Offshore Process Plant Integrity & Health & Safety Law - An Overview

Andy Duncan, IOMMM, CEng
Lead Consultant
Intertek Production & Integrity Assurance

http://www.intertek.com/exploration-production/integrity-assurance/

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CONTENTS

• Introduction to UK Health & Safety law & Regulations wrt process plant integrity management
• Health & Safety at Work Act
• Supporting Regulations – what they mean for integrity management
• Lord Cullen - Piper Alpha
• Lord Haddon-Cave - Nimrod MR2
• Conclusions
Health & Safety At Work etc Act 1974:
Sections 2, 3, 7

(aka “The Act”)
STATUTORY INSTRUMENTS APPLICABLE ACROSS UK

• Management Of Health & Safety At Work Regs: Regs 3, 4, 5
• Provision & Use Of Work Equipment Regs: Regs 4, 5, 6, 12
STATUTORY INSTRUMENTS APPLICABLE ACROSS UK

Dangerous Substances And Explosive Atmospheres Regulations: Regs 5, 6

(exc. Regs: 5 (2) (f)(g)(h)(i), 5 (4) (c), 6 (4) (d), 6 (5) (b)(e)

(Explosive Atmospheres Directive: ATEX 137)
STATUTORY INSTRUMENTS APPLICABLE OFFSHORE

- Prevention Of Fire And Explosion, And Emergency Response Regulations: Regs 5, 9
- Offshore Installations And Wells (Design & Construction Etc) Regulations: Regs 5, 8
- Offshore Installations (Safety Case) Regulations: Regs 7, 12
“What do companies need to do to comply with health and safety law?

The health, safety and welfare of all personnel on offshore installations is protected by law. UK health and safety law follows a goal-setting approach.

Instead of a prescribed checklist of things to do, which may not be right for all circumstances, goal-setting law sets out the objectives to be achieved.

Duty holders must:
- systematically identify hazards;
- assess the risks and the consequences of those hazards being realised; and
- put in place suitable procedures and measures to control the risks.

Goal-setting law allows duty holders to choose the most appropriate methods or equipment available to meet the legal requirements”.

www.hse.gov.uk
Section 2(1): “It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.”

Section 3(1): “It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not exposed to risks to their health or safety.”
The definition set out by the Court of Appeal (in its judgment in Edwards v. National Coal Board, [1949] 1 All ER 743) is:

“‘Reasonably practicable’ is a narrower term than ‘physically possible’ … a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them.”
• Cost of reducing risks shouldn’t be grossly disproportionate to benefit gained.

• ALARP principle arises from fact that infinite time, effort and money could be spent attempting to reduce risk to zero – which is not reasonable.

• ALARP isn’t simply a quantitative measure of benefit against detriment.

• ALARP is use of best common practice of judgement of the balance of risk and societal benefit.
Section 7 General Duties of Employees at Work. It shall be the duty of every employee while at work –

(a) to take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions at work; and

(b) as regards any duty or requirement imposed on his employer or any other person by or under any of the relevant statutory provisions, to co-operate with him so far as is necessary to enable that duty or requirement to be performed or complied with.
Regulation 3: Every employer shall make a suitable and sufficient assessment of-

• The *risks* to the health and safety of his *employees* to which they are exposed whilst at work; and

• The *risks* to the health and safety of persons *not in his employment* arising out of or in connection with the conduct by him of his undertaking
How to assess the risks in your workplace (5 steps to Risk Assessment)

1. Identify the hazards
2. Decide who might be harmed and how
3. Evaluate the risks and decide on precautions
4. Record your significant findings
5. Review your assessment and update if necessary

Risk = Probability x Consequence
<table>
<thead>
<tr>
<th>Frequency per year</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>I (highest)</td>
<td></td>
</tr>
<tr>
<td>II</td>
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<td>III</td>
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<tr>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>V (lowest)</td>
<td></td>
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</table>
### Table 7.4 Barrier Diagram Risk Matrix

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Category F</th>
<th>Number of Barrier Points Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent Event - Twice a week or more</td>
<td>6</td>
<td>2</td>
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<tr>
<td></td>
<td></td>
<td>6</td>
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<td>10</td>
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<td>14</td>
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<td></td>
<td></td>
<td>18</td>
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<tr>
<td>Normal Event – a few times a year</td>
<td>5</td>
<td>3</td>
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<td></td>
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<td>7</td>
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<td></td>
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<td>11</td>
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<tr>
<td></td>
<td></td>
<td>15</td>
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<tr>
<td>Unusual Event – less than once a year</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
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<tr>
<td></td>
<td></td>
<td>13</td>
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<tr>
<td>Rare Event – less than once per 100 years</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Very Rare Event – less than once per 10000 years</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Extremely Rare Event – less than once per million years</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category C</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Consequences</td>
<td>Insignificant Consequences</td>
<td>Noticeable Consequences</td>
<td>Significant Consequences</td>
<td>Serious On-Site Consequences</td>
<td>Major Accident</td>
</tr>
</tbody>
</table>
Requirement for Corrosion Risk Assessments (CRA) (aka Corrosion Threats Assessments, CTA) of process Safety Critical Elements (SCE):

- Piping, pressure vessels, pumps, valves, deluge system, escape routes(!)
- Identify: threats, likelihood (probability) and consequences:
  - Of materials of construction with internal and external environments
  - Predicted AND measured corrosivity
  - Predicted AND monitored cracking mechanisms

The CRA should be subject to regular review.
Regulation 4: Principles of prevention to be applied

Regulation 5: Health and safety arrangements:

• “Every employer shall make and give effect to such arrangements as are appropriate, having regard to the nature of his activities and the size of his undertaking, for the effective planning, organisation, control, monitoring and review of the preventative and protective measures”
This means duty holders shall:

- Prevent unsafe occurrences
- Protect workers from unsafe occurrences
- Plan to prevent unsafe occurrences
- Have a suitable organisation, including specialists, for the size of the operation
- Have suitable materials of construction
- Have suitable corrosion management strategies in place – materials of construction, coatings, corrosion inhibitors, de-hydration, inspection etc.
Regulation 9: Prevention of fire and Explosion:

(1) the duty holder shall take appropriate measures with a view to preventing fire and explosion, including such measures to –

   –(a) ensure the safe production, processing, use, storage, handling, treatment, movement and other dealings with flammable and explosive substances;
This means duty holders shall:

- Prevent fire & explosion
- Handle hydrocarbons safely
- Use appropriate materials of construction
- Have corrosion management strategies in place – for the anticipated field life
Regulation 19: Suitability and condition of plant

(1) The duty holder shall ensure that all plant on the installation provided in compliance with these regulations……

(a) is so constructed or adapted as to be suitable for the purpose for which it is used or provided; and

(b) is maintained in an efficient state, in efficient working order and in good repair

(2) …….the duty holder shall ensure that there is prepared and operated a suitable written scheme of examination, by a competent and independent person, of plant…….
This means duty holders shall:

- Design and build plant to be fit for purpose
- Maintain plant to be fit for purpose
- Have a written scheme of examination (MHSW Reg 3 – Risk Assessment)
Regulation 4: Suitability of work equipment

• Every employer shall ensure that work equipment is used only for operations for which, and under conditions for which, it is suitable.
• In this regulation “suitable” means suitable in any respect which it is reasonably foreseeable will affect the health or safety of any person.

Regulation 5: Maintenance

• (1) Every employer shall ensure that work equipment is maintained in an efficient state, in working order and in good repair.
Key words:

• Work equipment to be suitable for reasonably foreseeable events
  — Anticipate future risks and degradation
  — remember KP4? HSE’s Ageing & Life Extension programme

• Maintain work equipment in an efficient state
Regulation 6: Inspection

(1) Every employer shall ensure that, where the safety of work equipment depends on the installation conditions, it is inspected-

(2) Every employer shall ensure that work equipment exposed to conditions causing deterioration which is liable to result in dangerous situations is inspected-

(a) at suitable intervals; and (b) each time that exceptional circumstances which are liable to jeopardise the safety of the work equipment have occurred,

To ensure that health and safety conditions are maintained and that any deterioration can be detected and remedied in good time.
This means duty holders shall:

- Inspect work equipment at suitable intervals
- What is “suitable”?  
- This requires a Risk Based Inspection programme:
  - based on a Corrosion Risk Assessment (MHSW Reg 3), and
  - has a Written Scheme of Examination (PFEER Reg 19)

PFEER Reg 19: “the duty holder shall ensure that there is prepared and operated a suitable written scheme for the systematic examination, by a competent and independent person, of plant……”
OVERVIEW OF INTEGRITY RELATED LAW

The law requires owners:

- To assess the risks
- To have integrity management policies and strategies
- Not to expose employees to health and safety risks, so far as is reasonably practicable (SFAIRP)
- Have organisation suitable for preventative and protective measures
- Maintain plant effectively
- Inspect plant at suitable intervals
- Detect and remedy deterioration in good time
- Keep risks As Low As Reasonably Practicable (ALARP)
CORROSION MANAGEMENT
Headline Requirements

- Corrosion Risk (Threats) Assessments
- Risk Based Inspection programmes
- Written Schemes of Examination
- Corrosion Management Strategies
ALARP AND SFAIRP

- **ALARP**: As Low As Reasonably Practicable
- **SFAIRP**: So Far As Is Reasonably Practicable
- ALARP and SFAIRP are essentially the same thing
- Concept of “reasonably practicable”:
  - Weighing a risk against the trouble, time & money needed to control it
  - ALARP describes the level to which workplace risks are controlled
“Using “reasonably practicable” allows us (HSE) to set goals for duty-holders, rather than being prescriptive.

This flexibility is a great advantage but it has its drawbacks, too. Deciding whether a risk is ALARP can be challenging because it requires duty-holders and us (HSE) to exercise judgement. In the great majority of cases, we (HSE) can decide by referring to existing ‘good practice’ that has been established by a process of discussion with stakeholders to achieve a consensus about what is ALARP.

For high hazards, complex or novel situations, we (HSE) build on good practice, using more formal decision making techniques, including cost-benefit analysis, to inform our judgement.”
• Leak from condensate pump pipe work
• Safety valve removed – pipe blanked
• When pressurised at start-up leak occurred

Initial response from industry
• Improvements to "permit to work" systems
• Relocation of some pipeline ESDVs
• Installation of SSIVs
• Mitigation of smoke hazards
• Improvements to evacuation and escape systems
• Offshore Safety Case Regulations
• Firewater deluge system was on manual - but, had it been available, it might have had limited effect
• Firewater piping badly corroded
• Tests in May 1988 showed ca. 50% of the sprinkler heads in the condensate pump module were plugged
UKCS NORTH SEA LEAK FREQUENCIES

Clear evidence of leak frequencies by system and equipment.

Leak frequency by system

Leak frequency by equipment
Studies by Prof Jan Erik Vinnem (Preventor) for PSA Norway found:

- 60% of leaks due to human interventions:

- “It is not possible to demonstrate a correlation between leak frequency and the age of an installation”

- “Technical degradation caused ~21% of HC leaks


Guidance for corrosion management in oil and gas production and processing
External corrosion awareness handbook

A guide for visual recognition of external integrity threats to upstream oil and gas production plant
Figure 2: Framework for successful corrosion management

- **Clear policies and objectives** adopted by an organisation. (Section 2)
- **Organisational structure and responsibilities** within the organisation. (Section 3)
- **Corrosion risk assessment and planning** of activities according to risk. (Section 4)
- **Implementation and analysis** of planned activity and its reported outcomes. (Section 5)
- **Measure system performance** against pre-determined criteria. (Section 6)
- Systematic and regular **review of system performance**. (Section 7)
- Periodic **independent audit** of the management and monitoring systems. (Section 8)
REVISED HSG 65
Degradation threats to the oil process and produced water systems

**Internal threats: topsides**
Water-wet hydrocarbon fluids
- CO₂ / H₂S / O₂ / MIC / Galv / Weld / Groove
- Crev / SCC / Eros / Eros Corr / Ext Corr / Acid

**External threats: topsides**
Ext Corr / CUI / F&F

**Internal threats: downhole**
CO₂ / H₂S / MIC / Galv / Weld / Groove / Crev
- SCC / Eros / Eros Corr / Ext Corr / Acid

**External threats: downhole**
Ext Corr / F&F

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<table>
<thead>
<tr>
<th>#</th>
<th>Threat</th>
<th>Abbr’n</th>
<th>#</th>
<th>Threat</th>
<th>Abbr’n</th>
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<tbody>
<tr>
<td>1</td>
<td>Carbon Dioxide Corrosion</td>
<td>CO₂</td>
<td>9</td>
<td>External Corrosion</td>
<td>Ext Corr</td>
</tr>
<tr>
<td>2</td>
<td>Hydrogen Sulphide Corrosion</td>
<td>H₂S</td>
<td>10</td>
<td>Corrosion under insulation</td>
<td>CUI</td>
</tr>
<tr>
<td>3</td>
<td>Oxygen Corrosion</td>
<td>O₂</td>
<td>11</td>
<td>Stress Corrosion Cracking</td>
<td>SCC</td>
</tr>
<tr>
<td>4</td>
<td>Microbially Influenced Corrosion</td>
<td>MIC</td>
<td>12a</td>
<td>Erosion</td>
<td>Eros</td>
</tr>
<tr>
<td>5</td>
<td>Galvanic Corrosion</td>
<td>Galv</td>
<td>12b</td>
<td>Erosion Corrosion</td>
<td>Eros Corr</td>
</tr>
<tr>
<td>6</td>
<td>Weld Corrosion</td>
<td>Weld</td>
<td>13</td>
<td>Fatigue and Fretting</td>
<td>F&amp;F</td>
</tr>
<tr>
<td>7</td>
<td>Grooving Corrosion</td>
<td>Groove</td>
<td>14a</td>
<td>Misc. – Liquid Metal Embrittlement</td>
<td>LME</td>
</tr>
<tr>
<td>8</td>
<td>Crevice Corrosion</td>
<td>Crev</td>
<td>14b</td>
<td>Misc. – Acid Corrosion</td>
<td>Acid</td>
</tr>
</tbody>
</table>

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Main threats are shown in red
See Description section (pages 12-26) for information on the threats.

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Pipeline

Export Pumping

Degasser/CFU

Disposal

Metering

CD System

3rd Stage Separation/Coalescer

2nd Stage Separator

Hydrocyclones

1st Stage Separator

3 Phase Fluids
Degradation threats to the gas process system

**Wet gas Internal threats**
- CO₂ / H₂S / O₂ / MIC / Galv / Crev / Eros Corr / Acid

**Dry gas No internal threats**

**Wet gas Internal threats**
- CO₂ / H₂S / O₂ / MIC / Galv / Crev / Eros Corr / Acid

**Dry gas No internal threats**

**Total system External threats**
- Ext Corr / CUI / F & F

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**NOTE:**
1, 2 or 3 stages of compression prior to dehydration

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**From Separation**

- To Separation

**Dry Gas (above dew point)**

- To Separation

**Glycol Contactor**

**Glycol Regen.**

(Wet Gas - normally no flow)

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**Internal threats**

- CO₂ / Acid

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**Fuel Gas Conditioning**

**Fuel Gas Distribution**

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**Main threats are shown in red**

See Description section (pages 12-26) for information on the threats.

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**Corrosion threats guide**

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**Table:**

<table>
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<tr>
<th>#</th>
<th>Threat</th>
<th>Abbr’n</th>
<th>#</th>
<th>Threat</th>
<th>Abbr’n</th>
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<tbody>
<tr>
<td>3.</td>
<td>Oxygen Corrosion</td>
<td>O₂</td>
<td>11.</td>
<td>Stress Corrosion Cracking</td>
<td>SCC</td>
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<td>5.</td>
<td>Galvanic Corrosion</td>
<td>Galv</td>
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<td>Erosion Corrosion</td>
<td>Eros Corr</td>
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<tr>
<td>6.</td>
<td>Weld Corrosion</td>
<td>Weld</td>
<td>13.</td>
<td>Fatigue and Fretting</td>
<td>F &amp; F</td>
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<td>8.</td>
<td>Crevice Corrosion</td>
<td>Crev</td>
<td>14b.</td>
<td>Misc. - Acid Corrosion</td>
<td>Acid</td>
</tr>
</tbody>
</table>
# Threat #1 – Carbon Dioxide (CO₂) Corrosion

<table>
<thead>
<tr>
<th>Causes</th>
<th>Occurrence</th>
<th>Susceptible Systems</th>
<th>Inspection / Monitoring Methods</th>
<th>Management</th>
</tr>
</thead>
</table>
| - Dissolved carbon dioxide, produces carbonic acid  
- Inadequate corrosion inhibition | - All water-wetted locations in hydrocarbon systems  
- Pipework straights (6 o’clock), bends, tees, reducers  
- Welds, heat affected zone and downstream of welds | - All (water containing) hydrocarbon processing systems | - Process parameter monitoring, e.g. temperature, pressure, dew point  
- UT  
- Radiography  
- Corrosion probes/coupons  
- Intelligent pigging of pipelines | - Corrosion resistant alloy  
- Chemical inhibition  
- See EI Guidance Document, Appdx B, Sections 1, 6 and 13. |

## Degradation Morphology

- General corrosion (flow influenced)  
- Localised corrosion (low flow)  
- Preferential weld corrosion
## Threat #10 – Corrosion under Insulation

<table>
<thead>
<tr>
<th>Causes</th>
<th>Occurrence</th>
<th>Susceptible Systems</th>
<th>Inspection / Monitoring Methods</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Wet insulation</td>
<td>- CUI tends to be at 6 o’clock location on pipework / vessels / attachments; but can occur at any orientation</td>
<td>- Insulated pipework and vessels across all systems&lt;br&gt;- Heat traced components</td>
<td>- Visual inspection&lt;br&gt;- Strip and search&lt;br&gt;- Real time radiography&lt;br&gt;- Thermography for wet insulation&lt;br&gt;- Pulsed eddy current</td>
<td>- Avoid insulation where possible&lt;br&gt;- Effective coatings and maintenance of coatings&lt;br&gt;- Fabric maintenance&lt;br&gt;- RBI&lt;br&gt;- See EI Guidance document Appdx B, Sections 10 and 14&lt;br&gt;- See also: EFC WP15 Corrosion Under Insulation Guidelines</td>
</tr>
<tr>
<td>- Damaged or missing Cladding</td>
<td>- Higher probability and rate of corrosion on warm / hot pipework (40°C to 80°C for carbon steel)&lt;br&gt;- Chloride pitting and cracking of stainless steels</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Degraded seals on sheet metal cladding</td>
<td></td>
<td></td>
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<tr>
<td>- Missing or damaged coating</td>
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</tr>
</tbody>
</table>

### Degradation Morphology

- Corrosion under insulation (carbon steel pipework)
- Damaged cladding
- CUI with telltale staining (Vessel 6 o’clock location)
14 men died – disaster was avoidable.
Immediate cause: fuel leak – ignition from exposed element of hot air duct

**Contributory factors:**
- Age of non-structural components
- Unsuitable maintenance regime policy
- Lack of fire detection and suppression system
- SC failed to identify the potential threat
- SC a “paper exercise” – worthless as a safety tool
- Failure to identify implications of changes to fuel system
- Acceptance that fuel leaks were inevitable
• No trending of leak frequencies
• Overheat detection system in the wrong place
• Did not learn lessons from previous incidents
• Training courses did not provide skills to maintain 40 year old aircraft
• Stretched engineering resource:
  — loss of skilled personnel
  — dilution of engineering skills
• Lack of corporate memory
Britain faces £200bn oil loss: “$50 oil prices could lead to the early decommissioning of North Sea facilities and the loss of 6bn barrels of oil’’.

Sir Ian Wood: “The danger is that if we lose momentum now and lose resources and assets, and don’t get the fiscal regime fit for a quite highly mature area, we will come down to 10-11bn (oil reserves). That’s a huge economic loss and jobs loss for the UK.”

Wood Review March 2014: “Need for significantly improved asset stewardship”
CONSEQUENCES OF THE GENERAL LAWS OF CORROSION

- Coating disbondment
- Pit in stainless steel resulting from microbial corrosion after hydrotest
- Hydrogen induced cracking
- Corrosion under insulation
- Coating disbondment
CONCLUSIONS

• Degradation of offshore process plant and structures is a potentially serious risk to health and safety
• H&S law requires risks to be ALARP
• Risks can be mitigated by:
  – Corrosion Threats Assessments
  – Risk Based Inspection
  – Corrosion Management Strategies
  – “Written Schemes of Examination
  – Maintenance
Knowledge Transfer
Corrosion Matters Workshop

10th – 11th June 2015
Royal Over-Seas League (ROSL, London)

With the development of new industry sectors such as renewable energy, the focus on how corrosion knowledge is transferred has come under scrutiny. Mature industries such as oil and gas production have well established good practices, codes and standards to ensure compliance for the safe and efficient design and operation of assets.

- Are the tried and tested oil and gas guides and standards transferable to other industries?
- Are other industries guides and standards transferable to oil and gas?
- Are there opportunities for common guides and standards?
- How does the information learnt from one industry get transferred to another?
- Are lessons learned from operations being fed back into new designs to improve safety and reliability?

The Institute of Corrosion (Correx Ltd) and NACE GB recognise that to improve safety and reliability in different industries there is a need to improve the flow of knowledge transfer between them. This workshop can be considered the start of this process. By bringing together delegates from diverse industries, case studies can be used to identify potential areas of commonality and the best routes for knowledge transfer.