Catalytic oxygen removal from coal mine methane

A catalytic combustion process for oxygen removal enables maximum production of sales gas from an unconventional source of methane

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Oso Oil & Gas Properties installed a system to gather and process coalmine methane gob gas in Carbon County, Utah, near the city of Price. Coal mine gob gas is methane gas diluted with various contaminants from the mine air ventilation system. The gob gas comes from the long wall cave areas of the Aberdeen Tower Mine and is brought to the surface with vertical drill holes that have been installed by the mining company to ensure mine safety.

Under an exclusive agreement with Andalex Resources, the mining company that owns the Tower Mine, and the mineral estate owners, Oso collects the gob gas at the mine's vent wells. Oso compresses the gas and removes a small amount of hydrogen sulphide, then transports the remaining gas five miles to a facility where oxygen and nitrogen are removed.

The oxygen removal system is based on a catalytic combustion process. This oxygen removal process allows the gathering of the gob gas at a vacuum, so the maximum amount of gas can be recovered. The resulting gas is then transported to the Pioneer Castle Gate Field processing plant, where Oso and Pioneer gas is commingled and carbon dioxide and water are removed. The combined streams are then sold to Questar at the Whitmore Park interconnect approximately 20 miles from the Castle Gate Field. This project makes economic and environmental sense by allowing the recovery of a valuable gas stream that would otherwise be vented into the atmosphere.

Project overview

In 2005, Oso, in cooperation with Andalex, embarked on a coalmine methane (CMM) recovery project designed to capture mine gas continuously vented to the atmosphere at the Tower Mine in Carbon County, Utah. The Tower Mine is located approximately 90 miles southeast of Salt Lake City. The gas was being vented from gas vent holes (GVHs) drilled into

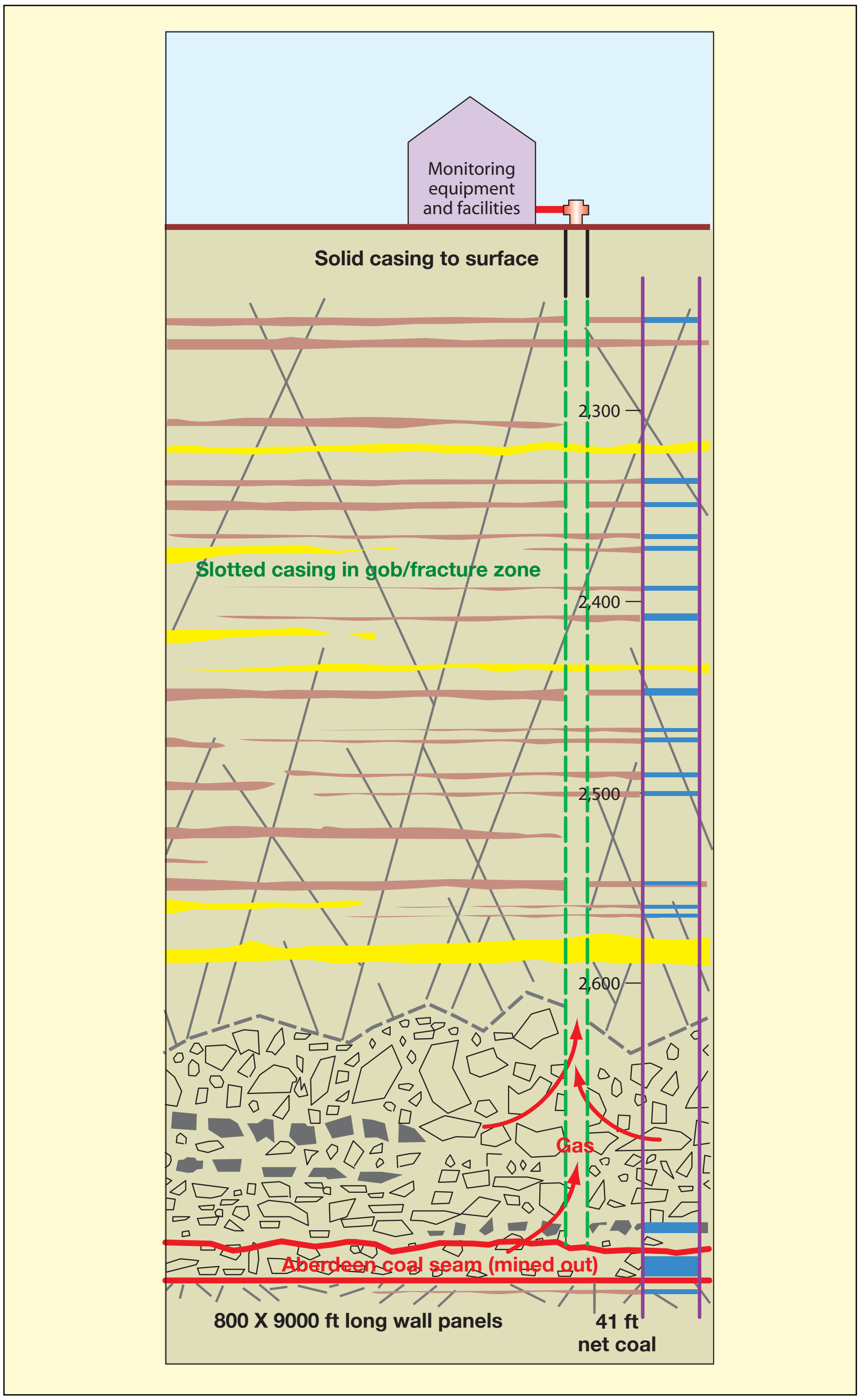

Figure 1 Cross-section of gas well and mine

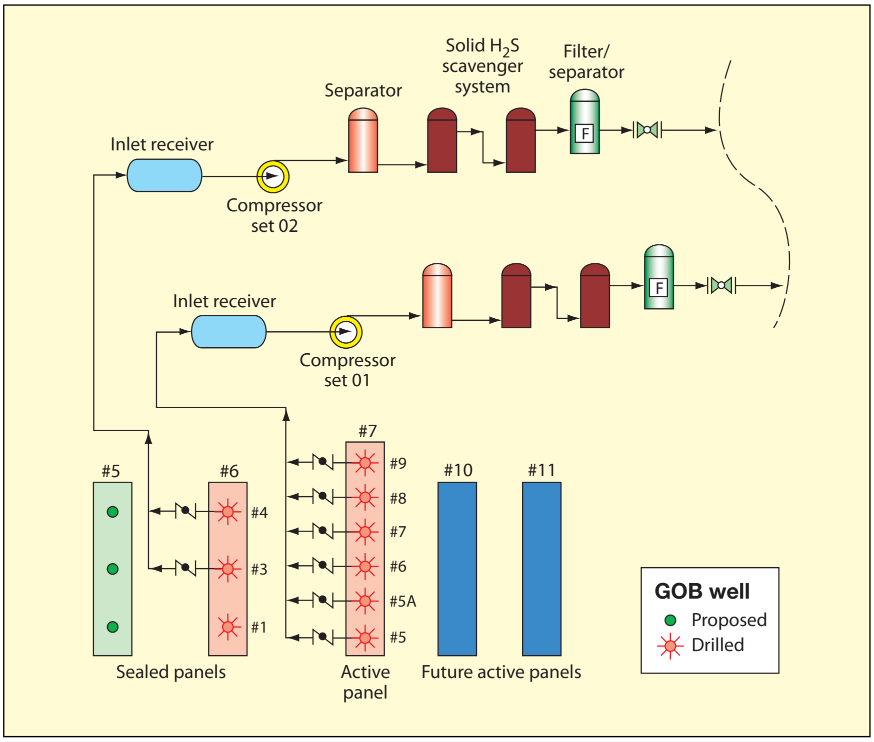

Figure 2 *Wells and compressor station*

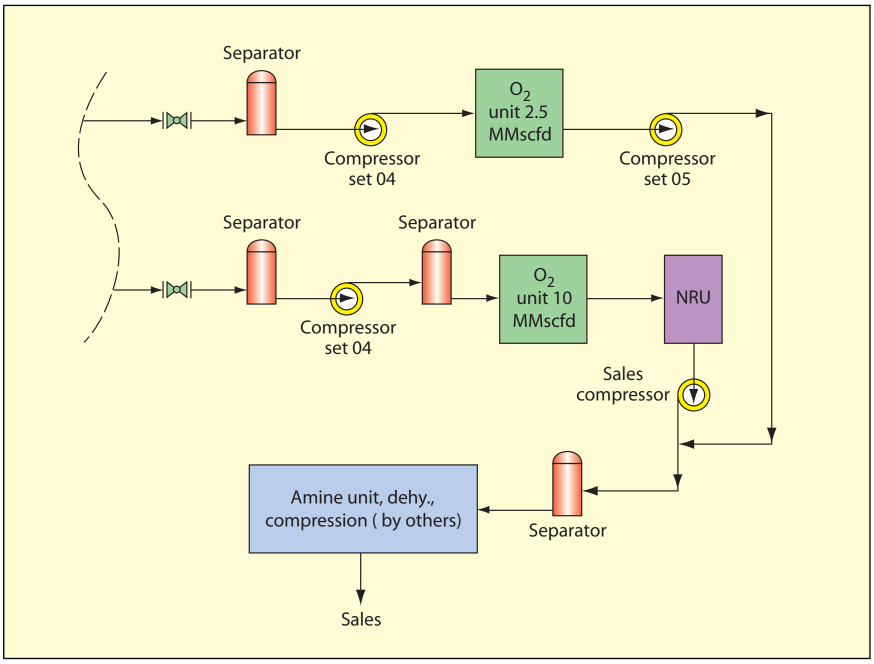

Figure 3 *Processing plant site*

the coal, sandstone and shale formations above the main Aberdeen coal seam to be mined (see Figure 1).

Gas production begins when the long wall cutting machine reaches the area beneath the GVHs and continues for many years after the mining has finished. The drainage of this gas is an operational and economic necessity for the mine due to the danger of methane explosion. Andalex had no interest in the investment to capture, process and sell this gas. Oso acquired the mineral leases and regulatory permits and installed the infrastructure to capture, transport, process and sell this gas into a local interstate pipeline.

Due to the gas content of the coals, the conventional air ventilation system was incapable of maintaining the methane content below the required limits set by the Mining Safety and Health Administration (MSHA), the mining equivalent of the Occupational Safety & Health Administration (OSHA). The GVHs extract methane from the gob and allow the ventilation air to maintain safe methane levels in the mine while mining ensues.

The coal is extracted by the long wall mining technique, which achieves high resource recovery. The long wall panels are approximately 9000 ft long, 800 ft wide and 10 ft thick. As the panel is mined, it is known as an “active panel”, and once the mining is complete it is called a “sealed panel”. However, as previously stated, the long wall mining process releases significant volumes of methane into the mine workings. A “rider” coal seam above the mined seam also contributes to gas production. As the coal is removed from the long wall face, the roof collapses and the floor heaves, fracturing the rock in the stratigraphic column approximately 360 ft above and 50 ft below the mined seam. The gas stored in this fractured zone is released and drawn into the mine workings. It is this gas that is targeted by the GVHs, with the objective of recovering high concentrations of methane before it enters the mine’s ventilation system.

Once the panel is mined and sealed, it continues to vent high-Btu methane, although at lesser rates than when the long wall panel is active. The average methane content of the gas vented from active panels is 75%, while the gas from sealed panels is 94%. These two gas streams are gathered, compressed and transported approximately five miles via pipeline to a processing plant. Oxygen, hydrogen sulphide, nitrogen and carbon dioxide are removed from the gas prior to sale. See Figures 2 and 3 for schematic drawings depicting the gathering pipelines, compression facilities and the processing plant.

During 2006, Oso installed a gathering system, field compression station and approximately five miles of 2–10 inch pipelines to the processing plant. The plant was completed in 2007. The project is currently selling gas to the local natural gas pipeline.

Gas sales reached almost 2000 Mscfd in July 2007. The startup of the nitrogen rejection unit (NRU) in mid-July 2007 allowed for the processing of high nitrogen content gas. The processing capacity of the NRU is 8000 Mscfd, and sales in this range were expected during the mining of the next active long wall panel. The expected life of the mine is at least another 11 years, with gas production expected for 18 years.

An important revenue stream expected to add significant economic value to this project is the greenhouse gas emission reduction credits, also known as voluntary emission reduction credits (VERs). The methane, which would otherwise be emitted into the atmosphere, is recovered and used as a clean-burning energy resource. As a result, the project qualifies as a verifiable greenhouse gas emissions reduction project.

A project design document (PDD) was prepared by Ruby Canyon Engineering for this project. The document describes the baseline emissions from the Tower

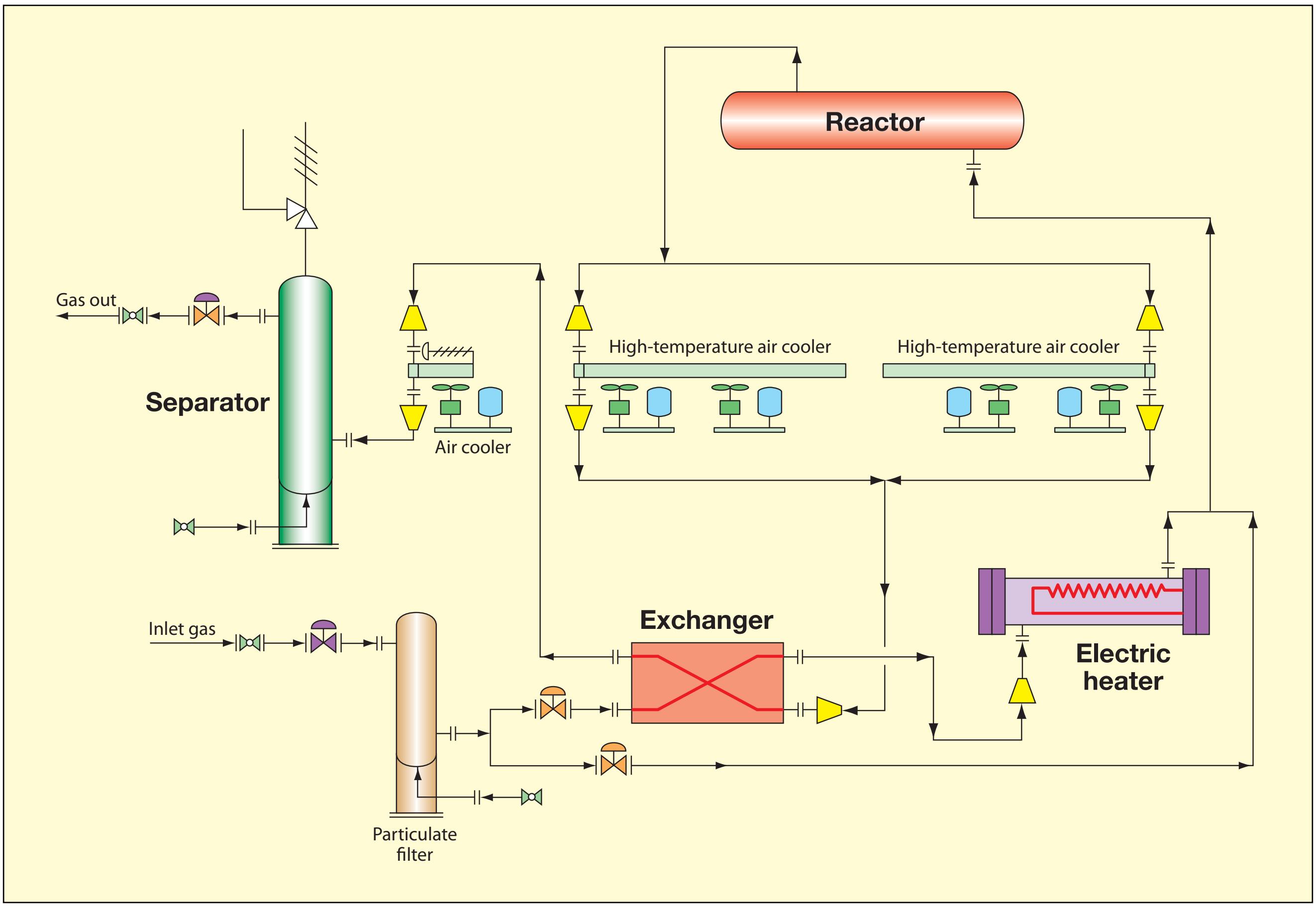

Figure 4 *10 MMscfd X-O_2 unit — 3% maximum oxygen*

Mine and the resulting emission reductions. The PDD addresses the issues of additionality, where it is clearly demonstrated that the project is not a conventional gas production and sales project. Many of the unique aspects of the project are described in the PDD, and a monitoring plan is outlined that describes how Oso is metering and documenting the methane emission reductions generated by the project.

Oxygen removal system

The oxygen removal system is based on the catalytic combustion of oxygen. The gas stream in this project contains a significant amount of C_3+ hydrocarbons. This lowers the ignition temperatures of the system when compared to a pure methane stream. Lower ignition temperatures reduce the maximum temperature required by the system when the heat of combustion is considered constant.

The inlet gas is introduced into a particulate filter after liquid separation. The removal of fine particulates prevents the clogging of the catalyst. The gas goes through a heat exchanger, where it is heated to the required reaction temperature during steady-state operation. There is a cool gas bypass to allow for the control of the temperature going to the reactor. During startup, an electric heater is used to heat the gas to the required reaction temperature. The heater can also be used continuously when there is not enough oxygen to maintain inlet reactor temperatures. The reactor contains the catalyst and is designed to have a sufficient volume of catalyst necessary to burn the amount of oxygen required. The gas then flows through two high-temperature air-cooled heat exchangers, each of which has two variable frequency drive (VFD) fans. These coolers are small, with dimensions of approximately 2 x 4 inch. They cool the gas leaving the reactor to reduce the temperature rating of the heat exchanger, as well as the temperature difference in the exchanger to the desired 38°C (100°F) (the VFD drive allows this level of control). The gas flows through the heat exchanger, where it is cooled further and introduced into the final air cooler. Condensed water is removed in a separator and the gas exits the system. Combustion of the oxygen yields water and CO_2 and, depending on the inlet oxygen levels, can make the gas saturated and increase CO_2 levels significantly.

Two oxygen analysers are used in the system. One is in the inlet portion of the plant and used to shut down the plant if the oxygen level exceeds the plant maximum. Another is located at the outlet of the plant to verify the outlet specification of 10 parts per million (ppm). Systems used to treat low concentrations of oxygen do not require high-temperature air coolers, as the reactor temperatures are not required to be as high.

System performance

The first X-O_2 oxygen removal plant was leased to Oso and commissioned in November 2006. It was originally designed to remove 4% oxygen and deployed near Stephenville, Texas. The plant was refurbished and modified to remove up to 0.75% oxygen from the gas. This change in maximum oxygen content reduced the amount of equipment in the plant and allowed a quick turnaround. The reduction in allowable oxygen content also made sense from an operations' perspective, as gas with this much oxygen contains approximately 3% nitrogen. Three per cent total inert gas content is the pipeline limitation and, since the NRU was not available, a higher oxygen capacity did not appear necessary at that time. This oxygen plant had a maximum capacity of 2500 Mscfd. The installation of this plant allowed gas sales to start before the remainder of the plant was complete. This plant is skid mounted and took only one day to install, with startup requiring less than one day.

This plant treated the sealed panel gas, which has less oxygen content. Initial inlet oxygen concentrations were approximately 1.0% (well above the 0.75% design level) and volumes reached

***Figure 5** 2500 Mscfd X-O_2 oxygen removal unit*

***Figure 6** 10 000 Mscfd X-O_2 oxygen removal unit*

1950 Mscfd. The sales gas recipient had considerable trouble accurately measuring oxygen in the ppm range. In fact, the laboratory hired for this task insisted that the plant was not removing the oxygen below 0.2%. After increasing the reactor temperature several times, the outlet oxygen concentration remained constant. Due to the fact that reactor efficiencies increase with rising temperature, this was not possible and indicated faulty testing procedures. A new laboratory with more experience was hired, and the oxygen content was not detectable at less than 1 ppm. This plant remained in service until September 2007, when the full processing system was brought online.

The X-O_2 oxygen removal plant that was specifically designed for this system can remove up to 3% oxygen at 10 000 Mscfd. The outlet oxygen specification was maintained at less than 10 ppm. The system was designed to be self-sustaining at oxygen concentrations over 1%. This means that after startup with oxygen levels above 1%, the electric heater is not used and the plant will consume only the electricity required by the air-cooled heat exchangers (23 hp). This plant was delivered in January 2007 and was not started until July when the NRU became available. This system is also skid mounted on two 10 x 30 inch skids.

As the oxygen content of the gas is determined by the phases of the mining operation, the maximum oxygen content that has been treated is 2.0% at about 4500 Mscfd. At these levels, the plant has performed well and not failed to meet treating specifications. During operations, the inlet oxygen concentrations have varied from 0.15–2.0%. When the oxygen concentrations are lower than 1%, the electric heater automatically starts to maintain reactor temperatures. If required, a larger heat exchanger could be installed to reduce the self-sustaining oxygen content. Runtime for the system is in excess of 99%, with the only problem being the failure of the electric heater sheath over temperature controller (OTC). The plant has been able to remain running without problem or operational changes even when troubleshooting other equipment that caused gas flows to be stopped and started repeatedly. The plant has also operated well in the harsh environment on top of the Book Cliff mountains at an altitude of 7500 ft. The ambient temperature has reached as low as 4°C (40°F) in the winter and over 38°C (100°F) in the summer.

Treating costs

The plant will use a maximum of 23 hp to drive the electric air cooler motors. The catalyst is guaranteed for three years and has a replacement cost of $320 000. The maximum treating capacity over a three-year period at 99% runtime is 10 840 MMcf. This results in a theoretical treating cost of $0.033/Mcf (assuming $0.075 per kWh for purchased power). The catalyst is anticipated to last five to ten years. The resulting treating cost over five years is $0.021/Mcf. The actual treating costs are higher, on an mscf basis, due to the reduced gas flow rates currently being experienced. This reduced gas flow also decreases the electricity used by the air coolers and extends the life of the catalyst in the reactor. Another benefit of this system is that the catalyst is sulphur and chlorine tolerant. This tolerance reduces the possibility of deactivation of the catalyst caused by the unlikely introduction of H_2S into the reactor. This greatly reduces the potential for expensive catalyst replacement due to plant upsets.

Conclusion

The gas streams targetted by this project require more than an amine plant and a TEG dehydration unit to reach the market. Through Oso's experience at the Tower Mine, oxygen removal can be achieved safely and effectively using a catalytic oxygen removal system. In order to be effective, the designer must be aware of the operation and design of the entire system to ensure the system is neither over- nor under-designed. The ability of Oso and Newpoint to work closely together has made the oxygen removal system a success and an integral part of the gas treating system of the Aberdeen Coal Mine Methane Project in Carbon County, Utah.

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