrate gas membrane if sufficient force is applied (courtesy Smith Grant)*

Figure A4.61 ‘Stripping’ occurs on gas membranes that contain aluminium foil. The foil gets too hot under the outer layer of LDPE or PP and the top layer of the gas membrane sticks to the roller which strips it off, leaving the aluminium completely exposed (courtesy MEC Environmental Ltd)

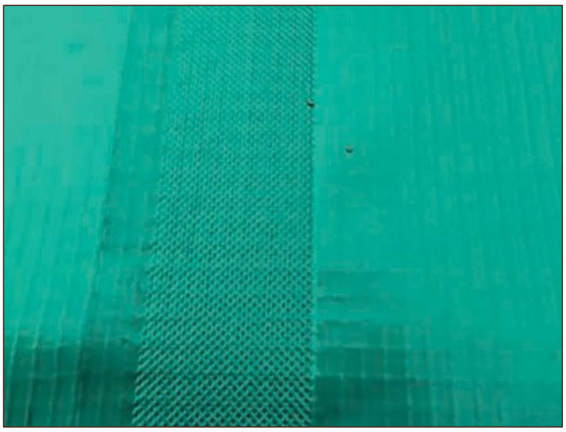


Figure A4.62 Wedge weld on an LDPE aluminium gas membrane, where the installer used metal nip rollers. This destroyed the top layer and probably the bottom layer, leaving aluminium exposed between the weaves. This failed dielectric testing along all joints (courtesy MEC Environmental Ltd)

A4.3.2 Bad practice – gas membranes installed incorrectly

Figure A4.63 Absence of surface preparation prior to laying of gas membrane, debris likely to pierce gas membrane (courtesy Card Geotechnics Limited)

Figure A4.64 Insufficient length of gas membrane protruding through wall to overlap with gas membrane within building (courtesy Card Geotechnics Limited)

Figure A4.65 Wrinkling of gas membrane over joint has resulted in gaps (only visible due to the use of a transparent gas membrane) and the secondary seal uses ordinary gaffer tape rather than a proprietary product (courtesy Smith Grant)

Figure A4.66 Follow-on trades proceeded work before gas membrane joints sealed (courtesy Card Geotechnics Limited)

Figure A4.67 Traffic over mesh resulted in several punctures, in addition most joints were found to be poorly constructed. Taped joints are difficult to construct in adverse weather (courtesy Smith Grant)

Figure A4.68 A pre-formed corner unit would have been preferable. The installer could not produce sufficient quality despite the amount of tape applied (courtesy Smith Grant)

Figure A4.69 Attempt at corner detailing using non-proprietary duct tape (courtesy Smith Grant)

Figure A4.70 Inadequate corner detailing. The use of preformed proprietary products would have avoided such bad practice (courtesy NHBC)

Figure A4.71 No corner detailing leading to stress point on gas membrane (courtesy Smith Grant)

Figure A4.72 Joint between top hat and gas membrane has lifted due to poor fit and attempt to construct in very wet conditions (courtesy Smith Grant)

Figure A4.73 *No bead of double sided butyl tape provided between interfaces of ID top had and OD service pipe: cannot be compressed enough to form seal (courtesy Smith Grant)*

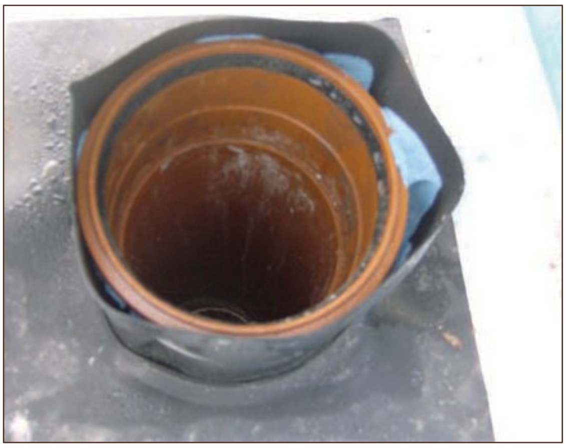


Figure A4.74 *Gap between OD of service pipe and ID of top hat to large: cannot be compressed enough to form seal, even with the application of additional tape (courtesy Smith Grant)*

Figure A4.75 *Jubilee clip on service entry insufficiently tightened so joint is uncompressed (courtesy Smith Grant)*

Figure A4.76 *No double sided tape used in joints (courtesy Smith Grant)*

Figure A4.77 *Small lap and no single sided tape used to achieve secondary seal (courtesy Smith Grant)*

Figure A4.78 *Gap in jointing over wall cavity big enough to insert fist (courtesy Smith Grant)*

Figure A4.79 Gas membrane not continuous over internal wall. It had been deliberately cut open for unknown purpose (courtesy Smith Grant)

Figure A4.80 Column left unsealed (courtesy PAGeotechnical Ltd)

Figure A4.81 No seal to perimeter pipe (courtesy PAGeotechnical Ltd)

Figure A4.82 Gas membrane used to bridge cavity wall instead of DPC, leaving it exposed to damage by follow-on trades (courtesy Smith Grant)

Figure A4.83 Poor quality installation of liquid gas membrane. Liquid gas membranes come in two colours (black and white) allowing coverage of each coat to be easily assessed. Here the gas membrane has been spread too thinly and inconsistently. In addition, it appears to have been applied to a damp surface, causing blistering (courtesy Card Geotechnics Limited)

Figure A4.84 Taped joints are difficult to construct in adverse weather. Also difficult to inspect if covered with snow (courtesy Smith Grant)

A4.3.3 Bad practice – passive venting systems

Figure A4.85 *Clean single sized stones with no fines acting as venting media, however no ventilation gaps in internal sleeper walls (courtesy Smith Grant)*

Figure A4.86 *Cavity is becoming blocked with detritus. The vent holes in the beam are no longer visible (courtesy Smith Grant)*

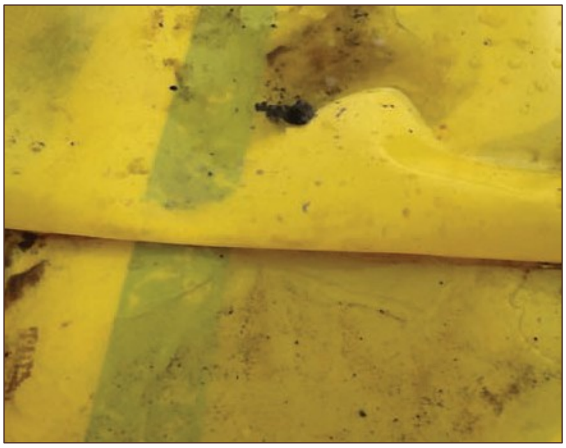


Figure A4.87 *Tape joint with crease running through and air bubbles where gas membrane not in complete contact with tape. Rollers should have been used to produce a consistent seal (courtesy MEC Environmental Ltd)*

Figure A4.88 *Ventilator becoming detached to fit to external block work. This is due to builders requiring increased cavity widths to achieve thermal properties expected by Building Regulations (courtesy NHBC)*

Figure A4.89 *No ventilation in internal sleeper wall (courtesy Smith Grant)*

Appendix 5 –Verification Proforma

Copied Directly From Appendix A5 CIRIA C735

Mallett, H, Cox (nee Taffel-Andureau), L, Wilson, S, Corban, M (2014) Good practice on the testing and verification of protection systems for buildings against hazardous ground gases, CIRIA, C735, London (ISBN: 978-0-86017-739-5). Go to: www.ciria.org

VISUAL INSPECTION OF GAS PROTECTION MEASURES

Site name:	Gas characteristic situation:
Job number:	Type of development and building/block checked: (residential/ commercial/other)
Date:	Building description:
Visit by:	Foundation type: (suspended floor/raft/other)
Weather at time of inspection:	Gas protection type: passive/active

No.	Item	Comments (see notes)
1	***Gas membrane***	
1.1	Condition of sub-grade and underside of gas membrane	
1.2	Gas membrane type	
1.3	Gas membrane condition	
1.4	Joining tape product	
1.5	Lapping design	
1.6	Laps, welds and joints seals	
1.7	Service entries seals	
2	***Passive venting***	
2.1	Sub-floor void	
2.2	External wall airbricks	
2.3	Internal sleeper walls	
2.4	External vent trenches/ducts	
3	***Active venting***	
3.1	System details	
Additional notes:		

Notes: inspection checklist

1.1	Underside of gas membrane	Check that the sub grade does not contain rough/uneven surfaces, is appropriately clean and that there are no hard/sharp objects. That protective sand blinding or geotextile (if specified) is present and meets the design criteria.
1.2	Gas membrane type	Manufacturer and product specification, gauge, colour, brand/name, material batch/roll numbers, storage arrangements (protected from dirt/damage?)
1.3	Gas membrane condition	Open punctures, tears, rips, stretching? Excessive footprints/evidence of traffic? Presence of debris? Repairs? Signs of weakness such as raised or sunken indentations? Protection plan in place to restrict access to lain gas membrane?
1.4	Joining tape product	Product type, brand, thickness, material, width, colour? Use of double sided tape?
1.5	Lapping design	Joints lapped and sealed in accordance with manufacturer's requirements/ specification? Minimum overlap insured? Sections taped twice?
1.6	Laps and joints sealed	Welds complete? Appropriate joining/double sided tape used?
1.7	Service entries sealed	Top hats seal arrangements fixed around service entries? Use of Jubilee clips?
2.1	Sub-floor void	Is a check possible? Void former? Gravel (type/specification)? Height of void space? Is it clear?
2.2	External wall airbricks	Numbers, size, positions as design drawing?
2.3	Internal sleeper walls	Ventilation holes (honeycomb brickwork/pipe crossings?) – size, spacing, location in accordance with design?
2.4	External vent trenches/ducts	Located and constructed in accordance with design drawings? If open-topped gravel – gravel type/presence of fines? If pipe or other vent, check position and construction for functionality and absence of blockages. Ability of void former to withstand bearing of the superstructure?
3.1	Active venting	Type of air supply: mechanical, natural, combined? Location/condition/number of fans and vents? Location and size of inlets? Provision of air-cleaning devices and air heaters? Supply and exhaust ductwork? Alarm provision/installation? Gas monitoring system in under-floor void?

Photographs

No.	**Description**

The gas protection measures inspected:	a Are acceptable and comply with the specification
	b Are acceptable but attention is drawn to issues related to item no. xxx
	c Are not acceptable due to the issues related to item no. xxx

Name: **Signature:** **Date:**