

## DEP SPECIFICATION

# WET H<sub>2</sub>S REQUIREMENTS FOR DOWNSTREAM PROCESS EQUIPMENT AND PIPING

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## DESIGN AND ENGINEERING PRACTICE

### DEM1



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**TABLE OF CONTENTS**

|           |                                                                                                                                              |           |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| <b>1.</b> | <b>INTRODUCTION .....</b>                                                                                                                    | <b>4</b>  |
| 1.1       | SCOPE .....                                                                                                                                  | 4         |
| 1.2       | DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS .....                                                                               | 4         |
| 1.3       | DEFINITIONS .....                                                                                                                            | 5         |
| 1.4       | CROSS-REFERENCES .....                                                                                                                       | 6         |
| 1.5       | SUMMARY OF MAIN CHANGES.....                                                                                                                 | 7         |
| 1.6       | COMMENTS ON THIS DEP .....                                                                                                                   | 7         |
| 1.7       | DUAL UNITS.....                                                                                                                              | 7         |
| 1.8       | NON NORMATIVE TEXT (COMMENTARY).....                                                                                                         | 7         |
| <b>2.</b> | <b>WET H<sub>2</sub>S SERVICE, DEFINITION AND PROCESS SEVERITY ASSESSMENT .....</b>                                                          | <b>8</b>  |
| 2.1       | GENERAL .....                                                                                                                                | 8         |
| 2.2       | DEFINITIONS – H <sub>2</sub> S CONTENT, CYANIDE CONTENT, CARBONATE CONTENT.....                                                              | 8         |
| 2.3       | PROCESS SEVERITY CATEGORIES.....                                                                                                             | 8         |
| <b>3.</b> | <b>CARBON STEEL PROCESS EQUIPMENT IN WET H<sub>2</sub>S SERVICE.....</b>                                                                     | <b>11</b> |
| 3.1       | GENERAL REQUIREMENTS FOR CARBON STEEL PROCESS EQUIPMENT IN WET H <sub>2</sub> S SERVICE .....                                                | 11        |
| 3.2       | SUMMARY FOR PROCESS EQUIPMENT IN SSC SERVICES .....                                                                                          | 16        |
| 3.3       | SUMMARY FOR PROCESS EQUIPMENT IN HIC/SOHIC SERVICES .....                                                                                    | 17        |
| 3.4       | SUMMARY FOR PROCESS EQUIPMENT IN CARBONATE CRACKING SERVICES .....                                                                           | 20        |
| <b>4.</b> | <b>CARBON STEEL PIPING FOR WET H<sub>2</sub>S SERVICE.....</b>                                                                               | <b>21</b> |
| 4.1       | GENERAL .....                                                                                                                                | 21        |
| 4.2       | HIGH SOUR SERVICE.....                                                                                                                       | 22        |
| 4.3       | MODERATE SOUR SERVICES .....                                                                                                                 | 23        |
| 4.4       | SEAMLESS PIPING SYSTEMS IN SSC SERVICES.....                                                                                                 | 23        |
| 4.5       | ENHANCED PWHT FOR ADDITIONAL RESIDUAL STRESS REDUCTION.....                                                                                  | 24        |
| <b>5.</b> | <b>OTHER METALLIC MATERIALS .....</b>                                                                                                        | <b>24</b> |
| 5.1       | INTRODUCTION .....                                                                                                                           | 24        |
| 5.2       | MATERIAL REQUIREMENTS FOR ALLOY STEEL, CAST IRON AND DUCTILE IRON.....                                                                       | 24        |
| 5.3       | MATERIAL REQUIREMENTS FOR ALLOYED STEELS AND NON FERROUS MATERIALS.....                                                                      | 24        |
| <b>6.</b> | <b>FABRICATION REQUIREMENTS, BOLTING, PLATING, COATINGS, AND DIFFUSION PROCESSES, SPECIAL COMPONENTS, VALVES, COMPRESSORS AND PUMPS.....</b> | <b>25</b> |
| 6.1       | GENERAL REQUIREMENTS.....                                                                                                                    | 25        |
| 6.2       | PUMP REQUIREMENTS .....                                                                                                                      | 25        |
| <b>7.</b> | <b>REFERENCES .....</b>                                                                                                                      | <b>26</b> |

**APPENDICES**

|                   |                                         |           |
|-------------------|-----------------------------------------|-----------|
| <b>APPENDIX A</b> | <b>ENHANCED PWHT REQUIREMENTS .....</b> | <b>29</b> |
|-------------------|-----------------------------------------|-----------|

## 1. INTRODUCTION

### 1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and qualification of cracking resistant metallic materials for service in wet H<sub>2</sub>S 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 conditions that may lead to carbonate stress corrosion cracking (wet H<sub>2</sub>S service is often associated with high pH streams containing carbonate and cyanides).

This DEP addresses all mechanisms of cracking that can be caused by wet H<sub>2</sub>S and wet 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 H<sub>2</sub>S environments
- Other alkaline stress corrosion cracking mechanisms (e.g., caustic stress cracking)
- Amine stress cracking
- Loss of material (mass loss) corrosion or localized corrosion

Many of the sulphide stress cracking requirements in this DEP are based on NACE MR0103, while requirements for other mechanisms are based on NACE SP0472.

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

This DEP is a revision of the same number dated February 2016; see (1.5) regarding the changes.

### 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 shall 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.

The word **may** indicates a permitted option.

#### 1.3.2 Specific definitions

| Term                              | Definition                                                                                                                                                                                                                                  |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Process Equipment</b>          | For the purposes of this DEP, includes vessels, columns, exchangers, etc. with the exception of pipe or piping systems. Process equipment manufactured from pipe materials is considered to form part of this process equipment definition. |
| <b>Wet H<sub>2</sub>S service</b> | The term commonly refers to refinery and gas plant (downstream) environments containing liquid water and H <sub>2</sub> S (plus other corrosives or contaminants).                                                                          |

**1.3.3 Abbreviations**

| <b>Term</b>             | <b>Definition</b>                                                                                    |
|-------------------------|------------------------------------------------------------------------------------------------------|
| <b>ASCC</b>             | Alkaline Stress Corrosion Cracking                                                                   |
| <b>ASME</b>             | American Society of Mechanical Engineers                                                             |
| <b>ASTM</b>             | American Society for Testing and Materials                                                           |
| <b>AWS</b>              | American Welding Institute                                                                           |
| <b>CE</b>               | Carbon Equivalent                                                                                    |
| <b>[CNFree]</b>         | Free cyanide in aqueous solution = $\text{HCN}_{\text{aq}} + \text{CN}^-$                            |
| <b>FCAW</b>             | Flux Core Arc Welding                                                                                |
| <b>GTAW</b>             | Gas Tungsten Metal Arc Welding                                                                       |
| <b>[H<sub>2</sub>S]</b> | Total Sulphide in aqueous solution = $\text{H}_2\text{S}_{\text{aq}} + \text{HS}^- + \text{S}^{2-}$  |
| <b>HAZ</b>              | Heat Affected Zone                                                                                   |
| <b>HB</b>               | Hardness Brinell (hardness Brinell with a carbide ball indenter according to ASTM E 10 is noted HBW) |
| <b>HIC</b>              | Hydrogen Induced Cracking                                                                            |
| <b>HV</b>               | Hardness Vickers                                                                                     |
| <b>NACE</b>             | National Association of Corrosion Engineers                                                          |
| <b>NACT</b>             | Normalised, accelerated cooled and tempered                                                          |
| <b>PQR</b>              | Procedure Qualification Record                                                                       |
| <b>PWHT</b>             | Post Weld Heat Treatment                                                                             |
| <b>SMAW</b>             | Shielded Metal Arc Welding                                                                           |
| <b>SOHIC</b>            | Stress-Oriented Hydrogen-Induced Cracking                                                            |
| <b>SSC</b>              | Sulphide Stress Cracking                                                                             |
| <b>TMCP</b>             | Thermal Mechanical Controlled Process                                                                |
| <b>WFMT</b>             | Wet Fluorescent Magnetic Test                                                                        |
| <b>WPQT</b>             | Welding Procedure Qualification Test                                                                 |

**1.4 CROSS-REFERENCES**

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets ( ).

Other documents referenced by this DEP are listed in (7).

## 1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2016. The only changes are to DEP cross-references to reflect changes in the DEP library in 2017.

## 1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

|                                                                      |                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Shell DEPs Online</b><br>(Users with access to Shell DEPs Online) | Enter the Shell DEPs Online system at <a href="https://www.shelldeps.com">https://www.shelldeps.com</a><br><br>Select a DEP and then go to the details screen for that DEP.<br><br>Click on the "Give feedback" link, fill in the online form and submit.           |
| <b>DEP Feedback System</b><br>(Users with access to Shell Wide Web)  | Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal <a href="http://swww.shell.com/standards">http://swww.shell.com/standards</a> .<br><br>Select "Submit DEP Feedback", fill in the online form and submit. |
| <b>DEP Standard Form</b><br>(other users)                            | Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at <a href="mailto:standards@shell.com">standards@shell.com</a> .                                                                                                 |

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

## 1.7 DUAL UNITS

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.

## 1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

*Non-normative text is normally indented slightly to the right of the relevant DEP clause.*

## 2. WET H<sub>2</sub>S SERVICE, DEFINITION AND PROCESS SEVERITY ASSESSMENT

### 2.1 GENERAL

*"Wet H<sub>2</sub>S" service is the term commonly used for refinery and gas plant (downstream) environments containing liquid water and H<sub>2</sub>S (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.*

1. All carbon steel process equipment and piping operating in downstream applications and exposed to process streams that result in potential cracking mechanisms caused by wet H<sub>2</sub>S service environment, shall be designed and fabricated in accordance with the requirements of this DEP.
2. The materials selection, testing, and post weld heat treatment (PWHT) requirements shall be determined by the severity of the environment with respect to all applicable wet H<sub>2</sub>S damage mechanisms.

### 2.2 DEFINITIONS – H<sub>2</sub>S CONTENT, CYANIDE CONTENT, CARBONATE CONTENT

1. The 'H<sub>2</sub>S content of water' in the context of this DEP means the sum of the dissolved (molecular) H<sub>2</sub>S, bisulphide ion (HS<sup>-1</sup>), and sulphide ion (S<sup>-2</sup>) concentrations in the water phase, that result from the presence of H<sub>2</sub>S in the process system.
2. The 'cyanide content of water' means the concentration of 'free' cyanide [CN<sub>Free</sub>], expressed in ppmw, in the sour water that results from the presence of HCN and CN<sup>-</sup> in the process stream. [CN<sub>Free</sub>] is the sum of dissolved (molecular) HCN and cyanide ion (CN<sup>-</sup>) concentrations in the water phase.
3. The carbonate ion (CO<sub>3</sub><sup>-2</sup>) concentration used to determine the susceptibility to carbonate cracking means the actual carbonate ion concentration in the water phase.

### 2.3 PROCESS SEVERITY CATEGORIES

#### 2.3.1 General

1. Carbon steel susceptibility to each different cracking mechanism is determined by the process environment (water, [H<sub>2</sub>S], [CN<sub>Free</sub>], CO<sub>3</sub><sup>-2</sup>) and material properties (chemistry, mechanical properties, and thermal history).

#### 2.3.2 Process severity category

1. One of four severity categories shall be defined for each mechanism for the purposes of setting the material and fabrication requirements. These categories are:
  - a. Not;
  - b. Low;
  - c. Moderate;
  - d. High.
2. 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 primary environment being considered is the environment present during normal operations.
  - a. Transient conditions (startup, shutdown, presulfiding, process upsets, etc.) shall also be considered because some damage mechanisms can occur rapidly, while others result from accumulated damage over numerous transient periods during equipment service life.
  - b. If transient conditions increase the environmental severity category, then the potential for rapid or cumulative damage during such transients shall be considered for material specification.

3. Potential mechanisms are not exclusive, i.e., if there is more than one mechanism active, the materials and PWHT requirements shall be combined to address the severity of more than one environment.
4. If this DEP is used to specify replacement of in-service equipment (or equipment in a directly comparable service) and the equipment has been damaged in service, the Principal's material engineer shall be consulted to assess the process severity.
5. In high pH streams containing 50 ppmw or more H<sub>2</sub>S and carbonate ions, an assessment of the process severity for carbonate cracking shall be conducted per (2.3.6).
6. The severity category assigned to each type of equipment shall be subject to the approval of the Principal's materials engineer.

### 2.3.3 Additional mitigation measures

1. For carbon steel pressure equipment and piping, where additional mitigation measures such as injection of polysulphide or inhibitors may be required, the Principal's materials engineer shall be consulted.

### 2.3.4 Process severity for SSC

1. If there is no free water present during normal operation, then the material should not be considered susceptible to SSC.
2. If water is likely to be present during start-up/shutdown or transient conditions: the environmental conditions during these transient periods shall be assessed for sulphide cracking and material controls specified accordingly.
3. The environmental severity for SSC shall be assessed in accordance with Table 1a.

**Table 1a SSC severity categories**

| pH of water | Cyanide content<br>[mg/kg (ppmw)]<br>(Item 3) | Sulphide content of water<br>[mg/kg (ppmw)] |          |            |          |
|-------------|-----------------------------------------------|---------------------------------------------|----------|------------|----------|
|             |                                               | < 2                                         | 2 to 49  | 50 to 1000 | > 1000   |
|             |                                               | SEVERITY CATEGORY                           |          |            |          |
| <4.0        | (Item 4)                                      | Low                                         | Moderate | High       | High     |
| 4.0 to 5.4  | (Item 4)                                      | Not                                         | Low      | Moderate   | High     |
| 5.5 to 7.5  | (Item 4)                                      | Not                                         | Low      | Low        | Moderate |
| 7.6 to 7.9  | < 50                                          | Not                                         | Low      | Moderate   | High     |
| 7.6 to 7.9  | ≥ 50                                          | Low                                         | Moderate | High       | High     |
| ≥ 8.0       | < 20                                          | Not                                         | Low      | Moderate   | High     |
| ≥ 8.0       | ≥ 20                                          | Low                                         | Moderate | High       | High     |

4. If the cyanide level cannot be established during design or from experience, the Principal's materials engineer shall be consulted for an assessment based upon the type of process unit, feed, water wash practices, etc.

*The level of cyanide has no significance at pH 7.5 and below.*