Design and Development of Airlock Contamination Detection Kits for the Space Shuttle and International Space Station

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NASA White Sands Test Facility (WSTF) has designed and developed toxic vapor detectors for flight applications. Three types of detectors are discussed in this paper: (1) a Draeger-Tube® encapsulation device (DTED) that detects parts per million (ppm) levels of ammonia (NH_3); (2) a detector using a gold salt (potassium tetrachloroaurate), which changes color from yellow to purple on exposure to hydrazines, that detects monomethylhydrazine (MMH) and unsymmetrical dimethylhydrazine (UDMH); and (3) a prototype detector for UDMH fuel/oxidizer reaction products (UFORP) that, after design and testing, is ready for flight qualification when needed. The first two vapor detectors are now included in airlock contamination detection kits on the International Space Station (ISS).

Extravehicular activity (EVA) operations sometimes require astronauts to move along translation paths near thrusters, thus placing them at risk of exposure to MMH or UDMH as a residual or from leaks in the thruster valves. Some ISS EVAs also require disconnecting and connecting NH_3 coolant lines, and leaking NH_3 can contaminate EVA suit materials. All of these compounds are toxic and must be under spacecraft maximum allowable concentration limits within the habitable areas of the shuttle or ISS. In a case of suspected contamination, the sampling protocol at the end of an EVA requires astronauts to enter the airlock, repressurize it to 5 psia, and then check for residual compounds using the contamination detection kit. MMH and UDMH require a 10-minite sample, and ammonia requires 3.5 minutes at the 5-psia hold pressure.

Draeger-Tube® Encapsulation Device

Draeger-Tubes® are sealed glass tubes containing a color change reagent that changes color when exposed to the chemical of interest. The length of the color change can be used to determine the concentration of the chemical. Normally, the tube is opened on each end using a tool that scores and breaks off the tips, thus producing small sharp pieces of glass from the broken ends. To eliminate problems of handling and floating orbit debris, WSTF devised a DTED fixture (figure 1). The DTED incorporates anodized aluminum end caps to hold the Draeger-Tube® within a clear Lexan® sleeve. A flow restrictor is installed at the outlet end to limit the nominal flow to 50 sccm and provide for a distinct color front in the tube. Viton® O-rings inserted into a groove in each end cap seal the Draeger-Tube® in place. Tether rings, mounted on the end caps, open the flow path for sampling when broken off. The DTED is assembled under an inert nitrogen atmosphere to prevent moisture and air from degrading the color change reagent over time.

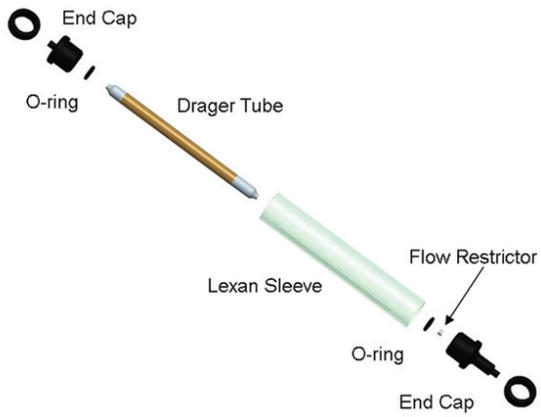

Fig. 1. *Exploded view of the Draeger-Tube® encapsulation device (DTED).*

The ISS airlock contamination kits are supplied with prepared DTEDs. After the airlock has been repressurized at 5 psia for 10 minutes, an adaptor is placed over the airlock manual pressure equalization valve (AMPEV) and the opened detector is inserted in the adapter. The AMPEV is then opened and air is drawn through the detector and out to an external vent. Figure 2 provides a

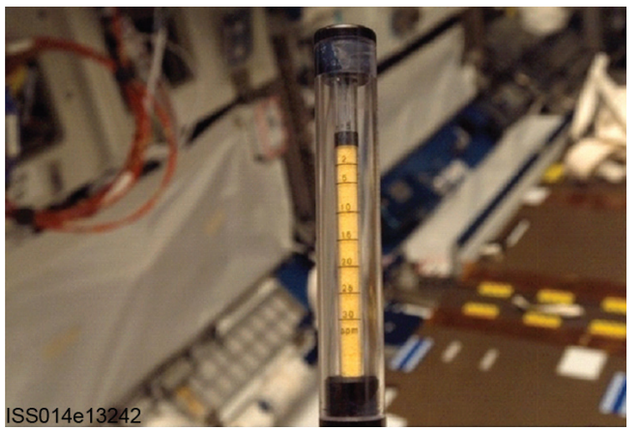

Fig. 2. *A used DTED floating in the ISS airlock.*

photograph of a used DTED floating in the ISS airlock after sampling (photo by Astronaut M. Lopez-Alegria).

Gold salt detector

WSTF developed a detector for the colorimetric determination of trace hydrazine, MMH, and UDMH vapors. In this application, a filter treated with potassium tetrachloroaurate is reduced to elemental gold by the hydrazine fuels, resulting in a purple or grey coloration on the pad. The intensity of the color change is proportional to the concentration of hydrazine, MMH, or UDMH, and users determine this concentration by comparison to a color reference chart. The flight-certified gold salt detector for the ISS consists of the treated filter pad with a porous backing, a pad holder with tether holes, and a retaining cap (figure 3). NASA includes gold salt detectors and the color reference chart in ISS airlock contamination detection kits. For use, the detector is removed from its protective wrapper and placed in the AMPEV adapter, and a sample is pulled through the detector for 10 minutes. The user compares the resulting color with the color reference chart to determine whether the concentration is above or below a critical concentration.

Fig. 3. *Gold salt detector showing parts of the assembly, packaged for flight, and the color card.*

UFORP detector

This protoype detector combines two commercial off-the-shelf technologies: a U.S. Department of Justice-approved presumptive forensic field test method for methamphetamine, and a nitrite test strip for water quality. The prototype detector indicates dramatic color changes in the presence of the two components of UFORP, dimethylamine and nitrite, both of which are toxic in an airlock environment. The methamphetamine test kit is a durable plastic pouch containing reagent ampoules that, when broken and mixed, change color in the presence of a secondary amine (although it is a much smaller molecule, dimethylamine, like methamphetamine, is a secondary amine). The user removes a clip to open the pouch, adds the UFORP material, and closes and clips shut the pouch. Nitrite concentration is first determined from the nitrite test strip color change; the reagent ampoules are then broken in sequence and agitated, and the resultant color due to the presence of dimethylamine is observed.

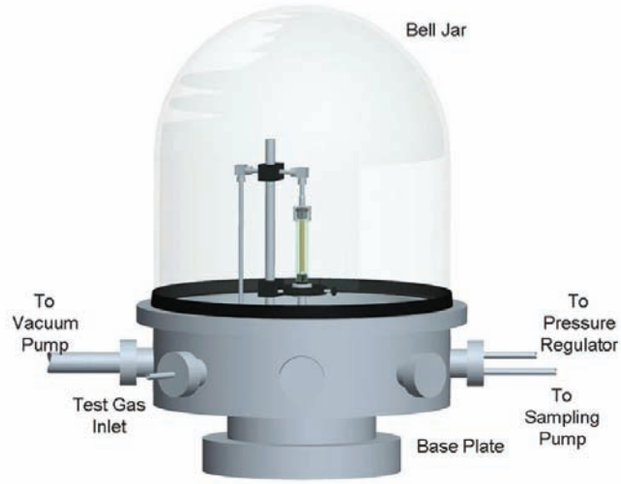

Fig. 4. *Reduced pressure exposure system.*

Qualification testing

We tested and qualified for flight the ammonia DTED and the gold salt detector using a reduced-pressure exposure test system (figure 4) that maintained a simulated 5-psia airlock pressure. We passed the target gas standard through a flow meter, into the chamber, and terminated it in the sampling cup placed over the inlet of the detector. We then attached the sampling end of the detector to feed through a mass flow meter and a sampling vacuum pump, thereby simulating the vacuum produced by the AMPEV in the airlock and providing the necessary airflow for sampling.

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