

Corrosion Control in Sea Water Injection Pipelines

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ABSTRACT

Dubai Petroleum (the Operator) operates five oil fields in the offshore Dubai area of the United Arab Emirates. Within these operated fields there is a network of over 30 unlined carbon steel sea water injection pipelines that are presently in use, with abandoned or mothballed pipelines taking this number to over 50. This publication discusses the experience of the Operator, where the operating life of these pipelines has typically exceeded 20 years, and on occasion has exceeded 40 years. This is compared with the experience of the UK sector, where failures in as little as four years have been noted and many pipelines have failed to reach 15 years of service. The prevalent corrosion mechanisms are discussed and a comparison of corrosion control measures such as de-aeration and microbial control is made. An assessment of the Operator's pipeline corrosion, chemical, monitoring and inspection data is discussed. Evidence is presented that operational pigging of sea water injection pipelines can reduce corrosion rates and significantly extend pipeline life in combination with other industry standard corrosion control measures such as de-aeration, chlorination and batch biocide treatment.

Key words: Corrosion, Pipelines, Sea Water Injection, De-Aeration, Biocide, Anti-Foam, Pigging, Monitoring.

INTRODUCTION

Dubai Petroleum (the Operator) operates five offshore oil fields in the Emirate of Dubai (Fateh, South West Fateh, Falah, Jallilah and Rashid), in addition to various onshore gas production, storage, distribution and import facilities, and LNG import facilities. The assets within these offshore fields consist of approximately 80 platforms of various sizes, comprising central bridge linked processing facilities in Fateh and South West Fateh, and outlying normally unmanned wellhead production platforms. These platforms are linked by a network of over 150 subsea pipelines, of which over 30 are presently operational sea water injection pipelines

A schematic of these offshore platforms and the associated sea water injection pipelines is presented in Figure 1, overleaf;

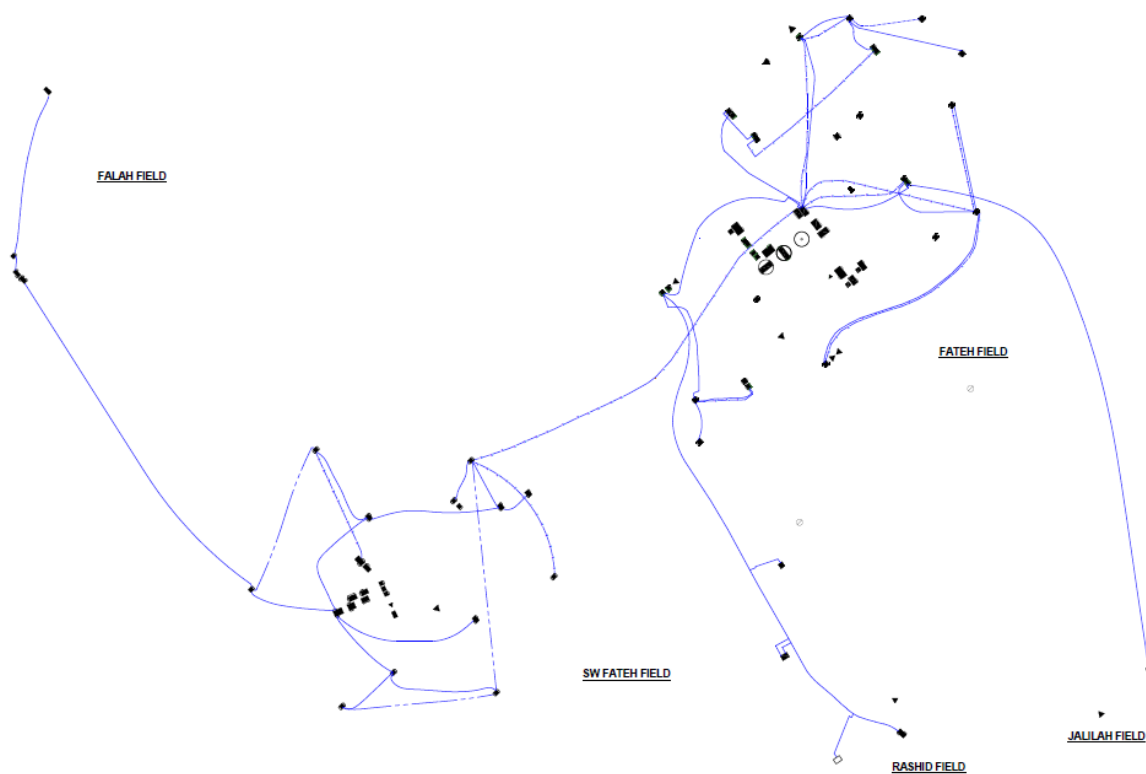


Figure 1 Operated Fields and Sea Water Injection Pipelines

Sea Water Injection Pipeline Network

The offshore sea water injection pipeline system consists of over 50 pipelines, of which more than 30 are operational. Of the remaining balance, a number of pipelines have failed and have been replaced, and others have been placed into suspension where no longer required for support of production. The purpose of water injection is to maintain production pressure in the reservoirs and replace produced liquid volume.

Oxygenated sea water is raised at the Fateh and South West Fateh complexes, where it is chlorinated and de-aerated using standard vacuum de-aerator towers. Batch biocide treatment is also performed. The de-aerated sea water is then pumped at high pressure through the pipeline system to the outlying normally unmanned wellhead production installations, where it is then injected via injection wells.

Corrosion in Offshore Sea Water Injection Pipelines

Failure of sea water injection pipelines is a common occurrence. As described by Marsh et al.¹, from experience in the North Sea, sea water injection pipelines can last for as little as 4 years, and a 15 year life is often not achieved.

This has been documented in the Boreas JIP on water injection system failures, where a number of operators pooled their experience. A total of 23 water injection pipelines were examined. Although the

report as a whole is not in the public domain, its conclusions are available.^{1,2} These can be summarized as:

- Of the 23 pipelines in the study, 9 had failed in service
- Failure was predominantly by 6 o'clock long axial grooving, with corrosion product present circumferentially except at the groove, which was shiny and metallic in nature.
- The failures were ascribed to Microbial Influenced Corrosion (MIC), though the presence of the shiny groove could also indicate an additional erosional or flow associated component.
- Once microbial issues were noted, the average life was typically around 8 years, though it could be as short as 4 years
- The typical corrosion rate was 2 mm/yr
- Only one pipeline in the study had successfully exceeded 15 years of life

As a result of their experience, most operators in the UK and latterly the Norwegian sectors of the North Sea moved to HDPE lined water injection pipelines.

Corrosion Mechanisms

There is still considerable discussion ongoing in the industry as to the primary causes of corrosion in water injection pipelines. The three primary mechanisms typically proposed are;

- Oxygen Corrosion
- Microbial Influenced Corrosion (MIC)
- Oxygen Scavenger Overdosing

ISO 21457 recognizes Oxygen corrosion and MIC as the primary mechanisms for sea water injection pipelines.³

This discussion is further modified by the fact there are additional factors for low flow (< 1.5 m/s) and high flow (> 2-5 m/s), leading to the addition influence of;

- Corrosion Under Deposits
- Erosion/Flow influenced Corrosion

Oxygen Corrosion

Control of Oxygen corrosion in sea water systems is by de-aeration. This will typically be based on either standard vacuum de-aeration towers or more modern methods such as the MINOX system. Different operators have varying targets for residual Oxygen concentration ranging from 20 ppb to 5 ppb. Oxygen scavenger is typically used where Oxygen levels remain above the required threshold post to de-aeration. NORSOK M-001 previously recommended a maximum Oxygen concentration of 20 mg/m³ (2004) for de-aerated unchlorinated water, but no longer provides this guidance (2014).⁴ ISO 21457,³ also indicates a maximum threshold of 20 mg/m³ Oxygen concentration for de-aerated unchlorinated sea water.

The Operator uses standard vacuum de-aeration. Oxygen levels are monitored by Orbisphere. It has been found that by careful selection and dosing of anti-foam into the de-aeration towers, Oxygen levels below 20 mg/m³ are obtained. When correcting for the effect of residual chlorine on the measurement, Oxygen is typically lower than 10 mg/m³. As such, Oxygen scavenger is not typically injected in the sea water injection system by the Operator.

One exception, where Oxygen scavenger is injected, is for Oxygen control during direct injection of sea water. This has been used on occasion for isolated platforms when de-aerated sea water from the central facilities has not been available.

However, control of Oxygen has not always been as effective historically as it is presently. An internal study performed in 2003 indicated significant short term deviations in Oxygen control, and led to a tightening of procedures and KPI compliance.

Microbial Influenced Corrosion

A number of studies have assessed the effect of microbial activity on the corrosion of water injection pipelines. Comanescu et al,⁵ identified from laboratory tests that corrosion rates were higher by a factor of 10 for bacterial samples obtained from a North Sea water injection system when compared to samples from power station water systems onshore. The Boreas JIP assessed 23 pipelines and identified microbial corrosion as the primary corrosion mechanism, with a rate of 2 mm/yr. Heidersbach and Roodselaar,⁶ have identified a corrosion rate range of 1-2.5 mm/yr for microbial induced erosion corrosion in sea water injection pipelines. Markfoged et al,⁷ assessed corrosion rates and pigging products for a 16" diameter and 9.6 km long injection water pipeline from the platforms Dan FF to Halfdan A and further to Halfdan B. The data was used as input into a model developed for predicting potential pit generation rates and time for MIC corrosion to develop in environments over a temperature range of 25 to 85 degC.

The present Operator practice for microbial control is based on three primary mitigation techniques. These are;

- Chlorination via hypochlorite injection or electro-chlorination, in line with general industry practice, with the aim of having 0.25-0.3 ppm residual chlorine at the de-aerator outlet booster pump.
- Alternating batch biocide treatment, again in line with general industry practice, using 500 ppm of high concentration glutaraldehyde and quaternary amine biocides (50% active ingredients) for a minimum of 2 hours every 10 days.
- 3 Monthly or 2 yearly operational cleaning pigging.

Planktonic SRB microbial counts are measured monthly across both the complexes and the injection manifolds of the remote production platforms. Counts are typically 0-10/ml. If values greater than this are noted at any location on 2 consecutive assessments, additional batch biocide treatments are implemented. Pig trash samples are also analyzed, and if elevated levels of microbial activity are noted, additional treatments are implemented.

Oxygen Scavenger Overdosing

Oxygen scavenger overdosing has been proposed as an alternative mechanism to MIC where iron sulphide is identified in the corrosion products. However, the specific mechanism and the level of corrosivity have not been fully defined. Studies have been performed to assess the effect of ammonium bisulphite Oxygen scavenger injection on corrosion in sea water systems. Jackson et al,⁸ noted that an increase in corrosion rate could occur when the chemical was first injected, but no longer term corrosion effect could be observed and the chemical was deemed to be safe when used at the recommended dosage.

The Operator does not inject Oxygen scavenger into the water injection system, with the exception of isolated platforms that do not receive de-aerated sea water from the central facilities.