DEP SPECIFICATION

CORROSION PREVENTION AND CONTROL OF WATER INJECTION SYSTEMS

DEP 31.01.10.11-Gen.

February 2014

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies design requirements and gives recommendations for corrosion prevention, control and surveillance of water injection systems associated with hydrocarbon recovery and disposal operations. This DEP does not include operational practice, except as expected and agreed practice may impact the design.

This DEP includes design expectations for water processing, chemical injection and surveillance. The equipment scope includes source water gathering, water filtration, water deoxygenation by process and chemical systems, water conditioning equipment such as reverse osmosis or sulphate removal systems, pumps, injection flowlines, injection wells, monitoring and associated jewellery.

Injection water sources include seawater, aquifer water, produced water, surface water, low-sulphate seawater, and reverse osmosis-treated water or a combination of these. In the case of produced water re-injection (PWRI), the remit of this DEP will commence downstream of all processing equipment and tanks.

Locations include systems onshore, offshore, deepwater, and subsea.

The DEP focuses upon functional design requirements for corrosion control, prevention and surveillance in water injection systems. Detailed mechanical and process equipment design requirements to meet the function requirements herein are beyond the scope of this DEP, although materials selection and corrosion prevention requirements for specific components are included.

This DEP is intended to augment DEP 39.01.10.11-Gen. and DEP 39.01.10.12-Gen. These DEPs shall be used as the basis of waterflood system design for all items that are not addressed specifically in this DEP.

This is a revision of the DEP of the same number dated February 2012; 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 and gas production. 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.

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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 word **should** indicates a recommendation.

1.3.2 Abbreviations

Term	Definition
AISI	American Iron and Steel Institute
ASME	American Society of Mechanical Engineers
CRA	corrosion resistant alloy
CS	carbon steel
CSCC	chloride stress corrosion cracking
CUI	corrosion under insulation
dP	differential pressure
EOR	enhanced oil recovery
GRP	glass reinforced plastic (fibreglass). It is also known as FRP (fibre reinforced plastic) or GRE (glass reinforced epoxy)
HDPE	High density polyethylene
ISO	International Organization for Standardization
MIC	microbial influenced corrosion
MPN	maximum probable number
MTD	Marine Technology Directorate
NAB	nickel aluminium bronze
NACE	National Association of Corrosion Engineers (International)
NDT	nondestructive testing
NPSH	net positive suction head
NRB	nitrate reducing bacteria
NRSOB	nitrate reducing – sulphide oxidising bacteria
PE	polyethylene
PPB	parts per billion
PPM	parts per million
PRE_W	pitting resistance equivalent number = % Cr + 3.3 % (Mo + 0.5W) + 16 % N. Without W the definition is PRE_N
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
PWC	preferential weld corrosion
PWRI	produced water re-injection
RO	reverse osmosis

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Term	Definition
RTP	reinforced thermoplastic pipe
SCC	stress corrosion cracking
SIC	short interval control
SRB	sulphate reducing bacteria
TDS	total dissolved solids
TSA	thermal sprayed aluminium (sometimes called flame sprayed aluminium) TSA covers both arc and flame sprayed.
TSS	total suspended solids
VFA	volatile fatty acid

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 (6).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a minor revision of the DEP of the same number dated February 2012. The main revisions to this DEP have been:

- Made specific references to microbiological corrosion (6 o'clock grooving) of carbon steel, and required more detailed assessment of source water corrosivity
- Added reference to DEM1 DEP 25.80.10.18-Gen. for H_2S prediction.

The following are the main, non-editorial changes.

Section/Clause	Change
2.3	Remove "EP" as limitation
2.3	Incorporated specific references to microbiological corrosion (6 o'clock grooving) of carbon steel.
2.6.1	Added consideration of impact of corrosion by halide compounds on materials and biocidal effectiveness.
3.2	Added specific referenced to DEM1 DEP 25.80.10.18-Gen. for H_2S prediction.
6	Added references for DEP 00.00.05.80-Gen. and DEP 25.80.10.18-Gen., Deleted reference to withdrawn DEP 70.48.11.30-Gen.

1.6 COMMENTS ON THIS DEP

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

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.

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DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://sww.shell.com/standards. Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com.

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.

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2. INJECTION SYSTEM OVERVIEW AND FUNCTIONAL REQUIREMENTS

2.1 GENERAL

A typical configuration for water injection systems to meet specified requirements should be as shown in Figure 1. The selected configuration shall be determined by assessment of the reservoir injection requirements (e.g., whether injection is matrix or fractured), limitations on reservoir impact (e.g., souring, scaling, degree of fracturing), and agreed operating philosophy, as further identified in DEP 39.01.40.30-Gen. for seawater treatment and DEP 39.01.40.31-Gen. for produced water streams.

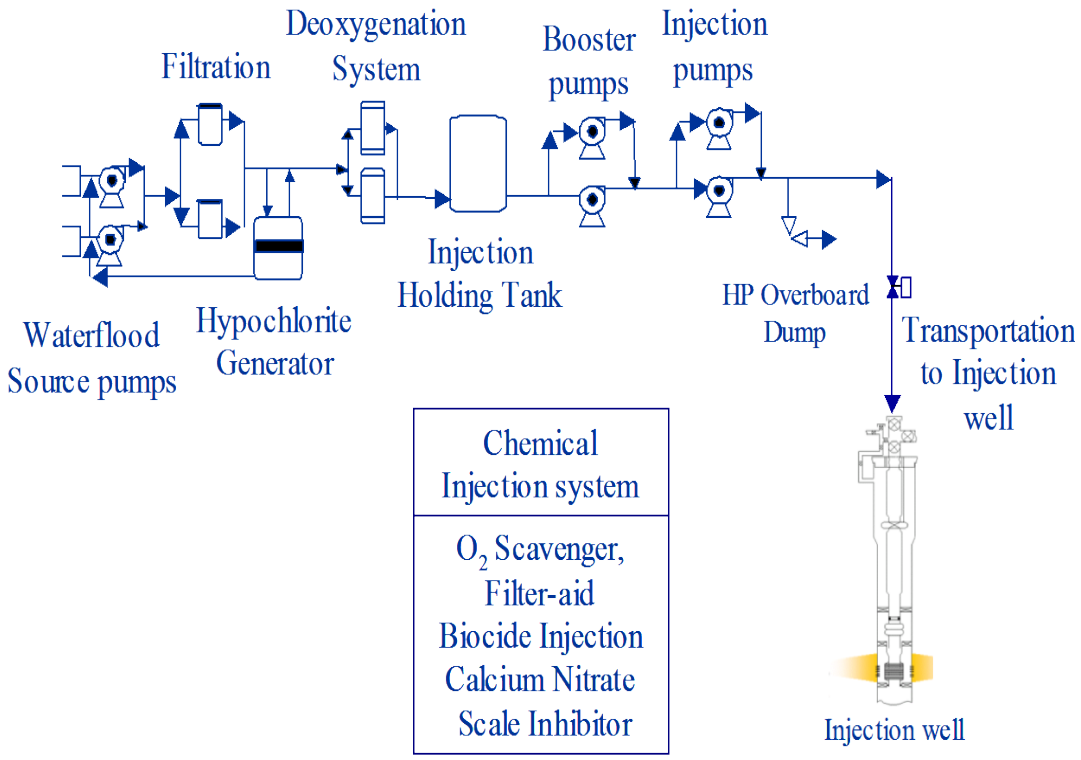

Figure 1 Water injection system overview

2.2 CONTROL OF SOURCE WATER SOLIDS - FILTRATION

Required filtration shall be determined on the basis of a review of the reservoir rock proposed injection methodology (i.e., fracturing or matrix injection) to establish limitations on maximum injected particle size, associated limitations on the total suspended solids (TSS) and solids impact on reservoir souring. Filtration should include an initial coarse strainer to remove large particles after the source pumps, a intermediate multimedia or continuous backwash screen filter to reduce TSS, and dual guardian cartridge, metal matrix, or ceramic filters to assure the final filtration requirements of the formation are met, even in the event of an intermediate filter upset or downtime. The review shall assess the impact of organic debris on reservoir souring (e.g., as a nutrition source for bacteria). Filtration may include membrane systems to control water salinity or remove specific ions, e.g., sulphate removal for souring or scale control. The filtration requirements and associated filtration design shall be agreed by the Principal prior to implementation of the design.

2.3 CONTROL OF BACTERIA AND BIO-FOULING

Equipment shall be provided to achieve control of bacteria and bio-fouling both in water injection equipment from the source water inlet to the well injection point and within the reservoir, The design basis shall identify the proposed chemicals (and dosages) or other proposed functional basis, and the design of Chemical Injection Systems shall comply with

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DEP 31.01.10.10-Gen. The design shall comply with local regulations with respect to chemically treated water, including e.g., chemically acceptable discharge of excess treated water to local surface waters, limitations on chemical treatment of injection water, and limitations on use of chemical composition.

The chemical injection system shall provide for batch biocide injection to provide control of biological activity and prevent microbiological corrosion (e.g., 6 o'clock grooving) of carbon steel, if present, and fouling to the point of reservoir injection. When source waters are biologically active (e.g., seawater, surface fresh water, contaminated produced water), the bio-treatment system shall provide continuous bio-treatment at or near the system inlet by either injection of an active halide (e.g., free chlorine by chlorination, bromination) or other continuous sanitization system approved by the Principal.

Batch biocide should typically be injected just before the oxygen removal step, while nitrate should be injected as late as practical in the process, typically at the water injection pump. Use of alternative injection locations shall be approved by the Principal.

An approved system for batch biocide injection shall include injection of Tetrakis Hydroxymethyl Phosphonium Sulfate (THPS) at 500 ppmv (active). Gluteraldehyde, cocodiamine (quaternary ammonium compounds), DBNPA (2,2 dibromo-3-nitrilopropionamide) or other compounds may be approved by the Principal. Approved systems of continuous treatment shall include chlorination and bromination, as designed to achieve a minimum free halide dosage of 0.5 - 0.8 ppm wt (maximum excursions to 2 ppm wt). Continuous treatment systems based upon metal ion generation (e.g., copper) shall not be used. Systems employing continuous treatment based on mildly corrosive compounds shall consider the potential impact of consumption of the agent in lines longer than 0.25 km (800 ft) and the associated corrosion impact on metals and non-metallics.

Where continuous treatment systems employ electrolysis to generate the free halide, the following requirements shall be met by the system:

- Electrodes shall be designed to provide a minimum of 5 years service life;
- Flow rate across the electrodes shall be adequate to prevent scaling by the source waters, such that electrode acid cleaning is required less than once per year.

2.4 CONTROL OF DISSOLVED OXYGEN - OXYGEN REMOVAL SYSTEMS

Where source waters may or do contain oxygen, a provision for deoxygenation shall be made. Oxygen removal may be made by using mechanical deoxygenation systems, chemical injection or a combination of these two systems. Selection of the deoxygenation system shall be made to achieve the lowest expected system lifecycle cost, including costs for operation and maintenance of the deoxygenation equipment, chemicals used, and a review of potential downstream repair costs based on probable downstream corrosion in the event of uncontrolled upsets. Deoxygenation systems shall be designed to produce injection water with maximum in-situ oxygen content below 5 ppb. With the realistic understanding that many conventional monitoring approaches can easily induce ~5 ppb oxygen contamination, a net monitoring level of 10 ppb maximum oxygen shall be required.

Approved deoxygenation approaches shall include the following:

1. Mechanical removal with a three-stage vacuum tower.
2. Mechanical removal to an intermediate oxygen content, followed by chemical oxygen scavenger polishing. Approved mechanical techniques for this approach shall include two-stage vacuum towers, gas stripping towers, oxygen stripping using catalytic combustion, and membranes.
3. Chemical oxygen scavenger polishing.

Alternative deoxygenation approaches shall be approved by the Principal's TA1 for Process Engineering and Design Engineers with concurrence from Materials and Corrosion Engineer.

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