Micro- and Ultrafiltration Technologies Offer New Options for Offshore Waterflooding

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The number of offshore facilities employing waterflooding with desalination continues to grow. Currently, more than 50 sulfate removal units are in operation offshore with a total capacity of approximately 8 million BWPD. The number of installations has doubled in just 6 years.

Because of the technical challenges of offshore desalination and its growth in the oil and gas industry, it has been the topic of October 2012 and February 2013 Water Treating Insights.

Because of weight and space constraints, offshore desalination is almost always carried out using spiral wound membranes. The equipment required for thermal desalination (distillation, evaporation) is too large and heavy.

In October, Kevin Reyntjens of Dow Process and Water Solutions discussed nanofiltration (NF), a type of desalination, which is used to remove sulfate from seawater and hence reduce or eliminate sulfate scaling of the producer wells. He wrote that desulfated seawater is less likely to produce hydrogen sulfide in the reservoir than when sulfate is present. In February, Gina Rowland of Global Water Intelligence discussed low-salinity waterflooding for enhancement of hydrocarbon recovery. LoSal, an enhanced oil recovery process championed by BP, typically requires both NF and reverse osmosis (RO) to achieve the required salinity and ionic composition.

NF and RO desalination technologies are marvels of materials science and engineering that enable economic large-scale offshore desalination. However, fouling of NF or RO membranes from the suspended solids (e.g. plankton, algae, bacteria, silt, and silica) typically found in seawater must be prevented to maintain the life of the membranes. Membrane replacement can cost upward of several million dollars and cause weeks of waterflood downtime.

New Filtration Technologies Gain Acceptance

Microfiltration (MF) and ultrafiltration (UF) are new filtration technologies, different from NF and RO, which are currently being taken up rapidly by some of the major operators. Before we dive into the technical details of the technologies, let us consider the filtration options available to a typical waterflood systems designer.

Not more than 5 years ago, before MF and UF became available, there were only two filtration options available for waterflooding, neither of which was satisfactory.

One option was to use coarse strainers followed by multimedia filtration, which was followed by cartridge filtration. Multimedia filtration provides most of the removal of fine particulates and can be backwashed. Therefore, it is not consumed and no waste is created, because the backwash water containing the filtered solids is discharged directly overboard. The cartridge filters act as a guard bed, preventing the passage of solids during upsets and provide a final barrier to prevent fouling of the NF or RO membranes. If the system is properly designed, the cartridge filters will require a changeout once every few months.

This design is not without problems. Multimedia filtration is prone to bacteria accumulation, channeling that causes poor performance, chemical complications, and an assortment of mechanical failures. The equipment is also large, heavy, and expensive for offshore installation.

The second option was the use of coarse strainers followed by cartridge filtration. The use of cartridge filtration alone (without multimedia) is well-known in the industry. The design is intended to capture nearly all of the fine suspended solids with the cartridge filters. If this is indeed what happens, then fouling of the NF or RO membranes is prevented. In general, cartridge filter systems are smaller

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than multimedia filtration systems, and elimination of the latter is a capital cost-saving measure.

However, the cartridge filters are consumed and must be replaced when they have reached their holding capacity for solids. The design challenges rest in selecting the optimum type and pore size of the cartridge filter and in designing the system such that changeout of the filter elements requires the least amount of operator time.

In some cases, using cartridge filters without multimedia filtration works well. In other cases, it does not. It is difficult to predict accurately the suspended solids loading of seawater in various locations in the world. Direct measurement over several months is generally required, but this is impractical.

A project in Brazil, where cartridge filters were installed without multimedia filtration, required changeout of cartridge filters every day during peak fouling season. The NF membranes required frequent cleaning and changeout because of particulate leakage through the cartridge filters.

The cost for this worst-case scenario can run into millions of dollars per year and illustrates the risk involved in not installing multimedia filtration.

With the introduction of MF and UF technology to the industry, a third option now exists. MF and UF are dead-end filtration technologies in which the feedwater passes through the membrane, and all particles larger than the pore sizes of the membrane are stopped at its surface. Periodic backwashing removes the filtered particles from the membrane surface. An advantage of MF and UF systems is that they withstand hypochlorite, making possible periodic deep cleaning of the membranes to ensure the prevention of biological fouling.

Historically, MF and UF were considered as two distinct technologies. In some industries, this is still the case. However, nowadays, for seawater application, distinguishing between MF and UF is pointless.

The typical MF and UF systems used for seawater filtration upstream of an NF or RO system use membranes with an average pore size between 0.02 and 0.06 micron. The dominant brands of MF and UF systems are similar to each other in the pore size distribution, with an average pore diameter of 0.04 micron.

Offshore MF and UF Installations Score Success

Strong uptake of MF and UF systems for onshore desalination facilities began around 2007. Nearly 60 milllion BWPD of MF and UF capacity has been installed onshore for seawater RO desalination. Flux rate (number of membrane units/unit flow), backwashing systems, and chemical cleaning processes have been optimized. For onshore installations, the performance of the MF and UF systems, instead of weight and space, is the main benefit.

The first installation of UF offshore was the EnCana (now Nexen) Buzzard project in the United Kingdom North Sea. The Buzzard system was designed for a nominal capacity of 250,000 BWPD. The MF and UF module had a dry lift weight of 900 tons. In operation, the system is a qualified success. It requires frequent wash cleaning, maintenance cleaning, and chemical cleaning. The membrane elements had to be replaced within a year. In hindsight, it turned out that a slightly high flux rate was chosen for a low number of membrane elements, and a relatively weak membrane material had been selected. The weak membrane material had a tendency to leak.

Over the past several years, Total has taken an interest in MF and UF technologies and has carried out extensive testing, including a pilot test on its Girassol platform offshore Angola. The pilot test led to an installation on the Pazflor floating production, storage, and offloading vessel—making this the second offshore installation of MF and UF.

The water treating system on Pazflor started up in September 2011. The MF system design capacity is 300,000 BWPD. Upstream filtration consists of 150-micron coarse screens. No other filtration is used; the cartridge guard bed has been eliminated. Compared with the Buzzard installation, a stronger membrane material (polyvinylidene fluoride) was selected, and a greater number of elements were selected to reduce the flux rate.

Total reports success in using the Pazflor MF and UF system. Two other Total projects are slated for installation of the MF and UF systems. While the Buzzard and Pazflor installations represent only two systems in operation, given the onshore experience, the onshore testing, and the offshore pilot studies, it appears that sufficient experience is available to provide a reasonably conservative design for future offshore installations.

Implementation of MF and UF systems as pretreatment for NF or RO membranes is a significant improvement over the alternative lineups, including cartridge filter systems or multimedia filter/cartridge filter systems in terms of quality of water delivered to the NF and RO membranes and operability. The MF and UF systems result in longer life of the NF and RO membranes and elimination of rapid cartridge filter loading.

In addition, installation of MF and UF systems is being considered for waterflood projects where desalination is not required. In those cases, the clean water resulting from MF and UF is less likely to fracture and thus translates into better hydrocarbon sweep and recovery. **OGF**