UK Onshore Well Integrity

Project Report – Conference Paper

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Institution of MECHANICAL ENGINEERS

The Institute of Materials, Minerals and Mining

CONTENTS

1. **INTRODUCTION: PAGE 3**
   Purpose
   What is well integrity?
   Background
   Project driver

2. **CONCLUSIONS & OBSERVATIONS: PAGE 5**
   Conclusions
   Observations

3. **WHY SHALE GAS IN THE UK?: PAGE 7**
   Concerns
   Future gas prospects
   Gas represents
   Energy security
   Major economic benefits of shale gas

4. **PROJECT METHODOLOGY: PAGE 9**
   Methodology
   Project documentation
   Workshop
   Workshop feedback
   Introduction to risk assessment with case study on shale gas

5. **CONTEXT: PAGE 14**
   UK onshore shale gas well construction and operation
   Well integrity and UK requirements
   The role of the well examiner

6. **DOCUMENTATION REVIEW: PAGE 20**
   Key documents reviewed
   Regulations
   Guidelines

7. **IMechE/IOM3 OPERATOR SURVEY: PAGE 23**
   Background & objectives
   Responses

8. **WORK IN PROGRESS: PAGE 25**
   Ongoing studies

9. **APPENDIX: PAGE 27**
   Additional documents reviewed

10. **GLOSSARY: PAGE 30**
    Common abbreviations, terms and definitions used

Introduction

Purpose

The purpose of this report is to detail the existing regulations and guidelines in respect of well integrity in oil & gas exploration and production on the UK mainland, with specific reference to shale gas.
This report is primarily to inform the general public about onshore well integrity and to give an informed view of current practices.

What is Well Integrity?

Oil & Gas UK defines well integrity as "the application of technical, operational and organizational solutions to reduce the risk of uncontrolled release of formation fluids throughout the life cycle of the well".

Background

Following the discovery of substantial gas reserves in the North Sea in the early 1960's the United Kingdom (UK) moved from coal to gas as the fuel of choice for power generation and domestic heating/cooking. This trend was accelerated in recent years in an effort to reduce carbon dioxide emissions, with gas being viewed as a cleaner fuel than coal.

Domestic gas production from the UK Continental Shelf (UKCS) is insufficient to meet UK demand, currently supplying around 48% of demand. The UK is therefore reliant on importing gas to meet the majority of the demand. Approximately 38% of UK gas is supplied through pipelines from continental Europe and Scandinavia. With the remaining 14% of demand being met by Liquefied Natural Gas (LNG) supplied by ships, primarily from the Middle East. Imported gas is less secure than domestic gas, has commercial risks associated with currency exchange rates, has a negative impact on the UK balance of payments and does not contribute the revenue associated with gas production into the UK economy.

The United States (US) has led the large-scale development of shale oil and gas using high volume hydraulic fracturing. This has been transformational for the US economy, by increasing the availability and reducing the cost of this energy source. But they have a different land-ownership regime. The UK has extensive onshore shale gas and oil resources located in central Scotland and England. The UK Government has issued licences to enable companies to undertake exploration work to determine if UK shale gas and oil can be economically developed. The first dedicated shale gas well was drilled at Preese Hall in Lancashire in 2010. During the initial stages of high volume fracturing of the well low level earth tremors were recorded and the operation was shut down. There was significant media interest and the UK Government imposed a moratorium on further activity. The moratorium was lifted following evaluation and agreement on guidelines for future activity.

Project Driver

Proposed onshore UK shale gas and oil exploration has continued to attract significant attention from the media, politicians, environmental groups, protest groups, business groups and the public at large. Local councilors turned down
an application for further shale gas exploration activity in Lancashire and there is significant resistance to an application for fracking in North Yorkshire.

The information often used to oppose shale gas extraction through hydraulic fracturing often includes experience from the US, which is not in line with the UK regulatory framework.

There has been opposition to extraction of natural gas through hydraulic fracturing and much information has been made public that supports opponent's viewpoints; this has often included experience from the US, which is not relevant to the UK. One of the key topics of discussion has been well integrity.

The Institution of Mechanical Engineers and the Institute of Materials, Minerals and Mining have collaborated to form a joint work group to provide the public with an engineering view on well integrity pertaining to UK onshore shale gas wells to assist the public to have an informed view.

This Report reviews the regulatory framework and activities surrounding onshore UK well integrity, as this covers most areas of concern.

Note: *Since this study has started there has been an agreement between Oil & Gas UK and UKOOG that Issue 3 of the Oil & Gas UK's OP095 will updated to incorporate the recommendations of the UKOOG's Guidelines, thus creating a single "bible" for both the offshore and onshore Oil & Gas Industry.*

Conclusions & Observations

Conclusions

ONSHORE oil and gas operations have been managed safety and with minimal impact on the UK's natural and human environment for over 100 years. The current UK "Goal Setting" Regulatory Regime and associated independent verification has been found to be robust and effective. This regime has been further enhanced, in recent years, by the publication of detailed Guidelines containing good practices to maintain well integrity throughout the well life cycle from design through to eventual abandonment. The UK Regime is significantly different to that in the United States of America, which adopts a more prescriptive approach.

There exists significant knowledge on what can go wrong and the controls required to remove and manage the risk or mitigate the impacts, should an issue arise. However, it is also apparent that no 'one solution' can be applied across all assets and that good design, management, engineering judgment and risk assessment are critical factors in a safe and successful well operation.

UK onshore well operations vary significantly in scale from a few wells to a hundred or more wells in one Field. Well operators maintain and apply asset management systems commensurate with the scope and scale of their operations.

The UK Regulators are actively discharging their duties, including site visits where they are testing the application of good practice and adherence to UK requirements.

It was noted that there are in effect two documents relating to guidance for well integrity in the UK: those of the UK Onshore Operators Group (UKOOG) and those of Oil & Gas UK (OGUK). The OGUK Guidelines cover both onshore and offshore wells, are endorsed by UKOOG and are cross-referenced from the UKOOG Guidelines. The action to make the OGUK Well Life Cycle Integrity Guidelines the industry "bible" for well integrity is supported and encouraged.

Observations

	Item	Description	Comment
1	Communication	Keep communicating with clear, transparent and un-technical explanations	The media have taken an exaggerated view of onshore oil & gas to the public, with widespread misconceptions and misinformation. This requires the Engineering Institutions to give clear, accurate, unbiased information and explanations
2	Consider Whole Life Cycle for all assets	The operators are responsible for the asset right through to safe decommissioning.	Oil & Gas UK's Guidelines for the Abandonment of Wells. Ensure that the full life cycle of the wells have been catered for and this will include post-decommissioning. No well is to be abandoned without following the Guidelines.
3	One set of Well Life Cycle Integrity Guidelines	This will require Oil and Gas UK's Well Life Cycle Integrity Guidelines and UKOOGs Shale Gas Well Guidelines to be combined into one set of integrated guidelines, which are pro-active and demonstrate "Best Available Techniques" (BAT)	Agreed. Oil & Gas UK – Well Life Cycle Integrity Guidelines will be the lead document. Suggestions from the onshore operators will be incorporated in Issue 3.
4	Inspections Develop a recognized programme of ad-hoc visits and audits	In March 2015 the EA issued a 'Regulatory Position Statement' which made the facilities the focus of a permitting review exercise, which will look to assess each installation and issue permits based upon current and proposed operations to allow for regulation of the facilities by the EA going forward.	All operators will need to make themselves familiar with this new and changing legislation where each individual site would have to have its own permit and with the possible requirement for baseline monitoring in place before any operations can start.
5	Adopt appropriate Asset Management systems	Adopt a fully transparent asset management system, appropriate for the size and number of assets.	That records all key information about the well and its operation throughout its operational life and post decommissioning to the point at which permits are surrendered and planning conditions exercised.
6	Risk Assessment	Develop a format to cover the multi-disciplinary requirements of Shale Gas exploration and production	The risk assessment, which is done as part of the historical and ongoing well operations in the UK is proven to be sound. This needs to be maintained in line with the asset management systems.
7	Training	There is an opportunity for Institutions to develop a centralized training regime.	This is a suitable project for the National Skills Academy

Why Shale Gas in the UK?

The wells mainly under consideration for UK well integrity are those exploring for shale gas and the economic arguments align with this energy source. Following identification of the need to collect interested parties together, the IMechE has held a series of UK Shale Gas "Engineer's Summits", in 2014 & 2015, with another planned for February 2016. These have been entitled "The Engineers' Summit", as it is felt that engineers should understand this topic better and be the advocates.

Concerns
Feedback from these Summits showed a lack of a "Social Charter" to develop onshore shale gas operations. There are worries about groundwater contamination, fugitive emissions and induced seismicity, which relate to Well Integrity. Additionally, continuing misinformation, using bad and misguided examples from North America stokes this fire, showing there is a need for clear information that identifies the potential cause of the misgivings and aims to provide details of the regulatory regime.

Future Shale Gas Prospects
The UK needs new domestic gas supplies, as increasing gas usage will pull in imports, gas or LNG and cannot be replaced overnight by intermittent renewables, which, typically only generate electricity.

Recent estimates by the British Geological Survey indicate that the gas in place in the central shale basin totals up to 1,300 trillion cu.ft. of shale gas, compared with the total UK annual consumption of gas of around 3tcf

Gas represents (DECC)
Overall– c.33% of all energy consumed in electrical power generation in 2014
Power – c.27% of UK Electricity generation
Heat – c.83% of UK households
Gas is the "backup" energy source
Feedstock – for the UK chemical industry
Positive impact on the environment

Job creation - £20 bn /year to the UK economy, provides direct and indirect employment for over half a million people

Energy Security:
a) Electricity Power Generation
There is a shortage of electrical power in 2015/6, which cannot be made up with renewables, because they cannot be called up quickly at peak load times and so not "despatchable"

Generating capacity is falling year-on-year
Current margins of supply vs. demand are below 5.1%?
Without "incentives" this would fall to 1.2%

b) Gas
Gas should not be confused with electricity.

It is a direct source of heat energy and chemical feedstock. Gas is the necessary complement to intermittent renewable energy sources, increasing gas dependency on imported LNG and pipeline gas from Europe.

Environmental benefits of natural gas are:

- Lower Emissions than imported coal
- More versatile than renewables

Major economic benefits of shale gas
Jobs – 74,000 (IoD)
Supply chain – peak investment £3.7m/annum (IoD)
Energy security
Tax – important replacement for North Sea revenues
Lower price volatility
Community benefits
Possibility of LNG exports in the future

Project Methodology

Methodology

To conduct an independent and detailed review of the existing UK "published" onshore energy industry guidance and industry practices for the management of onshore well integrity and to provide a status report which:

i. Provides a review of the documentation and identifies any potential gaps.

ii. Reviews "other" information/documentation available through service companies and other organisations.

iii. Considers if these "published" documents are fit for purpose, in the context of UK guidelines and standards. Where applicable/available use statistical evidence on historic performance and "other" information/documentation as presented in well operations documentation

iv. Hold a review workshop with all involved parties to discuss the draft document and argue the requirements.

v. Publicises the results of the survey to help allay the public's fears that onshore well integrity might be an unacceptable risk and if necessary proposes recommendations that can make the wells/industry safer. Write and publish a report of the findings, with recommendations for any improvements.

Project Documentation

The documents considered the most important to review for this project are listed in the Appendix. These documents were examined for their relevance and completeness. The operators with onshore licences were subjected to a questionnaire and the results have been included in Section 7 (page 23).

Workshop

The report draft was made available for comments and reviewed by 15 engineers from the IMechE, IOM3, HSE, EA, Academia, Consultants, Contractors and Operators, at a full day's workshop convened by the IMechE, in November 2015.

Following presentations about the project driver and the current guidelines, relevant to onshore operations and risk assessment, there was an open discussion about the necessary requirements for a safe industry.

Three actual detailed case studies, demonstrating the use of the OGUK Guidelines, were presented from UK operations, on:

- New well construction;
- Well integrity management system;
- Well recovery in the event of an issue.

DNV GL presented an introduction to risk analysis and a specific Case Study relating to shale gas and the potential of groundwater contamination via cement failures. This was taken from a real life exercise, as shown below.

Workshop Feedback

This report is very comprehensive.

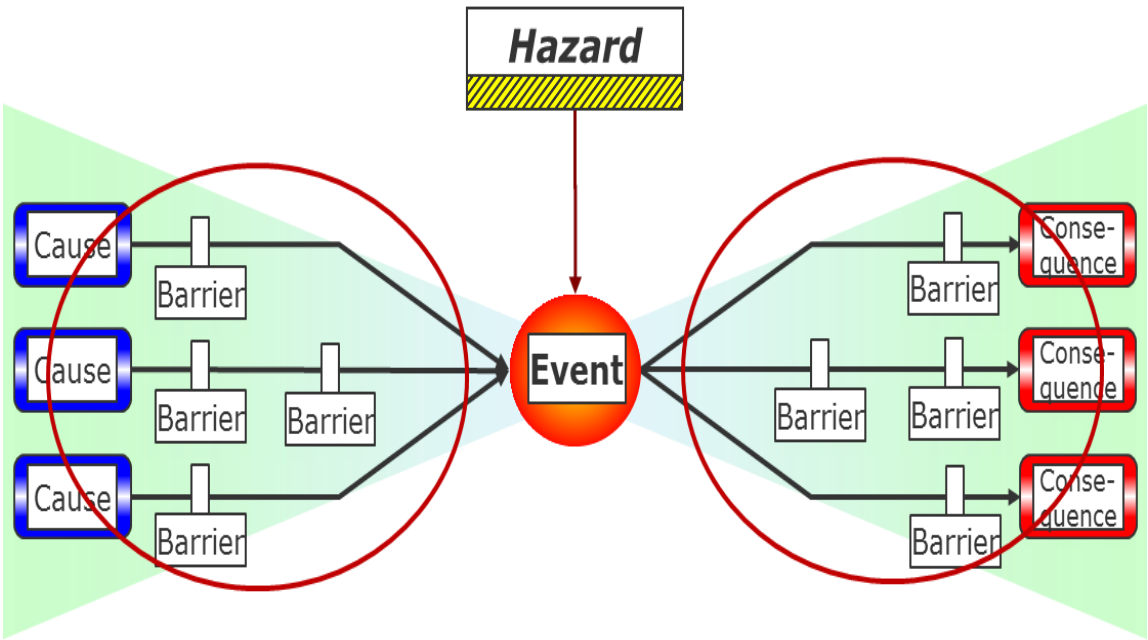
- The Well Integrity Management System used was a software-based scheme that logs all parameters from all their wells (approx. 200 wells). This might not suit smaller operators, for whom a spreadsheet scheme might prove sufficient.
- Should references be made to the upcoming ISO Standard? - This has been accepted in principle and will be referenced in Issue 3 of the Guidelines when issued.
- The risk assessment presentation gave rise to considerable discussion. The main concern being that the study was to show near-zero leakage of gases from the well and this is unrealistic and needs to be shown in context.
- It was considered that, although sympathetic to the topic, it might be considered too complex for the report's target audience and could lead to misinterpretation to an uninformed audience.
- There is no evidence of "significant" leaks from wells at present and this required meaningful comparisons be made.
- The UK's "benign" geology would reduce the risk, against more "active" regions of the world, such as California.
- In the ReFINE project there were small leakages noticed in abandoned wells. This was now addressed in the Regulations. But, it was agreed that signs of seepages would initiate most oil & gas exploration.
- Is anything missing from the paper?
  Suggestions included:
    - Future developments in the Industry, including:
    - Wireless monitoring
    - Alternative materials
    - New propants
    - Expanding cements

Introduction to Risk Analysis with Case Study on Shale Gas
DNV GL Presentation to IMechE Well Integrity Steering Group Workshop, November 2015.

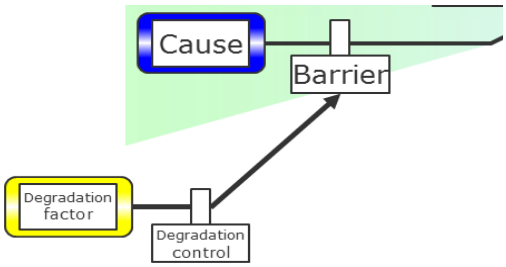
The presentation started by explaining the fundamental risk management process steps undertaken to support managing the risks form hazardous assets and activities. There are five questions to answer:

1. What can go wrong? (Hazard/Risk identification);
2. How often? (Frequency analysis);
3. How big? (Consequence analysis);
4. So what? (Risk evaluation);
5. What do I do? (Risk treatment).

It was also noted that "risk analysis" is the frequency analysis and consequence analysis together, i.e. both steps 2 and 3 and that risk assessment is the combination of the hazard / risk identification, the risk analysis and the risk evaluation, i.e. the first four questions. The description / story of a risk can typically be depicted using a bowtie diagram, with a specific hazard and event at the centre, multiple potential causes feeding into it and multiple consequences resulting from it. Barriers to prevent or mitigate the risk are shown on the cause to event and event to consequence scenarios.



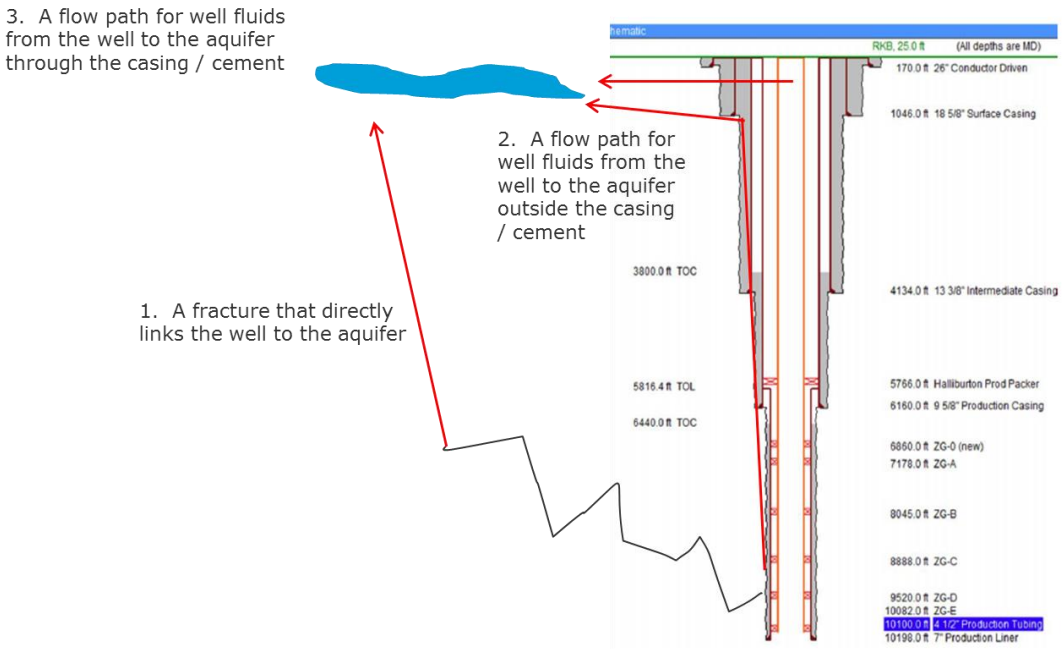
Degradation factors, which weaken the barriers, may also be presented on the bowtie diagram, along with controls that are in place to maintain the effectiveness of a barrier.



Many different hazard / risk assessment techniques are available, and the correct one(s) to apply for a particular study will depend upon the specifics of the case. The different techniques can generally be categorised as either qualitative of quantitative.

DNV GL has been working with a UK Operator to provide a risk analysis of the potential for aquifer contamination associated with shale gas activity in a well. Initially three scenarios were identified for consideration:

1. A fracture that directly links the shale gas geology to the aquifer.
2. A flow path for well fluids from the shale gas geology to the aquifer outside the casing / cement.
3. A flow path for well fluids from the well to the aquifer through the casing and cement



Scenario 2 was selected for detailed analysis at the present time. Following a review of data available for the well and the planned frac activity, a risk workshop was held to discuss and define the various terms of the analysis (e.g. what would count as failure), what paths are there for fluid from the well to aquifer, what barriers to flow exist, what causes are there for failure and what mitigating actions could be taken. Using this information, fault trees have been prepared to map out the different factors identified and how they are linked. There are two trees, one for Scenario 2 occurring during the frac, the other for the scenario occurring after frac, i.e. during production from the fractured well. Currently, work is on-going to generate the probabilities for the base events in the fault trees. This involves specialists in three DNV GL offices (London, Houston, Oslo) and discussion with the operator. Once complete, this will give an estimated probability for the potential of frac fluid or gas reaching the aquifer following the Scenario 2 flow path.

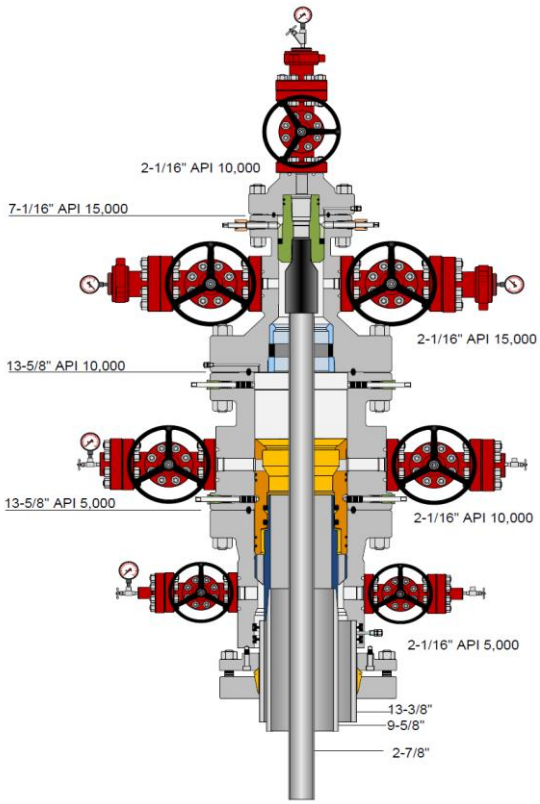
Context

UK Onshore Shale Gas Well Construction and Operation

Currently there are around 2000 land drilling rigs working on oil and gas drilling globally with many hundreds of thousands of oil and gas wells in operation. Oil and gas wells are constructed by rotary drilling.

Before drilling can start, geologists, geophysicists and other subsurface professionals will develop an anticipated geological model from surface. The reservoir and petroleum engineers will determine the target formation and requirements for the well. The drilling team will collate all the required information to design the well to meet the objectives and ensure full life cycle integrity. Each well is individually engineered.

Once the well has been designed an independent expert will examine the well design to ensure that it meets Industry standards and best practices. The drilling team will submit the well design and the associated drilling programme to the Regulatory Authorities for the necessary consents.



The drilling process involves deploying a drill bit on a drill string that consists of 9m long sections of steel drill pipe with sections of thicker heavy pipe at the bottom containing any tools required for steering the drill bit, determining the position of the drill bit and/or acquiring and transmitting downhole information.

The mechanism for drilling consists of rotating the drill bit and applying weight. The drill bit may be steered in three dimensions to access the target zone using downhole tools. Multiple wells are drilled from a single site to access the target formations over a wide area with minimum surface impact.

Drilling fluid is pumped down the drill string and up the annulus between the drill string and the drilled wellbore. The drilling fluid cools the drill bit, provides hydraulic power and lubrication, transports the drilled cuttings to surface and stabilises the wellbore. It also provides hydrostatic pressure to ensure that formation fluids remain in the formation and provides a mechanism for transmitting information between the bottom of the drill string and surface using pressure pulses.

At surface the drill cuttings are removed and analysed to determine the formation characteristics. The drilling fluid is treated and re-used.

Blowout preventors are installed to close off the well if the drilling fluid fails to contain the formation fluids.

Typically many different types of formation will have to be drilled through before the target is reached. The different formations will have different characteristics and key properties include the rock strength, pressure within the formation, fluid content and the permeability or ease at which a fluid can flow through the rock. The variation in characteristics means that a well cannot be drilled from the surface to a deep target in one go.

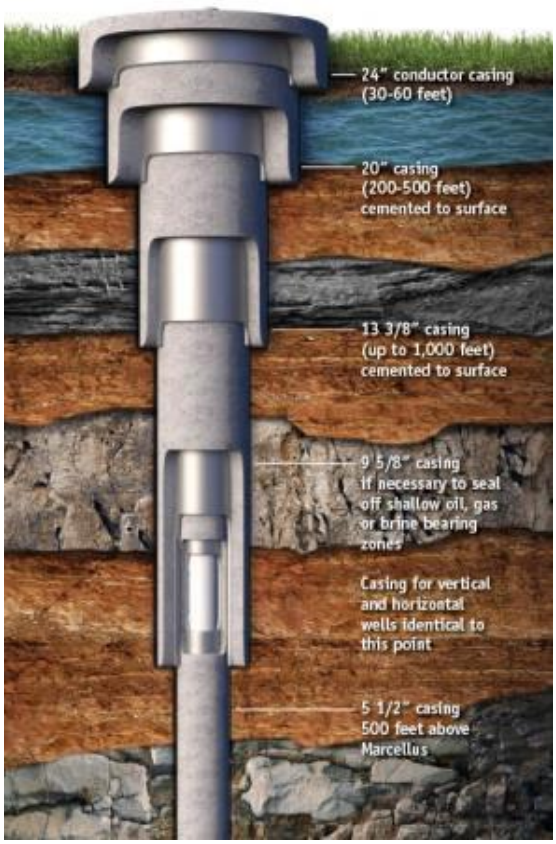
At selected points the drill bit will be pulled from the well and steel pipe called casing will be run into the well. Like drill pipe the casing comes in 9m lengths that are screwed together. The casing diameter will be matched to the size of the hole drilled. The thickness of the casing will be selected to provide the burst and collapse strength required through the life of the well, while the metallurgy of the steel used will be selected to resist the fluids that the casing will come into contact with during its life.

Once the casing has been run to the bottom of the well cement is pumped down the casing and up the annulus. The cement is allowed to set in the annulus to form a seal between the casing and the formation and to isolate the formations and their contents from each other.

A wellhead is installed on top of the casing to provide a mechanical seal at surface with access to the annuli via valves. After installation of the wellhead the casing is pressure tested to ensure that it is leak tight. A new drill bit is then run and the next section of the well is drilled.

The process of drilling a section, acquiring information on the formations drilled, casing, cementing, installing the wellhead seal continues, until the target formation is reached.

Each casing that is installed has a smaller diameter than the previous casing and is by design stronger in terms of collapse and burst rating. The result of the drilling process is a series of concentric steel tubes cemented in place, as illustrated with typical sizes shown:

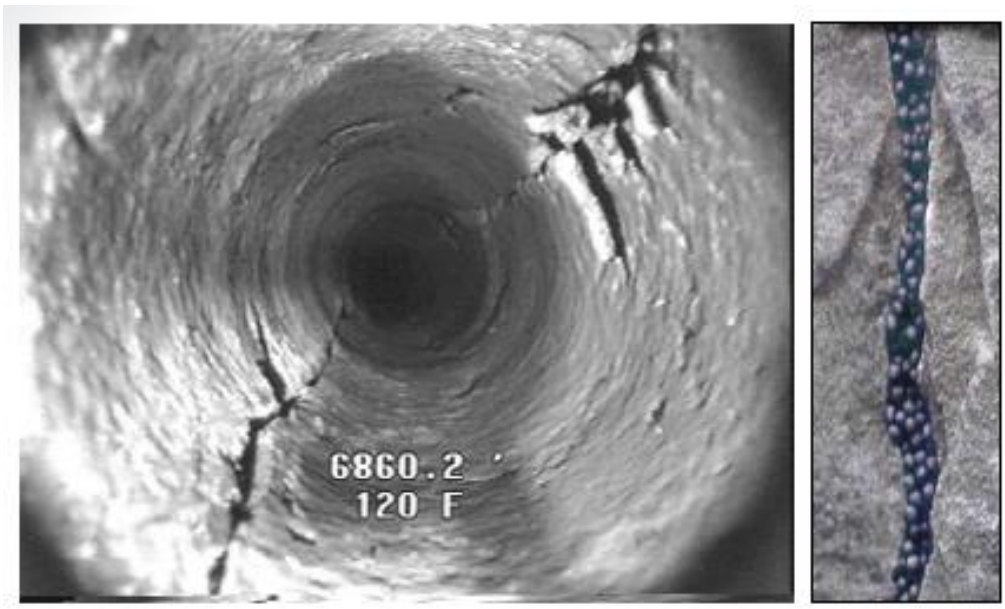


The schematic illustrates a cross section through a wellhead showing the surface arrangement of mechanical seals, with an example onshore UK well shown in the photograph.

In the case of a shale gas well when the target shale has been drilled and isolated the shale has to be hydraulically fractured to create sufficient permeability for the gas within the shale to flow.

Without hydraulic fracturing the gas is unable to flow through the formation. Hydraulic fracturing involves using pumps to create sufficient pressure to exceed the fracture strength of the shale and create a fracture. Once the fracture has been created a permeable material termed a proppant has to be pumped into the fracture such that when the pump pressure is released the proppant remains in the created fracture to provide the flow path. Without the proppant when the pressure is released the weight of the rock will cause the fracture to close and the gas will not be able to flow. Typically sand is used as a proppant.

The photograph below on the left is looking down a wellbore, without the casing installed and shows a fracture. The picture on the right is a cutaway showing proppant in the fracture.



The hydraulic fracturing programme is carefully engineered to place the fracture in the gas bearing shale. Once it has been established that the well will produce gas it is completed, this may be done before the well is fractured. The completion involves installing steel tubing with downhole devices to facilitate flow control, monitor production rates and isolate the gas zone as required. On top of the wellhead an arrangement of valves called the Xmas tree are installed to provide a means of opening and closing access to the well. The photograph below shows a Xmas tree and full wellhead.

Typically the wellhead will sit below ground level and the surface equipment will be screened from view by trees. The drilling rig will be on the well site for the drilling and completion of the well and will then be moved. Once the Xmas tree has been installed the well will be commissioned or connected to the production facilities.

All the safety critical components on or in the well will have a performance standard that specifies the monitoring, maintenance, inspection and testing requirements. An independent expert will check that the operating company adheres to these requirements for every well and takes action to maintain the well in a safe condition. Well equipment will be repaired or replaced as required, in addition to monitoring and inspection. At the end of the well life cement and/or mechanical plugs will be installed in the well to fully isolate the formations from each other and the surface. The Xmas tree and wellhead will be removed and the well capped below ground level with a steel plate welded over the well such that there is no evidence of the well.

Well Integrity and UK Requirements

Well integrity may be defined as the application of technical, operational and organisational solutions to reduce the risk of an uncontrolled release of formation fluids throughout the life cycle of a well. Following the loss of the Piper Alpha installation the enquiry led by Lord Cullen recommended a complete overhaul of UK legislation pertaining to oil and gas operations.

A key recommendation relating to wells was the introduction of the principle of "goal setting" as opposed to "prescription". This principle was adopted and is illustrated by the following extract from Statutory Instrument 913 known as the Well Design and Construction Regulations 1996 or "DCR":

"The well-operator, shall ensure that a well is so designed, modified, commissioned, constructed, equipped, operated, maintained, suspended and abandoned that –

a. so far as is reasonably practicable, there can be no unplanned escape of fluids from the well; and
b. risks to the health and safety of persons from it or anything in it, or in the strata to which it is connected, are as low as is reasonably practicable"

The above requirement applies to all onshore wells in Great Britain for the purpose of exploiting naturally occurring hydrocarbons and applies throughout the whole well life cycle. DCR requires the well operator to maintain well integrity.

The requirement "so far as is reasonably practicable" is generally termed ALARP or "As Low As Reasonably Practicable". Industry Standards and document what is considered good practice and well operators must be able to demonstrate that that they have considered these good practices and either conform or can demonstrate why they believe that it is not practicable to conform.

Since Industry Standards and Guidelines are continually evolving in response to learning and new technology what is considered reasonably practicable continually evolves. Through Oil and Gas UK and the UK Onshore Operators Group the UK was the first, and to date the only Country in the world, to publish full life cycle well integrity guidelines.

The first issue was published in 2012, the second issue in 2014 and the next issue is being progressed for publication in 2016.

DCR further requires the well operator to employ independent experts to check that the above requirements are met in addition to Regulatory approvals and oversight. The requirements for ALARP, well examination and independent verification were first introduced in Great Britain and ensure that the UK has what is believed to be the most robust regulatory requirements for oil and gas wells in
the world. A list of key documents pertaining to the integrity of shale gas wells can be found in the Appendix to this paper.

The Role of the Well Examiner

This role is defined under DCR 1996 Regulation 18. The Independent well examiner is to examine information on the design and construction of a well and the sub-surface environment including any hazards which the geological strata and formations may contain and to examine any work in progress, in order to provide assurance that a well is designed and constructed properly and is adequately maintained. The purpose of examination is to provide quality control and quality assurance that ensures, so far as is reasonably practicable, there can be no unplanned escape of fluids from the well; and risks to the health and safety of persons from a well are as low as is reasonably practicable.

Documentation Review

Key Documentation Reviewed

The workgroup undertook a review of documents related to shale gas well integrity. From the review the workgroup concluded that the key documents relating to the management of UK well integrity were as listed below. Other documents reviewed are listed in the Appendix.

Regulations

Borehole Sites & Operations Regulations 1995 (BSOR)
Offshore Installations and Wells (Design & Construction etc.) Regulations 1996 (DCR)

These Regulations were produced following the enquiry led by Lord Cullen into the Piper Alpha tragedy and form part of the UK "goal setting, with independent verification, regulatory regime", this approach has been recognised as global best practice. BSOR apply only to onshore wells while DCR apply to all wells in Great Britain for the purpose of the exploitation of naturally occurring hydrocarbons – including shale gas. The Regulations set the requirement for well integrity as follows: -

"The well-operator, shall ensure that a well is so designed, modified, commissioned, constructed, equipped, operated, maintained, suspended and abandoned that:

(a) So far as is reasonably practicable, there can be no unplanned escape of fluids from the well; and

(b) risks to the health and safety of persons from it or anything in it, or in the strata to which it is connected, are as low as is reasonably practicable."

Guidelines

Oil & Gas UK (OGUK) OP095 - Well Life Cycle Integrity Guidelines, (WLCIG) Issue 2, June 2014 (2014)

In response to the 2010 Deepwater Horizon tragedy in the Gulf of Mexico a review of key factors relating to well control on the UK Continental Shelf was undertaken by the Technical Review Group. A recommendation from the Technical Review Group to form a workgroup to produce and maintain full life cycle well integrity guidelines was taken up by the trade association OGUK. A workgroup comprising representatives from: UK onshore and offshore well operators, UK Regulators (HSE and DECC), well service contractors and drilling contractors was formed in early 2011. The workgroup undertook a review of available industry standards, recommended practices and guidelines. From this review it was determined that full life cycle well integrity guidelines covering the scope of the DCR did not exist. Norway had full life cycle well integrity guidelines, Norsok D-010, but this document only covered offshore wells found on the Norwegian Continental shelf. The workgroup established a working relationship with the Norwegian workgroup with the intent of aligning UK and Norwegian as far as practicable.

The workgroup sought to document current good industry practice that could be adopted to assist well operators in maintaining well integrity and meeting UK Regulatory requirements. The workgroup sought to reference, rather than duplicate, existing

published documents wherever practicable. The current Issue identifies 132 relevant documents with links where the document is publically available. Issue 1 of the WLCIG was agreed by the UKOOG and published by OGUK in July 2012. The document included the following: -

- Summary of key UK regulatory requirements pertaining to well integrity.
- Requirements of a well integrity management system.
- Requirements for identifying, testing and maintaining well barriers.
- Requirements to manage change.
- Key requirements to establish and maintain well integrity through each stage of the well life cycle: design and operations planning, drilling, well testing, completion, commissioning, operation and maintenance, intervention and workover, suspension and abandonment.

The document incorporated a feedback mechanism. The workgroup undertook extensive communication. OGUK ran workshops to obtain feedback and input which contributed to Issue 2 that was agreed by the UKOOG and published in May 2014.

The workgroup undertook communication of Issue 2 and ran more workshops to gather feedback and good practices. Issue 3 has been drafted and at February 2016 was going through review prior to anticipated publication in March 2016.

It was noted that OGUK issued and maintain other Guidelines that are relevant to well integrity, key documents reviewed include the following: -

- Guidelines for the abandonment of wells, Issue 5, July 2015.
- Guidelines on competency of wells personnel, Issue 1, January 2012.
- Guidelines for well operators on well examination Issue 1, November 2011.

The OGUK Guidelines also reference American Petroleum Institute (API) documents that are widely used and considered to represent good Industry Practice. More information on the documents reviewed is provided in the Appendix.

UK Onshore Operators Group (UKOOG): UK Onshore Shale Gas Well Guidelines

Exploration and appraisal phase - Issue 3 March 2015

In response to the seismic event recorded during the high volume hydraulic fracturing of the first UK shale gas exploration well at Preece Hall in Lancashire the UKOOG formed a workgroup to produce guidelines. The workgroup included operating and service companies with input from DECC, HSE and the EA/SEPA. The intent of the Guidelines was to document good industry practices to assist well operators comply with UK Regulations pertaining to well integrity and hydraulic fracturing, including fracturing fluids and flow back fluids. The workgroup took the approach of referencing, or duplicating, the OGUK Well Life Cycle Integrity Guidelines wherever relevant.

The Guidelines apply to the exploration and appraisal phase of shale gas development and cover the following: -

- Safety and environmental management.
- Disclosure and transparency.
- Regulatory requirements.
- Well design and construction.
- Fracturing/flowback operations.
- Fracturing fluids and water management.
- Minimising fugitive emissions.

As the OGUK Well Life Cycle Well Integrity Guidelines have been updated so have the UKOOG Onshore Shale Gas Guidelines. Once Issue 3 of the OGUK Guidelines are published UKOOG intend removing any remaining duplication in the UK Onshore Shale Gas Guidelines such that the Onshore Guidelines simply direct the reader to the OGUK Guidelines for all well integrity issues. The reason for this is that it has been recognised that shale gas wells have no unique features that cannot be addressed within the OGUK Guidelines pertaining to all oil and gas wells in the UK.

IMechE/IOM3 Operator Survey

Background & Objectives
In September 2015 the United Kingdom Onshore Operators Group (UKOOG) issued a UK shale gas well integrity survey to all of their member companies on behalf of the IMechE/IOM3 shale gas well integrity workgroup. The objectives of the questionnaire were as follows:

- Ascertain where in the UK Companies intend drilling shale gas wells.
- Ascertain whether or not there will be conformance to the UKOOG Shale Gas Guidelines and identify suggestions for any changes required to these Guidelines.
- Ascertain whether or not there will be conformance to the Oil and Gas UK (OGUK) Well Life Cycle Integrity Guidelines (WLCIG) and identify suggestions for any changes required to these Guidelines.
- Ascertain whether or not a Well Integrity Management System that meets the minimum requirements specified in Chapter 3 of the OGUK WLCIG is in place and if not which minimum requirements are not being met and why.
- Identify the most significant concerns with respect to UK onshore shale gas well integrity and why.

Responses
The survey received responses on behalf of eight companies holding the majority of the UK licences covering areas with the potential for shale gas.

Areas in the UK for Shale Gas Activity Covered by the Survey
The companies who responded advised that they hold licences in the following English counties: Cheshire, Lancashire, Leicestershire, Lincolnshire, Merseyside, Nottinghamshire and Yorkshire. In addition a Company advised that they hold licences in Scotland and intend drilling shale gas wells.

Conformance to UKOOG and OGUK Well Integrity Guidelines
The survey found that all the responding companies are using and conforming to both the OGUK Well Integrity Guidelines and the UKOOG Shale Gas Guidelines. In addition all the companies either already have, or are in the process of finalising, well integrity management systems that conform to the Guidance contained in the OGUK Well Integrity Guidelines.

Suggested Changes to the UKOOG Shale Gas Guidelines
A number of companies commented that the OGUK Well Integrity Guidelines are the primary guide for onshore and offshore oil and gas well integrity and suggested that the UKOOG Shale Gas Guidelines could be simplified by having one statement to refer to the OGUK Well Integrity Guidelines for all Guidance on well integrity. Currently the UKOOG Shale Gas Guidelines refer to the OGUK Guidelines, while also including extracts and referencing specific sections of the OGUK Guidelines.

One Company highlighted that the UKOOG Shale Gas Guidelines reference the OGUK Guidelines for Well Integrity and Well Abandonment, however shale gas formations

typically have extremely low permeability and therefore some of the requirements in the OGUK Guidelines may be inappropriate: inflow testing and the length of annular cement required were given as examples. Rather than each shale gas well operator having to undertake an individual risk assessment it was suggested that generic issues be identified and an agreed position documented in the Shale Gas Guidelines. As an alternative the OGUK Guidelines could be updated to address generic issues.

Suggested Changes to the OGUK Well Integrity Guidelines and/or Well Abandonment Guidelines

Further to the suggestions to refer to the OGUK Guidelines for all onshore and offshore oil and gas well integrity guidance it was suggested that onshore well operators should have greater input to the OGUK well integrity workgroup to ensure that the Guidelines fully address good practices relevant to onshore shale gas wells.

Most Significant Concerns Regarding UK Onshore Shale Gas Integrity

Seven companies provided feedback on key concerns. The most common concern was public perception; reference the following quote from the feedback: "The understandably low level of knowledge of well integrity issues amongst the general public coupled with targeted misinformation from those groups opposed to shale gas development has led to undue concerns/fears around this issue. Industry and competent bodies such as the EA, HSE and OGA/DECC need to robustly defend current regulatory practice."

Work in Progress

On-going Studies

It is recognised that this topic is fluid and other studies are being performed at this time. The following indicate some of the work being done.

OGUK - Well Life Cycle Integrity Guidelines

As detailed in the documentation review Issue 3 of the above Guidelines was being finalised in parallel with the development of this paper. Onshore well operators had provided input to the development of Issue 3 and indeed the process of developing this paper had encouraged additional input from onshore well operators. UKOOG endorsed the draft Issue 3 in January 2016. At the same time UKOOG agreed to simplify the UK Shale Gas Guidelines to remove any duplication with Issue 3 of the OGUK Well Integrity Guidelines thereby addressing a key piece of feedback from the well integrity survey. UKOOG further supported communication of Issue 3 and input to Issue 4 of the OGUK Well Integrity Guidelines. At the beginning of February 2016 Issue 3 of the OGUK Well Integrity Guidelines was being finalised for publication in March 2016. Thereafter the intent was to communicate Issue 3, obtain feedback on Issue 3 and develop Issue 4.

The IMechE/IOM3 shale gas well integrity workgroup commend the above approach.

Emissions Monitoring

While the review of UK onshore shale gas well integrity was on-going the ReFINE group were undertaking sampling of emissions from historic onshore UK gas and oil wells. Reports on this work were published in January 2016: Boothroyd, I.M., et al., Fugitive emissions of methane from abandoned, decommissioned oil and gas wells, Sci Total Environ (2015), http://dx.doi.org/10.1016/j.scitotenv.2015.12.096

The workgroup did not have sufficient time to cover this new work in this paper.

Environment Agency Consultation

The Environment Agency regulates the environmental aspects of the onshore oil and gas industry in England through the Environmental Permitting Regulations (EPR) 2010.

There is a Memorandum of Understanding between the Environment Agency and the HSE [Ref 3], to ensure effective coordination of the regulation of plant, processes and substances and measures to protect people and the environment, which are subject to regulation by both the Environment Agency and the HSE. An onshore operator must acquire environmental permits from the EA prior to carrying out any oil and/or gas exploration or appraisal activities, which include the following:

- the management of extractive waste, whether or not this involves a waste facility (as a mining waste operation)
- flaring of waste gas using a flare, which has the capacity to incinerate over 10 tonnes a day (as an installation)
- a water discharge activity
- a groundwater activity, such as an indirect discharge of pollutants as part of high pressure high volume hydraulic fracturing

- waste being managed that meets the thresholds for radioactivity set out in the 2010 Regulations (as a radioactive substances activity)

The permitting process is independent of any other licence or consent, e.g. planning, and is subject to consultation to ensure that the appropriate level of due diligence is carried out on the proposed operation prior to award of the permits. Whilst many of the industry's good practices are requirements of licences and consents issued by DECC and of the HSE via the DCR and BSOR, the environmental permitting process requires the operator to detail compliance with these regulations.

Prior to commencement of any proposed operation the Environment Agency acts as a statutory consultant on other mandatory consents, such as planning permission, to allow for input on matters of environmental protection.

The existing oil and gas facilities (i.e. production well sites) in place prior to October 2010 have typically been regulated by the local authorities Environmental Health Officer. This regulatory position applied to all facilities and was separate to activities covered by operation specific permits.

In March 2015 the EA issued a 'Regulatory Position Statement' which made the facilities the focus of a permitting review exercise which will look to assess each installation and issue permits based upon current and proposed operations to allow for regulation of the facilities by the EA going forward. All operators will need to make themselves familiar with this new and changing legislation where each individual site would have to have its own permit and with the possible requirement for baseline monitoring in place before any operations can start.

ISO/DIS 16530-1.2 Draft International Standard Petroleum and natural gas industries – Well integrity – Part 1 Life cycle governance

The above document has been developed by a workgroup of the International Oil and Gas Producers Association. The International Standards Organisation (ISO) issued the first draft version to member nations for ballot in March 2015. Following the ballot and feedback the workgroup updated the draft and the second version was issued for ballot on the 17th December 2015 with responses due by the 17th March 2016. The OGUK well integrity workgroup have reviewed the draft documents and ensured that Issue 3 of the OGUK Well Integrity Guidelines align with the drafts. Any substantive inconsistencies will either be addressed in Issue 4 of the OGUK Well Integrity Guidelines and/or any unnecessary duplication the OGUK Guidelines will be removed.

Appendix

Additional Documents Reviewed

The following documents were reviewed by the workgroup, in addition to the key documents, listed above.

	Document Title and Comments
No. 1	**Managing for Health and Safety: HSG65 Third edition 2013** This document explains the Plan, Do, Check, Act approach and shows how it can help achieve a balance between the systems and behavioural aspects of management. Health and safety management treated as an integral part of good management, rather than as a stand-alone system. The workgroup considered that this document was not specifically related to well integrity.
No. 2	**ISO/TS 16530-2:2014 Well integrity -- Part 2: Well integrity for the operational phase** This document provides requirements and methods to the oil and gas industry to manage wells during the operational phase. The operational phase is considered to extend from handover of the well after construction, to handover prior to abandonment. The workgroup view was that the Oil and Gas UK Well Integrity Guidelines by and large addressed these activities.
No.3	**Oil & Gas UK: Guidelines for well operators on well examination, Issue 1, November 2011** Well examination is a British Regulatory requirement for independent assurance of well design, construction and maintenance throughout the well life cycle. These Guidelines document good Industry Practice for well examination to meet the Regulatory requirements. The Guidelines address the findings from HSE inspections of well examination. These Guidelines were in the process of being updated to address legislative changes for offshore wells following the issue of the Offshore Safety Case Regs 2015 on 19th July 2015.
No.4	**Oil & Gas UK: Guidelines on competency of wells personnel, Issue 1, January 2012** These Guidelines document the Regulatory requirements for competency, competency management system requirements and competency assurance for well personnel. An associated document provides example competency profiles for some core roles.
No.5	**Norsok: Standard D-010 well integrity in drilling and well operations, Rev 4, June 2013** This document contains detailed Guidance that is used by Norwegian well operators as a "standard". The document is widely referenced but is written for wells on the Norwegian Continental shelf and therefore does not address specific considerations for land wells.

No. 6	**Norwegian OLF 117: Recommended guidelines for well integrity, Rev 6, June 2011** This document provides a Norwegian view on well integrity training, well integrity management system, sustained casing pressure management and well categorisation.
No. 7	**Maitland Report: Offshore oil and gas in the UK an independent review of the regulatory regime, December 2011** Independent review that compared the UK regulatory regime to that in the Gulf of Mexico following the loss of the Deepwater Horizon. This document is relevant as the key well integrity related elements of the UK regulatory regime apply to UK onshore wells. The review found that the UK has a robust Regulatory framework.
No.8	**ISO Standard 16530-1: Well integrity life cycle governance DRAFT** This document was in draft and still going through development. The document follows a similar life cycle format to the Oil and Gas UK Guidelines. Conformance to the Oil and Gas UK Guidelines will generally meet the proposed requirements in this document. The Oil and Gas UK Guidelines will be updated to address any inconsistencies.
No.9	**API RP100-1 Well Integrity and Fracture Containment** Recommended practices for onshore well construction and fracture stimulation design and execution relating to well integrity and fracture containment. The Oil and Gas UK Well Integrity Guidelines generally cover well construction requirements but there are additional recommended practices for fracture stimulation in the API document.
No.10	**API S65-2: Isolating Potential Flow Zones during Well Construction** This document covers the use of cement and mechanical barriers, including considerations to enhance the effectiveness of zonal isolation through design, testing, practices and associated equipment. The document includes information on loss of well control/ annular flow studies from the UK, US, Russia and Canada. The Oil and Gas UK Well Integrity Guidelines cover much of the material in this document: the author of the UK loss of well control study was the Consulting Technical Author of the Oil and Gas UK Guidelines.
No.11	**API HF1, 2 and 3: Hydraulic Fracturing Guidelines** A set of three documents issued from 2009 to 2011. HF1 covers high level well design and construction considerations for maintaining well integrity along with information on hydraulic fracturing. HF2 provides guidance and key considerations to minimize environmental impacts associated with the supply, use, treatment and disposal of water and other fluids used in hydraulic fracturing, with a focus on shale gas wells. HF3 describes best practices to minimise potential surface environmental impacts associated with hydraulic fracturing operations, with a focus on shale gas wells. All three documents are quite high level with limited specifics on well integrity.
No.12	**API Bulletin E3: Environmental Guidance Document: Well Abandonment and Inactive Well Practices for US Exploration and Production Operations** This guidance document is focused on onshore US wells with a particular focus on groundwater protection. The document was initially issued in 1993 and re-affirmed in 2000. API S65 has superseded information on abandonment practices. The document includes some data analysis and suggested monitoring requirements for inactive wells.

No.13	**API Bulletin 100-3: Community Engagement Guidelines** This document presents a five-stage model for oil and gas developments with guidance on potential community engagement options for each stage.
No. 14	**API Bulletin 100-3: Community Engagement Guidelines** This document presents a five-stage model for oil and gas developments with guidance on potential community engagement options for each stage.
	Technical Papers
No.15	**Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation Richard J. Davies, Sam Almond, Robert S. Ward, Robert B. Jackson, Charlotte Adams, Fred Worrall, Liam G. Herringshaw, Jon G. Gluyas, Mark A. Whitehead (Marine and Petroleum Geology 2014)** In this paper the authors provided a review of available well integrity from a number of countries and made observations on the relevance to potential UK onshore shale gas wells.
No.16	**Discussion of "Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation" by R.J. Davies, S. Almond, R.S., Ward, R.B. Jackson, C. Adams, F. Worrall, L.G. Herringshaw, J.G. Gluyas and M.A. Whitehead. (Marine and Petroleum Geology 2014)** **John L. Thorogood, Paul L. Younger** In this discussion paper the authors raise significant flaws in the initial paper. The paper highlights the robustness of the UK Regulatory framework. It should be noted that no UK onshore well integrity failures were identified in the paper since the Well Design and Construction Regulations were issued twenty years ago.
No.17	**SPE 166142: Environmental Risk Arising From Well Construction Failure: Difference Between Barrier and Well Failure, and Estimates of Failure Frequency Across Common Well Types, Locations and Well Age George E. King, Apache Corporation and Daniel E. King, WG Consulting** In this paper the authors explain why there are relatively few incidents of loss of well integrity worldwide and even fewer incidents of pollution from a loss of well integrity event. The authors provide comparative data with other pollution events.
No.18	**House of Commons BRIEFING PAPER Number SN06073, 15 January 2016 Shale gas and fracking** This briefing paper addresses the following topics and provides useful links to other documents: - 1. Hydraulic fracturing, or fracking 2. The shale gas resource in the UK 3. Regulatory regime 4. The Infrastructure Act - access rights, protected areas and other issues 5. Environmental considerations 6. Support for the industry and support for communities

Glossary

ALARP: As Low As Reasonably Practicable

DECC: Department of Energy & Climate Change

DNV: Det Norske Veritas

EA: Environmental Agency

Fracking: Hydraulic fracturing

IMechE: The Institution of Mechanical Engineers

IoD: Institute of Directors

IOM3: The Institute of Materials, Minerals and Mining

LNG: Liquefied Natural Gas

NORSOK: Norsk Sokkels Konkuranseposisjon
(Norwegian Standards developed by the Norwegian Technology Centre and in accordance with PSA)

OGUK: Oil & Gas UK

PSA: Petroleum Safety Authority (Norway)

ReFINE: Researching Fracking in Europe (Newcastle & Durham Universities)

UKCS: UK Continental Shelf

UKOOG: UK Onshore Oil Group

WLCIG: Well Life Cycle Integrity Guidelines