

DEP SPECIFICATION

CORROSION PREVENTION AND CONTROL OF WATER INJECTION SYSTEMS (EP)

DEP 31.01.10.11-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies design requirements and gives recommendations for corrosion prevention, control and surveillance for water injection systems associated with hydrocarbon recovery and disposal operations in EP. 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.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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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.

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
AIISI	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
RTP	reinforced thermoplastic pipe

Term	Definition
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 number is shown in brackets (). Other documents referenced by this DEP are listed in (6).

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

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. 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.

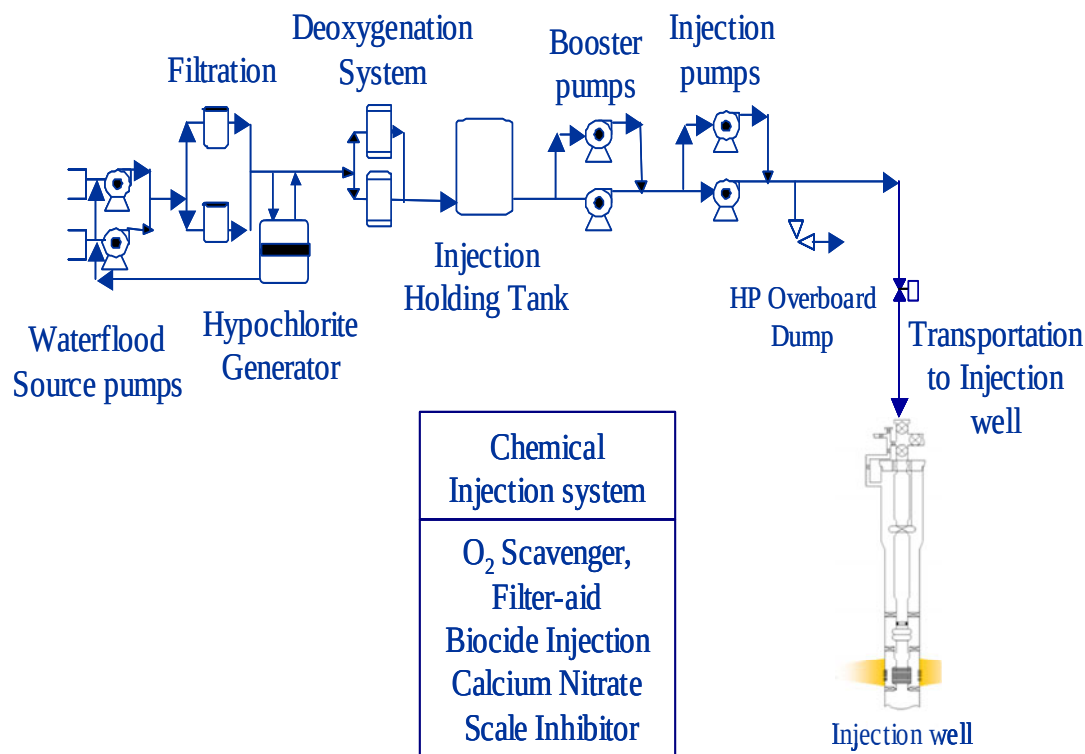


Figure 1 Water injection system overview

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 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 fouling to the point of reservoir injection. When source waters are biologically active (e.g., seawater, surface fresh 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 (e.g., UV systems).

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.

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 basis 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.

All chemical scavenger based systems shall incorporate mixing systems and residence time in the surface systems sufficient to assure the specified monitoring oxygen content is met prior to the injection pumps.

As part of the assessment of the potential downstream repair costs, an assessment of the reliability of the deoxygenation systems shall be made. Reliability of all systems may be adjusted basis planned monitoring and response as agreed with operations staff. Mechanical system reliability should be assessed basis a component reliability study per published reliability estimates. Systems incorporating chemical use shall use reliability values as identified in DEP 31.01.10.10-Gen, plus added loss in performance due to the effect of chemical incompatibility between biocides and oxygen scavengers which often causes an oxygen excursion during biocide treatments. Dual train chemical oxygen scavenging systems (i.e., two(+) separate trains to provide mixing and needed residence time) may mitigate loss in performance due to chemical incompatibility basis planned operating protocols for such systems.

Guardian oxygen removal systems may be incorporated into injection system design, which systems may allow by their very high expected reliability, the use of low alloy steel without oxygen attack, downstream of their installation point. Such a system design shall be approved by the the Principal's Design Engineer with concurrence from Materials TA1. A guardian oxygen removal system should be provided downstream of any possible oxygen recontamination point. An approved guardian oxygen removal system shall be the presence of a large surface area of bare carbon steel (e.g., a long flowline), whose design shall incorporate sufficient material or corrosion allowance to accommodate the projected lifecycle upsets in the oxygen removal system. Corrosion allowance for pipe in such an application shall be designed based on the projected corrosion rate calculated by HYDROCOR. Oxygen removal shall be calculated basis a minimum projected corrosion rate, which shall not exceed one-fourth of the corrosion rate calculated by HYDROCOR. For such systems, the potential for MIC corrosion attack shall still be considered present and the impact of added suspended corrosion product solids on formation injectivity shall be reviewed and impact addressed as needed.

The use of sacrificial carbon steel sections should only be done after a thorough risk assessment and with the approval of the Materials TA1.

2.5 EXCESS WATER DESIGN REQUIREMENTS

Provisions to handle excess water (e.g., treated water flow in excess of injection well ramp-up capacity, treated water beyond capacity of an impaired well capacity, water flow needed to satisfy minimum pump limitations, pressure relief discharges) shall be made in a manner that meets local regulatory and discharge permit requirements for potential injection water discharge. For the basis of this assessment, all biocide injection sources shall be considered active. Provision to handle excess water shall be made by either assuring that such water is acceptable for discharge or by recycle of such water back into a vessel or other container possessing a suitable gas head to avoid overpressure by a sudden hydraulic discharge.

2.6 RESERVOIR AND PRODUCTION SYSTEM ASSESSMENT REQUIREMENTS

Design of the injection water system shall consider the safety impact and probable cost of injected water on reservoirs. Design of the injection system shall include adherence to a documented assessment of injection requirements to avoid unacceptable out of zone fracturing. A design review of systems injecting into reservoirs from which production is or may occur shall be performed and shall include the potential for reservoir souring, the probable degree of reservoir souring (i.e., a p50 and p90 value for ppm or partial pressure of hydrogen sulphide), the associated souring impact on the future design or existing safety of production equipment (i.e., wells and surface systems), the potential impact of the well on production system corrosivity, and the potential impact of injected water on production rates (e.g., scaling impacts). Reservoir injection studies should include the benefits and costs of optional systems to mitigate injection water impacts (e.g., sulphate removal, nitrate injection).

2.6.1 Prediction of hydrogen sulphide production

A prediction of H₂S production during the life of a field shall be developed for assets considering water injection for secondary recovery and pressure-maintenance activities.