Bay Area Air Quality Management District
939 Ellis Street
San Francisco, California 94109

APPROVED MINUTES

Advisory Council Regular Meeting
Joint Public Health & Technical Committee Meeting
1:30 p.m., Monday, June 30, 2003
4th Floor Conference Room

1. **Call to Order – Roll Call.** 1:36 p.m. Public Health Committee Quorum Present: Brian Zamora, Chair, Elinor Blake, Ignatius Ding, Victor Torreano, Linda Weiner. Technical Committee Quorum Present: Robert Harley, Ph.D., Chair, Louise Bedsworth, Ph.D., William Hanna, Stan Hayes, John Holtzclaw, Ph.D. Technical Committee Members Absent: Sam Altshuler, P.E., Norman Lapera. Other Advisory Council Member Present: Irvin Dawid, Air Quality Planning Committee.

2. **Public Comment Period.** Irvin Dawid, Air District Advisory Council, referred the Committee members to a paper that he received at a recent Local Government Commission conference in San Diego, California, entitled "Urban Sprawl and Public Health" by Howard Frumpkin, M.D., Ph.D.

3. **Approval of Minutes:**

   (A) Public Health Committee Minutes of May 19, 2003. Mr. Torreano moved approval of the minutes; seconded by Ms. Blake; carried unanimously.

   (B) Technical Committee Minutes of May 29, 2003. Dr. Holtzclaw moved approval of the minutes; seconded by Mr. Hanna; carried unanimously.

4. **The Role of Optical Remote Sensing Technology in Flare Emission Evaluation.** Ted McKelvey, Terra Air Services Project Coordinator, stated he has been the Project Manager for the ConocoPhillips Refinery project since 1998. He described how Optical Remote Sensing (ORS) equipment projects a beam of infrared (IR) or ultraviolet (UR) light to measure fugitive emissions along fencelines or near process units, emissions from vehicle or ambient air content. Along facility fencelines, ORS is used for source identification/separation, early detection and employee safety. The data generated by the ConocoPhillips refinery fence line monitors can be accessed via dial-in and will soon be posted on the website of the Contra Costa County Health Department.

   The application of ORS monitoring systems applied to refinery plume flare evaluation would be limited by several factors: (a) the requirement to have reflectors or transmitters behind the plume, (b) the relatively high elevation of the flare stacks, (c) the distance it takes for the flare plume to reach ground level, (d) the difficulty in intercepting the plume properly. Laser Detection and Ranging (LIDAR) systems have been used to monitor flare plumes. However, these systems are limited to measuring a single compound, and they are highly expensive. Fourier Transform Infrared Spectroscopy (FTIR) is currently being developed by the Environmental Protection Agency (EPA) to produce three-dimensional plots of a near ground level plume, and in Texas efforts are underway to use passive FTIR as a means of measuring the content of a variety of compounds from flare stack emissions.

Robert L. Spellicy, Ph.D., President, Industrial Monitor & Control Corporation (IMACC), Round Rock, Texas, presented "Tomographic Inversion and Flare Efficiency by Passive FTIR." He displayed a diagram of a waste site in which radial plume mapping was conducted to identify emission hot spots. Infrared beams were transmitted to corner reflectors distributed in angular and radial patterns at and above ground level. The reflectors were fixed on grid vertices and the readings from them provided a series of measurements of the source emissions. This type of data allows for inversion of the individual integrated path measurements to produce a three-dimensional mapping of the plume. With the addition of wind field information one can determine total flux. Tomographic inversion can be used to map emissions from an area source or the plume at a refinery fence line.

EPA recently conducted validation tests of this system by distributing corner reflectors throughout a region. This region had controlled point sources as well as a simulated area source (soaker hose fed with cal gas). EPA then used the measured FTIR data in the tomographic inversion software, to see how well the software could replicate the actual measurements. For the point sources, the accuracy of the software in locating the position of the release was within one-half of a pixel (about 2.5 meters), and it recovered 93% of the total emissions. Lawrence Livermore Laboratory has conducted similar optical measurements for homeland security purposes, using multiple beams in a comprehensive crisscross pattern indoors to map possible releases in public buildings. However, this system is complex and very expensive.

EPA also used optical scanning to measure emissions of methane and ammonia at a Kentucky landfill. The system in this case had a computer-controlled scanner that measured transmission to a wide array of corner cubes on site. A single set of scans to all corner cubes can reproduce the source distribution and hot spots, but several cycles are usually averaged to account for source variabilities. Several hot spots in the landfill were identified. In another test, vertical paths were used to look at downwind plumes from a chicken farm before and after a waste area was covered. After the waste area was covered, ammonia emissions were seen to reduce from 0.33 to 0.07 grams/second with the methane remaining essentially unchanged at 0.62 to 0.67 grams/second. EPA is in the process of purchasing additional optical systems to evaluate landfills and other sources, and developing methodological protocols for this type of optical measurement method.

In terms of practical limitations of open path measurements, optical signal quality decreases as the distance of the measured path increases. Integrated path measurement works best between about 300 - 500 meters one-way and remains adequate up to approximately 700 meters. Measuring at distances greater than this will encounter significant interference by atmospheric constituents, particularly water vapors and carbon dioxide and the analysis of many compounds will suffer. The longer pathways generally require splitting the path up to maintain optimum detectivity. Monostatic systems (corner cube plus transceiver) if converted to bi-static systems (combined transmitter and receiver) will improve the signal-to-noise ratio perhaps 10 to 100 times. The path is cut in half, however, so this can degrade minimum detection levels in shorter path systems.

In reply to Committee questions, Dr. Spellicy noted:

- tomographic inversion works best along unobstructed pathways where there is an unobstructed path allowing for integration along the path. This type of scenario also allows for greater ability to measure total flux. In its vertical path configuration, it is designed primarily to provide maps of emissions leaving a site. Total flux can also be determined but this depends on the frequency of measurements, how often they are averaged, as well as the impact of wind speeds. Data from these systems can provide input to citizen warning systems or it can be used to provide evidence after a release for purposes of source attribution.

- Elevation of corner reflectors depends on the source. It would be difficult to suspend corner reflectors at refinery stack heights of 300 feet. Scissor jacks can elevate up to a maximum of 50-60 feet. Around some refineries, nearby hills allow the siting of a measuring device to within 50-60 feet of the top of the flare. However, this could access a high plume rise.

- tomographic models map emissions and provide concentration estimates at specific points within the course contour. The number of compounds measured does not entail a practical trade-off in routine operational feasibility. Rather, the challenge is to generate the spectrum at a high enough signal-to-noise ratio to be able to discern a sufficiently low concentration.

For major releases shorter averaging periods could be used to achieve a better temporal resolution and early warning. The speed of response is a function of the threshold of lowest concentration. FTIR gathers one spectrum per second. These scans are averaged to produce a higher signal-to-noise ratio in the spectrum. This allows smaller absorption features to be detected and thus lower concentrations of constituents of concern. Optical measurement systems are now sufficiently capable that they can be set up to discern both routine low-level data and high concentrations from a release. FTIR detection limits for emergency response are governed somewhat by the strength of absorbance of each measured gas. Through variable sequencing, five-minute averages could be used to detect fugitive emissions and low-level ambient concentrations along the fence line; and shorter scanning averages could be used to detect higher concentrations expected during an accidental release. Short averaging periods could be used to identify high emission levels. These high speed spectra could be averaged together to increase the signal-to-noise ratio allowing for post-process evaluation of low-level emissions. Longer averaging time allows for identification of consistently low-level emissions, although transient emissions would be less detectable.

New algorithms are now available that simultaneously allow for the evaluation of the infrared spectrum automatically correcting and refining the analysis procedure as needed. At a toxic waste site in Texas with relatively low emission levels, the system corrects for changing atmospheric water vapor due to seasonal variation in humidity. This is an important improvement that eliminates residual effects that usually interfere with the analysis.

Monostatic scanning equipment and accompanying software cost about $100,000; pre-fabricated equipment housing from $20,000 - $30,000; and replicated corner cubes from between $6,000 - $10,000 each. Mr. McKelvey added that annual maintenance and data analysis for two monostatic systems with a total of four paths would cost between $100,000 - $200,000.

Dr. Spellicy stated that LIDAR technology is excellent for measuring plumes, but it is limited to a single compound and costs approximately $1 million per unit. The Alberta Research Council has contracted with Spectrolite from the United Kingdom to perform measurements on SO_2 with a multiple-laser LIDAR to assess wildcat flares in Alberta. When new wells are drilled at these Alberta oil fields, the gases are sent to a flare while testing on flow, and pressure is conducted. The Alberta ambient air quality regulations require that emission levels from a plume when they reach ground level must be below the ambient air quality standards. Use of a LIDAR allows for mapping of the plume from the flare measuring concentration as a function of distance from the flare. This should allow LIDAR to assess if the regulations are being met when the plume reaches the ground.

Passive FTIR measurement of flare efficiency is underway in Texas to identify ozone precursors near industrial facilities. Houston is an ozone non-attainment area. NASA fly-bys identified hot spots downwind of certain facilities that could not be accounted for by current emission factors.

The issue was whether variance in normal flare operations at facilities affected such hot spots. FTIR should allow for the continuous, unmanned measurement of combustion and destruction efficiency of elevated flares in near real-time. The Texas program will demonstrate this and determine the measurement accuracy of such a system. The State of Texas is working on a protocol for continuous FTIR monitoring for flare measurement. This effort is based on emission spectroscopy. When gases are heated they emit radiation with the same infrared signatures as exhibited in their absorption spectrum. Therefore, hot gases emitted by a flare can be identified and quantified by measuring the flare radiant signature. The FTIR signal derives from measurements of background radiance, flare radiance, atmosphere path radiance and atmospheric transmission. Natural background radiance and atmospheric temperature are negligible. The major measurement is then the radiance of the plume as transmitted through the air.

Dr. Spellicy displayed spectral signal charts of several plumes showing emissions of organics and hydrocarbons, with water content and CO_2 content carefully distinguished in each. Comparisons with reference spectra and temperature provide the measurement criteria essential to this process. The measurement of combustion efficiency requires the quantification of carbon monoxide, carbon dioxide and organics. CO, CO_2, and an approximation to total organics is comparatively easy to determine, so combustion efficiency can be measured. Total hydrocarbons can be approximated by calibrating against a mix of heavy organics or using a representative heavy organic. The measurement of destruction efficiency requires analysis of individual organics and this is more difficult. Speciation of non-methane organics is possible for the lighter compounds (< C5).

Atmospheric path transmission between the FTIR and the flare is needed to correct the observaions for atmospheric effects. This transmission can be measured by observing an infrared source over a horizontal path from the FTIR to the flare base. This signal is then corrected by measuring radiance with the black body removed which accounts for any atmospheric path radiance (this is usually very small). This path transmission is then used to deduce gas concentrations in the horizontal path, which in turn are used to compute slant-path atmospheric transmission to the flare exhaust. Flare radiance is measured with FTIR directly. An iterative calculation of flare temperature and its opacity is then performed using the intervening atmospheric transmission to correct for the air path. This produces concentrations of all compounds observed in the plume.

The Texas Flare Measurement Program will measure flare combustion efficiencies up to 99.95%, and destruction efficiencies for highly reactive organic compounds of concern in ozone production. Program phases include analytical simulation to assess maximum observable efficiency and miniium detectable concentration levels for organics, and controlled source-emission tests to demontrate the accuracy of the inversion process. A plume generator spiked with typical gases at accurately known concentrations will be measured from a moderate distance with FTIR. Field tests will follow to scan several industrial flares to assess combustion/destruction efficiencies.

5. **Committee Member Comments/Other Business**. Ms. Blake stated that at the most recent Public Health Committee meeting in Rodeo, it was good to see several District field staff in attendance.

6. **Time and Place of Next Meeting**. 1:30 p.m., Monday, August 11, 2003, 939 Ellis Street, San Francisco, California

7. **Adjournment.** 3:06 p.m.

James N. Corazza
Deputy Clerk of the Boards