Paper Session I-C - Main Three Contamination Monitoring Cart for Support of Highly Contamination-Sensitive Payloads

Jean S. Abernathy
NASA, Payload Fluids and Contamination Control Engineering

Follow this and additional works at: http://commons.erau.edu/space-congress-proceedings

Scholarly Commons Citation
Main Three Contamination Monitoring Cart for Support of Highly Contamination-Sensitive Payloads

Paper Session: Military, Beyond 2000
Jean S. Abernathy
NASA Payload Fluids and Contamination Control Engineering
NN-M4
Kennedy Space Center, FL 32899
Email: Jean.Abernathy-1@ksc.nasa.gov
Phone 407-867-6152
Fax 407-867-6570

Introduction

The Main Three Contamination Monitoring Cart (M3) is an assembly of three different types of real-time contamination sensors packaged into an integrated, portable, user-friendly system. Previous methods of monitoring were real-time only if personnel could gain access to them for observation or for data download from them. The operational constraints of the payload processing environment minimized their real-time ability. The M3 system augments these technically advanced sensors’ abilities by bringing the data from the payload location to the user for truly real-time assessment and corrective action. This is very important for highly sensitive payloads in an environment that is, by nature, difficult to control from a contamination standpoint. These technological and operational advances in molecular and particulate contamination monitoring will enhance our access to space as new spacecraft materials and functions necessitate better cleanroom controls in the launch environment.

Dynacs Engineering built the M3 under the technical guidance of civil service employees to be used by NASA/KSC Payloads Contamination Control Engineering.

History

Before real-time contamination monitoring sensors proved their accuracy and overall benefits in the payload-processing domain, lab analysis methods alone were employed to assess the molecular and particulate fallout contamination levels of cleanrooms. Real-time measurement of cleanroom temperature, relative humidity, and airborne particle counts was already available. However, particle fallout, non-volatile residue (surface deposition of molecular contaminants), and airborne hydrocarbons were still being monitored by the use of fallout filters/silicon wafers, witness plates, and evacuated canisters, respectively, that were then taken to the lab for analysis. These methods are still used as comparison and backup data to sensors since they are reliable, and are, in-fact, the only methods used during a standard non-sensitive processing flow. However the amount of information that can be acquired from the data from these methods is limited. The data shows an incomplete picture of what the payload has been exposed to with little opportunity to take any preventative action during a contamination incident. These standards were used in the process of validating the data obtained from the real-time sensors during their developmental phases.
The sensors were developed individually with the intention of bringing real-time, accurate data representing the molecular and particulate signature of the room to the user. Efforts to reduce human error, transportation discrepancies, and uncertainties in the complex nature of contamination deposition and migration brought these sensors into the spotlight. Although the equipment collected and logged data real-time, prior to the M3 cart the data was not always easily accessible in a payload-processing or launch environment. The sensors had to be linked to a computer for the user to see the data. This configuration was not usually allowed to be left unattended given the hazardous classification of processing facilities or the sensitive nature of the payload. However, providing a person to keep watch over the data 24 hours a day in the locale of the sensors was not always practical or feasible. Occasions during which users may find most need for the sensors (highest threat of contamination) were sometimes the very occasions that observers could not be present, for safety reasons, to monitor their data. Therefore, the capability for real-time data was there, but the data was not easily accessible.

With the Main Three Cart, the data from the three types of sensors are integrated into a single software package that runs on the cart controller computer. Here, the data is logged in a disk file and presented to the user in several forms, including tabular and graphical. The user can opt to view any or all of the cart measurements. The cart controller software was written in Microsoft Visual Basic (Ref. 1).

All of the data from the cart is put into a single data stream and sent via a serial link to a remote computer that can be located in another building. Here, the data is presented in the same way as on the cart controller computer, so the user at the remote site sees exactly the same data in real time. This remote system is also configured as a user datagram protocol (UDP) server and, if connected to a local area network (LAN) that supports Internet Protocol, can broadcast the cart data in real time to many remote users simultaneously anywhere in the world. These very remote users can see the same screens as the local users, but can select their own options for which data to view. The user can then choose to view the data from each instrument in tabular or graphical formats. The user can also change x and y scales on the axis. The software provides online chat between all connected users. The data sent to the user’s computer is logged into files that can be imported into a spreadsheet.

The server can be configured to selectively allow certain domains to access the information so that the availability of the data can be restricted based on prior authorization. This is the same technology that is used for “Internet broadcasts” of video and audio. To view the data from anywhere in the world, all that is required is the UDP client software (also written in Visual Basic) and a PC compatible with an Internet connection and authorization on the UDP server to allow the user to connect (Ref. 2).

Three Types of Sensors and How They Work

The Main Three Contamination Monitoring Cart includes three types of sensors: Fourier Transform Infrared (FTIR) for monitoring airborne hydrocarbons, Surface Acoustic Wave (SAW) non-volatile residue (NVR) monitors, and Optical Fallout Monitors (OFM) for detecting particle fallout.

The FTIR technology, with its inherent ability to discriminate a large number of compounds, offers a tremendous advantage over other types of instrumentation. Commonly used hydrocarbon monitoring instrumentation, such as flame ionization detectors, yields no information about the source or identity of the compounds they detect. The hydrocarbon monitoring subsystem of the M3 consists of two modified MIDAC FTIR instruments; a computer providing control, user interface, and communications; and a sampling system. The graphical user inter-

The sensors were developed individually with the intention of bringing real-time, accurate data representing the molecular and particulate signature of the room to the user. Efforts to reduce human error, transportation discrepancies, and uncertainties in the complex nature of contamination deposition and migration brought these sensors into the spotlight. Although the equipment collected and logged data real-time, prior to the M3 cart the data was not always easily accessible in a payload-processing or launch environment. The sensors had to be linked to a computer for the user to see the data. This configuration was not usually allowed to be left unattended given the hazardous classification of processing facilities or the sensitive nature of the payload. However, providing a person to keep watch over the data 24 hours a day in the locale of the sensors was not always practical or feasible. Occasions during which users may find most need for the sensors (highest threat of contamination) were sometimes the very occasions that observers could not be present, for safety reasons, to monitor their data. Therefore, the capability for real-time data was there, but the data was not easily accessible.

With the Main Three Cart, the data from the three types of sensors are integrated into a single software package that runs on the cart controller computer. Here, the data is logged in a disk file and presented to the user in several forms, including tabular and graphical. The user can opt to view any or all of the cart measurements. The cart controller software was written in Microsoft Visual Basic (Ref. 1).

All of the data from the cart is put into a single data stream and sent via a serial link to a remote computer that can be located in another building. Here, the data is presented in the same way as on the cart controller computer, so the user at the remote site sees exactly the same data in real time. This remote system is also configured as a user datagram protocol (UDP) server and, if connected to a local area network (LAN) that supports Internet Protocol, can broadcast the cart data in real time to many remote users simultaneously anywhere in the world. These very remote users can see the same screens as the local users, but can select their own options for which data to view. The user can then choose to view the data from each instrument in tabular or graphical formats. The user can also change x and y scales on the axis. The software provides online chat between all connected users. The data sent to the user’s computer is logged into files that can be imported into a spreadsheet.

The server can be configured to selectively allow certain domains to access the information so that the availability of the data can be restricted based on prior authorization. This is the same technology that is used for “Internet broadcasts” of video and audio. To view the data from anywhere in the world, all that is required is the UDP client software (also written in Visual Basic) and a PC compatible with an Internet connection and authorization on the UDP server to allow the user to connect (Ref. 2).

Three Types of Sensors and How They Work

The Main Three Contamination Monitoring Cart includes three types of sensors: Fourier Transform Infrared (FTIR) for monitoring airborne hydrocarbons, Surface Acoustic Wave (SAW) non-volatile residue (NVR) monitors, and Optical Fallout Monitors (OFM) for detecting particle fallout.

The FTIR technology, with its inherent ability to discriminate a large number of compounds, offers a tremendous advantage over other types of instrumentation. Commonly used hydrocarbon monitoring instrumentation, such as flame ionization detectors, yields no information about the source or identity of the compounds they detect. The hydrocarbon monitoring subsystem of the M3 consists of two modified MIDAC FTIR instruments; a computer providing control, user interface, and communications; and a sampling system. The graphical user inter-
face runs on the cart controller computer, which has a keyboard, mouse, and monitor. The hydrocarbon portion of the cart is capable of measuring a variety of compounds and can be reconfigured to accommodate new compounds of interest. The MIDAC instruments were modified by the addition of a small computer inside the instrument case that controls the operation of the FTIR and provides deconvolution of spectral data. Each FTIR module sends gas concentration data to the cart controller computer, is equipped with a 1.8-meter gas cell, and runs at a resolution of 4 wavenumbers. The sampling system consists of two eductor pumps supplied by the system purge gas. There are also flow failure indicators that are monitored by the cart controller computer. The FTIR module makes use of a classical least square (CLS) algorithm in the analysis of spectral data. The traditional CLS method has been modified by the use of baseline correction algorithms, which correct errors due to instrument warm-up, aging of the source, and degradation of the optics due to contamination. This correction is accomplished by performing a parametric shape fit for the baseline using three parameters: bend, tilt, and offset (Ref. 1).

The FTIR’s are currently capable of measuring eleven compounds simultaneously out of the following compounds:

<table>
<thead>
<tr>
<th>Methanol</th>
<th>Ethanol</th>
<th>IPA</th>
<th>Freon 113</th>
<th>Methylene chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>Methane</td>
<td>Hexane</td>
<td>Propane</td>
<td>Benzene</td>
</tr>
<tr>
<td>Toluene</td>
<td>Acetic acid</td>
<td>MEK</td>
<td>Ethylene Glycol</td>
<td>Ethyl Ether</td>
</tr>
<tr>
<td>Methyl Silicone</td>
<td>Vinyl chloride</td>
<td>Styrene</td>
<td>Ethyl benzene</td>
<td>DM Pentane</td>
</tr>
<tr>
<td>Total Hydrocarbons</td>
<td></td>
<td></td>
<td></td>
<td>DM Butane</td>
</tr>
</tbody>
</table>

The NVR detection instrument is based upon a temperature controlled Surface Acoustic Wave (TCSAW) crystal device, built by Femtometrics, Inc. This device consists of two small quartz crystals, one exposed to the environment and the other sealed (called the “reference crystal”). Both are mounted on a common substrate and are connected to an electronics package that provides circuitry to mix the frequencies of the two crystals and derive a difference frequency that is output to a frequency counter. The quartz crystals themselves are overlaid with interdigitated metallic fingers at a spacing which defines the wavelength of the transverse surface acoustic waves which travel back and forth along its length. The increase in mass due to the residue deposition on the crystal causes a shift in the resonant frequency of the crystal, which then can be used to quantify the residue mass. The SAW devices of the M3 consist of a control unit inside the purged cart and a sensor head with an exposed quartz crystal. The SAW is extremely sensitive, roughly 100 times the sensitivity of a Quartz Crystal Microbalance. A 50-hertz shift in the frequency of the SAW crystal corresponds to only 1 nanogram per square centimeter mass density (Ref. 3).

The OFM is based on light scattered from particles deposited on a silicon witness surface. The scattered light is collected by optics and focused on a detector. The signal at the detector is proportional to the Percent Area Coverage (PAC) of the witness surface. The instrument is designed so that the silicon witness surface can be removed and scanned in an Estek™ surface scanner. This device has been tested by several commercial companies, field tested at KSC, and licensed non-exclusively for production and commercial sales by two different companies (Ref. 4).
Safety Issues

One of the greatest hurdles to operating the M3 in Kennedy Space Center facilities was ensuring its safe operation while unattended. Since the M3 started out as a prototype ammonia monitoring unit, the basic GN2-purged cabinet containing the two FTIR modules and computer was validated by Safety and Reliability Assurance and received a full System Assurance Analysis. However, the modifications to the basic cart required a reassessment of the system safety for several reasons.

Areas where the M3 is used may often be a Class I Division 2 hazardous environment. A Class I, Division 2 location is a location in which flammable fluids are used but in which the fluids are normally confined but can escape accidentally, or in which ignitable concentrations of such fluids are normally prevented but might become hazardous through failure of ventilation equipment. A purged and pressurized enclosure for electrical equipment is considered a suitable protection technique for Class I, Division 2 environments. However, on the M3, some of the electronics are now exterior to the purged cabinet, including the OFM and SAW sensors and associated cables. Therefore, per the National Electric Code, the next reasonable option was to make the exterior equipment intrinsically safe per ANSI/UL-913.

The OFM was submitted for evaluation to the NASA Materials Science Division Analysis Lab to determine if it met intrinsically safe requirements per ANSI/UL-913. The monitor meets NEC Class I requirements as indicated in paragraphs 501-3, (b) (1) and 501-3, (b) (2) and complies with UL-913 paragraphs 7.1.2-6 as an intrinsically safe device. For added precaution, a Zener barrier was incorporated on the power supply. In addition, the system housing was tested for electro-static discharge characteristics. As a result, the original plastic housing was replaced with an aluminum version.

The SAW assessment was more complicated since it is built by Femtometrics and some useful information is proprietary. Testing for intrinsic safety is ongoing. If the SAW does not meet the NEC and UL-913 specifications, these sensors alone would be turned off during active fueling activities. This can be done from the remote primary computer. The SAW temperature controllers (Peltier Coolers) were disabled as they were seen as a potential spark hazard.

Operationally, the cart power can be terminated using a switch on the door or remotely from the serial-linked computer. The power also terminates if the purge pressure in the cart is lost, whether from the front or rear door of the cart opening or from purge supply disturbance.

The weight and center of gravity of the cart significantly changed as well. A tip-over analysis and proofloading of the lifting eyes was performed at KSC.

Conclusion

The Main Three Contamination Monitoring technology shows great promise in bringing us closer to optimum cleanroom processing of payloads at KSC. This advance in real-time monitoring is a developmental gain toward the successful implementation of contamination-sensitive missions.
References