



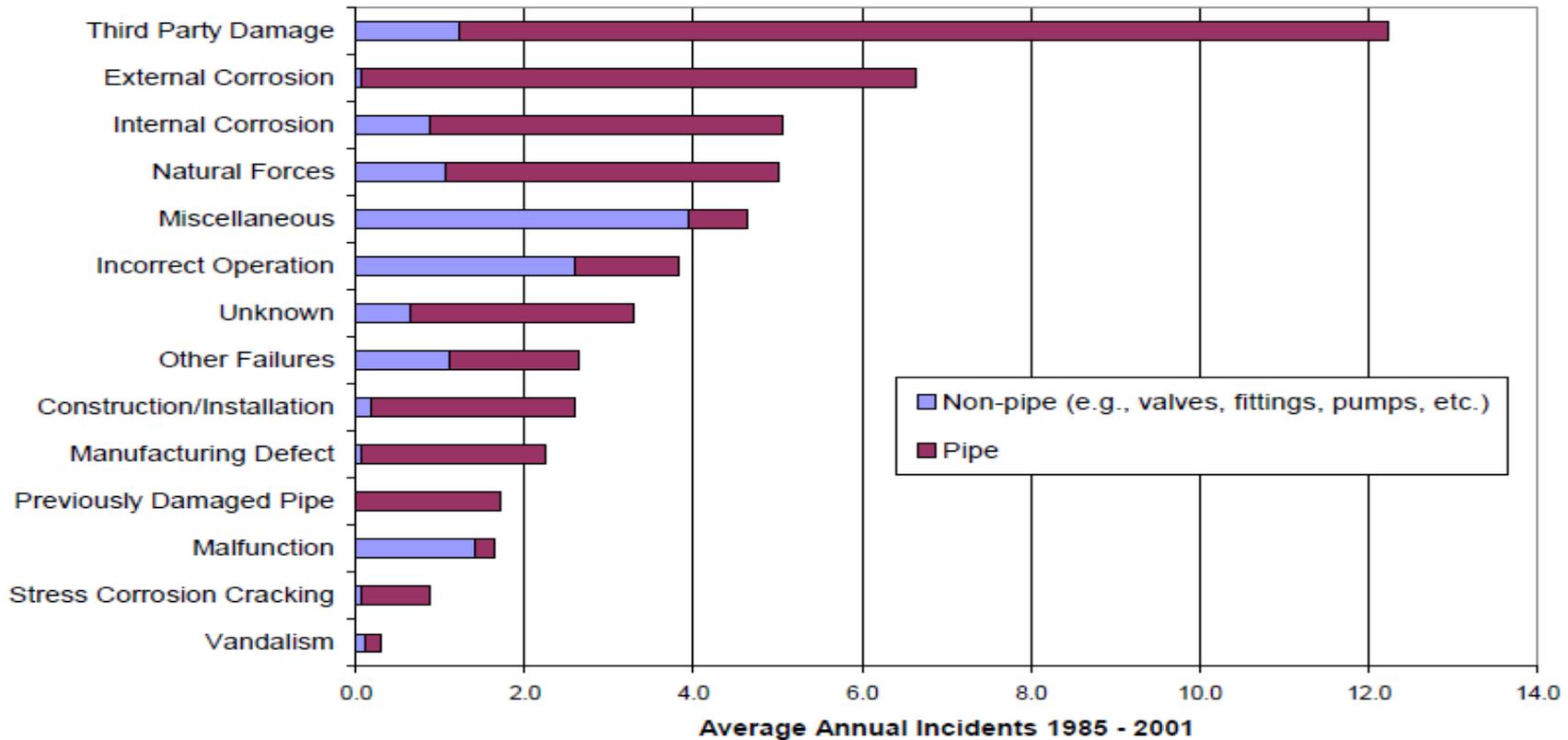
UK ONSHORE PIPELINE OPERATORS' ASSOCIATION - INDUSTRY GOOD PRACTICE GUIDE

**Near Neutral pH and High pH
Stress Corrosion Cracking**

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Section 1: Introduction - Threats to Pipelines



Section 1: Introduction - Threats to Pipelines

‘A possible threat to structural integrity of high pressure pipelines is external SCC’.

Although there is no documentary or anecdotal evidence of external SCC being experienced in the UK, many of the attributes (age, steel grade, coating types, operating conditions etc.) of UK pipelines are common with those on which SCC has occurred elsewhere in the world .

Section 1: - Introduction

The information in the guide should allow the reader to understand:

- What is already known about SCC and what more we need to know?
- Where SCC found
- The frequency and consequence of SCC-related failures
- The susceptibility parameters of SCC
- How SCC is located and characterized
- What tools exist for detecting SCC and their reliability
- What guidance is available for assessing risk and for managing pipes with SCC

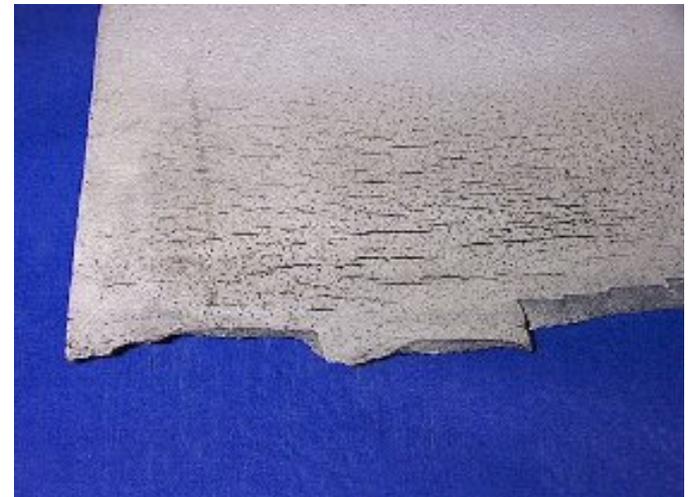
Section 2: Scope

The guidance document is applicable to all buried steel pipelines operated by UKOPA Member Companies including:

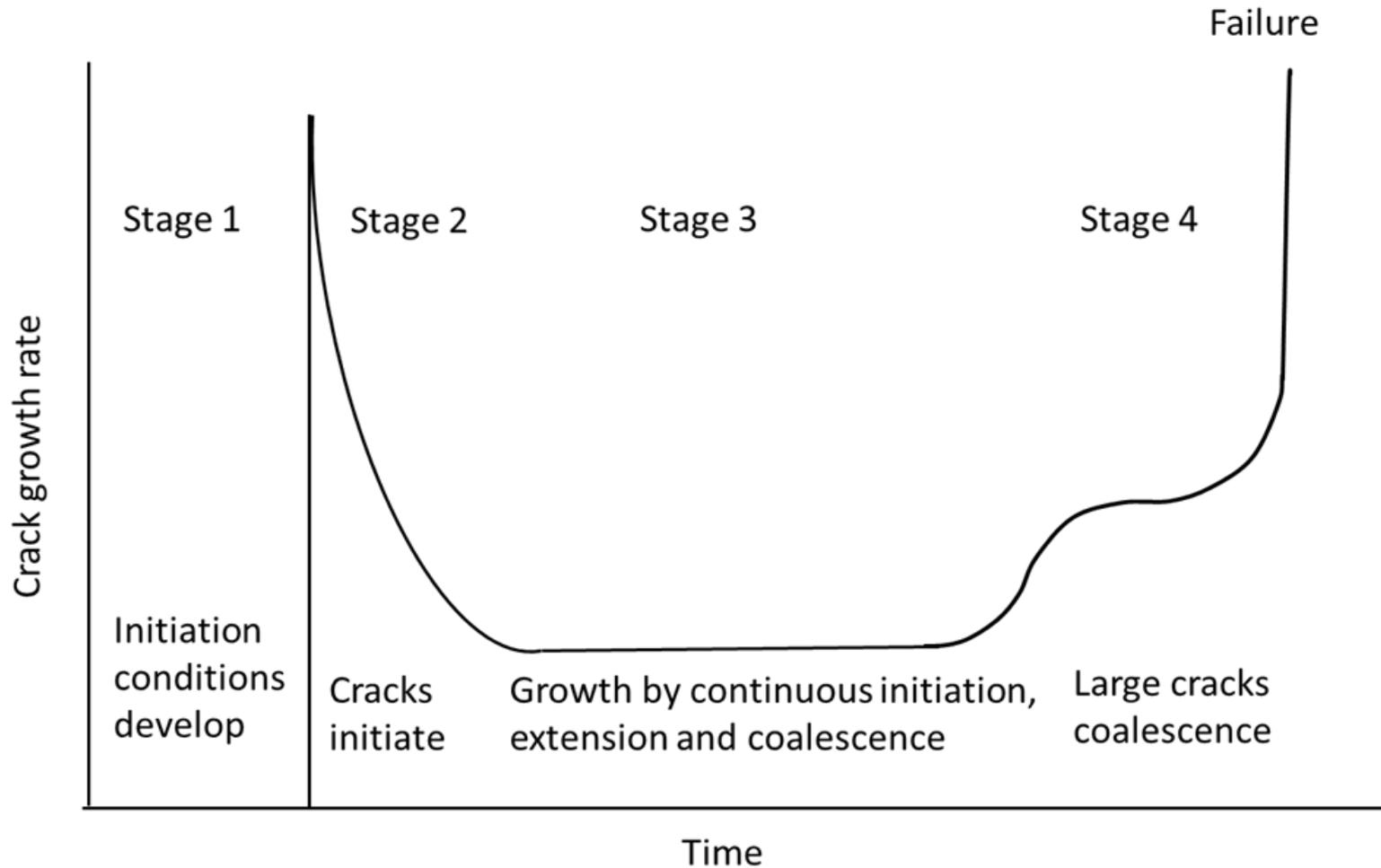
- Natural gas transmission and distribution pipelines
- Petrochemical liquids and gas pipelines
- Oil & refined liquid pipelines

Section 3: Understanding SCC – SCC types

- SCC in pipelines is characterised as “High pH SCC” or “Near neutral pH SCC (NNSCC)”. The ‘pH’ relating to the environment at the crack location.
- The most obvious characteristic of SCC in pipelines, irrespective of type, is the presence of colonies of parallel cracks on the external surface.
- The cracks are closely spaced, are of varying length and depth and are perpendicular to the direction of the highest stress (generally the hoop stress) on the external surface.

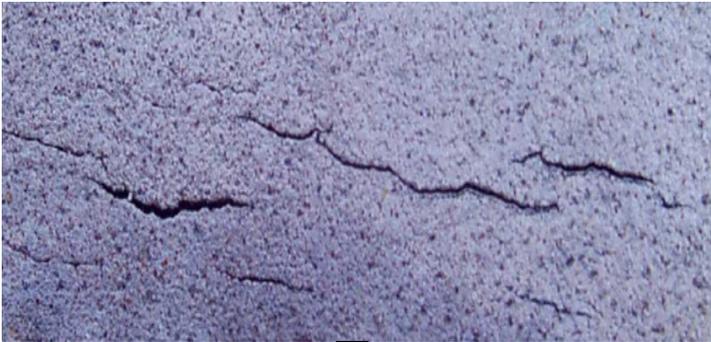


Section 3: Understanding SCC – Life Cycle



Section 3: Understanding SCC – Crack growth

Smaller cracks tend to coalesce to form longer and deeper cracks, which in some cases can lead to a rupture. Cracks do not need to fully penetrate the wall for a rupture to occur.

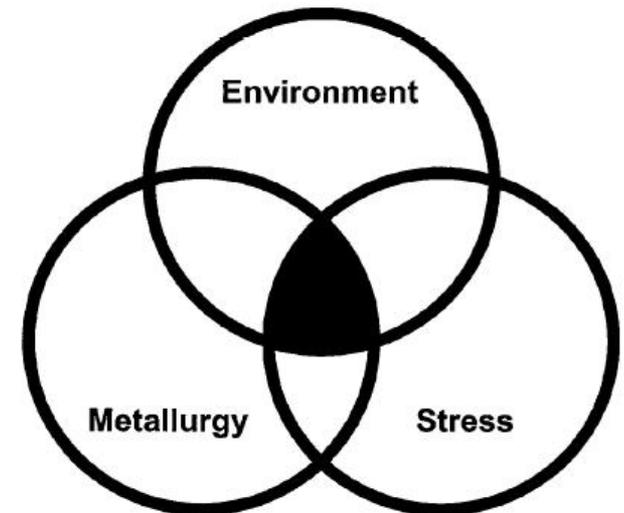


If cracks are sparsely spaced they might grow through wall and leak before they reach a length that is sufficient to cause a rupture.

Section 3: Understanding SCC – Requirements for SCC to occur

For SCC to occur three conditions must be satisfied simultaneously:

- A tensile stress must be present in the pipe higher than the threshold stress, frequently including some cyclic or dynamic component to the stress.
- The pipeline steel must be susceptible to SCC.
- A potent cracking environment must be present at the metal's surface.
- Fourth condition could be pipe potential ?



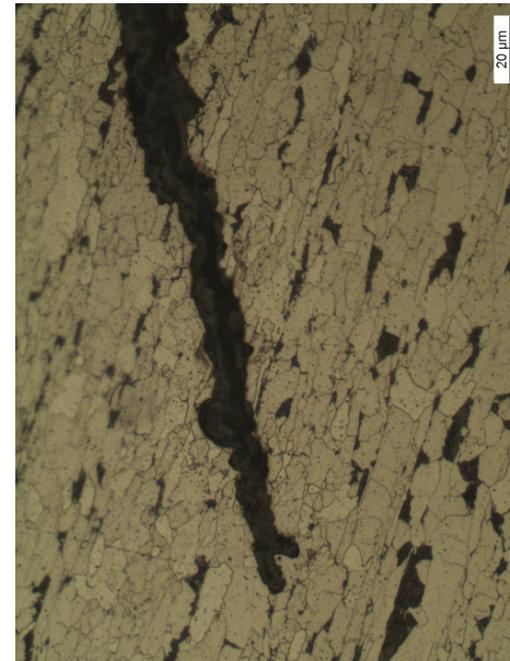
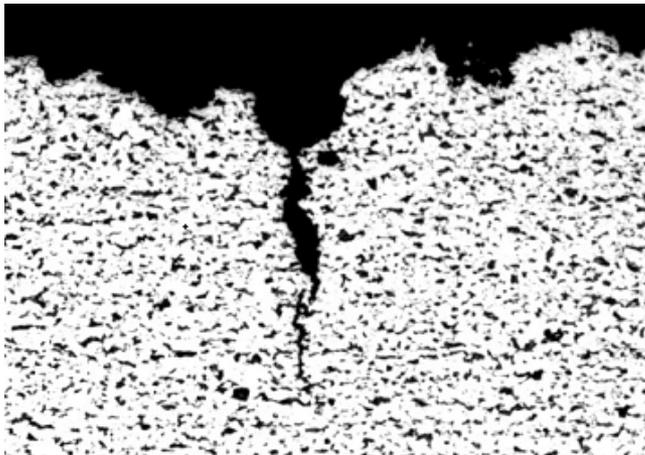
Section 3.1: Understanding SCC - High pH SCC

- First found in the USA in the 1960's under field applied CTE, Asphalt and Tape.
- Occurs under a disbonded coating which is still receiving CP current
- Carbonate/bicarbonate environment at pH >9
- High pH SCC cracking is caused by the dissolution of grain boundaries in a stressed metal which is in contact with ground water.
- It is most frequently observed as intergranular cracking.



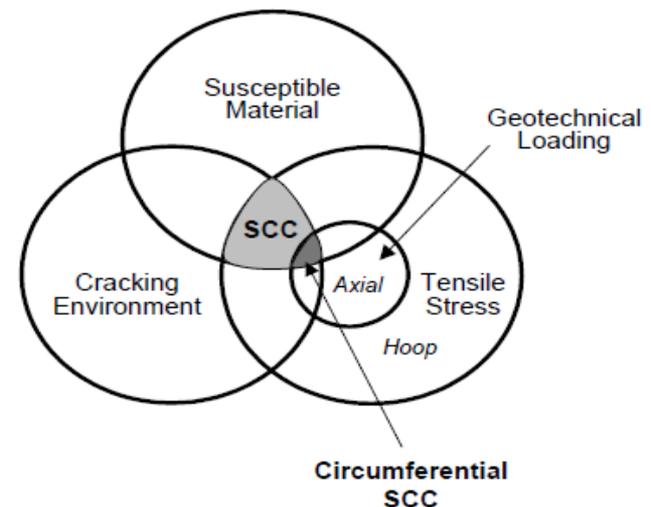
Section 3.2: Understanding SCC - Near Neutral pH SCC (longitudinal)

- First experienced in Canada in 1985 on Tape, CTE and Asphalt coated pipe
- Occurs under a disbonded coating which is shielding the pipe from CP
- Associated with underfilm corrosion and near neutral cracking tends to initiate from corrosion pits
- Cracking occurs in a transgranular manner under near neutral conditions (pH 5 – 7.5).



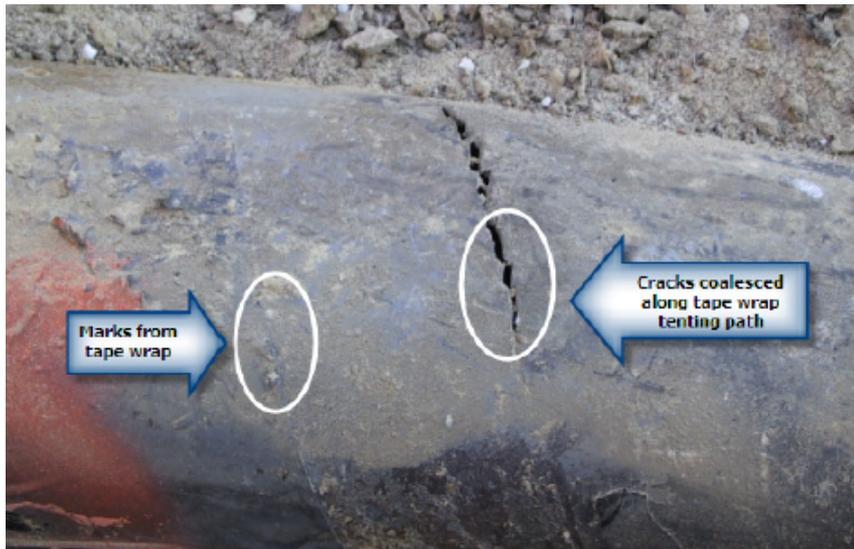
Section 3.2.3: Understanding SCC - Circumferential Near-neutral pH SCC

- Circumferential SCC is a subset of NNSCC in which the principle stress acting on the pipe is a bending stress
 - Soil creep
 - Slope movement
 - External loading (residual stresses at tie in welds)



Section 3.2.3: Understanding SCC - Circumferential Near-neutral pH SCC

- Circumferential SCC accounts for approximately 10% of NNSCC failures
- Since 1985 at least 10 circumferential SCC failures have been documented
 - 7 were leaks, 3 were ruptures
 - 7 were associated with tapes, 2 with HSSs and 1 with CTE
 - 2 were on liquid lines and 8 on gas lines



Appendix B: Factors that Contribute to SCC – North American Experience



High pH SCC

- 90% of failures occurred within ~30km of compressor station
- 85% of failures occurred on pipe operating above 60% SMYS
- Failures occurred under CTE, asphalt and tape coatings
- Majority of failures occurred within 10 – 30 years of commissioning
- Failures occurred on pipelines constructed between 1940 – 1969

Near neutral pH SCC (longitudinal)

- Majority of failures occurred within ~30km of compressor station
- All failures occurred on pipe operating above 60% SMYS
- Failures occurred under Tape, CTE and asphalt coatings
- Majority of failures occurred within 12 – 22 years of commissioning
- No failures have occurred on pipelines constructed after 1981

** No form of SCC has ever been experienced on FBE, single layer PE, 2-layer PE, 3-Layer PE, or liquid epoxy, epoxy urethane or polyurethane coatings*

Appendix B: Experience with SCC – North America

- Majority of SCC has been experienced on pipelines in North America.

Occurrences of in-service and hydrostatic failures due to high pH SCC

Year	65/70	71/75	76/80	81/85	86/90	91/95	96/00	01/05	06/10	Totals
In-service failures	7	12	2	9	8	10	7	4	0	59
Hydrostatic test failures	52	71	8	10	45	49	31	19	13	298

Occurrences of in-service and hydrostatic failures due to NNSCC

Year	65/70	71/75	76/80	81/85	86/90	91/95	96/00	01/05	06/10	Totals
In-service failures	1	2	2	1	1	5	6	5	3	26
Hydrostatic test failures	32	18	0	0	10	18	7	11	63	159

Appendix B: Experience with SCC - Europe

The EGIG gas pipeline incident report last published in 2015, indicates that 8% of external corrosion incidents (13 incidents) were due to SCC.



Diameter (mm)	WT (mm)	Strength	SMYS (Mpa)	UTS (Mpa)	Coating Mainline	Field Joint Coating	Pressure MOP (bar)	Commisioned
954	12.6	X60	415	550	Asphalt	Tape	67.5	1974

Appendix B: Experience with SCC (UK)

- The product loss incidents reported by UKOPA over the period 1962 – 2011, which represents 811,923km.yr of operation, include no incidents due to external SCC.
- Attributes (pipe steel, coating type, operating conditions) of many pipelines operating in the UK are similar to those on which SCC has occurred elsewhere in the World
 - Conservative engineering (pipe strength, wall thickness etc.), stringent construction practices, and better pipeline route selection to avoid the introduction of axial stresses.
 - High standards employed during coating application, in particular the level of surface preparation applied.
 - The requirement for regular coating condition assessment (Pearson and DCVG) to locate and repair coating damage.
 - The requirement to cathodically protect pipe and confirm that pipe-to-soil potentials are within agreed limits.
 - Operation of pipelines to minimise pressure cycling and high pipe temperatures.

Section 4: Detection of SCC

- Hydrostatic Testing



- In-Line Inspection

- EMAT (cracking/disbonding)
- Ultrasonics



Operator Experience (Near Neutral pH SCC)

- ILI conducted using MFL tool during which metal loss was located under disbonded tape coating at field joint.
- On excavation, cracking was detected.
- ILI conducted using EMAT tool to locate cracking:
 - Unsuccessful at crack location.
 - Successful at locating coating disbonds at field joints.
- ILI repeated using UT tool to locate cracking.

- NACE SCC Direct Assessment Methodology

Section 5: SCC Prevention & Mitigation

Section 5 discusses the role of the following in SCC prevention and mitigation

- Coatings
- Cathodic protection
- Repeat hydro-testing
- Pipeline repair and refurbishment

Section 5.1.3: Prevention and Mitigation – Hydrostatic Testing

Repeat hydro-testing is the most reliable way of demonstrating pipeline integrity and mitigating the effects of SCC

- It provides a margin of safety against in-service failures
 - removes near-critical cracks
 - blunts non-critical cracks
- Need to have a good knowledge of crack growth rates to schedule subsequent tests
- Only applicable to longitudinal cracking



Section 5.1.4: Prevention and Mitigations – Pipeline Repair

Expert advice indicates that SCC defects can be managed or eliminated by:

(i) Grinding



(ii) Pressure containment using repair sleeves (steel or composite)



(iii) Pipe removal and replacement



Section 6: Managing Pipelines with SCC - Regulatory Practices and Industry Standards



Canadian Standards Association CEPA SCC Recommended Practices

- published following the National Energy Board enquiry into NNSCC incidents in Canada
- comprehensive standalone document intended to be read by individuals without a sound knowledge of SCC
- provides detailed guidance for assessing the susceptibility and for managing **gas** and **liquid** pipelines at risk from NNSCC
- the approach employed in the recommended practice is equally applicable to high pH SCC

Section 6: Managing Pipelines with SCC - Regulatory Practices and Industry Standards

U.S. Regulations and Industry Standards

ASME B31.8S (Managing System Integrity of Gas Pipelines)

- applies to **gas** pipelines at risk from SCC
- provides criteria for assessing risk from NNSCC and high pH SCC
- offers guidance on integrity assessment
- recommends methods of prevention and repair
- provides advice on re-inspection intervals based on crack severity and growth rate.

NACE SP0204 – Stress Corrosion Cracking Direct Assessment

Methodology

- intended to be used in conjunction with ASME B31.8S
- applicable to both types of SCC and to both **gas** and **liquids** pipelines
- intended to identify areas where SCC has occurred, might be occurring or might occur in the future
- relies upon ASME B31.8S for initial selection of pipeline segments that might be at risk from SCC, for guidance on SCC mitigation and for assessing re-inspection intervals based on crack severity.

Section 6: Managing Pipelines with SCC

ASME B31.8S (Managing System Integrity of Gas Pipelines) uses certain criteria to predict whether pipeline segments might be susceptible to NNSCC.

- (i) Operating stress $>60\%$ SMYS
- (ii) The pipeline is > 10 yrs. old
- (iii) Coating is other than FBE or liquid epoxy

If the above conditions as well as the two below are met the pipeline may be susceptible to high pH SCC:

- (iv) Operating temperature $>38^{\circ}\text{C}$
- (v) Distance from a compressor station within 20 miles (32 km)

Application of ASMS B31.8S Criteria to National Grid Transmission (NGT) pipelines

Risk from near neutral pH SCC:

- The operating stress is >60% SMYS (30% of NGT lines operate above 60%)
- The pipeline is >10 years old (100% of NGT lines are older than 10 yrs.)
- The coating is other than FBE or liquid epoxy (68% of NGT lines CTE coated)

At risk ~30% of lines

Risk from high pH SCC:

- Operating temperature > 38°C (?)
- Distance from a compressor station within 32 km (13% of NGT lines run within 32 km of a compressor station)

At risk ~13% of lines

Pertinent facts related to National Grid pipelines

- SCC has not occurred on any National Grid pipeline, evidenced from NDT inspections conducted at digs following in-line inspection and other opportunistic excavations, despite some lines being in service for in excess of 45 years – *failures in North America occurred within 10 – 30 years of commissioning.*
- The majority of SCC that has occurred elsewhere in the World has been under coatings applied in the field over mechanically prepared (wire brushed) surfaces – *National Grid pipelines have all been mill coated over either acid pickled or grit blasted surfaces.*
- Significant attention has been given by National Grid to avoiding pipe-to-soil potentials falling into ranges at which SCC can initiate – *National Grid has regular and frequent spacing of test posts, they use both 'Off' as well as 'On' pipe-to-soil potentials to monitor CP and conduct regular CIPS.*
- The use of after-coolers at compressor stations has helped maintain temperatures below those at which high pH SCC might occur.

Section 7: Summary

- Re-iterates experience of SCC in mainland Europe and the UK
 - Reasons attributed to why SCC has not occurred in the UK e.g. more conservative construction practices, higher quality coatings, good CP practices, control over operating conditions
- Summarizes information provided in Section 3 of the guide related to:
 - SCC types
 - Environments for the initiation of cracking
 - Crack characteristics, categories, and crack growth rates
- Stresses the importance of external coating type on a pipelines susceptibility to SCC
- Summarizes Integrity management processes
 - Prevention
 - Detection
 - Mitigation