The Next-Generation Water Filter for the Oil and Gas Industry

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Many segments of the oil and gas production industry need improvements in water filtration over traditional methods. This is true because of the trend toward oil and gas production in tighter, less permeable reservoirs and the greater use of enhanced oil recovery (EOR) techniques, many of which involve injecting water into the oil reservoir. To protect the integrity of such reservoirs, the amount of solids introduced into the reservoir through water injection, even solid particles down to 1 µm in size, must be minimized. Conventional filtration methods generally do not meet this requirement. An enhanced filtration technology known as Spectrum Plus Filtration, which incorporates the use of granular micro media, has been proven in other industrial applications and has been introduced and successfully proven in the treatment of produced water. This technology holds the promise of meeting the new requirements while being economical and robust.

New oil production practices often involve more water treating and more water injected into wells and reservoirs that are tighter and more costly to develop. This means that there is a greater concern about injecting excessive amounts of solids into these wells and reservoirs. The consequences of this can be:

- Reservoir plugging, which can cause production declines or inadvertent fractures.
- Greater frequency of well and reservoir plugging requiring workovers, acid treatments, and new wells with the associated production loss.
- Reduction in production or in the total recoverable potential of the reservoir.

TABLE 1—

Filtration Technology	Comments
Cartridge filters	Low capital expenditure, but operating expenditure depends on flow and solids content in feed. Practical for low flows and low solids content water. Higher flows and higher solids require frequent cartridge replacement. To achieve fine filtration to less than 2 micron requires more expensive cartridge elements that clog quickly and require even more frequent replacement.
Bag filters	Less expensive to replace than cartridge filters, but the depth filters clog more quickly. Generally more practical for larger solids that are noncompressible and can form a cake.
Backwashable strainers	Generally more practical for larger solids (>10 µm). Cleaning may not be effective with oil present.
Hydrocyclones	Generally more effective for larger solids (>10 µm)
Backwashable sand filters	Generally can remove particles to the 5–10 µm range, depending on factors such as media particle size, bed depth, flow rate, and feed water characteristics.
Backwashable nutshell filters	Similar to sand filters, but with the ability to "release" free oil accumulated on the nutshell media.
Backwashable multimedia filters	Similar to sand or nutshell filters, but with somewhat improved removal of small particles depending on the media size. Generally limited effectiveness <5 µm in particle size.

- Souring of wells through introduction of sulfur-reducing bacteria from water injection.

In response to the concerns that solids injected into wells can have, specifications for the water quality being injected into such wells are increasingly being defined by a particle size cutoff at about 2 μm, with many specifications requiring that 95% to 98% of the particles greater than 2 μm are removed.

Some other new production practices involve other water conditioning process equipment, which in turn requires excellent filtration for it to perform properly.

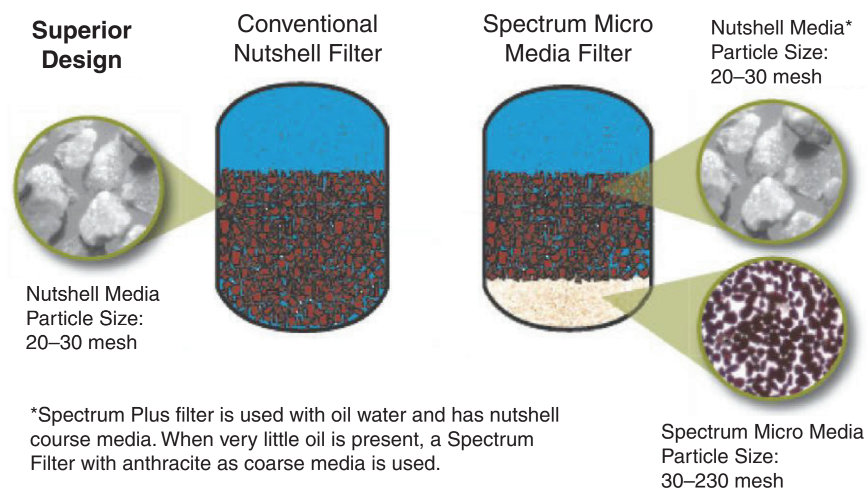

Fig. 1—Conventional nutshell filter compared with Spectrum micro media filter.

Traditional Water Filtration Methods

Table 1 lists some traditional water filtration technologies and their limitations in meeting the new requirements.

When alternative filtration technologies have been considered in recent years, the discussion often turns to membrane filtration using polymeric, or more recently, ceramic or metallic membranes, which are rated as microfilters or ultrafilters depending on the pore size of the membrane. Although such filters have had some success in industrial applications, they have not been widely deployed in the filtration of produced water for a number of reasons:

- The initial cost of the filters is considerably more than the traditional water filtration systems.
- Membranes are made to have very small pores to allow water to pass, but not suspended solids or oil droplets. To keep the pores open, the flow through the filters is tangential to the flux across the membrane (i.e. crossflow). This often requires pumping much more fluid in a recirculation loop than is filtered. Further, regular backpulsing of the flow is required to keep the pores clean. Ultimately, the membranes have a limited life and must be replaced at considerable cost.
- Some polymeric membranes are incompatible with hydrocarbons while some are also temperature sensitive and cannot be used when the produced water is warm (typically limited to <40°C).
- Many pilot tests have been conducted using membranes for filtering produced water, but with limited success because of their propensity to foul irreversibly with oil and dirt. If the operating conditions and cleaning regimes are not properly maintained, the life of the membranes may be significantly compromised and require premature replacement.

Granular Micro Media Filtration

An alternative filtration technology has been introduced that fulfills the promise of meeting the new filtration requirements without many of the drawbacks of membrane filtration. This new process is known as granular micro media filtration. **Fig. 1** illustrates the key difference between this filter and a conventional nutshell or sand filter.

The granular micro media filter has an upper layer of nutshells or anthracite to remove larger particles and oil droplets. It also has a lower layer known as micro media, because of its much smaller particle size in comparison with the upper layer media. A key feature of the micro media is that it is also much denser than the upper media. This ensures that after backwashing, during which both media are fluidized simultaneously, the dense micro media quickly settles to form a distinct layer below the coarse upper media layer. This allows it to act as an integral polishing filter capable of removing much smaller solid particles and oil droplets, which normally pass through a conventional media filter.

The micro media filter was developed initially as a prefilter for packed ion exchange systems using fine mesh ion exchange resins. Such ion exchange systems have significant advantages over conventional ion exchange systems for applications such as water demineralization or softening and chemical process separations. However, since the resin beds are packed and do not get backwashed, they require removal of all solids that may cause plugging. It has been determined that this corresponds to a feed suspended solids specification of <0.2 ppm total suspended solids (TSS), with nominal particle removal <1 μm.

Such filters were developed and have been in operation for more than 20 years in a variety of process applications including prefiltration of surface and well waters for demineralization.

In 2000, two systems of granular micro media filtration were supplied for the filtration of produced water in heavy oil production in northern China. Since 2009, the filters have been used to filter produced water from heavy oil production in the Bakersfield, California, area.

Field Performance Testing

Field testing was carried out on commercially operating filters at eight sites near Bakersfield. Four sites were operating granular micro media filters and four sites were operating either nutshell filters or sand filters. The granular micro media filter sites performed significantly better than the conventional sites. Conventional filters removed 74.9% of TSS fed to them while the granular filters removed 99.8% of solids (as measured by the Standard Method, using 1.2 μm Millipore discs). Free or dispersed oil removal was 26.1% by conventional filters and 91.8% with the granular filters.

In addition to the data that overwhelmingly showed the superior performance of the granular micro media filters, photos of the Millipore discs used for determining the TSS showed positive results. Despite the fact that considerable greater water volumes had to be passed through the discs to develop enough material to be weighed for the analysis, the discs' markedly lighter appearance after the granular micro media is further evidence of a performance advantage.

Conclusion

The oil and gas industry is evolving in the direction of greater reliance on EOR techniques to recover greater quantities of oil from mature reservoirs and to recover oil from tight, lower porosity reservoirs. The success of many of these processes could be improved if the water injected into these reservoirs contains fewer solids. This is being recognized in the industry as seen by specifications for injection water quality that increasingly require significant removal of solids down to 2 μm in size. Filtration to this level would also result in a significant removal of sulfate-reducing bacteria being injected downhole. Conventional filters (nutshell, sand, cartridge, etc.) are generally not capable of meeting such limits. Membrane filters, which may be capable of meeting this performance, in addition to being very costly, are challenged to treat produced water without fouling. The performance and operability of granular micro media filters as shown to date, with the ability to remove solid particles and oil droplets to 1 μm in size, make them an attractive consideration for a variety of water treatment applications in the oil and gas industry in the future. **JPT**