Hazardous Liquids Airborne Lidar Observation Study (HALOS)

Quarterly Status and Progress Report

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In this project, with support of DOT/PHMSA, ITT Industries intends to extend its current Airborne Natural Gas Emission Lidar (ANGEL) technology to create a conceptual design for an airborne hazardous liquid leak detection system. This report consists of five distinct sections: Processed Data from Existing Sensor and Findings; Overview of Software Modifications; Overview of Hazardous Liquids Pipelines; Spectral Characteristics of the Target; and Plume Characteristics.

Processed Data from Existing Sensor and Findings

As was reported in the 15 July Quarterly Status and Progress Report, data was collected in support of HALOS over areas in Kingsville, Texas and Spencerport, New York. Post collection project work has focused on HALOS algorithm implementation and analysis. During this performance period, we processed DIAL data for Propane and generated a series of analysis output visualizations. Output visualizations draped over high spatial resolution imagery will aid an in-depth investigation of the DIAL data and processing algorithm validity. Algorithm implementation and data processing focused on subsets of DIAL returns over bare soil and gas field condensate tanks at the Kingsville site and grass and sand within the Spencerport test site. As part of the analysis, in early October Darryl Murdock and Steve Stearns visited the Pollution Prevention Partnership at Texas A&M Corpus Christi. During this trip we analyzed and discussed early results from the Texas collections. Preliminary results are encouraging for Propane and gas condensate vapor presence/absence, plume size, geo-location and concentration. Data processing and analysis routines continue improving and development of the “Real World Flight Test Report” is well underway.

Overview of Software Modifications

Three algorithms have been coded in support of the HALOS program. Algorithm development was performed in two parts. The first part developed tools for segmenting imagery into regions of like reflectivity. These tools were used to produce test data sets from the Corpus Christi and Spencerport flights. The second part of the algorithm development produced an optimized detection algorithm. Additionally, two DIAL algorithms, each using a different selection of two out of the three ANGEL wavelengths, were coded for comparison. The algorithm suite was used to detect propane and methane plumes. Methane plumes were used as a confounding signal to ensure we did not merely find a plume shaped anomaly in the data, but in fact found the target gas.

Preliminary results appear very promising. The optimized algorithm seems to have done well in detecting the plume**s** of released gas.

Overview of Hazardous Liquids Pipelines
The analysis of the GC-MS data from gasoline obtained for the HALOS project was extended during this period to provide an analysis of diesel fuel. The study has included an effort to describe the evolution of the vapor concentrations as the sample aged as it looses its more volatile components. The evaporation rate of the gasoline was also examined to study the loss rate of the first few volatile species in the presence of solar insolation.

The expectation has been that the vapor spectra of gasoline and diesel fuel would be dominated by a few vapor components and that the subsequent identification of the 5 most likely major components may be sufficient to characterize the vapor plumes. It was found that although gasoline has more than 60 individual components, the N–Pentane and I-Pentane dominated the vapors released from a gasoline leak during the early stages of evaporation. Evaluation showed that the spectral features of these species do exhibit the major characteristics observed in the spectra of saturated gasoline vapor. Thus, it appears that gasoline detection may be simplified by only requiring consideration of few components. However, the detection and identification of gasoline is complicated by the fact that its spectrum does not contain unique and sharply defined optical features, like those found in natural gas.

The volatile fraction of the diesel fuel is miniscule compared with the gasoline and the vapor detection appears problematic. GC-MS analyses of a consumer-brand diesel fuel identified more than 900 different components in this complex hydrocarbon mixture. Most of these components are heavy and are not expected to volatilize at atmospheric conditions. Upon reaching the ground surface, it is possible that these compounds may volatilize into the immediate vicinity of the leak. The fraction of volatile components in the diesel sample is about 15.93%. This fraction is much smaller that the fraction of volatile components found in gasoline, which is more than 40%. Currently, we are performing experiments to determine the rate of volatilization of these fuels under atmospheric conditions, and measure the amount of each component volatilized over a few hours and days. This study will provide information to characterize the emissions from the leak site and thereby, determine the most effective “marker” components for each fuel.

Spectral Characteristics of the Target
In addition to the approximately 100 targets measured prior to the July 15 Progress Report, backscatter MWIR reflectance spectra of 40 summer ground covers (vegetation, soils, etc.) were measured in the July 28 – August 2 timeframe, and 34 fall ground covers (color turned in vegetation) were measured October 3 – October 6. We believe this gives a reasonable collection of MWIR backscatter reflectance spectra of groundcovers spanning the 4 seasons.

Finally, three experiments were completed to examine the backscatter spectra associated with a hazardous liquid spill. Two of the experiments were measurements of soil contaminated with diesel fuel and with gasoline; in the latter case measurements were obtained every 3 minutes after addition of gasoline for ½ hour to examine the time dependence associated with evaporation of the liquid in the soil. The key feature of backscatter spectra of soil wet with liquids (independent of the liquid) is a marked decrease in reflectance across the entire MWIR. Just as in the visible, the entire MWIR becomes "darker" when the soil is wet. It is only after the liquid begins to evaporate and the overall reflectance begins to increase that the continuing low reflectivity at the wavelengths that the liquid absorbs becomes obvious. Said another way, soil wet with liquid has low spectral contrast for the liquid absorbed; as the soil dries, the contrast with the spectrum of the contaminating liquid increases A third experiment measured the backscatter spectra of dry soil just downwind of soil contaminated with gasoline.

Plume Characteristics

Plume modeling efforts are currently underway at CPP in Fort Collins Colorado where time dependent measurements are being taken of simulated gasoline/diesel vapor releases in a controlled wind tunnel. These data along with computer model simulations from both CHARM and ITT AES should produce a compelling picture of what sort of real world plume densities we can expect to encounter from a gasoline pipeline spill. The wind tunnel and higher-order accurate computer models, when compared to CHARM should allow for increased understanding of the success of and any limits to using CHARM as a predictive analytical tool. The capturing of time dependent wind tunnel data from this current modeling effort will also increase our fidelity in determining the detectability of a gas leak. Because the ANGEL sensor detects an instantaneous integrated path length the instantaneous measurement of a given column density of gas as a function of time will be a more direct comparison with the performance of our sensor.

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