Long term well plug integrity assurance

A probabilistic modelling approach

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Well P&A required to protect **people** and **environment**, prescribed by **regulations** and remains responsibility of operator in **perpetuity**

- Across the North Sea between 2017 and 2025
  - 349 fields to be decommissioned (214 on UKCS)
  - 2500 wells for P&A
- £1.8bn for decommissioning on UKCS (2017)
  - 49% spent on P&A
- $P_{50}$ estimates of £60bn to be spent up to 2025
  - Target to reduce to £39bn

**HOW?**
- New technology $\rightarrow$ step change in costs & performance
- Risk based approach to P&A design

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Challenges: Current practice & guidelines

• Cement: the de facto barrier material
• Well data varies with age and region
• Most P&A jobs require rigs
• Regulations and guidance differ between regions
• Prescriptive guidelines: a barrier to introduction of new technology
  – New materials: resins and Bismuth alloys
• UK Regulator imposes eternal responsibility
• Verification test: life assurance limitations

[6] Decommissioning case study pack, Claxton
Objectives

- Develop models and tools to support high integrity seal reliability prediction
  - Casing plugs
  - Annulus plugs
  - All well barrier elements
- Support technology qualification of new materials for P&A
- Prediction of plug life and overall well P&A integrity
- Supporting risk based approach to P&A design
- Supporting development of Bismuth alloys for P&A with a statistical plug life exceeding 3000 years
Benefits of a risk based approach to P&A

• Risk based P&A
  – Minimise environmental and safety risks
  – Optimise business risk

• Well specific P&A solutions
  – Simpler designs for lower risk wells
  – Increased focus on high risk wells

• Well barrier failure modes and failure mechanisms formally assessed

• Assess impact of new technology on risk
  – New plugging and sealing materials
  – New deployment technology

Risk based approach combined with new technology expected to deliver 30-50% reduction in costs
Plug technology qualification guidance

- New technology for P&A
- Technical Qualification Guidance
  - Oil and Gas UK: Materials and plug deployment focus
- TQP process guidance
  - DNVGL RP A203 or API RP 17Q
- TQP supports integrity assurance
Well barrier elements can fail

- Loss of barrier integrity a significant problem
  - Chance for hydrocarbon leakage to environment
  - Potentially irreparable for abandoned wells

a) Casing/annular cement micro-annulus
b) Cement plug micro-annulus
c) Bulk permeability
d) Damaged/corroded casing string
e) Fracture in annular cement
f) Annular cement/formation micro-annulus

Leak potential for a well barrier

- Leak needs failed barrier element with pressure differential
- Darcy’s equation used to assess flow potential for each path between isolated zones
- Plug failure logic represented as flow path block diagram

\[ Q_{WB} = K_{eff} \frac{1}{\mu} \Delta P \]

Each mechanism has likelihood and consequence

Impact of uncertainty on long term WB performance

- Well barrier element parameters
  - Sampled distributions reflect degree of confidence / uncertainty
- Model parameters are dynamic
  - Time and environment dependent
  - Requires construction of material specific degradation models
- Leak rates and volumes
  - MCS approach
  - Demonstrates sensitivity of output to input parameters

Multiple barriers will improve reliability performance

Requires a system model
System model for well P&A: STEM-flow

- Multiple plugs, barriers and zones to be isolated
- Requires system model - **Seal Technology Evaluation Model (STEM-flow)**
Well P&A integrity system model

Well condition data
- Well design
- Drilling logs
- Cementing logs
- Pressure monitoring
- Fluid compositions
- Well surveys

Well barrier models
- Casing plug
- Annulus plug
- Additional barrier

Barrier data
- Barrier materials
- Deployment method
- Casing inspections
- Cement bond logs
- Barrier position

System model

Parameter uncertainties

STEM-flow

Output

Casing plug sub-model

Annulus plug sub-model
Well P&A integrity modelling output

**Pressures**

Isolated Zone Pressures vs Time

**Leak rates & volumes**

Flow rate across the barrier vs Time

**Leak acceptance criteria**

Probability of Failure

**Statistical life of plug**

Current technology
New technology

**Statistical life of well**

Well life W(F)
Support for seal technology qualification

Predictive modelling is only realistic approach to demonstrate 3000 year life
Support for risk based well P&A integrity modelling

- Well P&A barrier design
- Plug deployment method

Impacts/Consequences:
- Financial
- HSE

Input Data

STEM-flow

Leak rate
Volume emitted

Probability of failure
- Plug Life, $P(F)$
- Well Life, $P(F)$

Risk evaluation

Risk Acceptable?
- No
- Yes

Integrity Report

Consistent with DNVGL-RP-E103

Potential for simpler designs consistent with level of risk
Summary of STEM-flow applications

Application

• Predictive STEM-flow tool
  – Individual & multiple plugs
  – Statistical life and well integrity risks

STEM-flow provides support for

• New P&A technology development
  – Technology qualification / risk assessments
    • New plug / sealing materials and technology
    • Novel deployments

• Operator integrity assurance
  – Assessment of plugging / sealing technology
    • Existing technology
    • New technology
  – Quantitative evidence to support P&A well integrity assurance

Rawwater Bismuth alloy plug installation
Thank you for listening

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