

GATE KEEPER

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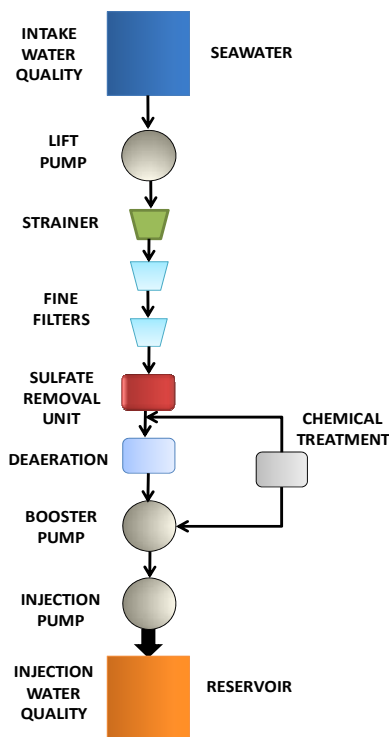


Figure 1: Conventional WI System Schematic

Subsea Raw Water Injection

Water injection is often an integral part of the field development plan adopted for subsea developments, where projects may not be economically viable in its absence. However, a significant drawback to the use of topsides water injection facilities for offshore developments is the weight and space required for equipment. As outlined in Figure 1, this can typically include pumps, filter packages, deoxygenation and sulfate removal units. These limitations become particularly problematic for retrofit systems with limited design flexibility and for floating production platforms where weight and space are often tightly limited.

A relatively recent development has been to move the water injection equipment away from the topsides and to place it subsea. This enables the retrofit of seawater injection capabilities to facilities that otherwise would not be able to accommodate the increased infrastructure and reduces the required hull size and riser count of floating production units. This approach is known as Subsea Raw Water Injection (SRWI). The term 'raw' refers to the fact that the water is not deoxygenated, as for most seawater injection projects, and that it is generally less finely filtered and minimally chemically treated. It does not mean that the water receives no pre-conditioning prior to injection.

A significant additional benefit associated with SRWI includes the ability to place injection wells where they are most appropriate from a reservoir management perspective, rather than having their position dictated by available water injection riser & flowline positioning and routing options.

Although SRWI generally provides a cost effective comparison to regular seawater systems due to the large reduction in topsides equipment and the elimination of subsea risers and flowlines, mechanical reliability is a concern. Many fields require that a strict voidage replacement ratio (VRR) is maintained in order to keep the reservoir at a pressure where production is optimized. This is particularly critical for reservoirs with pressures close to bubble point, as gas breakout in the formation significantly impairs future production.

Equipment vendors have invested significant time and resources into ensuring that subsea injection equipment is robust and reliable. However, formations that are particularly sensitive to maintaining the VRR are less suitable candidates for SRWI based on the time required to retrieve and replace any failed components. However, this risk can be offset by the provision of redundant injection capacity in critical locations.

Subsea Raw Water Injection—Additional Considerations

In addition to mechanical reliability and field design issues, there are a number of considerations that must be addressed when evaluating SRWI suitability for a given location.

Filtration: As briefly mentioned above, one of the most significant differences on a SRWI system compared to a conventional WI system is the level of filtration applied. On a SRWI system, seawater can be filtered down to about 30µm, where the water intake needs to be placed at least 5m (16 ft) above the seabed. The filters on a SRWI system are typically analogous to coarse strainers on a conventional system and can limit SRWI to formations or completion types that are not sensitive to solids and can limit injection to systems operating above the reservoir fracture pressure.



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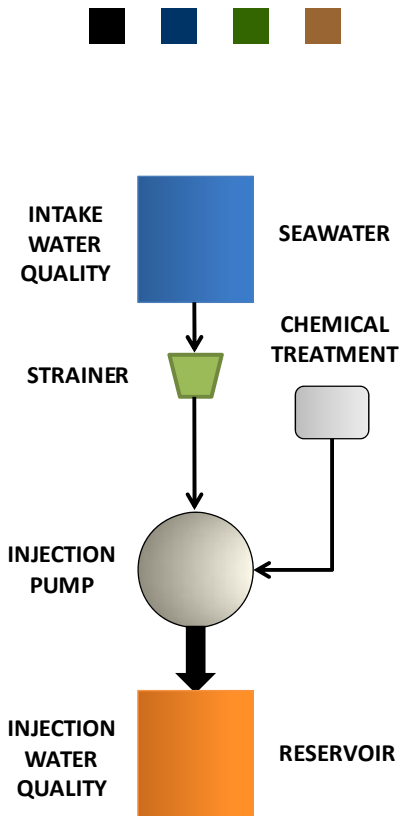


Figure 2: Subsea Raw Water Injection System Schematic

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Injector Materials Selection: SRWI involves injection of fully oxygenated seawater. This is a very corrosive environment for carbon steels and lower grade corrosion resistant alloys (CRA). Therefore, tubing, completions and jewelry need to be specified from alloys with a Pitting Resistance Equivalent Number (PRE_N) of greater than 40. This limits materials to grades with corrosion resistance equivalent to, or greater than, that of Super Duplex Stainless Steel (SDSS). Glass-Reinforced Epoxy (GRE)-lined carbon steel tubing is also appropriate for vertical injectors, but its installation can be challenging in highly deviated or horizontal wells.

Use of dissimilar metals in the water injection system also poses a galvanic corrosion threat due to the presence of high levels of oxygen. However, this risk can be minimized by appropriate materials selection.

Fouling of injectors by bacteria means that hypochlorite treatment is often required. This can present a corrosion risk in its own right, where the over-dosage of hypochlorite is known to cause rapid corrosion of high-grade CRA materials such as SDSS.

Scaling Risk: Full sulfate seawater injection presents a significant scaling risk. As a result, it is important to treat the first 300,000 to 1 MM barrels (first wave) of injection water with a compatible scale inhibitor. Beyond this, the risk of scaling in the production system will have a strong influence on whether SRWI is a suitable approach. Formations with elevated barium or strontium levels can cause rapid deposition of largely insoluble sulfate scales on injection water breakthrough at the producers. Scale squeezes can control this, but these can be problematic to apply and monitor in deepwater fields and can be difficult to place effectively in horizontal or multi-zone completions. Hence, an assessment of scaling risks is often required to determine whether SRWI is appropriate or whether topsides injection incorporating a sulfate removal unit is the most effective means of scale management for a given field.

Reservoir Souring: Reservoir souring risks can be increased over topsides injection systems when applying SRWI. The high sulfate concentration in the injected water provides an abundant energy source to Sulfate Reducing Bacteria (SRB) in comparison to water treated with a topsides sulfate removal unit. Furthermore, the decreased filtration and potential for increased biological activity in SRWI systems can promote souring beyond traditional seawater injection arrangements without sulfate removal. Hence, the cost savings associated with SRWI use need to be balanced against the cost of designing production facilities to accommodate anticipated levels of H₂S production and the need to treat produced fluids to ensure that H₂S export limits are maintained.

Conclusions:

SRWI is an attractive option for increasing residual oil recovery rates from subsea developments. It is particularly effective for retrofit projects or where facilities are otherwise limited by weight and space. In such situations, it can result in significant capital cost and operational cost savings over the use of traditional topsides injection facilities. However, potential SRWI projects must be carefully evaluated with respect to their whole-life cost in association with their mechanical reliability, filtration requirements, materials selection, and scaling and souring issues.

As the industry continues to focus on subsea developments, it is likely that the use of subsea raw water injection will continue to see increased uptake and that it will ultimately evolve into a fundamental part of the toolkit available to operators when evaluating the most effective way to develop their fields and maximize their return on investment.

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