

DEP SPECIFICATION

WET H₂S REQUIREMENTS FOR DOWNSTREAM PRESSURE VESSELS AND PIPING

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the selection and qualification of cracking resistant metallic materials for service in wet H₂S containing environments for downstream based equipment and piping systems. It also specifies the requirements and gives recommendations for the selection and qualification of metallic material exposed to condition that may lead to carbonate stress corrosion cracking (wet H₂S service is often associated to high pH streams containing carbonate and cyanides).

This DEP addresses all mechanisms of cracking that can be caused by H₂S and Carbonate, including:

- Sulphide stress cracking
- Hydrogen induced cracking and stepwise cracking
- Stress-oriented hydrogen induced cracking
- Carbonate cracking

Excluded from the scope of this DEP are:

- Hydrogen charging cracking in non-wet H₂S environments
- Other alkaline stress corrosion cracking mechanisms (e.g. Caustic Stress Cracking)
- Amine Stress Cracking
- Loss of material (mass loss) corrosion or localized corrosion

This DEP replaces the requirements of the following former DEP appendices:

- Appendix IX of DEP 31.22.20.31-Gen.; Pressure Vessels (ASME)
- Appendix 4 of DEP 31.22.10.32-Gen.; Pressure Vessels (PD 5500)
- Appendix 4 of DEP 31.22.11.32-Gen.; Pressure Vessels (EN 13445)
- Appendix IX of DEP 31.22.31.31-Gen.; Pressure Vessels (GB 150).
- Appendix 10.6 of DEP 31.38.01.11-Gen. (Piping General Requirements).

This DEP is also based on NACE MR0103.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of

this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
ASCC	Alkaline Stress Corrosion Cracking
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Institute
CE	Carbon Equivalent
CEN	European Committee for Standardization
[CN_{Free}]	Free cyanide in aqueous solution = $\text{HCN}_{\text{aq}} + \text{CN}^-$
FCAW	Flux Core Arc Welding
[H₂S]	Total Sulphide in aqueous solution = $\text{H}_2\text{S}_{\text{aq}} + \text{HS}^- + \text{S}^{2-}$
HAZ	Heat Affected Zone
HB	Hardness Brinell (hardness brinell with a carbide ball indenter according ASTM E 10 is noted HBW)
HIC	Hydrogen Induced Cracking
HV	Hardness Vickers
NACE	National Association of Corrosion Engineers
PWHT	Post Weld Heat Treatment
SOHIC	Stress Oriented Hydrogen Induced Cracking

SSC	Sulfide Stress Cracking
TMCP	Thermal/Mechanical Controlled Process
WFMT	Wet Fluorescent Magnetic Test
WPQT	Welding Process Qualification Test

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (11).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

**Amended per
Circular 16/12**

Dual units have been incorporated throughout this DEP.

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. REQUIREMENTS FOR CARBON STEEL PRESSURE VESSELS AND PIPING IN WET H₂S SERVICE

2.1 GENERAL

All carbon steel pressure vessels and piping operating in downstream applications and exposed to process streams that result in potential cracking mechanisms caused by wet H₂S service environment, shall be designed and fabricated in accordance with the requirements of this DEP.

2.2 DEFINITION OF WET H₂S SERVICE, SUSCEPTIBILITY TO WET H₂S

2.2.1 General

"Wet H₂S" service is the term commonly used for refinery and gas plant (downstream) environments containing water and H₂S (plus other corrosives or contaminants). The term "sour service" is also used.

The approach to materials selection and testing has been standardised and is described in the applicable sections of this DEP.

The materials selection, testing, and PWHT requirements SHALL [PS] be based upon an assessment of the severity of the environment and susceptibility of materials to each potential damage mechanism anticipated or experienced, as defined in this DEP.

2.2.2 Definition – H₂S content, cyanide content, carbonate content

The 'H₂S content of water' in the context of this DEP shall be understood to mean the sum of the dissolved (molecular) H₂S, bisulphide ion (HS⁻¹), and sulphide ion (S⁻²) concentrations in the water phase, that result from the presence of H₂S in the process system.

The 'cyanide content of water' shall be understood to mean the concentration of 'free' cyanide [CN_{Free}], expressed in ppmw, in the sour water that results from the presence of HCN and CN⁻ in the process stream.

The carbonate ion (CO₃⁻²) concentration used to determine the susceptibility to carbonate cracking shall be understood to mean the actual carbonate ion concentration.

2.2.3 Susceptibility to cracking and severity categories

2.2.3.1 General

Carbon steel susceptibility to each different cracking mechanism is determined based on the process environment (Water, [H₂S], [CN_{Free}], CO₃⁻²) and material properties (chemistry, mechanical properties, and thermal history)

2.2.3.2 Process severity category

Four severity categories are defined for each mechanism for the purposes of setting the material and fabrication requirements. These categories are Negligible, Low, Moderate and High severity.

Tables 1a, 1b and 1c shall be used to assess the severity of the process environment as applicable to the type of damage mechanism being considered. When using these tables, the environment being considered should be present during normal operations. Short-term upsets should only be considered if the damage mechanism anticipated or experienced is also likely to occur in the short term (e.g. sulphide stress cracking).

Potential mechanisms are not exclusive, i.e. if there is more than one mechanism active, the materials and PWHT requirements may have to be combined to address the severity of more than one environment.

If this DEP is used to specify replacement of any in-service equipment (or equipment in a directly comparable service) and the in-service equipment has been damaged by significant hydrogen blistering and/or HIC, the replacement equipment should be assessed as being in a "Moderate" or "High" Severity environment. Equipment that has experienced SOHIC

should be assessed as a “High” Severity environment. In such cases, the materials engineer of the Principal shall be consulted.

In high pH streams containing significant levels of sulphide and carbonate ions, measures shall be taken to prevent carbonate cracking, which is a form of alkaline stress corrosion cracking (ASCC).

The severity category assigned to each equipment shall be subject to the approval of the Principal's materials engineer.

2.2.3.3 Additional mitigation measures

For carbon steel vessels and piping, additional mitigation measures, such as injection of polysulphide or inhibitors may be required; the materials engineer of the Principal shall be consulted.

2.2.3.4 Process Severity to SSC

If there is no free water present then the material is **not** considered susceptible to SSC. However, if water is likely to be present during start-up/shutdown or transient conditions, the environmental conditions during these transient periods should be assessed for sulphide cracking and material controls should be specified accordingly.

The environmental severity for SSC shall be assessed in accordance with Table 1a.

Table 1a SSC severity categories

pH of water	Cyanide content [mg/kg (ppmw)] (Note 1)	Sulphide content of water [mg/kg (ppmw)]			
		< 2	2 to 49	50 to 1000	> 1000
		SEVERITY CATEGORY			
<4.0	(Notes 2,3)	Low	Moderate	High	High
4.0 to 5.4	(Notes 2,4)	Negligible	Low	Moderate	High
5.5 to 7.5	(Notes 2,4)	Negligible	Low	Low	Moderate
7.6 to 7.9	< 50 (Note 4)	Negligible	Low	Moderate	High
7.6 to 7.9	≥ 50 (Note 3)	Low	Moderate	High	High
≥ 8.0	< 20 (Note 4)	Negligible	Low	Moderate	High
≥ 8.0	≥ 20 (Note 3)	Low	Moderate	High	High
NOTES: 1. If the cyanide level cannot be established during design or from experience, the materials engineer of the Principal shall be consulted for an assessment based upon the type of process unit, feed, water wash practices, etc. 2. The level of cyanide has no significance at pH 7.5 and below. 3. Process conditions outside these ranges should be further assessed for Hydrogen blistering, HIC and SOHIC for piping (section 2.7), according 2.2.3.5 table 1b 4. Process conditions in these ranges do not need further assessment for Hydrogen blistering HIC and SOHIC for piping (section 2.7)					

2.2.3.5 Process Severity to Hydrogen blistering, HIC and SOHIC

If there is no free water likely to be present, then the material is **not** considered susceptible to hydrogen blistering, HIC or SOHIC.

If water is likely to be present, the environmental severity for blistering, HIC and SOHIC shall be assessed in accordance with Table 1b.