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Surface pumps sweep stranded oil

Use of multistage centrifugal surface pumping systems optimizes EOR using CO_2 flooding in mature fields.

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Basically, CO_2 enhanced oil recovery (EOR) works on a very simple principle. Given the right physical conditions, injected CO_2 is miscible in stranded oil and acts much like a thinning agent (similar to the way gasoline does with motor oil). After miscible mixing, the oil is displaced by the CO_2 or by water and CO_2 if the water alternating gas process is used. Both techniques form banks of fluids in the reservoir rock – oil, CO_2 and water that migrate from injection wells to production wells.

CO_2 experience is a key attribute

Denbury Resources Inc. currently operates 13 CO_2 floods on land in the US Gulf Coast region with three additional projects either in construction or in the final stages of engineering. The CO_2 is transported as a dense-phase, supercritical fluid at pressures to 1,900 psi. Surface injection pressure requirements range from 2,200 to 3,600 psi, depending on the reservoir depth and flow characteristics. In the 1980s, compressors and vertical positive displacement pumps were used for transport and CO_2 injection.

However, project expansion and increases in operating temperature as well as expensive maintenance costs led Denbury to re-evaluate the efficiencies of CO_2 compression and injection facilities. Of primary concern were the loss of efficiency due to the temperature increase and the high cost of purchasing and operating compressors and other components. While CO_2 EOR has achieved much success since its first use, significant potential remains for additional growth in production from this process. The potential is further enhanced by the possibility of using captured anthropogenic CO_2 in fields that are good candidates for EOR, but are far from natural CO_2 reservoirs. To capture this potential and improve upon compressor efficiency within the system, Denbury and Wood Group worked together to design multistage centrifugal SPS surface pumping systems that could deliver and inject the required volumes of CO_2 at variable densities with much lower installation, operating, and maintenance costs.

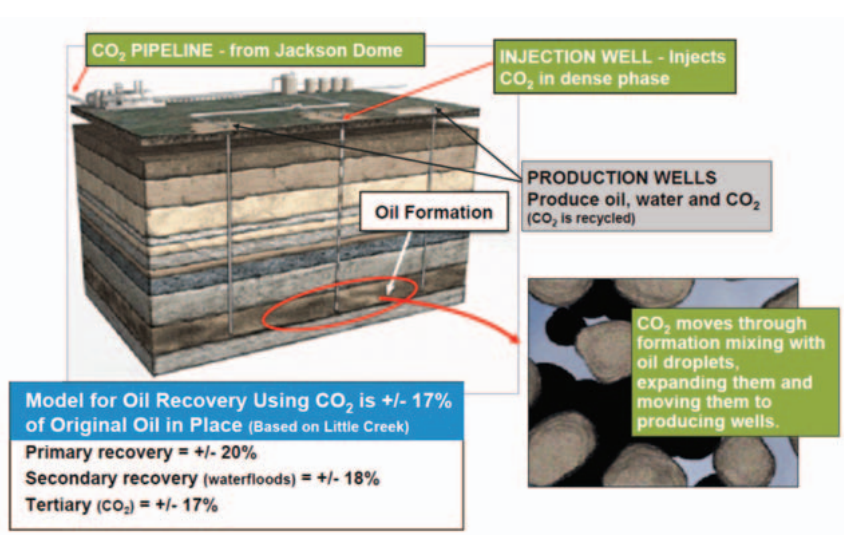
Surface pumps pay off in several ways

Denbury has 98 surface pumps in service in three general applications. At the Jackson Dome field, the pumps are used to boost declining CO_2 wellhead pressures to 1,400 psi. Two additional high-volume pumps were installed with improved seal assemblies, and the original pump was modified with added stages and a 200 hp motor that boosted its throughput to 30 MMcf/d.

In a second application, CO_2 recycle facilities are used to clean up produced gas, strip out any oil or water, and condition the CO_2 for reinjection. Multiple surface pumps are used for this purpose.

In a third application, seven trailer-mounted booster pumps were used to overcome short-term reluctance at some injection wells. The boosters solved the problem and soon had all wells taking gas at the desired 3,000 psi pressure and at a rate of 2.5 to 7 MMcf/d.

Wood Group worked with Denbury to design a new approach to this CO_2 EOR operation. Compressors were replaced exclusively with specially designed multistage centrifugal surface pumps. Due to the high-pressure, multiphase, non-lubricating environment, a detailed analysis and testing of all pump components was required during the system design and engineering stage. Aerospace technology was employed to develop reliable rotating-shaft seals. This resulted in a tandem cartridge, self-lubricating, mechanical shaft seal and supporting seal flush on the suction side of the pump intake. Wood Group patented the bolt-in packag-



A typical CO_2 production, injection, and recycling operation was used on a field in Mississippi. (Images courtesy of Denbury Resources Inc.)

ing of this seal assembly, which makes for more professional-looking installation and easy change-out.

The appropriate stage count of the pumps and selected stage designation were engineered to move the required volume of CO_2 at the reduced densities, which were hampering the existing compressors.

Problems have been minimal with this application, and reliability consistently averages 99%. Pump run times are excellent, with more than six years' history on many of the installed systems.

Some intermittent seal assembly failures occur due to impurities or particulate in the seal flush lines. Typically, Denbury replaces one seal per year per pump. The average cost to rebuild a seal is approximately US $1,500. Company mechanics provide the labor for seal change, resulting in a labor estimate of $500/seal. Hence, total annual maintenance cost for a surface pump averages $2,000. Compressor maintenance cost for the two original purchased compressors still in service runs close to $30,000/compressor per year.

The value of surface pumps has proven to be superior to the compressors originally installed. They have been very robust systems with minimal failures, low maintenance costs, and minimal down time. The purchase price differential of a single compressor designed to move 32 to 40 MMcf/d versus two surface pump skid units designed to move 25 to 30 MMcf/d with almost 100% redundancy is more than 75%. This represents significant savings in capital equipment costs.

Also, a compressor typically requires a nine-month delivery time and one full month to install. The surface pumps normally are delivered in less than eight weeks and take about seven to 10 days to install. Additionally, the site preparation/pad is one-tenth the size of a compressor pad, and the noise level at the facility is considerably lower.

The initial surface pumps installed at one unit transported 26.7 MMcf/d of product at a 450 hp load compared to the 700 hp compressor volume of 27 MMcf/d. This equates to 36% less horsepower to run the pumps, which delivers considerable savings in monthly power consumption costs.

Improvements are ongoing

Wood Group surface pumps for CO_2 service continues to evolve. In 2008, eight pumps were installed in parallel for a 600 psi average CO_2 pipeline boost at rates of about 700 MMcf/d on the Nejd pipeline. These were 18-stage TN35000 surface pumps with a best efficiency point of 73%.

The latest advances in pump stage technology offer the same volume and pressure rates with four surface pump assemblies instead of eight surface pump assemblies at an increase in pump efficiency ranging from 73% to more than 86%. This represents a tremendous decrease in the horsepower required and a 40% reduction in capital costs. The new design was scheduled for field implementation in late 2010.

ABOVE: Surface pumps drive the Soso recycling facility, recovering produced CO_2, stripping out oil and water, and prepping it for reinjection. **LEFT:** Booster trailers use surface pumps to help reluctant injectors ramp up to full capacity.

System benefits from high-volume, multistage pumps

The multistage centrifugal surface pumps provide a smaller, quieter, more efficient solution that is easier to install, requires less maintenance, and is more economical than the original compressor boosting and injection systems.

The project design based on the surface pumps allows Denbury to more economically expand its tertiary flood projects, which currently are injecting 2.25 Bcf/d of CO_2 and recycling 1.5 Bcf/d. Additionally, the use of multistage centrifugal surface pumps contributes to the company's goal of increasing oil production and reserves in depleted reservoirs through CO_2 EOR. ESP