The region is showing increasing interest in steam flooding to improve production, says Gregory Kreider of AMEC Paragon.

Operators assess economics of Middle East steam flooding

WITH EXISTING FIELDS in decline, operators throughout the Middle East have become highly interested in steam flooding to coax production from their underlying shallow formations of heavy oil sands - just the type of formation proven conducive to steam flooding in other producing regions.

As reported recently in the *Wall Street Journal*, the joint operators of the Partitioned Neutral Zone Wafra field have completed the first phase of an economic evaluation of field-proven steam flooding processes intended to extract its heavy oil from zones above its usual producing formations.

And they are not alone in the initiative to optimize steam flooding technology in the Middle East. The influx of consultation and proposal requests from Middle East operators is at an all-time high, and the sense of urgency to act is great. Large steam flood projects are being implemented in Oman (Makhaizna) and considered in other areas of the region which are underlain by these large heavy oil deposits.

Because Wafra would be the joint operators' first possible multi-well application of steam flooding in the region, and one of the first such attempts in the Middle East, an assessment program was initiated in 2003, which reflects the partnership's intention to maximize its return on its investment in thermally-enhanced oil recovery methods by determining the economically optimum processes for water treatment and steam creation.

Accessible reserves

Understanding the structure of this type of assessment program as well as the criteria used to evaluate steam flood operational issues will be useful to the region as operators consider and select from the myriad choices of steam flood technologies and applications.

As the region faces ever-increasing demand for crude locally, it also faces expectations from other nations to supply their escalating hydrocarbon needs, despite mature fields in decline.

A shared belief that technology will provide access to previously unrecoverable reserves and improve production rates is prompting operators to take advantage of the compelling price environment and the increasing availability of heavy-crude-capable refineries to test steam flooding effectiveness in the region's soft carbonate formations.

Specifically, though roughly 80 per cent of the world's most accessible reserves are located in the region, these operators, intent on meeting increased production goals, are deciding to exploit the now more favorable economics of tertiary recovery to add reserves for the expected annual 3.8 percent increase in world energy use, as reported by the U.S. Energy Information Agency in its June 2007 International Energy Outlook. And with commodity prices more than seven times their 1998 price collapse levels, the opportunity has presented itself for the region to now explore the technological options available to access these under-counted resources.

Based on the century of experience utilizing steam injection and steam flooding in other operating regions where the technique is a mature, essential recovery method, many joint operators are exploring steam injection, focusing specifically on steam flooding as its preferred methodology for consideration.

Porous formations

Prior to evaluating the processes that might be deployed in the region, it is important to understand the definitions of the technology involved. Though steam injection has been utilized in the oil and gas industry for more than a century, the process has largely been confined to use on the US West Coast, Canada and Venezuela where formations differ greatly from the more porous formations in the Middle East. Given its regional deployment, steam injection, and the various techniques for achieving it, is not a familiar process industry-wide, and therefore presents new risks to even the most experienced professionals who are considering it for the first time.

The basic definition of steam injection is simply the ability to inject steam. The methods of generating and injecting steam, however, are myriad and provide varying degrees of investment, practicality and effectiveness.

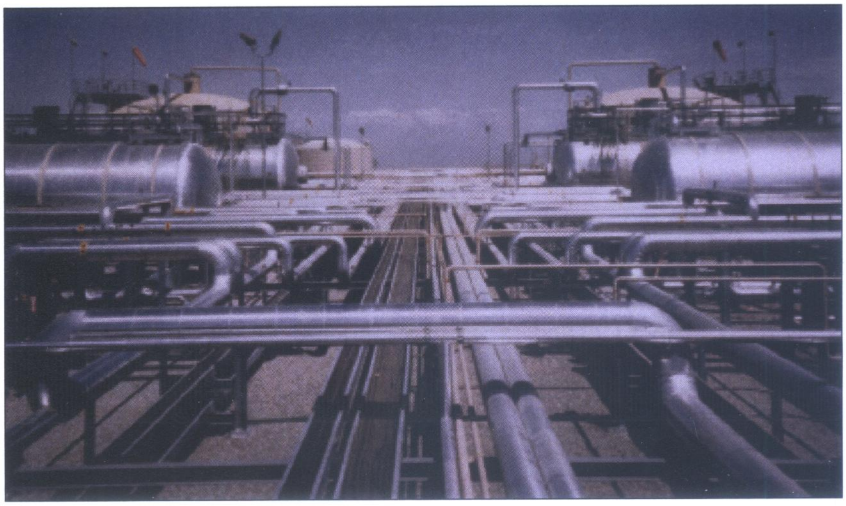
Steam injection, which has long proven effective, involves injecting steam and heat in an area 100 to 200 feet from the well bore, halting the injection, and then re-heating - a method operators have employed as the first step in coaxing heavy mineral-laden crude from carbonate crevices where pressures may be low.

Two types of steam injection exist which can be used separately or in some combination depending on steam availability. Steam flooding consists of continuous injection of steam via a dedicated injection well. Called a five-spot (seven spots are not uncommon), four producing wells surround a center well at various distances depending on formation characteristics, which serves as a dedicated injector of steam into the reservoir.

The second method, termed 'huff and puff', provides for no injector well. Rather, steam is injected intermittently into each producing well during the 'puff' cycle and the heated fluid produced back through the well during the "huff" cycle.

Both steam flood and huff and puff serve the same purpose: to heat the reservoir such that thick, hard-to-produce hydrocarbons fluidize, making extraction possible and economically attractive.

The economics of steam injection vary widely based on the method utilized to produce the steam that will be injected into the reservoir, of which there are many options. Further, each



option varies in its ability to efficiently produce the steam, based on the method's ability to purify the source water. Therefore, waste in the production of steam could significantly increase the total cost of steam injection in a massive field like many of those in the region.

For example, on the US West Coast, virtually all steam injection utilizes treated brackish water as its source for steam, employing myriad equipment choices to heat the water into steam. Elsewhere seawater is used as source water, but in any case, the purer the water used to create steam, the more likely a high percentage of the source water will become steam available for injection into the reservoir, and the more efficient use of the funds invested for the tertiary recovery.

Source water for steam may be made using reverse osmosis of seawater. However, this option can be cost prohibitive due to transportation costs and the fact that far less than 100 percent of this mineral-rich source water will become steam.

Similarly, brackish water, without the added benefit of reverse osmosis, can be employed as source water but some 30 to 50 per cent of the water is lost during steam generation due to the presence of moderate levels of dissolved minerals and salt.

Therefore, when considering total costs of enhanced recovery, its convenient availability may or may not compensate for its impurities and the resulting poor steam generating efficiency. A third option for source water is distilled water. However, the project costs will be impacted by either the transport of such purified source water distilled elsewhere, or the cost of on-site equipment to purify brackish water in the field.

Source water purity translates into the availability of more steam to flood the well bore. Water contains 212 calories but when heated, another 400 calories of latent heat are generated when that water is changed into steam, creating steam of 600-plus calories. The purer the steam, the more heat generated, which means the reservoir will be heated more quickly ? an important cost- and time-efficiency gain.

Higher costs

Ultimately, the benefit of steam injection is determined by which combination of source water, purification method, steam generation technique and injection method deliver the most heat in the reservoir, and therefore most improved production for the least total cost.

Given the higher costs of extracting heavy crude with any thermally-enhanced oil recovery method, as well as the potential for waste due to steam generation inefficiencies, the first phase of a recent steam flooding economic assessment, began with the goal of minimizing the heavy oil endeavor's production costs while optimizing results.

Houston-based AMEC Paragon, the energy

Gregory Kreider

division of the London-based worldwide engineering conglomerate AMEC, was retained to study the feasibility and cost-effectiveness of three methods for generating steam: an oilfield steam generator; a high-level, high-efficiency boiler; and a co-generation option. The model for the desk-top study assumed steam production of 1,000 bpd. The results of the evaluation would become the basis for execution of a field pilot program.

The first options considered in the study were oil field steam generators, commonly used in reservoir steam injection and therefore have a long track record for reliability. Portable steam generators, of which many brands and types are widely available, are transported to the site to create steam. Excluding transportation costs, the competitive environment among these manufacturers potentially make the option a cost-effective one.

Optimum combination

The second option, a high-level, high-efficiency boiler commonly normally used in refineries was considered. Its large size and efficiency in high-demand situations made it an attractive method for review, despite its complexity and the need for experienced, skilled labor capable of operating the equipment.

Third, the study evaluated the use of co-generation from existing electrical facilities situated nearby. Commonly used on the U.S. West Coast, co-generation makes heat available on site, which could potentially produce significant costs savings, if the associated equipment could be installed cost-effectively in the field. Numerous criteria were used to determine the optimum combination of water source, purification, and steam generation methods for use in a multi-well steam flood, including availability of each water source, cost of purification, transportation costs, efficiency of steam generated, cost and availability of steam generation equipment, track record of use in production fields, environmental impact, labor costs, training requirements, maintenance issues, and other risk factors.

The co-generation option, though field proven, was eliminated due to the need for reliance on an operation that existed for another purpose. It was found that even if the electricity provider that would double as the co-generation facility is owned by the operators of the field, the risk that production would be interrupted problems with the cogeneration equipment if power were not available for production activity when needed proved too great, and would be too costly a situation to remediate. Additionally, the time required to purchase and install the necessary equipment would create delays in realizing the benefits of thermally enhanced recovery.

The complexity and size of the boiler systems utilized in refineries proved too significant for adaptation to the oilfield, given the climate and topography where the equipment would be expected to perform, and the labor and cost associated with operating and maintaining such a sophisticated system. Therefore this second option was also eliminated in favor of a combination that produced the best source water for cost-effective steam generation within an attractive timeframe.

Production viability

The feasibility study indicated the use of brackish water desalinated through a specially designed evaporator never before used in the industry on this scale. This water purity would minimize the plating, or mineral deposits in steam generation equipment, and provide the operators water to produce virtually 100 per cent steam-generating efficiency at the most attractive total project cost.

The surface facilities design, utilizing common oilfield steam generators, would allow for timely delivery and installation of equipment, which could easily be operated by existing crews with minimal training, and would produce the greatest heat in the reservoir.

The *Wall Street Journal* article addresses the next step required, to prove production viability and sustainability of a designed steam flood program. This next step will be execution of a pilot flood in the target formation. Multiple five-spot injection-production patterns will utilize distilled-quality water at a rates of 20,000 to 30,000 bpd, and will be evaluated to determine optimum rates at which steam can be injected; the effects of steam flooding on these shallow formations' stability; the costs of separating the produced water mixed with the produced heavy oil and re-purifying the water for future steam generation; and ultimately, the impact of steam flooding on production rates.

If the steam injection program performs in the field's rich and massive heavy oil formations as it has in other regions of the world, the use of steam flooding may increase production by the industry-typical five to 15 per cent, an amount Saudi Arabia's Oil Minister Ali Naimi reported recently as 'tens of billions of barrels' of oil added to its reserves - a significant return on its investment in both the feasibility study and facilities design.