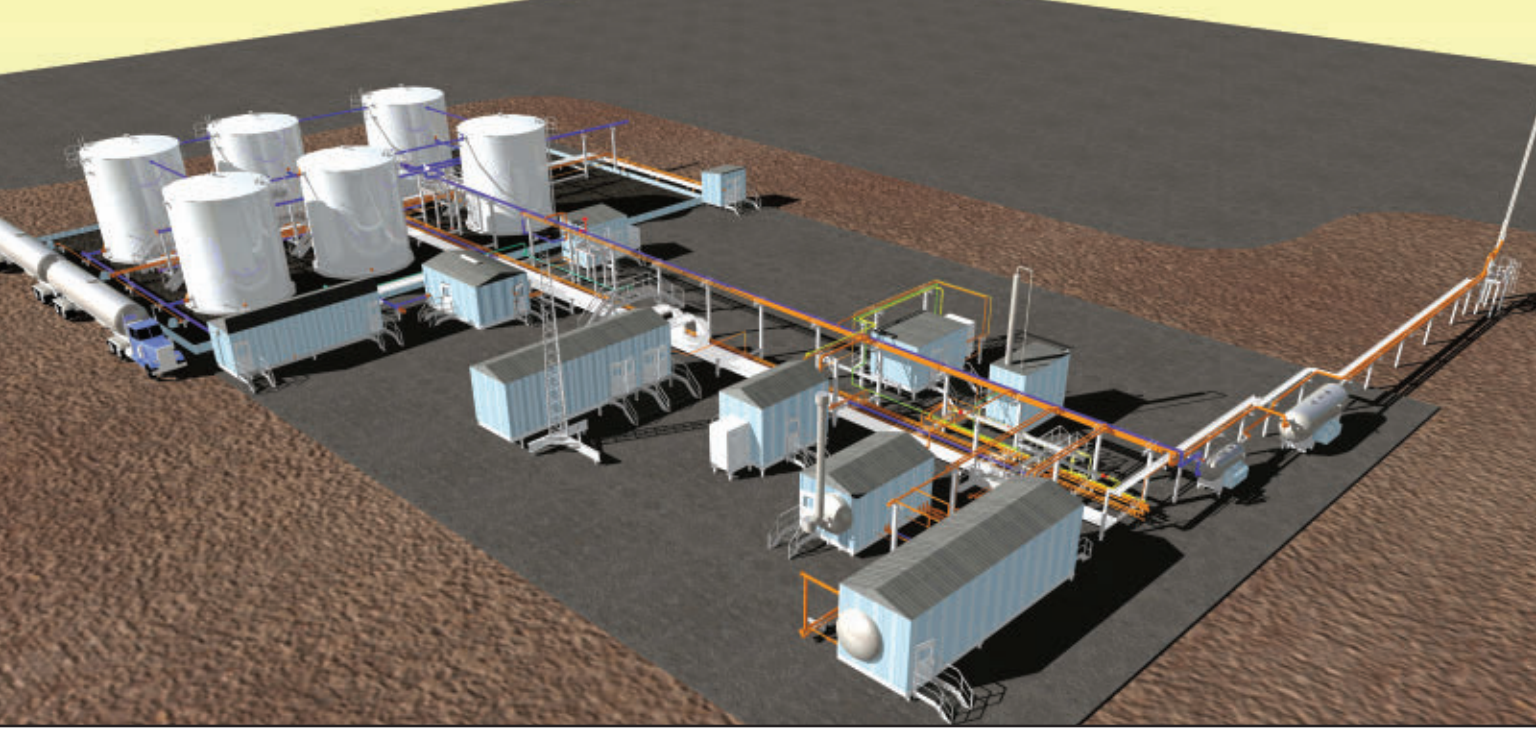

The crude oil and solution gas from the Bakken formation is delivered to free water knockouts and then to an oil battery (as shown in this image).

# USING SCREW COMPRESSORS TO PROCESS SOLUTION GAS

## Three-plus years of trouble-free operation proves screw compressors can effectively handle high-density natural gas

**By Neil Purslow**

Many individuals who work in and support the natural gas industry believe screw compressors are not suitable for solution gas applications.

Crescent Point Energy Corp., Cornerstone Engineering Ltd. and Sage Energy do not share that belief. All three companies are based in Calgary, Alberta, Canada.

"Bakken Shale gas is one of the heaviest gases around," said Dave Achtymichuk, facilities manager for Crescent Point. "The gas is in solution and produced with the oil. The gas that comes from our treaters and the vapors from the storage tanks can have a specific gravity that is as high as 1.2 — almost double that of most natural gas produced today.

"Our goal is to conserve all of our Bakken gas with no venting or flaring. This means that we need to have properly sized equipment that is reliable and serviceable. We also want the equipment to be capable of handling unforeseen operational problems, such as a small slug of liquid into the package. Although these events are rare, we don't want to have to take the equipment out of service for repairs when they occur. We like the reliability and durability that screw compressors offer, while providing the pressures we need to boost the gas for delivery to the gas plant," Achtymichuk said.

The crude oil and solution gas is produced from southeastern Saskatchewan wellheads and delivered to free water knockouts. The oil is then delivered to the treaters to be separated into oil, gas and water streams. The gas is processed through booster screw compressors and is delivered to the gas plant for processing.

Oil from the treater is moved to the tank farm and stored in fixed-roof stock tanks that range in size from 1000 to 2000 bbl. Natural gas is used to blanket the tanks and provide positive pressure to prevent them from collapsing. It also prevents oxygen ingress, which reduces the lower explosive limit (LEL) for the tanks. The stock tank vapors are recovered from the tanks, compressed by the vapor recovery units (VRUs) and delivered to the gas plant.

"The booster compression packages have to be able to handle the operating conditions for the gas coming from the treaters, while the VRUs must respond to flow rate changes quickly, since large volume swings are common when the oil flows in and out of the tanks," said Cornerstone President Ralph Dokter.

"We began by looking for a reliable screw compressor package with a good control system that would meet these operational and tank pressure requirements. This led us to Sage, who has worked very closely with us to develop these packages to suit Crescent Point's requirements."

The operating conditions for the inlet gas stream to the booster compressors include a very rich gas that contains a high concentration of natural gas liquids (primarily propane and butane with some pentanes) in vapor form. In addition, the temperature of the inlet gas can be as high as 140°F (60°C). The units are typically designed for a discharge pressure up to 200 psi (14 bar) depending on the application.

The stock tank vapors are the richest vapors recovered in the field. As such, Crescent Point is placing a VRU

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**The packages range from 50 to 350 hp (37 to 260 kW), using Sullair or Frick screw compressors, depending on the required pressure.**

wherever oil is collected to recover the vapors and deliver them to the gas plant for processing.

The gas plant currently handles about 30 MMscf ($0.85 \times 10^6$ $m^3$) of raw solution gas a day, and recovers about 120 bbl of liquid for every 1 MMscf ($0.028 \times 10^6$ $m^3$) of gas processed. The propane, butane and pentanes plus that are recovered from the gas are sold, and the gas not consumed by the utilities in the plant is also sold. The majority of the gas processed in the plant comes from the Bakken oil.

"We ran countless process simulations to ensure that the water and hydrocarbon vapors would not drop out of the gas during the compression cycle," said Trent Bruce of Sage. "We used a variety of inlet temperatures, gas compositions, and discharge pressures and temperatures to ensure there would be no dew point issues for the large range of operating conditions that will be encountered."

For the boosters, the inlet gas is very hot because the units are being fed directly from the treaters. Pre-coolers have been installed on the inlet gas stream to cool the gas by about 30°F (17°C) using ambient air. This removes much of the water vapor from the gas stream — which in turn makes a substantial difference to the dew point of the gas. Pre-coolers are not required on VRUs because the inlet vapor temperatures are lower.

One of the biggest challenges in the design was to control the discharge temperature of the gas from the compressors to ensure it remains higher than the dew point temperatures for both water and hydrocarbons.

Since oil-flooded screw compressors typically run a little cooler because of the injection of oil during compression, it was necessary to modify the lube oil cooling system to control the discharge temperature to prevent the vapors from condensing.

The discharge temperature of the gas is controlled by the oil feed temperature and the volume of oil injected into the rotors for lubrication during the compression cycle. The globe valve on the main injector line is used to reduce the volume of oil into the compressor. By restricting the flow of oil, less cooling results. This does not affect the operation or longevity of the compressor. The volume of slipstream oil that is used to lubricate the bearings and seals remains the same to protect the compressors.

The packages range in size from 50 to 350 hp (37 to 260 kW), with Sullair or Frick screw compressors installed on units depending on the pressure required. All packages use electric motor drives with speed controls. Bruce said that the units are basic sweet gas service packages that have been modified to handle the operating conditions for the solution gas in the area.

For the booster units, the treaters separate the gas from the oil and water, and the pre-coolers cool the gas to aid in the removal of water before the gas enters the compressor. Inlet scrubbers are used to remove the free liquids from the inlet gas stream.

With the VRUs, the separation process occurs in the stock tanks with mostly gas vapors exiting the tanks. If any free liquid is left in the vapor stream, the scrubbers will remove it.

Lube oil separators are used on all screw compressors as an oil sump. Although not required to process solution gas, immersion heaters have been added to the lube oil tank to keep the oil at 100°F (38°C) when the packages are not running. This makes cold weather starting easier and keeps water from forming in the lube oil during shutdowns.

Water prevention is important because the inlet gas stream is slightly sour, and by eliminating the water, a corrosive environment is eliminated. If the packages are shut down for any time, they are purged with sweet, dry natural gas to protect the equipment.

"Whether a VRU uses a rotary screw or a vane compressor, it is always difficult to determine the size of the units," Dokter said. "First, you need to consider the load in and out of the tanks. When the tank volume is increasing, the flow rate can very quickly jump by three or four times the normal rate. Then, when you add in things like ambient temperature changes, the sizing process becomes more difficult. What comes hand-in-hand with sizing are control systems, which have to respond quickly to protect the equipment."

Bruce said, "What we have found is that our PLC-based control system works well with solution gas. The system operates the same as with sweet dry gas,

**All of the packages are skid-mounted and come with insulated buildings and heaters for cold weather operation.**

but with greater precision. The VRUs are continually trying to manage the stock tanks so that the internal pressure is as close to zero as possible. The measurement needs to be accurate to maintain a couple of ounces of positive pressure.

"The big issue is volume control — 100% turndown is a must to cover the unit's entire operating range without shutdowns. The units that are under 100 hp [75 kW] do not have slide valves, so speed and bypass are used for turndown. For the larger units, speed, slide valve, and then bypass are used. This approach optimizes horsepower consumption in the unloaded state," Bruce said.

Achtymichuk said it is best to locate the pressure sensors as close to the tanks as possible. "We place the sensors at the very back of the tank farm and when it senses any change in pressure, the compressors react accordingly," Achtymichuk said. "If the tanks begin to pressure up, the compressors have to speed up to prevent the thief hatches from releasing."

All Sage screw compression packages use an indirect cooling system, which means the gas and lube oil never leave the package for cooling. They exchange their heat with a glycol loop in a plate exchanger, with the glycol going through the gas cooler first (because it has to be the coolest) and the oil cooler second, before being pumped to the aerial cooler to make the loop again.

This process was also redesigned because of the potential for light loads, which makes it difficult to keep the lube oil warm given the cooling capacity of the VRU. A second thermostat was installed on the oil side to ensure the oil stays hot to achieve a gas discharge temperature of 220°F (104°C) even when loads are light.

All of the packages are skid-mounted and come with insulated buildings and heaters for cold weather operation. They also contain LEL, $H_2S$ and all other necessary equipment to ensure the safe operation of the packages and the safety of the operators. All skids are mounted on steel piles, similar to the other on-site equipment.

"Our goal is to conserve all of our solution gas and we have found a successful way to do that," Achtymichuk said. "We've been using Sage screw compressors in these applications for over three years now. When we factor in maintenance and breakdown service with our operational requirements, we couldn't be happier with their performance."