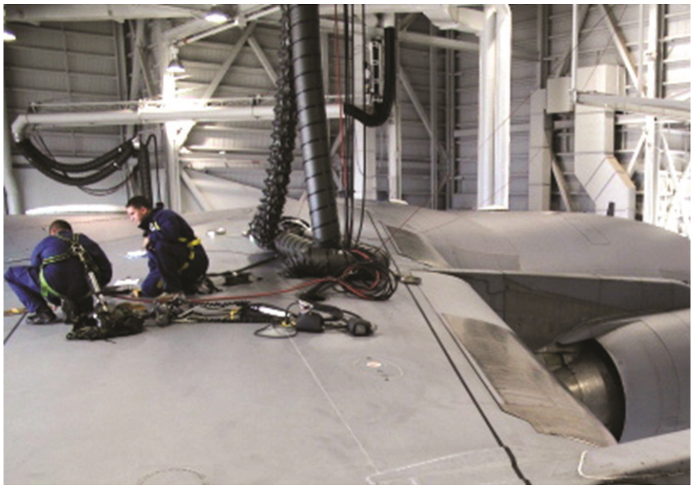
PHOTOIONIZATION DETECTORS (PIDS) AND AIRCRAFT WING TANK ENTRY



Aircraft maintenance requires workers to enter confined spaces that contain jet fuel vapors. As with all confined spaces, gas monitors are required to confidently decide if the atmosphere is safe for worker entry. Because of the physical qualities of jet fuel, specialized gas monitoring techniques should be considered.

THIS APPLICATION NOTE ADDRESSES THE FOLLOWING:

- Theory, operation and limitations of conventional catalytic bead LEL (Lower Explosive Limit) sensors as they pertain to accurate measurement of jet fuels
- Advantages of photoionization detectors (PIDs) as an optimal solution for measuring jet fuel vapors at both toxic and explosive levels as well as other chemicals commonly used in aircraft maintenance

Potential Users

- Aircraft Maintenance Teams
- Aircraft Manufacturers
- Jet Fuel Manufacturers
- Municipal Airports

WHY NOT USE A CONVENTIONAL LEL SENSOR?

While jet fuel is flammable, catalytic LEL sensors found in virtually every confined space monitor do not have enough sensitivity to accurately measure jet fuel. Furthermore, heavier hydrocarbons, such as jet fuels, have a hard time diffusing onto the LEL sensor bead through the flame arrestor, so in some cases, the LEL sensor may not respond to jet fuels at all. Workers can often see and smell jet fuel when in a wing tank, yet the LEL sensor would not detect it. This can seriously undermine workers' confidence in their monitor.

LEL Sensors Are Designed to Measure Methane

LEL sensors were originally designed to solve the problem of measuring methane levels in coal mines. Most LEL sensors use a Wheatstone bridge to measure the heat released when a flammable gas burns on a catalyst bead. The temperature rise causes a change in resistance, which is measured and converted to % LEL.

LEL Sensors Simplified

A Wheatstone bridge (catalytic bead) sensor is simply a tiny electric stove with two burner elements. One element has a catalyst (such as platinum) and one doesn't. Both elements are heated to a temperature that normally would not support combustion. However, the element with the catalyst "burns" gas at a low temperature and heats up relative to the element without the catalyst. The hotter element has more resistance and the Wheatstone bridge measures the difference in resistance between the two elements. Effectively, this sensor measures the heat released when a gas burns.

LEL Sensor Limitations

Four main factors affect the performance of Wheatstone bridge LEL sensors in a wing tank entry environment:

1. Gases burn with different heat outputs.

2. Gases have different LEL values, so some gases have more molecules present than others at the same %LEL.

3. "Heavier" hydrocarbons have difficulty diffusing through a flame arrestor to reach the LEL sensor.

4. Chemicals commonly used in aircraft maintenance can poison LEL sensors.

Overall Sensor Response

The overall sensor response is a combination of the first three factors. If the gas burns relatively hot, the response will be stronger. If the gas has a high LEL concentration, more gas will be present for a given %LEL and the response will be higher.

If the gas is "heavy" (high boiling point and flash point), the diffusion rate is slower and less gas gets to the sensor per unit time, causing a weak response. The metal frit flame arrestor that limits the diffusion is necessary to make the sensor intrinsically safe and prevent the hot sensor itself from igniting an explosion. It does not prevent gases like methane, propane and ethane from reaching the Wheatstone bridge. However, it severely limits the diffusion of heavy hydrocarbons like jet fuel, diesel, and some solvents.

The overall sensitivity of various gases compared to methane is listed in the table that follows. For example, ammonia has a higher response than methane because both are light gases, but the LEL for ammonia is higher. Jet fuel burns "hotter" than methane, but the overall response is much weaker because Jet Fuel is much heavier and has a much lower LEL. If an LEL monitor is calibrated on methane and then is used to measure jet fuel vapors, the monitor will theoretically display less than one third of the true reading. In some practical cases, we have found even lower response with Jet fuels and found that LEL sensors could not read diesel fuel vapors at all.

Gas/Vapor	% Vol. accounting for 100% LEL	LEL Sensor Sensitivity (%)
Acetone	2.2	45
Ammonia	15.0	125
Benzene	1.2	40
Hexane	1.1	48
Jet Fuel	0.8	30
Methane	**5.0**	**100**
MEK	1.8	38
Propane	2.0	53
Toluene	1.2	40

LEL readings can be corrected by choosing calibration gases that are more appropriate to the gas that you are measuring. It is impossible to make a compressed gas standard for jet fuel, however. Therefore, it is recommended that a "surrogate" calibration method be used.

The chart above shows that the LEL response of hexane is much closer to jet fuel than methane. Some manufacturers calibrate their LEL sensors to hexane for this reason. However, the response to jet fuel is just 68% of that for hexane. Therefore, when calibrated to hexane and reading 10% of LEL in a space containing jet fuel vapors, the real reading would theoretically be 16% of LEL. Testing by independent labs like TRW has verified that Wheatstone bridge sensors do not have appropriate sensitivity for jet fuel. Therefore, even when their output is boosted to allow for the low response to jet fuel, Wheatstone bridge LEL sensors lack the sensitivity for measuring at the jet fuel levels necessary to protect workers making confined space entries.

LEL Sensor Poisons and Inhibitors Used in Aircraft Maintenance

Under the best of situations it is difficult for catalytic bead LEL sensors to measure jet fuel vapors. To make matters worse, chemicals commonly used in aircraft maintenance can seriously degrade LEL sensor performance.

- The most serious poisons are silicon compounds. These compounds are used in a wide range of products, including lubricants, adhesives, silicone rubbers (including caulking and sealant compounds), and others. Just a few parts per million (ppm) of a silicon compound are sufficient to degrade the sensing performance of a Wheatstone bridge LEL sensor.
- Chlorinated hydrocarbons are another common group of chemicals that degrade LEL sensor performance. They are frequently found in solvents, including degreasing and cleaning agents used in and around aircraft. See Technical Note TN-144 for more information on LEL sensor poisons and how to handle them.

PID: A Better Jet Fuel % LEL Sensor

PIDs are highly-sensitive hydrocarbon detectors uniquely suited to measuring a hydrocarbon mixture like jet fuel. Best-in-class gas monitors equipped with a PID sensor are accurate, compact, rugged and well-suited for the aircraft maintenance environment.

As a general rule, wing tank entries should not be made if the concentration of jet fuel in a wing tank is over 10% of LEL (or 800 ppm of jet fuel vapor). A PID sensor has a much stronger response to jet fuel than an LEL sensor, so the PID readings are going to be more consistent and accurate for a decision at 10% of LEL.

PIDs Protect Maintenance Personnel from Chemical Exposure

Many chemicals are used in aircraft maintenance, including paints, degreasers, and solvents. The PID is a total hydrocarbon analyzer that measures all of these chemical vapors. While a PID can't differentiate among hydrocarbons, if the PID alarm is set for the "worst" chemical, then a worker will be safe in the presence of all the other chemicals.

Measuring Jet Fuels for Toxicity

The ACGIH (American Conference of Government Industrial Hygienists) recently established an 8-hour TLV (threshold limit value) of 200 mg/m3 (approximately 35 ppm) for kerosene products. Most jet fuels are kerosene mixtures that fall under this exposure limit. In order to attain this level of protection, confined space monitors that measure jet fuel in low ppm levels are required. PIDs offer a compact, reliable solution to the problem of protecting technicians who have to work in or around jet fuel. Catalytic bead LEL sensors have a lower detection limit of about 1,000 ppm for kerosene so they cannot possibly measure in the TLV range.

PID Action Levels

- Worker can enter wing tank without respiratory protection if PID reads below low alarm (35 ppm)
- Worker can enter wing tank with respiratory protection if PID sensor reading is above low alarm but below high alarm (between 35 and 800 ppm)
- Worker cannot enter wing tank if PID displays any high alarm (above 800 ppm or 10% of LEL)

PID BENEFITS FOR AIRCRAFT MAINTENANCE

A PID has the ability to measure jet fuel at levels below 1 ppm. No other technology currently available has the ability to reliably measure jet fuels at these low levels (for more info on PIDs, reference RAE Systems publications AP-211: "PIDs for Continuous Monitoring of VOCs" and Technical Note 106: "Correction Factors, Ionization Energies and Calibration Characteristics"). This unique ability provides the following benefits for aircraft maintenance:

Get into wing tanks sooner.

Measuring at ppm levels allows workers to enter wing tanks as soon as levels drop below 35 ppm rather than waiting a prescribed period for mechanical ventilation to remove fuel vapors (Boeing recommends ventilating for 24 hours). This reduces aircraft time on the ground and can dramatically decrease total maintenance costs by increasing aircraft availability.

Ventilation does not assure that all vapors are removed.

Measuring at ppm levels can protect workers while they are in a wing tank without wearing respiratory protection, if temperatures rise and pools of fuel start to evaporate.

Reduce or eliminate facemask usage.

Many wing tank entry programs call for the use of organic vapor masks to protect workers. But these masks reduce worker efficiency, particularly when crawling in tight, baffled wing tanks. Often they are not worn, because they are cumbersome, and workers go unprotected. The PID allows workers to enter wing tanks without a mask, yet know they are completely safe.

Reduce or eliminate colorimetric tube usage.

The PID's merits as a VOC monitor make it a simpler and more cost-effective solution for taking frequent measurements of the VOC's used in aircraft construction and maintenance than colorimetric ("Draeger") tubes.

Track Down Fuel Spills.

Traditionally, environmental firms have been called in to assess the damage caused by inadvertent fuel spills. The PID used for worker protection can also be used to survey soil and water for fuel contamination.

EFFECTS OF NEGATIVE PRESSURE ON PID, LEL, CO AND H_2S SENSORS

RAE Systems performed testing on the MultiRAE to evaluate the performance of the PID, toxic, combustible and oxygen sensors in the MultiRAE under negative pressure conditions found during wing tank leak testing. Based on this test data, the PID, oxygen and toxic sensors were not affected significantly by negative pressure of -2 psi. The combustible sensor saw a slight drop of sensitivity by about 5% under such negative pressure conditions.

Never Use Tygon Sample Tubing for Jet Fuel

Because Tygon sample tubing quickly absorbs jet fuel, it should never be used when sampling from spaces that contain jet fuel. Only metal, Teflon, or Teflon-lined Tygon tubing should be used.

PIDS: THE NEXT GENERATION OF GAS MONITORING FOR THE AIRCRAFT INDUSTRY

PIDs provide an accurate, reliable poison-resistant means of measuring gas vapors for both explosivity and toxicity. Their chemical resistance coupled with superior sensitivity to heavy hydrocarbons, like jet fuel, makes them the better choice for measuring jet fuel LEL, compared with catalytic bead LEL sensors, which filled this role in aircraft maintenance in the past. The US Navy, US Air Force, Air Command Canada and many commercial carriers and maintenance facilities have used PIDs as part of their confined space entry programs for over 10 years.

RAE SYSTEMS PIDS FOR THE AIRCRAFT INDUSTRY

ToxiRAE Pro PID

An affordable, lightweight PID that fits into a shirt pocket and can easily fit into cramped wing tanks. The ToxiRAE Pro PID is for those who already have a confined space monitor but need the benefits of measuring ppm levels of VOCs such as jet fuel.

MultiRAE Multi-Gas Monitor with PID

The PID (VOC) detector, in addition to oxygen, LEL, two toxic gas sensors like CO and H_2S, and an internal pump make it ideally suited for all aircraft applications:

Military-Grade. Independently tested and certified to comply with MIL-STD-810G performance standard

Next-Generation PID Sensor. Zero to 5,000 ppm range – broadest in its class; 0.1 ppm resolution (Isobutylene equivalent); fast response time

Extensive On-Board Gas Libraries. Cover 190 VOCs and 55 combustible gases (including jet fuels)

Wireless Improves Safety. An attendant can have remote wireless access to the real-time readings and alarm status of the monitor used inside the wing tank and can call for help quickly in case of emergency

Man Down Alarm with real-time remote wireless notification

Continuous Datalogging. 6 months for 5 sensors, 24x7

Rugged Design. Durable housing. Stainless steel face plate. Drop-tested for CSA approval. High resistant to EMI/RFI

High-Quality Backlit "Flippable" Display. Easy to read under any lighting conditions. Content automatically "flips" for convenient viewing if the instrument is used upside down

Powerful Built-in Pump. Supports remote sampling from up to 100 ft. (30 m). Shuts off and alarms when a blockage is detected to avoid sucking in liquids

Negative Pressure Tested. Unite performs under -2 psi; useful for leak detection testing

Multiple Powering Options. Rechargeable standard or extended Li-ion or alkaline batteries for up to 18 hours of runtime

Easy Maintenance. Replaceable sensors, pump, and plug-and-play battery. Fully automatic testing and calibration with the AutoRAE 2.

REFERENCES

Carol J. Maslansky, Steven P. Maslansky: Photoionization Detectors in *Air Monitoring Instrumentation*, Van Nostrand Reinhold, New York, 1993

Permissible Exposure Levels for Selected Military Fuel Vapor: Committee on Toxicology, National Research Council

NIOSH: P*ocket Guide to Chemical Hazards*, NIOSH Publications, Cincinnati, OH, 2004

ACGIH: Guide to Occupational Exposure Values, ACGIH, Cincinnati, OH, 2004

RAE Systems: Technical Note TN-106: Correction Factors, Ionization Energies and Calibration Characteristics

RAE Systems: AP-211: PIDs for Continuous Monitoring of VOCs

RAE Systems: TN-144: Handling LEL Sensor Poisons