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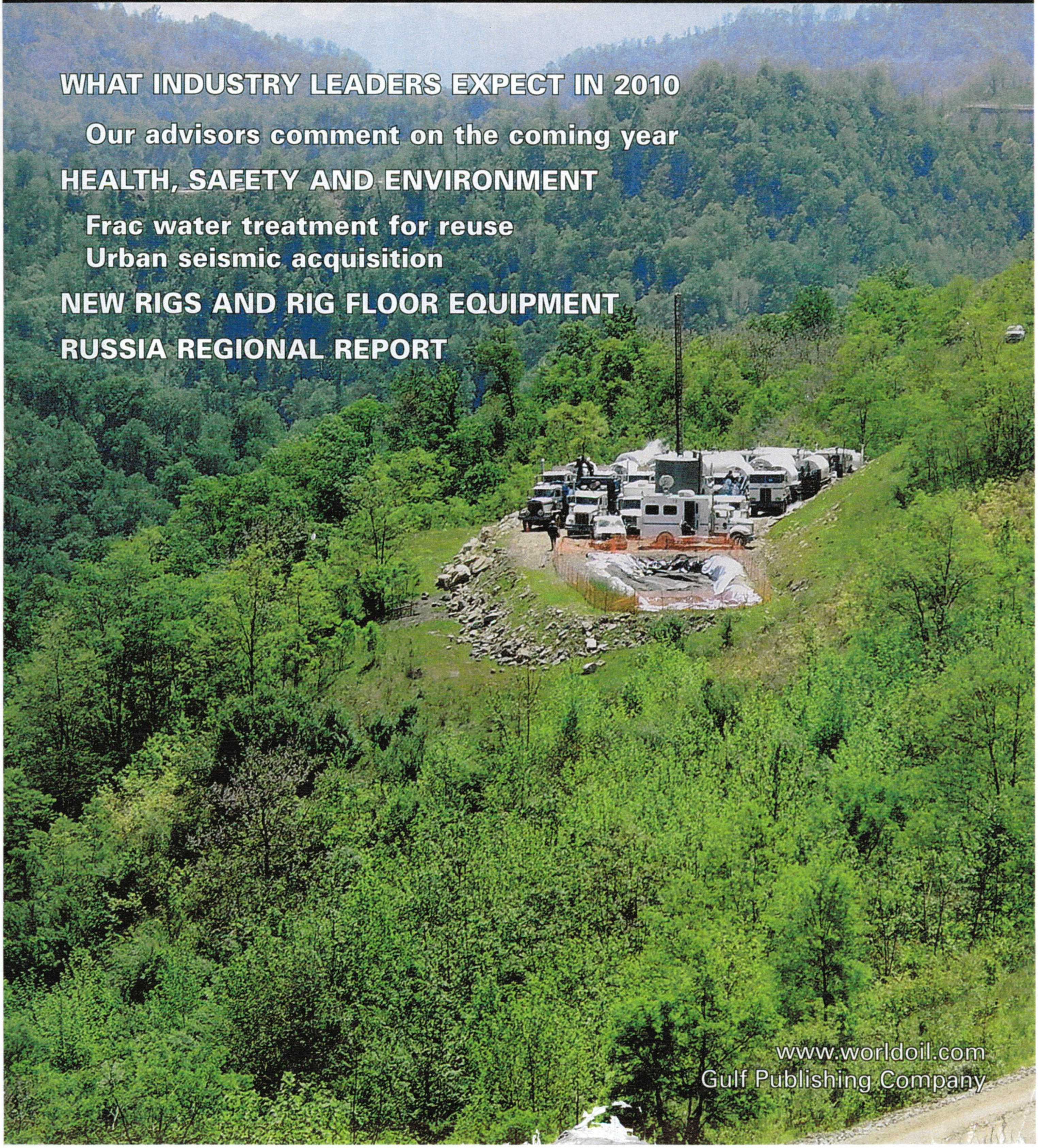

WHAT INDUSTRY LEADERS EXPECT IN 2010

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HEALTH, SAFETY AND ENVIRONMENT

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NEW RIGS AND RIG FLOOR EQUIPMENT

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Deoiling for discharge-quality water

An innovative chemical-affinity filtration process helped Anadarko to discharge water with a stringent 10-ppm oil content standard.

Parthasarathy Harikrishnan, MyCelx; **Ron Schlicher** and **Jack Yu,** MWH Global

Produced water from Anadarko's gas drilling and production operation in Vernal, Utah, contains light fuel condensate, as well as dissolved salts and suspended solids. While most of the condensate is recovered at wellsites by allowing produced water to settle in large gun-barrel tanks, a considerable fraction of the oil is still finely dispersed, or emulsified, in the produced water. The light fuel condensates are made up of diesel- and gasoline-range organics. Once they become mixed with produced water during drilling, they cannot be completely removed or separated easily using gun-barrel tanks alone. These hydrocarbons in the water are also not necessarily environmentally benign.

Reinjecting this organic-laden produced water for refracturing is generally not preferred because the organics can plug underground reservoirs. Reinjection into disposal wells was also not preferred because of this reason, and because of the high cost of transporting the water to a suitable injection site. Thus, Anadarko considered options to treat the produced water for discharge.

The company planned to use evaporation ponds at the end of its water treatment train. Regulations governing discharge to the ponds require a "no visible oil sheen" standard, to protect wildlife from being affected by oil or hydrocarbon vapor emissions from the ponds. However, Anadarko set its discharge criterion to more stringent standard of 10 ppm.

Consistently meeting the 10-ppm discharge standard and maintaining an economically viable operation posed a substantial technological and engineering challenge. In early 2007, Anadarko contracted MWH Global to design and implement a failsafe produced water treatment process that met these criteria. The resultant facilities, built and in use by late 2007, include an innovative filtration system that uses chemical affinity to polish the produced water to an exceptionally high quality. The facilities have a combined maximum processing capacity of about 45,000 bbl of water per day, and are designed to effectively handle variable water volumes in keeping with the site's gas production rate demands.

TREATMENT SELECTION

Various oil removal and water treatment technologies were considered. Results from a water sample analysis showed that the produced water from the gas wells had the following contamination characteristics:

- Oil and grease (O&G): 10–400 ppm
- Total suspended solids: 20–50 ppm
- Total dissolved solids (salt): 25,000–35,000 ppm

Evaporation ponds were chosen as the last stage of the treatment process. The produced water held there could be used later for reinjection. Further desalination of the water to remove dissolved solids and produce freshwater was not economically viable. In the short term, however, holding the produced water in lined ponds would only be possible if the treated water had no visible oil sheen on its surface, a regulatory standard that would be easily accomplished if the treatment process could meet Anadarko's 10-ppm oil content standard.

The free and soluble oils found in the produced water from the gas wells posed a challenge to this goal. The contamination included light fuel condensate, which consists of diesel-range organics, some gasoline-range organics, paraffin waxes and oil-coated solids. In order to produce a final treated water quality of 10-ppm oil in water, soluble oils needed to be removed in addition to free oil and waxes.

Traditional technologies that have been deployed and evaluated in other treatment schemes include: settling tanks, oil-water separators and coalescers, float cells (e.g., induced gas flotation, dissolved air flotation), and nutshell and multimedia filters. These technologies were incorporated into Anadarko's produced water treatment train, Fig. 1.

Settling tanks, which were selected as the first stage of the treatment train, work using gravity and time. Produced water sits for anywhere between an hour and a full day to separate the contaminants from the water. The free product (in this case, light fuel condensate) is recoverable from the tanks for sale.

Oil-water separators enhance this gravity separation using plates and weirs, while coalescers cause small free oil particles to join together into bigger ones that separate out of the water more easily. These technologies were placed in the treatment train to remove and recover any free oil remaining in the water after the settling tanks.

Float cells were also deployed to remove free and finely dispersed oils in the water. Finely dispersed air or gas introduced into the float cells enable the small oil droplets to rise to the surface, where they are separated and recovered. Sometimes chemicals are added in this process to flocculate the solids and to treat oily water emulsions.

Walnut-shell filters, also known as backwashable granular media filters, are used to remove trace amounts of finely dispersed oils and solids in produced water. The media bed is backwashed intermittently to regenerate the media's effectiveness.

Though the above-mentioned devices are useful in recovering some relatively free products in produced water, they have

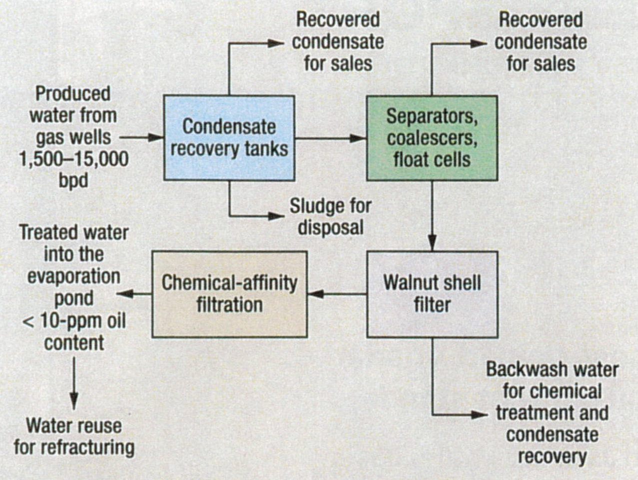

Fig. 1. Produced water treated scheme.

performance limitations that make them incapable of producing water with oil content of 10 ppm or less. The cost of implementing them on the scale necessary to meet this standard at the Anadarko operation would be economically prohibitive. Other key operating limitations include the inability to remove emulsified or soluble oils in water, or to handle process upset, high loading conditions, high fouling tendencies leading to high maintenance, or high waste generation volumes.

An additional treatment stage was needed to remove emulsified oils even under such difficult process conditions. Traditional technologies like organoclay and activated carbon were considered, but, for this project, their limitations outweighed any benefit. These limitations included susceptibility to fouling by upset oil loading conditions; inability to handle both waxes and emulsified oils efficiently; high maintenance requirement; and high operational cost.

CHEMICAL AFFINITY FILTRATION

To remove dissolved oils and polish water to less than 10 ppm O&G for discharge to evaporation ponds, a patented chemical affinity-based filtration system was selected.

The water polisher, provided by MyCelx, employs a patented molecule integrated into the filter media that exhibits high chemical affinity to hydrocarbon molecules. This affinity binds together and coagulates oils and semi-volatile organics into a water-repellant mass, enabling efficient capture of oil. Because chemical affinity is the separation mechanism instead of gravity or mechanical means, separation is accomplished without developing differential pressure across the filter.

There is no desorption or leaching, as the process permanently captures and immobilizes oil onto filters. In operational terms, the contact time for oil removal is less than 1 s and the process entails less than 1 psi operational pressure drop. The filtration system does not foul even under upset loading conditions. Fixed oil removal capacity per filter cartridge is 5–8 lb of oil, and is not affected by influent oil loading.

Another advantage is low waste generation relative to high oil removal capacity, since the filters do not hold water. Used media can be incinerated or otherwise disposed.

At the Vernan, Utah, operation, the polisher system is used to remove trace oils that remain in the water after it has passed through the settling tanks, oil-water separators, hydrocyclones, float cells and walnut shell filters.

TABLE 1. Performance data of the produced water treatment system

Outlet of condensate recovery tanks	Outlet of API separator/ coalescer	Outlet of walnut shell filter	Outlet of polisher system
O&G, ppm	O&G, ppm	O&G, ppm	O&G, ppm
48	21	18	< 2
149	145	121	< 5
14	13	8	< 5

IMPLEMENTATION AND RESULTS

A pilot system with a flow capacity of 10,000 bpd was installed in 2007. After undergoing 6–7 months of intensive field observation and study, the produced water treatment scheme was optimized and finalized for its full-scale implementation. The treatment facilities were enclosed in a structure built by MWH to allow continuous operation even during the harsh Utah winter.

As of October 2009, the process has effectively treated and discharged over 5 million bbl of water with an average treated water quality of less than 5 ppm oil in water, Table 1. The facilities have consistently treated and discharged water at variable influent oil loadings and process upset conditions. Maintenance and operating costs have been well below estimated costs.

"With the process that Anadarko Petroleum Company implemented for handling produced water, we were able to eliminate the conventional ground pits used by other operators for oil-water separation," said William Perry, Anadarko's facilities manager for the operation. "The installation of the MyCelx filtration gives Anadarko an assurance that no oil will be discharged to our open evaporation pits. This guarantee eliminated the need for netting and other intrusive precautions regarding wildlife."

Operating costs for the water treatment train are less than $1 per barrel, with the water polisher comprising less than 15% of overall costs.

Anadarko has also received positive feedback on the operation of the disposal ponds from the Utah Department of Oil Gas and Mining, which nominated the company for an environmental excellence award in 2008, which Anadarko went on to win. **WO**

THE AUTHORS

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