Capture and Use of Coal Mine Ventilation Air Methane

Final Report of Work Performed
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EXECUTIVE SUMMARY

CONSOL Energy Inc., with assistance from MEGTEC Systems, Inc. and the United States Department of Energy, successfully demonstrated a thermal flow reversal reactor (TFRR) system (specifically, the MEGTEC VOCSIDIZER™ oxidation system) using simulated ventilation air methane. While simulating the ventilation air stream using diluted coal mine methane, the key objectives of this project were to demonstrate that the low and variable concentrations of methane contained in the coal mine ventilation air can be converted to carbon dioxide effectively and economically; to determine the quantity of useful energy that can be economically produced when processing ventilation air from a working coal mine; and to perform an engineering/economic evaluation of the concept.

The location for the field demonstration was West Liberty, Brooke County, West Virginia, at a coal mine methane vent from the abandoned Windsor Mine. The initial tasks were to test the vent to determine if there was sufficient methane to conduct the demonstration project, determine if an air permit was required, and to determine the structural integrity of the soil to support the equipment. From the testing, it was determined that the vent could emit up to 1MM ft^3/day of gas containing 43% methane which was sufficient to demonstrate a single VOCSIDIZER unit. Based on the expected emissions of the process, it was determined that no air permit was required from the West Virginia Department of Environmental Protection. The existing soil was not sufficiently competent to support the equipment weight of 58.2 tons and the civil design selected used structured back-fill under concrete slabs for the support system.

Once the subcontract with MEGTEC Systems was finalized, it took less than a year to fabricate the equipment, install the system, and introduce methane to the unit. Fabrication of the equipment required about five months and, during that time, the site preparation was initiated. Equipment foundations and 3-phase power were the primary resources required to support the equipment. The VOCSIDIZER, fan, and control room arrived on site pre-assembled on skids, which minimized field installation time. In order to complete the system, a gas train to simulate ventilation air methane was built, and the power and control wiring were connected to the unit and the instrumentation. This installation required more instrumentation and safeties than what would typically be on a mine ventilation fan because simulated ventilation air methane had to be produced.

On February 11, 2007, the check-out was complete and simulated mine ventilation air methane entered the VOCSIDIZER for the first time. Unmanned operation of the equipment had three areas of focus. The first area was to conduct parametric tests to measure the ability of the unit to convert methane at the limits of the equipment. The tests were to determine the effects of the mine ventilation air flow rate and VAM concentration on the response of the TFRR and methane conversion. One set of parametric tests were conducted the week of April 9, 2007, and a second set of tests were conducted the week of April 28, 2008. All tests showed that operation was sustainable at low (0.3%) and high (0.8%-1.0%) methane concentrations entering the

VOCSIDIZER and low (15,000 scfm) and high (30,000 scfm) air flow into the VOCSIDIZER. Only one of the eleven tests, which was conducted at 1.0% methane and 15,000 scfm, failed to meet the manufacturer's guarantee of greater than 95% methane conversion.

The second area of focus during the operating phase was to conduct air emission tests to determine the composition of the air emitted from the stack and to verify the performance of the unit. Three campaigns were completed; August 7-9, 2007, August 5-7, 2008, and September 8-10, 2008. Considering all test results from the three campaigns, the typical measured concentration for each criteria pollutant were: 0-0.12 ppmv NO_x, 0-1.19 ppmv SO_2, 1.32-2.01 ppmv CO, and 0.06-2.81 lb/hr particulate matter. The low SO_2 levels were assumed to represent uncertainty in the measurement. The particulate matter was assumed to primarily be dust from the ceramic media. All other criteria pollutants were below the manufacturer's guarantee. The emissions of methane were from 126-186 ppmv which calculated to greater than 95% methane conversion.

The third area of focus was to conduct long-term testing at one set of conditions that are representative of a mine ventilation fans. During long-term testing, operating data were collected daily to review the operation of the system. Long-term operability of the equipment and maintenance issues were the two areas that were evaluated during the testing.

Two campaigns were run, with revisions made between campaigns to improve operability. In the first campaign from May 9, 2007, to November 30, 2007, there were 1300 unmanned hours logged on the equipment. In the second campaign, from May 1, 2008, to October 31, 2008, there were 2833 hours logged on the equipment. The second campaign showed a significant uptime improvement to 64.4%. Considering only core problems, the uptime on the equipment was 84.1%. The core problem was a loss of media at the corners of the bed, which caused the corner temperatures to drop and shut down the system. During the operating periods when the corner temperatures were dropping, the equipment continued to maintain methane conversions greater than 95%. After viewing the results from the initial campaign, the manufacturer changed the equipment specification and lowered the maximum methane concentrations that could be processed in the bed from 1.2% to 0.8%.

The equipment problems that caused downtime were failures of the air compressor, methane analyzers, flow meter, and bed thermocouples. It is critical that the methane analyzer measuring the inlet methane concentration to the VOCSIDIZER have a quick response with a high level of accuracy for safety reasons. Because the original analyzer did not meet the specification, it was replaced with a second analyzer from a different manufacturer. The replacement analyzer accurately measured methane with a response time from 5 to 6 seconds, depending on the probe length.

In addition to the mechanical problems, there were challenges to operating the equipment unmanned, in a remote location, without an operator available 24 hours a day. This contributed to downtime. Having an alarm call-out system was helpful in responding to problems in a timely manner.

When this technology is advanced to a mine ventilation fan, a typical abatement-only installation would consist of six beds the size of the demonstration unit that would capture 180,000 scfm of ventilation air. This system is only economically feasible when there is value for greenhouse gas emission reduction. Our baseline assumptions for the economic analysis are: a complete installation would cost $5.412MM, the maintenance costs are 5% of capital, the sales price for electricity is $0.058/kWh, manpower costs are $40/man-hour, the overall methane destruction is 95%, methane concentration is 0.6%, equipment availability is 97%, the equipment life is ten years on a single fan, and the carbon credit is $7.00/tonne CO_2e, The baseline case has an internal rate of return (IRR) of 2.5%. If optimistic conditions were selected, to achieve a 15% IRR, the value of the carbon credit would have to increase to $8.60/tonne CO_2e.

Considering a 180,000 scfm system having heat recovery with power generation , the capital investment increased to $15.335MM. Changes to the abatement-only baseline assumptions in the economic analysis included: the maintenance costs are $0.015/kWh, a full time onsite operator at $40/man-hour is required, and electrical efficiency is 28% on a LHV basis. The base case produced 3.07 MW of electricity with a 2.8% IRR. If optimistic conditions were selected, a 15% IRR could be achieved if the value of the carbon credit increased to $14.70/tonne CO_2e. High methane concentrations and high value of the generated electricity are favorable for considering power generation with the TFRR system.

The single bed unit, operating at 30,000 scfm and 0.6% methane at Windsor Mine, reduced methane emissions by 894 short tons during the 13 months of operation which is equivalent to 14,849 metric tonne of carbon dioxide. A large commercial-size installation (180,000 scfm) of TFRR technology on a single typical mine ventilation bleeder fan could reduce methane emissions between 11,000 and 22,100 ton per year (the equivalent of 183,000 to 366,000 tonne carbon dioxide) depending on the methane concentration. Adding power generation to the system would reduce the demand on fossil fuel generating stations, thus reducing the emissions of SO_2, NO_X, CO, and other criteria pollutants and CO_2. The system could produce 3.3-8.2 MW of electricity or 11-27 MW of thermal power.

Based on this demonstration project, the TFRR technology appears to be a viable technology to mitigate ventilation air methane. CONSOL Energy is interested in advancing this technology to an active mine site by initially relocating the existing VOCSIDIZER unit to a mine fan under the Mine Safety and Health Administration's (MSHA) guidelines. MEGTEC Systems is continuing to improve the equipment to obtain a more robust system and improve its operability. In a carbon-constrained world, this technology provides the capability of utilizing a waste stream to reduce green house gases as well as the potential to produce useful energy.