

Final Report

**SURVEY AND DEMONSTRATION OF MONITORING
TECHNOLOGY FOR HOUSTON INDUSTRIAL EMISSIONS
(PROJECT H31.2004)**

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January 12, 2005

ACKNOWLEDGMENTS

The work reported herein was performed under HARC Project No. H31.2004 by the Mountain View, California office of ENVIRON International Corporation. Mr. Alex Cuclis at the Houston Advanced Research Council (HARC) was the project coordinator with Mr. Russ Nettles and Ms. Karen Olson at the Texas Commission on Environmental Quality (TCEQ) providing technical support.

Michael Smylie of ENVIRON directed the overall effort. Mr. Don Robinson, Brian Gillis, Vineet Aggarwal, and Zachary Schaffer of ICF Consulting provided technical information.

The authors wish to acknowledge the cooperation and assistance of the technology manufacturers and marketers that provided technical data, including information and proprietary diagrams, on their various remote sensing equipment and services. Representatives from these companies also provided authorization to the project team for the reproduction of this data for use in compiling this report.

1. INTRODUCTION

In August and September 2000, an intensive field study, called the Texas Air Quality Study (TexAQS), was conducted in the Houston-Galveston area (HGA) to study ozone and other air pollution issues in that region. As part of TexAQS, aerial surveys of chemical species in the atmosphere above the HGA showed higher ozone and ozone-precursor concentrations than would be expected from the emission inventory of volatile organic compounds (VOCs). The findings resulting from the TexAQS study prompted the evaluation of a number of novel approaches to identifying and controlling sources of air pollution.

One such approach is the use of optical gas-imaging devices to identify emissions resulting from leaks in refinery and chemical plant process equipment, which have historically represented a large percentage of the volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from these facilities. Two studies recently conducted in Texas successfully demonstrated that gas-imaging devices offer an operator the ability to monitor process equipment from a distance and identify – in some cases instantaneously – leaking components (of a sufficient mass) within the line of sight of the optical imager.^{1,2} The remote sensing and instantaneous detection capabilities of optical gas-imaging technologies allow an operator to scan areas containing tens to hundreds of potential leaks, thus eliminating the need to visit and manually measure all potential leak sites.

As a follow-up to the above referenced studies demonstrating the effectiveness of gas-imaging devices for identifying equipment leaks, ENVIRON International Corporation was retained in October 2004 by the Houston Advanced Research Center (HARC) to manage a project entitled “Survey and Demonstration of Monitoring Technology for Houston Industrial Emissions (Project H31.2004). The primary objective of this project was to identify, assess, and demonstrate cost-effective monitoring systems and technology to measure integrated (as opposed to process-specific) emissions profiles.

PROJECT APPROACH

To successfully meet the objectives of the project, the study team evaluated a range of remote sensing and air sampling gas detection technologies suitable for identifying and monitoring hydrocarbon leak plumes from petroleum refineries and petrochemical plants as would be found along the Houston Ship Channel. The first step in the project was to determine the different technologies and companies capable of remotely detecting VOC emissions from a large industrial area. As a starting point, a 1999 compendium of sensing technologies developed by

¹ Houston Advanced Research Center. *Measurement and Assessment of Equipment Leak Fugitives in Industrial Ethylene and Other Chemical Sources*. 2003.

² Texas Commission on Environmental Quality. *Development of Emissions Factors and/or Correlation Equations for Gas Leak Detection, and the Development of an EPA Protocol for the Use of a Gas-imaging Device as an Alternative or Supplement to Current Leak Detection and Evaluation Methods*. 2004

ICF Consulting was used.³ This compendium was augmented using personal contacts with people in the industry and a general Internet search.

From these various sources, 29 companies were identified as potentially having remote-sensing technologies suitable for this project review. Upon further review, 21 of the 29 companies were found to have instruments that met the project qualifications. The following is a summary of these 21 companies:

- Four of the companies are based overseas in Sweden and Russia, two are located in Canada, and the remaining 15 are either US-based or have offices in the United States.
- 16 of the companies have technologies that are commercially available.
- Eight companies have technologies (instruments) capable of being operated from an aerial platform.
- Nine companies provided information on an instrument that can transmit a signal to a remote monitoring station.
- 16 companies have instruments with real time measurement capability.
- Six companies have instruments that are fixed-beam (i.e. “fence-line”) monitoring technologies.

The identified technologies were evaluated through the use of a number of criteria including effectiveness, sampling and post-processing time, accuracy, range, safety and utilization, annualized cost and commercial readiness. An evaluation matrix was prepared with multiple sub-criteria in order to compare the different technologies and instruments.

³ ICF Consulting. Compendium of Sensing Technologies to Detect and Measure VOCs and HAPs in the Air, 1999.

5. RESULTS AND DISCUSSION

In this section of the report, evaluation results for remote sensing and air sampling gas detection technologies are presented. In addition, information is provided on several possible applications of these technologies to the upcoming TexAQS II study.

SUMMARY OF RESULTS

Evaluation of each technology was carried out using common scoring criteria developed specifically for this study. Each technology was ranked in the following seven categories: effectiveness, sampling and post processing capability, accuracy, range, safety and utilization, annualized cost, and level of commercial readiness. The scoring of sampling and post processing capability as well as range produced nearly similar results as a large number of devices reported long ranges of effectiveness and near real-time sampling and processing speeds. As a result of this near similarity, technologies were primarily differentiated through their scoring in the other categories. Appendix G shows complete evaluation results and rankings.

Effectiveness

The effectiveness of each technology was scored based on three basic criteria: remote sensing capability, multiple gas detection capability, and leak quantification capability. The remote sensing technologies scoring highest in the effectiveness category were the Differential Absorption Lidar (DIAL) device from Spectrasyne, the Solar Occultation Flux (SOF) device from Chalmers Institute of Technology, and the FTIR from IMACC. Each of these technologies scored maximum points for three basic criteria (i.e., false detection, sensitivity, and resolution). The ability to quantify mass pollutant emissions in the area surveyed sets these devices apart from the others that were examined. The DIAL survey performed by Spectrasyne will scan a plume along several paths and use meteorological data obtained during the scan to calculate mass emissions. The SOF device from Chalmers Institute of Technology works in a similar fashion. It makes several concentration measurements of the plume using light from the sun along with wind speed data that is collected simultaneously to calculate mass emissions. The IMACC FTIR can identify specific compounds and measure their concentrations, in many cases down to low ppb-levels, in both its transmission and passive radiance modes. Many other technologies are able to remotely detect multiple chemical species simultaneously, but these are the only three that can quantify mass emissions.

For air sampling gas detection technologies, the PHASED approach provided by Honeywell scored higher than Ion Optics' IR-ISTM primarily because of its capability to detect multiple gases simultaneously. For the remote sensing and leak quantification criteria, both Honeywell and Ion Optics scored similarly.

Accuracy

Among the remote sensing technologies, the Ophir duoThane[®] system was rated highest in the accuracy category. Similar to the Effectiveness category, Accuracy scoring was also developed based on the three basic criteria of false detection likelihood, sensitivity, and resolution. Ophir's optical remote sensing system had no reports of false detections, a quality that was heavily weighted in this category, and therefore received the top score. The Remote Methane Leak Detector (RMLD) developed by PSI Corporation and marketed by Heath Consultants, ranked just below Ophir. The RMLD also had no reports of false detections but was lacking in resolution. The RMLD is designed to only detect methane, while Ophir's technology can detect and differentiate between both methane and ethane simultaneously. IMACC's FTIR device was ranked equivalent with the RMLD in overall accuracy. The FTIR had top marks in sensitivity and resolution but did have a small occurrence of false detections that lowered its score in this category.

Honeywell again scored the highest among the air sampling gas detection technologies for accuracy. This was based on its sensitivity to a broad range of chemical compounds and its resolution.

Safety and Utilization

Safety and utilization was the broadest category of analysis with rankings for five different criteria: safety, performance under different climatic conditions, equipment portability, delivery and set-up time, and measurement time. Technologies that rank high in this category can be considered very versatile and adaptable.

Among remote sensing technologies, OPSIS scored highest with its DOAS device receiving maximum points in performance under different climatic conditions, delivery and set-up time, and measurement time. This technology can continuously monitor a designated path with practically no adverse effects from the ambient environment. Heath Consultants' Optical Methane Detector (OMD) was ranked second behind OPSIS, reporting high portability and no adverse effects from the ambient environment. Ophir scored third highest with good safety, portability, and continuous monitoring capabilities.

Among air sampling gas detection technologies, Ion Optics scored highest based on measurement time. For all other criteria in this category, both Ion Optics and Honeywell had similar scores.

Annualized Cost of Technology

The annualized cost of each technology was calculated by amortizing capital costs over five years or with 50 applications per year of a service. Among remote sensing technologies, Ophir and Heath Consultants were both found to market relatively inexpensive devices. Ophir's optical remote sensing system was advertised to have a capital cost of approximately \$10,000 or

\$2,000/yr amortized over five years. The OMD from Heath Consultants is marketed with a \$22,000 price tag or \$4,400/yr amortized over five years. The gas detection surveys from Chalmers University of Technology and Spectrasyne were found to have the highest annual costs when performed 50 times per year – approximately once per week.

Both Ion Optics and Honeywell air sampling gas detection technologies scored similarly in this category. Moreover, the micro-electromechanical systems (MEMS) devices from Ion Optics and Honeywell Inc. were found to have the lowest annualized cost of any of the technologies studied. These devices are designed to be purchased in bulk quantities however, and may require a large capital investment to obtain enough sensors to properly monitor a wide area.

Composite Score Based on All Evaluation Criteria

An overall score for each technology was determined using a composite of each evaluation category. Technologies receiving the highest overall score represent those with the best effectiveness, sampling and post processing capability, accuracy, range, safety and utilization, annualized cost, and level of commercial readiness. The following companies were rated highest by technology category:

- Remote Sensing Technology
 - Plume Imaging Technology (including Active and Passive) – Leak Surveys Inc.
 - Optical Remote Sensing Technology (including OP-FTIR, LIDAR, TDLAS, and DOAS) – Ophir
- Air Sampling Gas Detection Technology
 - Honeywell, Inc.

All three of the highest ranked technologies in any category came from the Optical Remote Sensing category. Ophir was rated as having the best overall technology for monitoring a large area, such as the Houston Ship Channel, followed by IMACC and OPSIS. Each of these technologies can detect the concentrations of multiple species simultaneously from a long range. These technologies are also versatile and can be setup in a variety of configurations tailored to monitoring requirements.

A second set of ranking scores were developed using weighting specifically designed for monitoring of an individual plant site rather than the entire Houston Ship Channel area. For the remote sensing technologies, several weighting changes were made; for example, range was deemed less important while sensitivity was deemed more important for monitoring an individual facility. Overall scoring using this alternative weighting showed similar results to the scoring for remote sensing technologies to monitor a wide area. Ophir and IMACC were again ranked as the top two technologies while Unisearch Associate's FTIR device moved up in the ranking to become the third highest ranked technology.

It should be noted that the two air sampling gas detection technologies evaluated (Ion Optics and Honeywell) were only evaluated under one scenario (i.e., a large geographic area). These technologies are best suited for placement within a stationary network around a geographic area since they are “in contact” emission detectors (i.e., emissions have to physically come into contact with a sensor).

CONCLUSIONS

To meet the objectives of this project, over twenty remote sensing and air sampling gas detection technologies were selected for evaluation. Only seventeen devices were ultimately scored based on the availability of a complete set of evaluation data. While the information contained in this report offers a general review of the capabilities of these various technologies and provides a means for assessing the suitability of these technologies for a range of applications, of particular interest in this study are those technologies that can measure VOCs in conditions typically encountered at a refinery or chemical plant, or across the entire ship channel. To do that, the selected technology must demonstrate a broad range of capabilities including portability and the ability to view a range of hydrocarbon emissions.

Based on these criteria, the passive gas plume-imaging camera from Leak Surveys, Inc. and the FTIR system from IMACC represent the technologies best suited for further evaluation at this time. While the Ophir system ranked highest among the optical remote sensing technologies, its ability to only see methane and ethane at this time limits its broader application.