DOE/RMOTC - 41006

AVIATION TECHNOLOGY SERVICES:
PIPELINE LEAK DETECTION

Final Report for the Period of August to November, 2006

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DISCLAIMER

ABSTRACT

Aviation Technology Services, L.L.C. (ATS) conducted a series of pipeline leak tests with a proprietary, airborne, laser based detection system in September 2006 at the Rocky Mountain Oilfield Testing Center (RMOTC). The pipeline surveillance course is a simulated underground pipeline, 7.5 miles in length with 15 predetermined leak points. These leak points and leak rates were blind to the testers and were changed twice a day for the testing period. The leak rates ranged from 1.8 to 5,000 scfh. As part of the testing protocol, data analyses were submitted by ATS to RMOTC before the actual leak sites and rates were given to the testers. ATS then compared their results to the actual results.

The ATS helicopter-based system consistently detected methane leak rates of 500, 100, 10-15, and 1.8 scfh. These leaks, including the 1.8 scfh leak, were detected an average of 75% of the time. The 75% translates to 90 % of all emitted gas volume. Few false positive and false negative leaks were identified. The system had no “down-time” and remained operational throughout the three-day test. Compared with the previous tests, the ATS airborne methane detection system produced substantial improvement in gas leak detection making it a viable system for gas leak detection in the field.

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EXECUTIVE SUMMARY

Aviation Technology Services, L.L.C. (ATS) conducted a series of pipeline leak tests with a proprietary airborne laser based detection system in September 2006 at the Rocky Mountain Oilfield Testing Center (RMOTC), located 35 miles north of Casper, Wyoming. The pipeline surveillance course is a simulated underground pipeline, 7.5 miles in length with 15 predetermined leak points. These leak points and leak rates are blinded to the testers and were changed twice a day for the testing period. The leak rates ranged from 1.8 to 5,000 scfh. As part of the testing protocol, data analyses were submitted by ATS to RMOTC before the actual leak sites and rates were given to the testers. ATS then compared their results to the actual results.

The ATS helicopter-based system consistently detected methane leak rates of 10 to 5,000 scfh. These leaks, including the 1.8 scfh leak, were detected an average of 75% of the time. Ninety (90) % of all emitted gas volume was detected. Few false positive and false negative leaks were identified. The system had no “down-time” and remained operational throughout the three-day test.

The simulated pipeline was constructed in 2004 for previous leak detection testing. Previous tests were conducted under the same scientific conditions with gas detection systems utilizing several technologies including Passive Infrared Multi Spectral Scanning; Laser based Differential Absorption (Lidar), Hyper Spectral Imaging, and Tunable Diode Laser Absorption Spectroscopy. The systems were mounted in an automobile, helicopter or fixed wing aircraft. For these tests, the detection of leak rates of 500 scfh or higher was only 50% of the time with the detection rate rapidly decreasing to 5% for 10 - 15 scfh and 0% for 1.8 scfh leaks. Compared with the previous tests, the ATS airborne methane detection system produced substantial improvement in gas leak detection making it a viable system for gas leak detection in the field. Such a reliable pipeline leak detection system will vastly improve pipeline safety and reduce the lost product revenue.

INTRODUCTION

The Rocky Mountain Oilfield Testing Center (RMOTC) is located at the Teapot Dome oil field, also known as the Naval Petroleum Reserve No. 3 (NPR-3). The field is thirty-five (35) miles north of Casper, Wyoming (Figure 1). RMOTC is operated by the Department of Energy as a test site for new and developing oil and gas, and renewable energy related technologies.

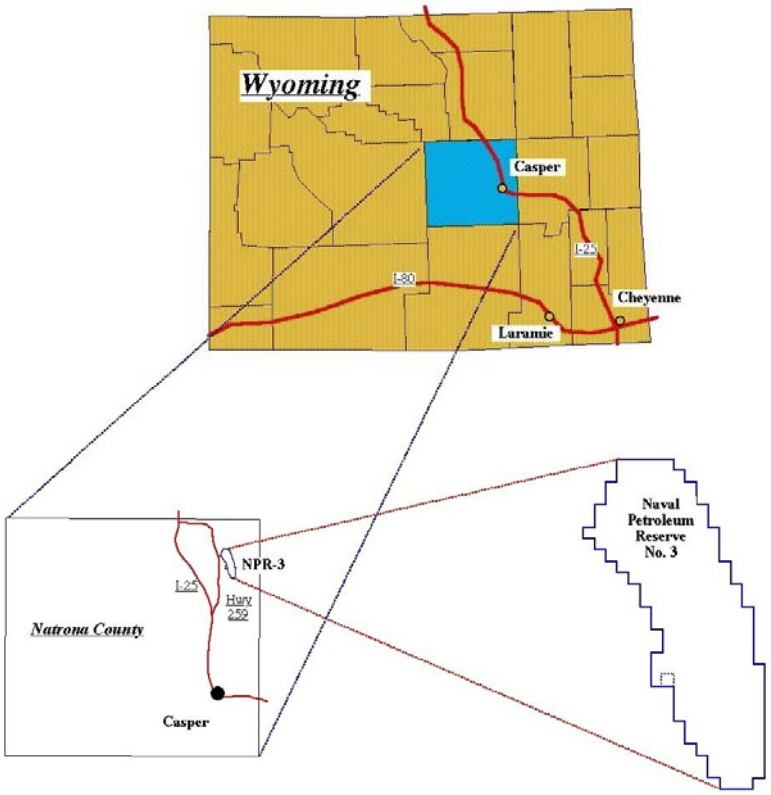

Figure 1. Location Map for Rocky Mountain Oilfield Testing Center

The oil and gas pipeline infrastructure within the United States is aging and deteriorating. The explosions and loss of lives in New Jersey and New Mexico, as well as major supply line closures in Alaska, have confirmed these facts. The industry needs a method to access individual pipelines and find leaks before they create major economic and personal loss.

The pipeline surveillance course at RMOTC is a simulated underground pipeline, 7.5 miles in length with 15 predetermined leak points (Figure 2). The course and leak points were constructed in 2004 for a series of leak detection tests (Buckingham, J. C., et.al., 2004). The majority of these leak points and leak rates are blinded to the testers and were changed twice a day for the three days of testing. One to two of the leak points and rates are given to the testers as calibration points. The leak rates ranged from 1.8 to 5,000 scfh.

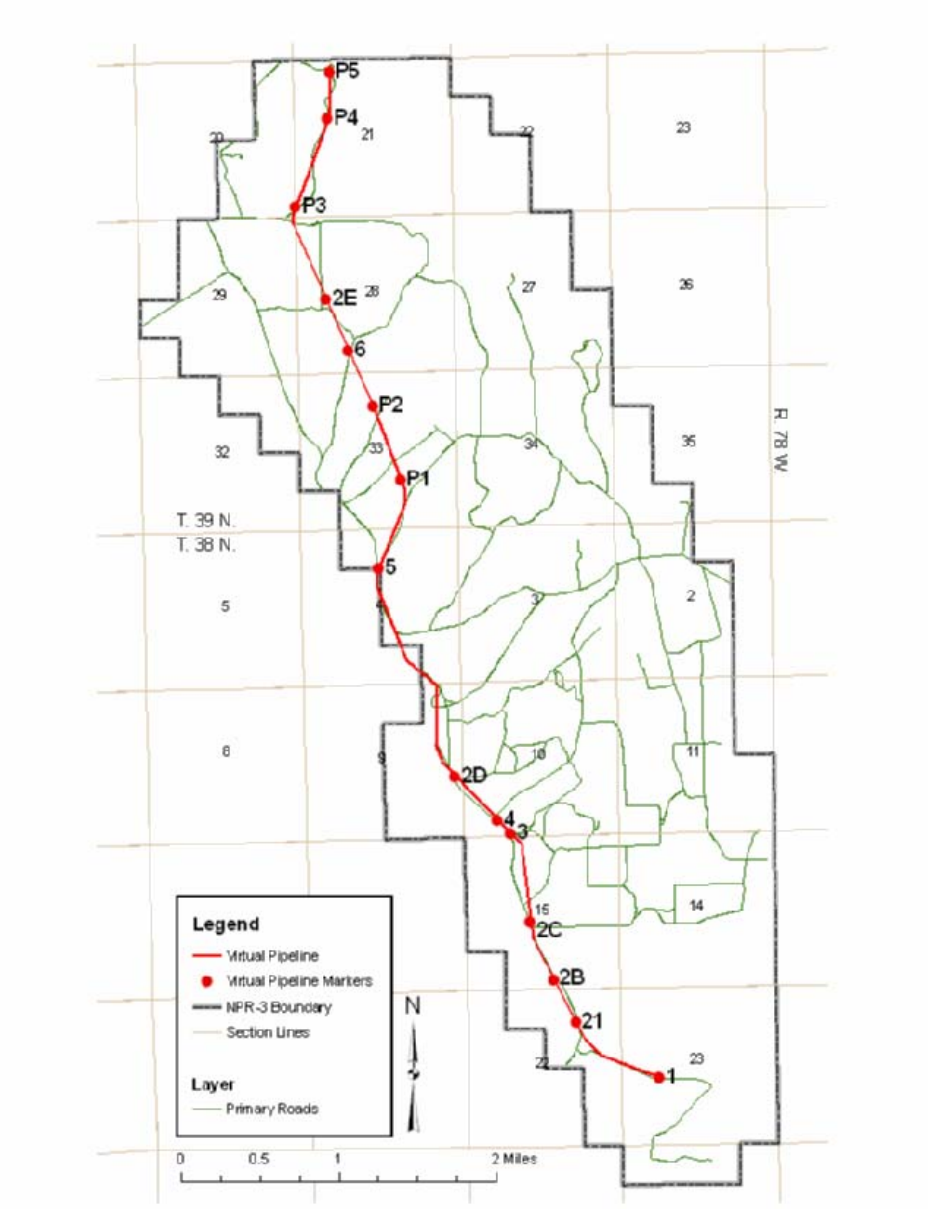

Figure 2. Virtual Pipeline with Leak Points

The purpose of this testing was to provide documentation of the durability, accuracy, sensitivity, and consistency of a helicopter-mounted Boreal laser system operated by Aviation Technology Services L.L.C. (ATS). The Boreal laser has been used previously in Canada, Mexico, Asia, Russia, and Europe to survey pipelines and refineries with proven leak detection capabilities. Previous tests at the RMOTC simulated pipeline have been conducted under the same scientific conditions with gas detection systems utilizing several technologies including Passive Infrared Multi Spectral Scanning; Laser based Differential Absorption (Lidar), Hyper spectral Imaging, and Tunable Diode Laser Absorption Spectroscopy. The systems were mounted in a vehicle, helicopter or fixed wing aircraft. Results of the previous tests were used for comparison of the effectiveness of the present tested system

ATS Laser Equipment Details

The ATS airborne leak detection service is based around the Boreal laser. The Boreal laser is a robust methane detection system, tuned to the absorption wave-length of the methane molecule and firing inside a porous, self-contained sensor cell attached near the bottom of the helicopter, Figure 3. Air passing through the laser cell is sampled over 300 times per second, accurately monitoring methane levels as low as one part per million (1 ppm). Laser accuracy is maintained through a patented self-calibration system which references its own pure methane sample every 3 to 6 seconds; thus increasing accuracy and eliminating background level drift. The laser samples the atmosphere over a pipeline and identifies rising methane plumes associated with leaks. At 50 mph and approximately 50 feet above ground level, the pilot follows a preloaded pipeline route using latitude and longitude points on a Global Positioning Satellite (GPS) receiver. Advantages to the system are that temperature changes, ground, and cloud conditions do not affect the performance of the Boreal laser. Excellent survey results are achieved in wind speeds up to 18 mph. To complete the airborne pipeline leak detection system, ATS uses a state of the art GPS directed mapping program linked to a color digital video and audio capture program that plots methane levels collected and records them to a hard drive. Post-survey analysis and archiving of the pipeline data can be viewed on the mapping program to visually review exact locations of problems such as right of way issues, exposed pipe,

dead vegetation, and encroachment. Combined, this provides a user-friendly interface and valuable information for clients.

Figure 3. The Boreal laser sensor cell, without cover.

The capability of the Boreal laser system continues to improve with advancements in detecting plumes and other molecules of interest such as Hydrogen Fluoride (HF) Hydrogen Sulfide (H_2S) Carbon Dioxide (CO_2) Ethylene (C_2H_4), and Acetylene (C_2H_2).

Testing Methodology

The facility used for this testing was a simulated pipeline at RMOTC, located 35 miles north of Casper, Wyoming. The pipeline surveillance course is a simulated, underground pipeline, approximately 7.5 miles in length, with 15 predetermined methane leak points. The pipeline configuration was determined during a previous test by an advisory panel made up of representatives from the Department of Energy (DOE), trade organizations, gas companies, and Southwest Research Institute. This panel determined all critical

issues such as leak rates, leak locations, topography, ambient conditions, and the creation of a "calibration" leak site (Buckingham, J. C., et.al., 2004).

For this series of tests, a predetermined schedule of leak sites and leak rates were developed. Each test day had two sets of rates and locations. Not all locations were used during a given period and the leak rates ranged from 0 to 5,000 scfh. All testing was planned to start near sunrise to minimize the effect of the wind. Each day, the second set of conditions was established after the tester was satisfied with their data collection for the first set of releases. A thirty (30) minute equilibrium period was set between each leak scenario. Leak rates were continually monitored during the testing.

ATS conducted a series of leak detection tests with its airborne laser methane detection system between September 12th and 14th, 2006. ATS flew their leak detection system over the pipeline each time the scenario was altered. To perform an impartial and controlled evaluation of ATS's airborne laser leak detection system, ATS was required to provide an analysis of their testing results prior to RMOTC providing the actual leak data scenarios. ATS then reevaluated their results based on the actual data.

Figure 4. Simulation of ATS's helicopter over a pipeline with the methane plume indicated in green**.**

TEST RESULTS

The following gives the client's observations and results for each of the testing periods. Also included for each scenario are the actual leak rates for each site.

September 12, 2006, Leak Scenario Number 1

8 AM, sky clear, temperature 15°C to 17°C, winds 4 gusting to 10 knots from SSW to SW. Data was collected over three passes of the course. The pilot and technician flew the course south to north 50 feet above ground level (AGL). The Boreal laser was in proper operation with no abnormalities.

Table 1. September 12, 2006 Leak Scenario Number 1, 09061

8 out of 11 leaks found. (09061)

September 12, 2006	Set 1 Leaks	Leaks Reported
Leak Site	scfh	
1	500	Yes
2A	0	*Suspicious
2B	0	
2C	0	
3	100	*
4	2,000	*
2D	14	*
5	5,000	Yes
P1	740	Yes
P2	100	Yes
6	1,000	Yes
2E	14	Yes
P3	14	Yes
P4	0	*Possible
P5	3.5	Yes
Total Gas Volume	9,485.5	

Breakdown Report 09061

*Site 2A

Listed as a suspicious area (low risk) a 1 ppm rise near leak point. Analyzed methane possibly drifted from leak site 1 along low terrain.

*Site 3 & 4

No elevation in methane levels. Analyzed methane plume was missed due to improper course offset because of a wire hazard environment.

*Site 2D

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

*Site P4

Listed as a possible leak (Moderate Risk), a 2.5 ppm rise near leak point.

Analyzed methane was possibly associated with nearby up wind leak P3.

September 12, 2006, Leak Scenario Number 2

12 PM, sky clear, temperature 21°C to 23°C, winds 8 gusting to 12 knots from SW to WSW. Data was collected over three passes of the course. The pilot and technician flew the course south to north 50 feet AGL. The Boreal laser was in proper operation with no abnormalities. Wind speed approached limits of creditable survey.

Table 2. September 12, 2006 Leak Scenario Number 2, 09062

8 out of 10 leaks found (09062)

September 12, 2006	Set 2 leaks	Leaks Reported
Leak Site	scfh	
1	6	Yes
2A	0	
2B	14	Yes
2C	0	*High
3	1,000	Yes
4	100	*
2D	0	*Suspicious
5	5,000	Yes
P1	740	Yes
P2	100	*
6	500	Yes
2E	0	
P3	14	Yes
P4	0	
P5	3.5	Yes
Total Gas Volume	7,477.5	

Breakdown Report 09062

*Site 2C

Listed as a leak (high risk) a 4 ppm rise near leak point. Analyzed methane elevation possibly from an unknown source not associated with test.

*Site 4

No deviation in methane levels. Analyzed methane from (25 meters) nearby leak site 3 elevated the atmosphere levels.

*Site 2D

Listed as a suspicious area (Low Risk) a 1 ppm rise near leak point. Analyzed methane from an unknown source not associated with test or methane possibly drifted from leak site 3 along low terrain.

*Site P2

No deviation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

September 13, 2006, Leak Scenario Number 1

7AM, sky clear, temperature 12°C to 13°C, winds 15 gusting to 20 knots from WSW to W. Data was collected over four passes of the course. The pilot and technician flew two passes of the course south to north 50 feet AGL and two passes north to south 25 feet AGL when possible. The Boreal laser was in proper operation with no abnormalities. Wind speed was at and above limits of a creditable survey and would not be conducted for clients.

Table 3. September 13, 2006. Leak Scenario Number 1, 09063

8 out of 12 leaks found (09063)

September 13, 2006	Set 1 leaks	Leaks Reported
Leak Site	scfh	
1	700	Yes
2A	14	Yes
2B	0	
2C	0	
3	2,000	Yes
4	50	Yes
2D	14	*
5	4,700	Yes
P1	740	*
P2	100	*
6	100	*
2E	0	*Suspicious
P3	250	Yes
P4	14	Yes
P5	1.8	Yes
Total Gas Volume	8,683.8	

Breakdown Report 09063

*Site 2D

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

*Site P1

No elevation in methane levels. Analyzed leak was not identified because of wind effect on terrain holding the plume near the ground.

*Site P2

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

*Site 6

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

*Site 2E

Listed as a suspicious area (Low Risk), a 1 ppm rise near leak point. Analyzed methane possibly drifted from nearby up-wind leak site 6.

September 13, 2006, Leak Scenario Number 2

10AM, sky clear, temperature 18°C, winds 20 gusting to 28 knots from W. Survey was not flown and data was not collected. Wind speed was over limits of creditable survey and was not conducted.

September 14, 2006, Leak Scenario Number 1

7AM, sky clear, temperature 10°C to 13°C, winds 10 gusting to 15 knots from SW to WSW. Data was collected over three passes of the course. The pilot and technician flew the course south to north 50 feet AGL. The Boreal laser was in proper operation with no abnormalities. Wind speed approached limits of creditable survey.

Table 4. September 14, 2006, Leak Scenario Number 1, 09064

11 out of 12 leaks found (09064)

September 14, 2006	Set 1 leaks	Leaks Reported
Leak Site	scfh	
1	100	Yes
2A	0	
2B	14	Yes
2C	0	*Possible
3	2,000	Yes
4	1,000	Yes
2D	0	*Suspicious
5	5,000	Yes
P1	740	Yes
P2	100	Yes
6	500	Yes
2E	14	Yes
P3	250	Yes
P4	7	Yes
P5	1.8	*
Total Gas Volume	9,726.8	

Breakdown Report 09064

*Site 2C

Listed as a possible leak (Moderate Risk) a 2 ppm rise near leak point. Analyzed methane possibly from an unknown source not associated with test.

*Site 2D

Listed as a suspicious area (Low Risk) a 1 ppm rise near leak point. Analyzed methane from an unknown source not associated with test or methane possibly drifted from leak site 3 along low terrain.

*Site P5

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

September 14, 2006, Leak scenario #2

11AM, sky clear, temperature 19°C to 22°C, winds 10 gusting to 15 knots from SW to WSW. Data was collected over three passes of the course. The pilot and technician flew the course south to north 50 feet AGL. The Boreal laser was in proper operation with no abnormalities. Wind speed approached limits of creditable survey.

Table 5. September 14, 2006. Leak Scenario Number 2, 09065.

8 out of 11 leaks found (09065)

September 14, 2006	Set 2 leaks	Leaks Reported
Leak Site	scfh	
1	500	*
2A	14	*
2B	0	*Possible
2C	0	
3	500	Yes
4	2,000	Yes
2D	0	
5	3,000	Yes
P1	740	Yes
P2	100	*
6	1,000	Yes
2E	0	*Suspicious
P3	250	Yes
P4	7	Yes
P5	1.8	Yes
Total Gas Volume	8,112.8	

Breakdown Report 09065

*Site 1

No elevation in methane levels. Analyzed leak was not identified because of the wind effect on terrain holding the methane near the ground and improper course offset due to wire hazard environment.

*Site 2A

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the methane near the ground.

*Site 2B

Listed as a possible leak (Moderate Risk) a 2 ppm rise near leak point. Analyzed methane from an unknown source not associated with test or methane possibly drifted from leak site 1 along low terrain.

*Site P2

No elevation in methane levels. Analyzed leak was not identified because of size and wind effect on terrain holding the plume near the ground.

*Site 2E

Listed as a suspicious area (Low Risk) a 1 ppm rise near leak point. Analyzed methane possibly drifted from nearby up-wind leak site 6.

CONCLUSIONS & DISCUSSION

The ATS helicopter-based system consistently detected methane leak rates of 500, 100, 10-15, and 1.8 scfh. These leaks were each detected an average of 75% of the time including the 1.8 scfh leak, Figure 5. Ninety (90) % of all emitted gas volume was detected. Few false positive and false negative leaks were identified. The system had no "down-time" and remained operational throughout the three-day test.

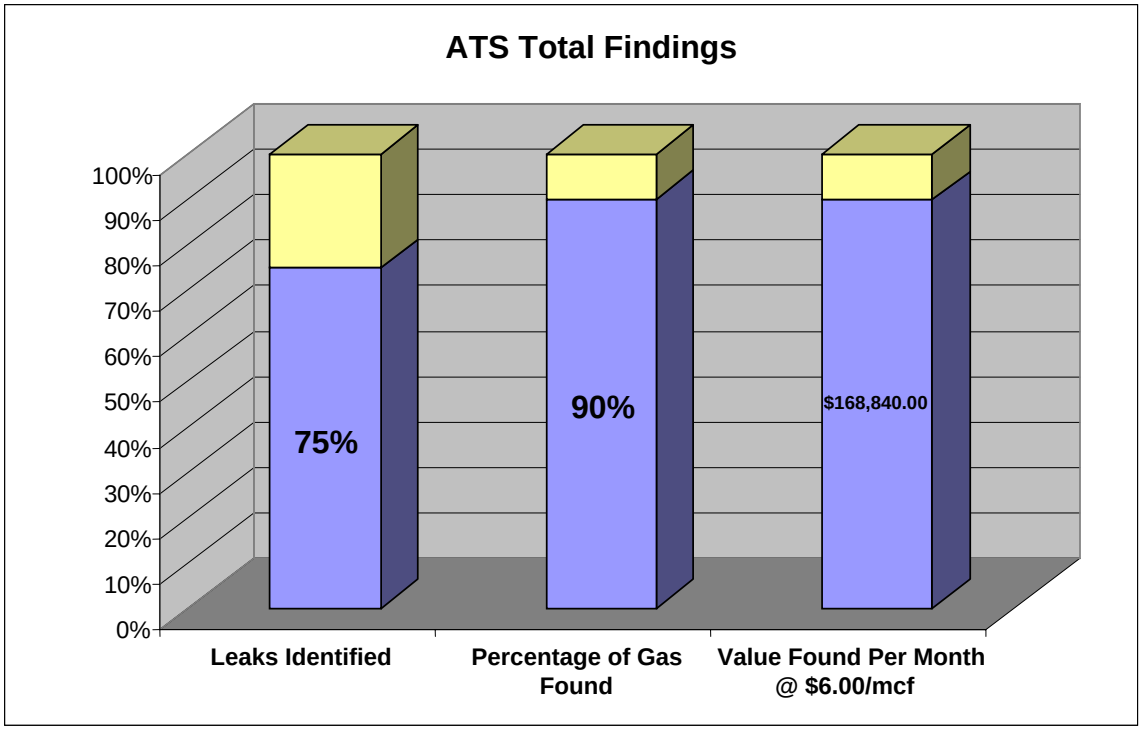

Figure 5. Test Results

Previous tests at the same site conducted under the same scientific conditions with various gas detection systems utilizing automobile, helicopter, or fixed wing aircraft produced the following results: leak rates of 500 scfh or higher were detected 50% of the time; leak rates of 100 scfh were detected 15% of the time; leak rates of 10 - 15 scfh were detected 5% of the time; and the 1.8 scfh leak was never detected.

In summary, the ATS leak detection system proved to be a reliable, rapid, and efficient leak detection system. The performance of the system substantially exceeded prior evaluated detection systems at RMOTC. The test demonstrated the system's strengths in measuring minute levels of methane in the air. And, the client demonstrated their ability

to interpret the collected data and determine when the conditions were not conducive for accurate measurements.

With new federally mandated leak detection for pipeline networks, this system could provide companies with an effective, rapid, accurate, and cost effective option.

REFERENCES

1. Buckingham, J. C., et al.: “Field Testing of Remote Sensor Gas Leak Detection Systems, Final Report,” Prepared for Department of Energy and Department of Transportation, SwRI Project No. 18.10485, December, 2004, Southwest Research Institute, Houston, TX.