SPE 101283

Aerial Leak Detection for Significantly Improved Integrity Assurance

Chad Lensing, BP America

This paper was prepared for presentation at the 2006 Abu Dhabi International Petroleum Exhibition and Conference held in Abu Dhabi, U.A.E., 5–8 November 2006.

Abstract

BP gas production operations in North America manages over 15,000 miles of onshore pipelines that make up our vast, complex, and aging gas gathering networks. Surveying these for leaks presents a huge resource challenge using current ground based technology and, in turn, impacts the assurance of the safety and integrity of these operations.

The Exploration and Production Technology Group evaluated new leak detection technologies using laser, thermal imaging camera and a high speed gas sampling detector that were deployed on aircraft and used global positioning systems coordinates to survey gas gathering pipelines. Field trials on gas gathering systems in the North Texas, Anadarko asset showed that the laser and gas sampling based leak detection systems were the most accurate, but the video imaging from the thermal camera made a powerful statement. Helicopters proved to be more suitable in leak detection surveys on gas gathering pipelines than that of fixed-wing aircraft.

The aerial leak detection technologies produce a significant increase in efficiency and productivity in managing the integrity of BP's gas gathering systems. While that improves business performance, perhaps more importantly is the fact that small gas leaks can be easily found before they become big ones. That reduces environmental damage and the potential for leaks to impact the public. The development and implementation of aerial leak detection in BP is being recognized as an integrity tool in providing a significantly improved integrity assurance to its gas gathering operations.

A. Introduction

The Exploration and Production Technology Group (EPTG) has worked closely with leading companies in the development of aerial gas leak detection technologies capable and suitable to the BP North America operations in gas production. Also potential applications lie in operations outside of North America as well as future capital projects.

The safety and integrity of BP operations has become increasing important as the oil and gas industry has become closely watched and scrutinized by stakeholders, government agencies and the public. BP has been working diligently in providing assurance to its facilities and processes especially its gas gathering systems. BP strives to achieve its safety values where No Accidents, No Harm to People, and No Damage to the Environment within its operations.

Several companies that were evaluated employing leading technologies in gas leak detection systems (LDS). Three different technologies for gas leak detection systems are laser, thermal camera, and sophisticated gas sampling based detection technologies and were tested in field trials. All of these technologies were installed on aircraft either helicopters or fixed-wing aircraft and can be deployed on the ground via vehicle mounted or hand held use. The remote detection capabilities of these technologies were attractive features that showed promise in using it on the BP gas gathering systems in order to meet its safety and integrity in the operation of gas gathering systems (GGS).

B. Leak Detection Technologies

The following technologies were reviewed: lasers, thermal camera and gas sampling based systems for leak detection systems (LDS). These hardware technologies have remote capabilities and can detect and locate leaks from a distance that can be deployed on fast moving aircraft giving them rapid measurement capabilities. There are obvious advantages in using aircraft compared to ground methods and will be discussed in the following section.

Lasers (in the infrared wavelength) using light detection and radar (LIDAR) principles, similar to that of

RADAR, is an active sensing leak detection type. Figure 1 shows a schematic showing the basic principle of an active versus passive sensor measurement. The laser is emitted and as it passes through a gas plume, the laser energy is absorbed by the gas molecules and then the laser beam is reflected back to the detector with less energy. The difference in the energy is then measured and analyzed. Active sensing types of LDS detect the methane and ethane components of the gas. These can often measure gas concentrations as small as 1-10 ppm levels depending on the path length or distance from the gas plume.

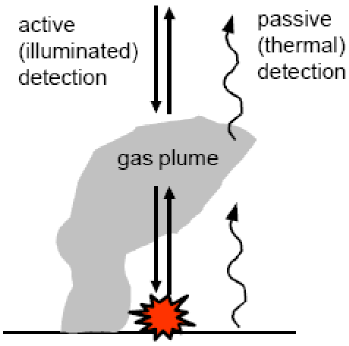

Figure 1 Active versus passive sensing types. [Ref. 1]

Special thermal imaging cameras can image hydrocarbon leaks based on their thermal properties to gas to that of thermal properties of the background environment. Thermal imaging cameras are passive sensing type that uses the background energy to be measured and displayed as an image, see Figure 1. The sensitivity is dependent on the differences between the environment conditions to that of the gas thermal properties. With little or small differences in thermal properties between the environment and gas plume will make it difficult to image gas leaks. However, these thermal imaging camera provide a powerful image of leaks not normally seen by visual inspection or by laser and gas sampling based LDS. Figure 2 shows a video snapshot of a thermal image of a staged gas leak off a wellhead flying overhead with a helicopter.

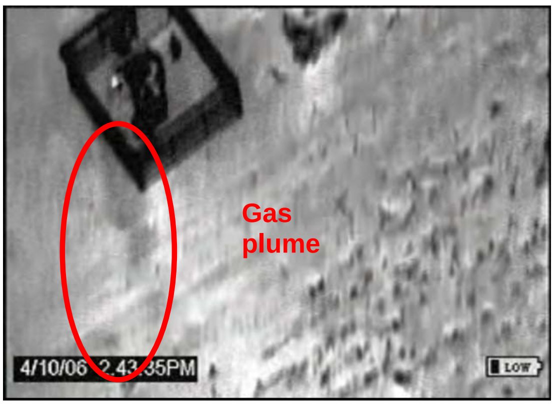

Figure 2 Gas plume off wellhead detected by thermal imaging camera.

Gas sampling is an in-situ method where the LDS must physically pass through a gas plume. A small sample of the leaked gas must be collected and transported to the detector, usually via flexible tube, for measurement. These detectors can be flame ionization detectors, mass spectroscopy or optical spectroscopy. As in the case for all LDS described in this paper, depending on the gas plume size, the gas release conditions are important to know on how it can effect the gas plume characteristics and its dispersion. Certain conditions, i.e. with high wind speeds, make a small gas plume difficult to detect.

C. Aerial Survey

Gas gathering system pipelines in North Texas have complex configurations with several wells that tie into the main gathering line to the central gas plant. These tie-ins or lateral lines can vary in length, as much as few miles, small diameters and lateral lines that are oriented in various directions. Figure 3 shows an example of the GGS pipeline configuration encountered in N. Texas.

These buried pipelines lie under various terrains from sandy and rocky terrain to crop fields and public land. Conventional methods by walking or driving the line can burden the resources and time available to survey the GGS pipelines. It is too often that leaks are reported by third parties and leaks have become large that require immediate response and often put unacceptable risk to people, operations and the environment.

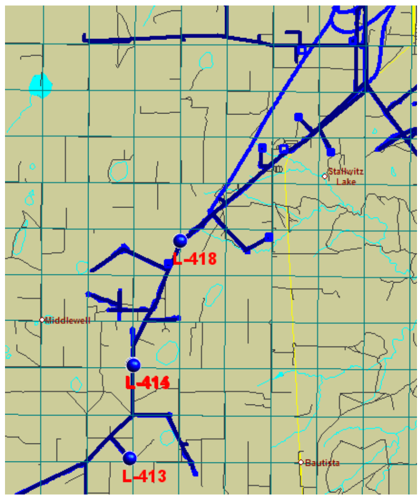

Figure 3 Layout of gas gathering system pipelines (dark blue lines). Aircraft travel path (light blue lines) and leak indications (in red)

Aerial platforms such as helicopters and fixed-wing aircraft have an obvious advantage over ground leak detection methods. With advances in LDS these technologies can be mounted on aircraft with rapid measurement capabilities. This combination allows for leak detection surveys to be conducted at heights from 50 to 200 feet above the ground at speeds from 50 to

200 mph or more. Helicopters have a certain advantage in surveying GGS pipelines as they are capable of maneuring the complex configuration of GGS pipelines including the lateral lines than that of a fixed-wing aircraft. Fixed-wing aircraft may have advantages in flying long linear pipelines such as that of transmission pipelines.

Another immediate advantage of aerial leak detection survey is the detection of leaks in areas that are difficult to access for ground based methods. Some of these areas that were encountered are farm/crop lands, rough rocky terrain, and areas with no access roads.

D. Field Trial

The participating companies and their LDS technologies were field trialed at a BP Anadarko asset in the North Texas panhandle. The gas gathering system (GGS) in the Anadarko asset provided a challenging environment in conducting a leak detection survey of its GGS pipelines. Approximately a total of 200 miles of the pipelines were tested from the months between late summer of 2005 to late spring in 2006 in which wind gusts up to 30-40 mph can be encountered on any given day. Typically wind speeds less than 20-25 mph a leak detection survey could be conducted.

Several test areas were identified and global positioning system (GPS) coordinates of the pipeline were used to ensure that aircraft maintained its course over BP's pipelines and the LDS were aimed for accurate detection. These test areas have pipelines sections that are up to 50 years old. These GGS pipelines operate at low pressures, typically around 20 psi. Specific areas of known leaks as well as staged leaks were available to evaluate the LDS. A calibration leak site was used prior to surveying test areas to ensure proper working order of the LDS and conditions were suitable for a leak detection survey.

Once the survey has been conducted, detection indications and locations were tagged via various GPS software maps provided by the companies. Ground verification using the conventional flame ionization detector (FID) and a hand held laser detector were used. A leak indicated by the aerial leak detection survey was marked as a leak if proven from ground verification. Once a leak was determined and located the source of the leak was then identified. Various leak sources encountered in the field trial are shown in Table 1.

A job safety analysis was conducted and hazards associated with flying were identified. These hazards include radio towers, power lines, other aircraft, and stacks from nearby gas plants and facilities.

E. How to Conduct an Aerial Leak Detection Survey

The basic process circle is shown in Figure 4 outlining the steps required to conduct an aerial leak detection survey.

Figure 4 Basic process circle for conducting an aerial leak detection survey.

The following is a summary of recommendations for each step of the process circle.

1. PLAN - Identify pipeline routes and provide GPS coordinates with maps, and other information that may assist in tracking the pipeline. Wind and weather conditions which may affect both aircraft operations and direction and dispersion of gas plume. Consider a calibration or test leak site with a sensible leak rate. Review communications, safety, hazard identification, and emergency response plans in response to a large leak found.

2. SURVEY- Prior to survey, test the operation of equipment on a calibration or test leak if available. Detection of leaks and observations must be recorded with tagged GPS coordinates and other means of documentation. Immediate communication should be made when large leaks are detected and response carried out per company's plan.

3. REPORT - A report with leaks and their GPS coordinates should be reported within a reasonable time after survey is completed. An official report should follow that provides details of the leak and its location. (i.e. description of site, visual observations, photographs, GPS coordinates, relative size of leak, etc.)

4. VERIFY & REPAIR - Use ground gas detection equipment such as FID (downwind direction) or active sensing laser based detector (upwind direction) to verify leak and pinpoint location of leak. Repairs should be made according to the company's specification.

5. ANALYZE - Data should be analyzed and documented to track pipeline leak history and for planning the next aerial leak detection survey.

F. Results & Discussion

The overall performance of the leak detection survey was considered a success. A first time application on GGS in using LDS deployed by aircraft and furthering its development in understanding its capabilities was achieved.

Five main criteria were used in evaluating LDS technology on aircraft and their combined performance for a gas gathering system operation.

Sensitivity or the ability to find the smallest leak size relied on the leak detection technology and the type of aircraft it was mounted on. Many factors influence into a gas plume size such as weather, soil, pipeline operating conditions, wind, etc. This paper does not go into these details but only considers when the conditions are right for a leak to occur.

From the calibration site and gas plume model calculations show that leak rates of 350 to 400 scfh could be detected under N. Texas conditions. Figure 5 shows an actual pipeline leak that had a 0.16 inch diameter hole. This was observed as a typical summer day in N. Texas. This appeared to be the limitation for a thermal imaging camera deployed on aircraft. Whereas, laser and gas sampling based LDS were much more sensitivive and is estimated to detect leak rates around 200 scfh.

The probability of detection for these leak rates is less unknown and would require further testing. However from the results of the field trial, detecting small leaks was not the problem but discerning them from other intereference sources and wind gusts that disperse the gas plume quickly can interfere with the detection, so the probability of detection may be slightly higher than expected.

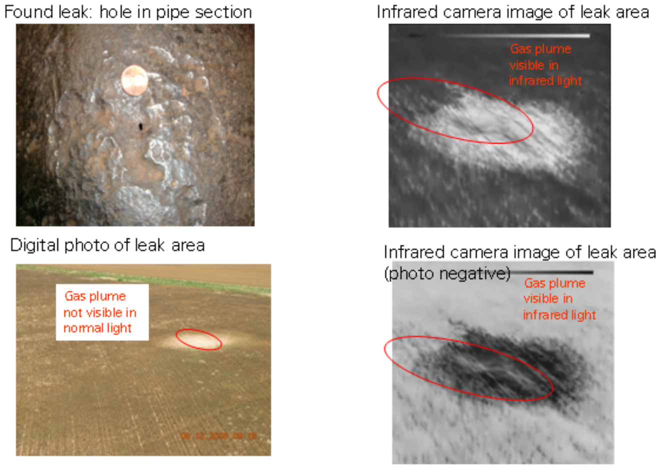

Figure 5 A pipeline leak shown with thermal imaging camera. From top left, externally corroded pipe, thermal image of a gas plume, negative image of the gas plume, and digital image of the same area.

False calls of a LDS are based on its accuracy or its ability to eliminate or reduce the number of alarms which indicate a leak but are not. Some of these LD systems regardless if they are active or passive sensing, must know more importantly where the source of gas is coming from. Other potential gas leaks for nearby operators or natural sources of methane gas, for example, can interfere with the detection of gas leaks from the GGS pipelines. The different types of leaks encountered in the field trial can be found in Table 1.

Table 1 Different types of leaks and their sources.

Leak Types	Source
Staged (known)	Valves releases
	Pipeline releases
Unstaged (unknown)	Production Wells
	Compressors
	Pipelines
	Inteference – gas plants
	Inteference – other operators
	Other – i.e. valves, tanks

In the field trial, false calls ranged from 11 to 20% depending on the LDS technology. There was a clear distinction between the performance of helicopter compared to that of a fixed-wing aircraft and less on the LDS technology. The maneurability, slower flight speeds and lower flight altitudes by helicopters can be attributed to the lower false calls. In some cases these LDS can be too sensitive and conditions at the location of the leak can change making it difficult for ground verification and measurem. This was such a case in which a small leak was found one month later.

Real time reporting was just as important in analysis and assessment of the data collected over the survey. This information also allows some level of qualtitave catergorization of leak sizes as well as more importantly reporting significant sized leaks so that immediate response is taken for locating, shut down and repair of the pipeline. Figure 6 shows an example of real time reporting.

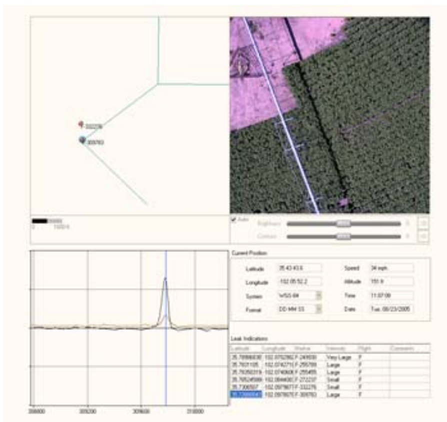

Figure 6 Typical reporting format consisting (starting top left), GPS map of pipeline and leak indications, digital image of area, leak data with GPS coordinates and pertinent data, and methane gas measurement.

Real time reporting of leak detection and their location is of primary importance to address repairs of leaks in a timely manner. The contractor should supply you with a quick summary of leaks found with tagged GPS coordinates recorded on a map. The path of aircraft should be shown on map and/or documented by video to help ground verification and sort out indications that might be on other operators pipelines. GPS coordinates units should be in X-Y, latitude and longitude decimal degrees, or degrees-minute-seconds to reduce the need for location conversions. Additional services, such as survey mapping, real time video and digital photographs can be provided by some of the companies.

Operational safety was another criterion for GGS operations. Since aerial leak detection is relatively new to BP and the risks in using low flying aircraft in its operations still needed better understanding. The field trial allowed us to consider the risk and impact of low flying aircraft in conducting LD surveys on the GGS. Especially the site of this field was characterized by few flying hazards and the majority of the GGS was located in remote rural areas. Furthermore the benefits of using aerial leak detection outweighed the potential consequences of a major leak to occur.

One of the main disadvantages of using gas sampling leak detection system than laser or thermal camera is that the aircraft must fly low enough for the sampling tof the gas plume. As seen in Figure 7, an elevation of 50 feet is required for helicopter flight thus limiting detection of gas plume sizes to 10 MCFD (red line) for the conditions described in figure. The operational safety must be considered for gas sampling leak detection and may be limited to rural, remote areas for detection of small gas plumes.

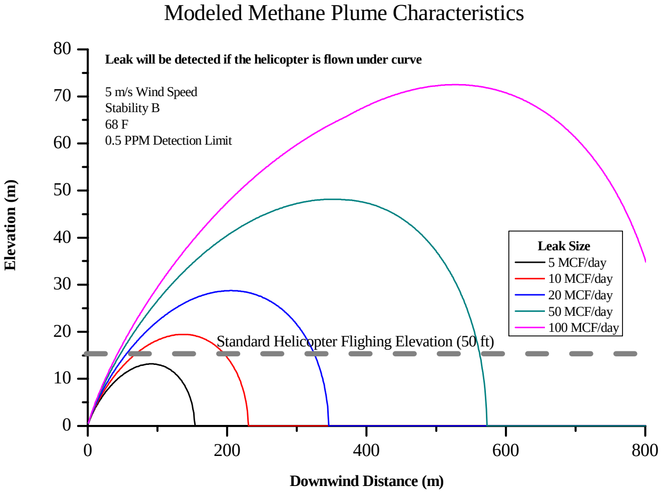

Figure 7 Methane gas plume model for various plume sizes in aerial leak detection (for 5 m/s wind speed).

The last criterion is the cost of leak detection survey. The main cost is attributed to the cost to operate a specific type of aircraft and the amount of flight time required to perform the leak detection survey. The cost to operate a helicopter or fixed-wing aircraft per hour of flight time can be readily found. For GGS this translates from about US$50 to US$100 per mile or more. The lowest cost in this range can be attributed to using a small piston based engine helicopter with a simple GGS pipeline configuration which approximately US$600-850 per hour of flight time. Additional costs can be incurred for additional services for pipeline inspection. Also a cost benefit analysis could be performed base on savings due to loss production.

G. Integrity of GGS Pipelines

Integrity management of GGS pipelines is part of an overall program and the requirements include that the materials, equipment and structures are fit for purpose, avoid loss of containment and maintain structural integrity throughout the lifecycle of the facility. Within this program it should establish safe operating limits for equipment and confirms operation within these limits. The program applies to all engineered equipment from well casing and tubing, through surface and sub-sea flow-lines, production and injection facilities, export systems, structures and lifting equipment.

Efforts in an effective maintenance and risk based inspection to assess the integrity of a GGS, for example its pipelines, will always be a challenge especially when limitations on the available resources, costs and technologies provided to carry out these activities are present. Despite these efforts, leaks can occur and rapid detection of leaks and its known location become increasing more important in assuring the integrity of the pipelines.

Once a leak has occurred leak detection systems can be the first line of defense in which they act as an early detection for escalation controls, i.e. to detect leaks when they are small, so that an assessment and response can be made in a timely manner before a more severe consequence, due to large leak, would occur.

Aerial leak detection can be used as a tool to manage the integrity of GGS pipelines and can compliment other inspection and monitoring tools. In BP's six months of experience in performing aerial leak detection surveys on its GGS pipelines the information gathered on leaks have shown certain pipeline sections more prone to leaks. Leaks were found on same sections of pipeline, in some cases, nearly at the same locations but detected six months apart. These areas have been targeted more effectively by placing the right resources and efforts of the maintenance and inspection plans as well as considering replacement with a new pipeline. The appropriate use of aerial leak detection in a leak detection plan and input of data back into the maintenance and inspection programs can enhance the integrity of GGS.

With ongoing aerial leak detection, we expect to show that the integrity of the pipelines can be improved and that resources and costs will be used effectively and that leak characteristics of all the pipelines in the asset will be better understood.

H. Conclusion

There are many benefits of using aerial leak detection:

Safety - aerial leak detection eliminates the exposure of personnel to the hazards associated with ground based leak detection. Capable of finding small gas leaks before they become large unsafe ones.

Environment - the amount of greenhouse gas emitted to the atmosphere is reduced or eliminated.

Cost & Efficiency - Compared to ground leak detection methods, aerial leak detection is cost effective with no impact to production operations. Also inaccessible areas (i.e. farmland) can be surveyed without interruption to landowner or seasonal delay in inspection.

Integrity – A “step change” in our ability to proactively demonstrate and assure the integrity of our GGS.

The development of leak detection systems deployed on aircraft to monitor for leaks in BP’s gas gathering pipelines show that there is significant potential as mentioned in the benefits but also clearly demonstrates that this tool can be used to manage and assure the integrity of BP’s gas gathering systems. One of the remaining challenges is in the implemention of this technology within BP’s land based gas production operations.

I. Acknowledgements

The author would like to thank the following individuals for their support in the field trial:

George Williamson, BP America, NAG SPU
Michael Orr, BP America, NGL BU
Harvey Lechner, BP America, NGL BU
John Alkire (retired), BP America, EPTG

J. Reference

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