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TESTING OF AHURA'S FIRSTDEFENDER HANDHELD CHEMICAL IDENTIFIER AGAINST TOXIC INDUSTRIAL CHEMICALS

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14. ABSTRACT The handheld Raman spectrometer for point detection of chemicals developed by Ahura Corporation was tested using toxic industrial chemicals (TICs). This report reflects extended capabilities of TRI Report # 200601131. The device was assessed for its capacity to detect and identify liquid and solid substances/mixtures through sealed glass containers (clear and amber) in a completely non contact not-destructive manner. The following TICs were tested: acetone, acetone cyanohydrin, acrolein, acrylonitrile, allyl alcohol, benzene, carbon disulfide, carbon tetrachloride, chloropicrin, dimethyl sulfate, dimethylamine, ethylenediaminetetraacetic acid, formaldehyde, gasoline, kerosene, lindane, M-cresol, methyl hydrazine, nitric acid, parazylyene, phenol, phosphorus trichloride, phosphoryl trichloride, potassium cyanide, propylene oxide (methyloxirane), sodium cyanide, sulfuric acid, tetrahydrofuran (THF), toluene, toluene 2,4-diisocyanate, xylene, and hydrazine.					
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PREFACE

The work described in this report was authorized under Project No. 0525T. This work was started in November 2005 and completed in January 2006.

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TESTING OF AHURA'S FIRSTDEFENDER
HANDHELD CHEMICAL IDENTIFIER
AGAINST TOXIC INDUSTRIAL CHEMICALS

1. INTRODUCTION

1.1 Background.

The rapid identification of unknown toxic industrial materials is becoming increasingly critical for industrial emergency response, military, and homeland security operations. Currently, deployed bulk identification techniques are only man-portable, and most require actually sampling or handling of the material of interest. Many of these tools are also far from the ruggedness and robustness needed in the field.

Raman spectroscopy is a technique that has been validated for rapid identification of unknown chemicals. When a laser beam is focused on a sample, inelastic Raman scattering is produced because of photon-molecule interactions between the material and the incident laser light. The frequencies and intensities of the Raman scattered photons relate to the conformation and electronic states of the probed molecule. Thus, the Raman spectrum of a material can be used as a unique chemical signature of the material. As a laser scattering technique, Raman spectroscopy allows "line-of-sight" interrogation of samples through clear packaging or containers. Various toxic chemicals, chemical weapons, narcotics, and other unidentified potentially hazardous substances can be analyzed in glass vials, or plastic bags, greatly reducing the possibility of either evidence corruption, cross contamination, or risk to response personnel.

Ahura Corporation (Appendix A) has developed a handheld (~ 4 lb) and rugged Raman chemical identification system. The unit is fully self-contained, performs chemical analysis on board, and renders a probabilistic based result. The unit allows the rapid (tens of seconds) identification of an unknown solid or liquid substance in a nondestructive manner. The system is environmentally robust and has passed a subset of Military Standard (MIL STD) 810F tests. This report provides the data and their respective analysis obtained during test performed at the Applied Test Team (ATT), U.S. Army Research Development and Engineering Command (RDECOM), U.S. Edgewood Chemical Biological Center (ECBC) in December 2005 under the Test Service Agreement (TSA) #0525T.

1.2 Objective and Scope.

The objective of this evaluation is to verify the performance characteristics of the FirstDefender, specifically its ability to detect and identify toxic industrial chemicals (TICs) in solid or liquid phase. A representative cross-section of TICs were purchased from vendors and tested without further purification. Three non-reactionary binary mixtures were also tested. As it is clearly desirable to avoid contact with these toxic chemicals in routine field use, all measurements were made with the samples sealed in glass vials and the device measuring through the wall of the vials. The unit was also used to directly identify chemicals in the manufacturer's original packaging (amber glass bottles).

2. DESCRIPTION OF THE TESTED HANDHELD INSTRUMENT

2.1 Principles of the Technology.

All molecules perpetually rotate, move, and contort in a complex manner at temperatures above absolute zero. Vibrational spectroscopy probes these contortions (or vibrations) of a sample to determine the composition and structure. Two common types of vibrational spectroscopy are infrared (IR) absorption/reflectance and Raman spectroscopy. In Raman spectroscopy, the sample is illuminated with monochromatic laser light and the scattered light is detected as a function of wavelength. The scattered light results from both elastic collisions (Raleigh scattering) of the photons with the sample's molecules, as well as inelastic collisions (Raman scattering) that result in a drop in frequency of the inelastically scattered light. The inelastic collisions impart energy from the incident light to the modes of the molecules vibration... A material "fingerprint" results from recording the intensity of the scattered light as a function of the energy difference between the laser and Raman scattered light (Figure 1). In IR spectroscopy, the sample is illuminated with a broad spectrum of light in the mid-IR region, and the transmission or reflection is recorded as a function of the frequency of the incident light. When the frequency of incident light equals the frequency of a specific molecular vibration, the sample tends to absorb some of the light. A material "fingerprint" results from recording the amount of light absorbed as a function of the wavelength (or frequency).

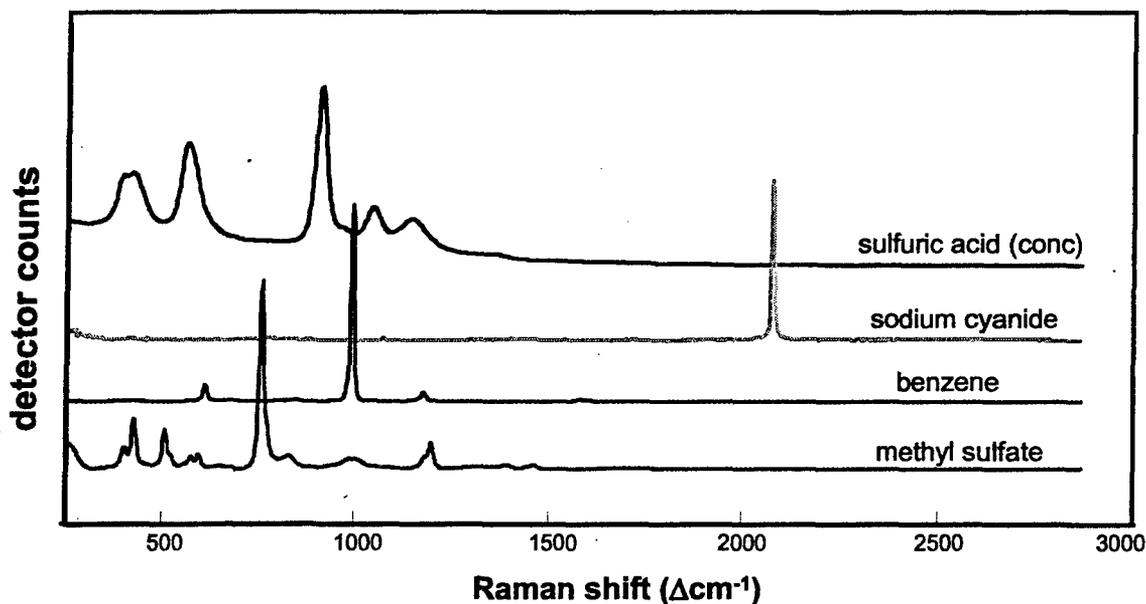


Figure 1. Examples of Raman Spectral Data Stored in a FirstDefender Unit

Although the level of uniqueness of Raman and IR molecular fingerprints is often similar for IR and Raman, field Raman instruments have several advantages over that of IR absorption/reflection instruments. For field toxic chemical applications, the key advantage of Raman technique over the IR technique is that Raman is a non-contact analysis method. Materials in glass and plastic containers can be analyzed in situ provided there is a line of sight to the substance in question, greatly reducing exposure and contamination risk for personnel. Non-contact analysis is also highly advantageous for preserving the

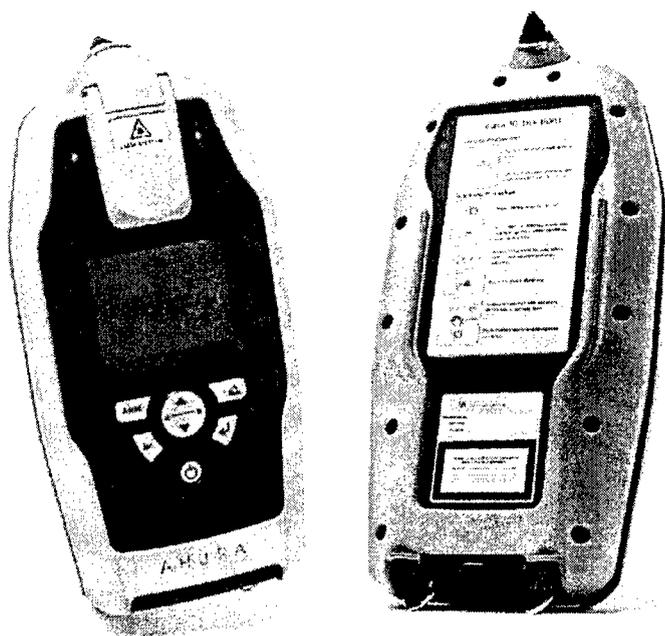


Figure 2. Photograph of the FirstDefender Raman-Based Handheld

integrity of evidence. In contrast, a probe or sampling interface must be in direct contact with the material in question for IR analysis, which means opening sealed containers, directly handling potentially lethal materials, and potentially contaminating or destroying evidence. Another advantage of Raman-based instruments is that chemicals dissolved in water (e.g., 1% hydrogen peroxide solution) can be analyzed. This is due to the fact that the water Raman spectrum contribution is negligible in the spectral region of interest ($250\text{-}2875\text{ cm}^{-1}$).

2.2 Instrument Hardware Characteristics.

Ahura's FirstDefender product is a rugged handheld chemical identification unit designed for point-of-use applications. A photograph of the FirstDefender is shown in Figure 2. This product allows the identification of liquid and solid toxic industrial chemicals (TICs), narcotics, contraband, and chemical weapons using the principles of Raman spectroscopy. It is enclosed in a lightweight, rugged, and weather/chemical resistant package, weighs approximately 4 lb and measures approximately 12 in. x 6 in. x 3 in. The unit is designed to operate over a temperature range of -20 to $+40\text{ }^{\circ}\text{C}$ in dry (desert) and wet (tropical) environments. The product and its subsystems are individually verified to meet military and commercial environmental standards for water sealing, mechanical shock, mechanical vibration, and thermal shock. (For details of compliance testing see Appendix B.)

The FirstDefender product has three modes of use. Two of the modes are point-and-shoot, and the third mode is an in-vial measurement. The first mode of use is to place the targeting cone (shown at the top of the Figure 2) onto the sample or container to be tested. In this mode, a metal cone contains the laser beam and keeps the needed focal distance to the sample. A second mode of use is to remove the laser cone and targeting foot to avoid coming in direct contact with the sample to be tested. In this mode, the unit is approximately 1.5 cm above the sample, thus limiting potential contamination and user exposure. This mode also allows the laser focal point to be placed onto materials contained in thick glass or plastic bottles. The third mode is a direct vial measurement. A hatch is present above the screen and beneath the logo marked area. When lifted, a hole is present for inserting a standard 4 ml test vial. The vial is positioned to allow measurements of both powders and liquids. The vials can then be saved for evidence collection or a confirmatory laboratory test.

The FirstDefender contains a source laser, an optical probe for directing light to the sample and collecting the Raman scatter, and a spectrometer for Raman spectrum analysis. The optical subsystems are manufactured using Ahura's proprietary "optical engine" technology. This technology allows for the integration of tens of micro optical elements into a single compact ($\sim 1\text{ in.}^2$) hermetically sealed package. Each optical engine is produced in a controlled clean-room environment and each process is designed to

be robust and reliable with mean times to failure beyond 10,000 hr (for active devices). Optical specifications of the resulting FirstDefender handheld are given in Table 1.

Table 1. FirstDefender Optical Specifications

Parameter	Specification
Monochrometer Spectral Range	781 nm-1014 nm
Raman Spectrum Range	250 cm^{-1} to 2875 cm^{-1}
Spectral Resolution	7 to 10 cm^{-1} (FWHM) across range
Laser (excitation wavelength)	785 nm +/- 0.5 nm (<2 cm^{-1} linewidth)
Laser Output	Settable, 30 mW, 100 mW, 300 mW
Rayleigh Rejection Filters	OD 7
Detector	Silicon CCD 2048 Pixels; TEC Cooled
Detection Mode	Direct Dispersive
Dispersion Mode	Single Pass Spectrometer (1200 groove/mm Blazed @ 900 nm)
Collection Optics	NA= 0.3

2.3 Instrument Embedded Software.

The FirstDefender relies on embedded custom decision support software to compare the measured data to library records of known materials. The use of custom software is necessary for two reasons. First, no commercially available package is available for the limited resources of the onboard PXA255 400 MHz based single board computer. Secondly, commercial packages do not apply rigorous evidence-based match criteria or provide automated formal mixture analysis.

The coarse architecture of the Ahura decision support software is shown in Figure 3. Four distinct modules are integrated: Belief Engine, Data Engine, Mixture Engine and the Decision Engine. These modules have the following individual responsibilities:

Belief Engine™: encode prior information available to the user

Data Engine™: acquire data such that enough Raman information is available to make informed decisions; probabilistically assess the consistency of the acquired data with library records.

Mixture Engine™: if the measured Raman data is not probabilistically consistent with any library record, it will propose mixtures of library records that explain the measured data.

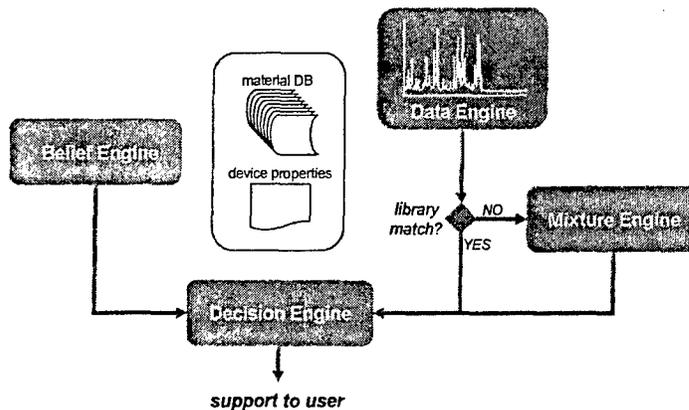


Figure 3. Architecture of the Embedded Decision Support Software in FirstDefender

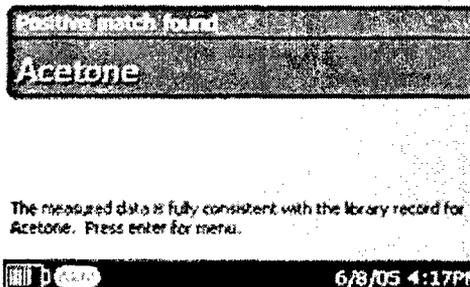
Decision Engine™: integrate information from the Belief Engine, Data Engine and Mixture Engine for probabilistic decision support.

The FirstDefender Belief Engine™ contains a library of high signal/noise ratio Raman spectra to which the field-measured spectra are compared. At the time of the test, this library contained the Raman spectra of over 1300 chemicals. They include common industrial chemicals, household chemicals, explosives, chemical warfare agents, and narcotics.

As noted, the data engine drives data acquisition. The FirstDefender has two general modes of data acquisition, which are the library and normal measurement mode. In library mode, the data engine collects data to a pre-determined level of high Raman fidelity. This is an important function, as low-quality library spectra severely limit the resolving power of the decision support software. In normal measurement mode (the mode employed for routine field-testing) the data engine automatically chooses settings so that data is collected to a level of fidelity that resolves the vast majority of field samples but minimizes the time required to execute a measurement. Normal measurement mode operation is therefore akin to the auto-exposure setting on most photographic cameras. Non-auto settings are available if an advanced user elects to override the system settings.

Following the data collection, the data engine rules out library records, which are probabilistically inconsistent with the measured data. If any library records remain that have not been ruled out, they are forwarded directly to the decision engine, which presents the user with information like the following:

Session002 : Scan001 (review)



The FirstDefender software does not report values akin to correlation or similar 'Hit Quality Indices'. In processing, and unseen to the user, it rules out library records that are spectroscopically inconsistent with the measurement data. If more than one record can not be ruled out, the device reports posterior probabilities (betting odds). In the case above, all library records except acetone have been ruled out. Because the probability overwhelmingly favors acetone in this case, the exact probability is not even shown. In the next example, multiple library records are consistent with the measured data.

Session001 : Scan001

Positive matches found



Lacquer Thinner 30.3%

The measured data is consistent with ALL of the above library items. The probabilities (%) indicate how much the measured data favors one item versus another. They are NOT concentrations.

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The decision support software has decided that all of these materials are statistically consistent with the measurement data (*i.e.*, could not be ruled out). The probabilities are directly quantifying how much the evidence favors each of them. (In this case, the data suggests that toluene is about two times more likely than lacquer thinner.) Alternatively, one could say that with probability near 100%, the material is either toluene or lacquer thinner. In some circumstances, the evidence will strongly favor one of the reported matches (e.g., 94% vs. 6%); although, in other circumstances, the evidence is less emphatic (e.g., 52% vs. 48%, or 40% vs. 32% vs. 28%).

If none of the library records are consistent with the data, the Decision Engine Mixture Extension (MX) attempts to resolve the measured data using mixtures of library records. Library spectra of actual mixtures are not required, because the software works directly from the library spectra of pure materials. Candidate mixture models are generated by an optimization procedure, and are solved formally in software, rather than through user-directed subtraction procedures. If a mixture of library records is found that explains a significant portion of the measured Raman data, the user will be presented with a screen similar to

Session004 : Scan008 (review)

Mixture	97%
2-Propanol	59%
Methanol	38%

The measured data can not be adequately described by a single library item, but a mixture of the above items accounts for 97% of the measured Raman data. Values shown are the amount of Raman data that can be described by each item.

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OR

L7hu : Scan007 (review)

Mixture	93%
Cluster of 3 items	89%
Japan Drier	
Kerosene	
Petroleum	
Gasoline	3%

The measured data can not be adequately described by a single library item, but a mixture of the above items accounts for 93% of the measured Raman data. Values shown are the amount of Raman data that can be described by each item.

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Note that in the second case, one of the constituents is called "Cluster" and has three members: Japan drier, kerosene, and petroleum. The Mixture Engine 'clusters' library records are very similar in Raman spectral response to speed and condition computational aspects of the mixture solution. If the proposed solution contains a cluster, as it does in the above example, it implies that a statistically equivalent solution could be obtained by using any member of the cluster.

The reported percentages for mixtures do not correspond to concentrations. They represent the amount of measured Raman data that is accounted for (recovered) by the inclusion of a particular constituent in the mixture solution. For the example above, the 89% of the Raman activity of the sample can be attributed to one of Japan drier, kerosene, or petroleum, and 3% can be attributed to gasoline.

Finally, if the Decision Engine and its mixture extensions cannot reach a reliable identification, the user will get a red results screen saying "NO MATCH FOUND". In cases where the measured material bears a resemblance to a library record, but some discrepancies exist, said library records will appear below the "NO MATCH FOUND" text on the red screen:

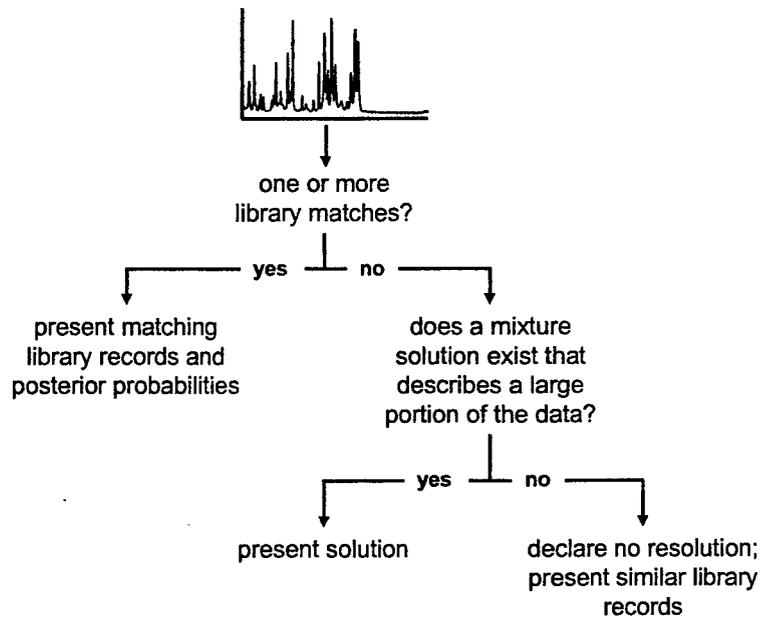
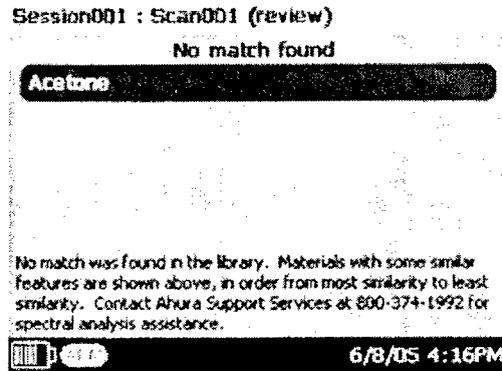


Figure 4. Decision tree for the Embedded Decision Support Software in FirstDefender

The overall decision tree for the decision support software embedded on the FirstDefender is summarized in Figure 4.

3. EXPERIMENTAL PROCEDURES

The testing was conducted on a FirstDefender handheld unit (Serial # FD1304). Kerosene and xylene samples were purchased from the Home Depot store (Edgewood, MD) and the gasoline sample was obtained from a Mobile gas station (Edgewood, MD). All other chemicals were purchased through Sigma-Aldrich about 1 week before testing.

About 0.2 mL of each sample was transferred from the manufacturer bottle to a standard 4 mL borosilicate glass vial. The Raman library spectra of all these chemicals were obtained from standard samples on a library system at Ahura and imported into the test unit. Binary mixtures were prepared by mixing the two chemicals with about equal volume. The two components for each mixture were chosen to be non-reactive.

Samples were measured using the vial holder and the point-and-shoot mode separately. A few samples were also measured by directly pointing the laser spot through the original manufacturer's amber glass bottle.

3.1 Verification Scan (using vial holder).

The first verification scan was performed in the vial holder. The scan mode was set to AUTO mode and a scan initiated. The results of the verification scan were immediately displayed.

3.2 Verification Scan (using point and shoot).

A second verification scan was performed using the point-and-shoot mode. The nose of the unit was placed against the glass vial containing the chemicals. The unit was held in position by hand. The nose cone was set on the handheld to be depressed fully to allow the focus of the laser to be inside the glass vial wall. The scan mode was set to AUTO mode and a scan was initiated. The results of the verification scan were immediately displayed. For direct measurement through the manufacturer's bottle, the nose cone was removed for appropriate focus.

4. RESULTS AND DISCUSSION

4.1 Toxic Industrial Chemical Testing.

The unit was tested with 31 different toxic industrial chemicals (TICs), encompassing four solids and twenty-seven liquids. Table 2 summarizes the results of TIC testing for vial-holder and free-space measurements. The system correctly identified the chemicals under consideration in 61 of 62 cases tested.

For those measurements with the vials placed in the vial chamber, the unit reported true-positive detection of the appropriate chemical for 31 of the 31 chemicals. For white powder sodium cyanide in the borosilicate glass vial, the unit test identified as a mixture of sodium cyanide and borosilicate glass. For xylene, the test resulted in a mixture. The first component was a cluster that containing three items (xylene; paint deglosser; MCI Urethane Wood Finish), and the second component was M-cresol.

For measurements performed with sample vial placed outside the unit using the point-and-shoot mode, the unit reported true-positive detection of the appropriate chemical for 30 of the 31 chemicals. For chloropicrin, the unit test reported as a mixture of chloropicrin and borosilicate glass. For sodium cyanide, the unit reported as a mixture of sodium cyanide, borosilicate glass, and silicon tetrachloride. For ethylenediaminetetraacetic acid (EDTA), the device reported "no match found" and displayed EDTA as a similar item. For kerosene, it reported a mixture of Japan drier, kerosene, petroleum, and gasoline. For toluene, a positive match was reported and two chemicals (toluene and lacquer thinner) were displayed. For xylene, the unit positively identified as one of MCI urethane wood floor finish, paint deglosser, and xylene.

The above results suggest that the unit operates with greater search precision when the sample vial is placed in the vial chamber, compared to point-and-shoot mode. In the point-and-shoot mode, for transparent samples, more alignment tolerance is afforded as the laser can be focused within the sample. For solid powder, however, it is necessary to place the focal point at the surface of the material to get the best results.

An example of the Raman spectra of toxic industrial chemicals that were collected during the course of testing is shown in Figure 5. The top red curve shows the Raman spectrum of acetone cyanohydrin that has been stored in the spectral library on the unit. The bottom blue curve shows the Raman spectrum acquired in AUTO mode on the test device at ECBC. AUTO measurement times were typically 1 to 5 sec, although for some samples up to 20 sec was required to achieve the target quality.

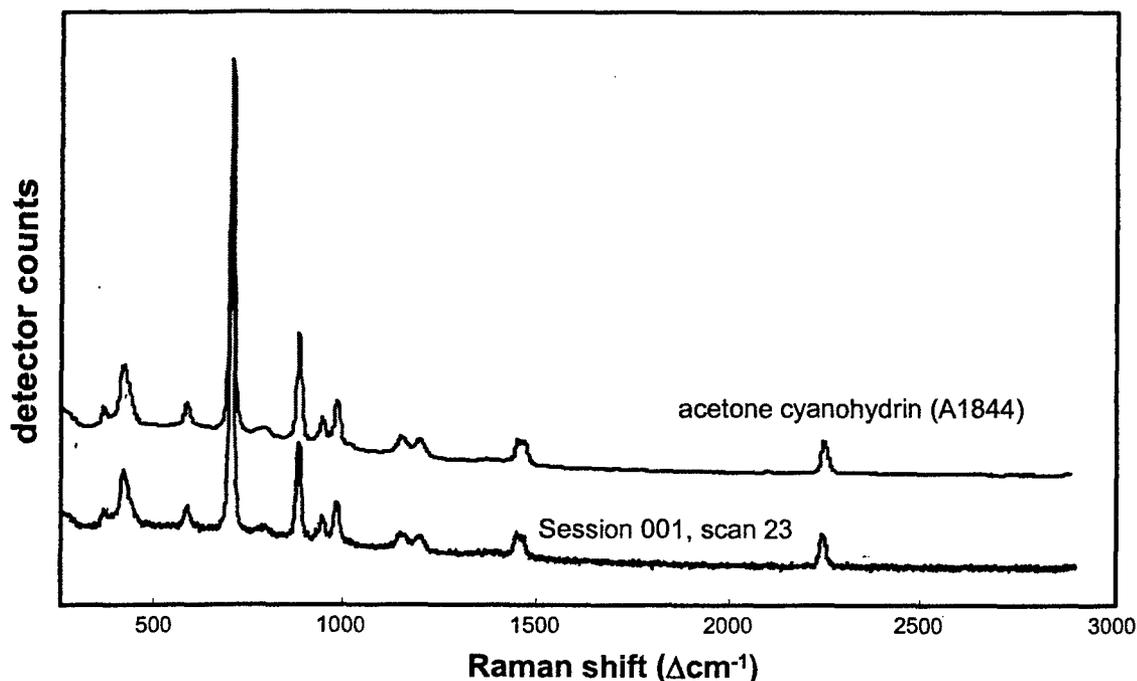


Figure 5. Acetone Cyanohydrin Uniquely and Positively Identified through Comparison of the Acquired Spectrum (blue) with the Unit's Library

The unit was used to measure lindane in its original Sigma-Aldrich amber bottle. The unit was set to AUTO point-and-shoot mode without the nose cone. Care was taken to place the laser focal point

right at the material near the bottle inner surface. The material was uniquely and positively identified as lindane. The total detector exposure time took 15 sec, which was 30 times the routine exposure time (0.5 sec) when a clear vial is used.

Table 2. Toxic Industrial Chemical (TIC) Test Results

Chemicals	Results (Inside VIAL HOLDER)	Results (FREE SPACE)
Acetone	positive match found Acetone	positive match found Acetone
Acetone Cyanohydrin	positive match found Acetone Cyanohydrin	positive match found Acetone Cyanohydrin
Acrolein	positive match found Acrolein	positive match found Acrolein
Acrylonitrile	positive match found Acrylonitrile	positive match found Acrylonitrile
Allyl alcohol	positive match found Allyl alcohol	positive match found Allyl alcohol
Benzene	positive match found Benzene	positive match found Benzene
Carbon Disulfide	positive match found Carbon Disulfide	positive match found Carbon Disulfide
Carbon tetrachloride	positive match found Carbon tetrachloride	positive match found Carbon tetrachloride
Chloropicrin	positive match found Chloropicrin	mixture (93%); chloropicrin (92%); borosilicate glass (1%)
Dimethyl sulfate	positive match found Dimethyl sulfate	positive match found Dimethyl sulfate
Dimethylamine	positive match found Dimethylamine	positive match found Dimethylamine
Ethylenediaminetetraacetic acid	positive match found EDTA	no match found: EDTA
Formaldehyde	positive match found Formaldehyde	positive match found Formaldehyde

Gasoline	positive match found Gasoline	positive match found Gasoline
Kerosene	positive match found Kerosene	mixture (93%): cluster of 3 items (89%)(Japan Drier; kerosene; petroleum); Gasoline (3%)
Lindane	positive match found Lindane	positive match found Lindane
Methyl hydrazine	positive match found Methyl hydrazine	positive match found Methyl hydrazine
Red Fuming Nitric Acid	positive match found Red Fuming Nitric Acid	positive match found Red Fuming Nitric Acid
PARAXYLENE	positive match found PARAXYLENE	positive match found PARAXYLENE
Phenol	positive match found Phenol	positive match found Phenol
Phosphorus Trichloride	positive match found Phosphorus Trichloride	positive match found Phosphorus Trichloride
Phosphoryl Trichloride	positive match found Phosphoryl Trichloride	positive match found Phosphoryl Trichloride
Potassium Cyanide	positive match found Potassium Cyanide	positive match found Potassium Cyanide
Propylene Oxide (Methyloxirane)	positive match found Propylene Oxide	positive match found Propylene Oxide
Sodium Cyanide	mixture (80%): sodium cyanide (77%); borosilicate glass (2%)	mixture (76%): sodium cyanide (68%); borosilicate glass (5%), silicon tetrachloride (2%)
Sulfuric Acid	positive match found Sulfuric Acid	positive match found Sulfuric Acid
Tetrahydrofuran (THF)	positive match found Tetrahydrofuran	positive match found Tetrahydrofuran
TOLUENE	positive match found TOLUENE	positive match found toluene; lacquer thinner
Toluene 2,4 – diisocyanate	positive match found Toluene 2,4 – diisocyanate	positive match found Toluene 2,4 – diisocyanate
XYLENE	mixture (92%): cluster of 3 items (92%)(paint deglosser; xylene; MCI Urethane Wood Finish); M-cresol (2%)	positive matches found: MCI Urethane Wood Floor Finish (47.5%); Paint Deglosser (26.9%); Xylene (25.6%);
hydrazine	positive match found hydrazine	positive match found hydrazine

4.2 Mixture Chemical Testing.

Tests were performed on three binary chemical mixtures. A binary chemical mixture is identified using the Mixture Engine™. Figure 6 shows the measured spectrum, the composite solution spectrum obtained through Decision Engine™ MX analysis, and the suggested individual component spectra of the binary mixture (carbon disulfide and tetrahydrofuran). The results for these three samples are summarized in Table 3. The analysis algorithms were able to positively confirm the presence of the components in all the five measurements.

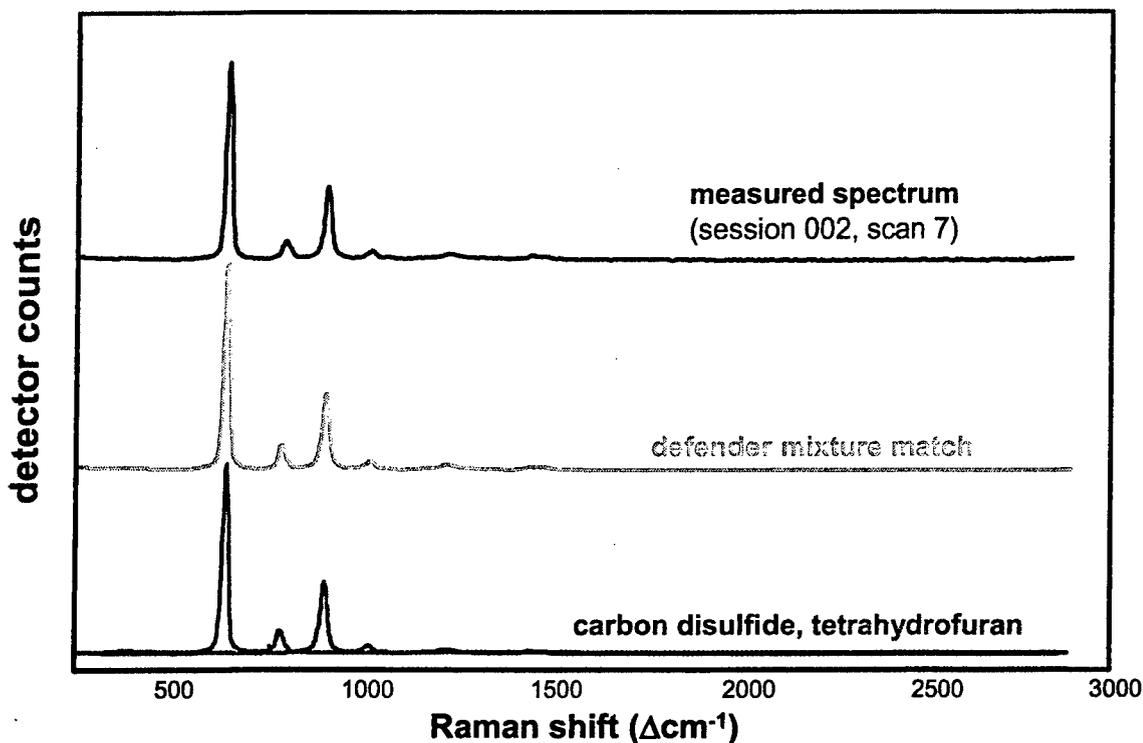


Figure 6. Binary Chemical Mixture of Carbon Disulfide and Tetrahydrofuran Identified using the Mixture Engine™. The bottom spectra are that of the pure components; the top black spectrum is that of the sample and the middle spectrum is the composite match spectrum proposed by the Decision Engine™ MX software.

Table 3. Mixture Test Summary

Mixtures	Results (Inside VIAL HOLDER)	Results (FREE SPACE)
carbon disulfide + tetrahydrofuran (~50/50V)	mixture (99%); carbon disulfide (90%); tetrahydrofuran (9%);	mixture (99%); carbon disulfide (89%); tetrahydrofuran (9%);
benzene + p-xylene (~50/50V)	mixture (99%); cluster of 2 items (78%) (sodium sulfate; benzene); p-xylene (22%);	mixture (99%); cluster of 2 items (78%) (sodium sulfate; benzene); p-xylene (21%);
acetone+2-propanol (50/50V)	mixture (94%); 2-propanol (24%); acetone (68%); cyclohexane (2%)	NOT TESTED

4.3 Search Precision.

Although true positive rate (positive detection when a toxic industrial chemical is present) is a critical parameter for deployable chemical identification systems, false-positive attributes are also important. The above testing does not constitute a comprehensive evaluation of false-positive rates for toxic industrial chemicals (TIC). However, the above testing does allow for an assessment of a related measure (search imprecision) relevant for chemical identification systems. For field-portable chemical identifiers like the FirstDefender, the material search could return no matching library records, one matching record, or multiple records. Clearly, if the identifier returned a large number of matching records for every analysis, it is more likely to present the correct compound in the list, but for the field user, a short list of materials is more valuable than a long list.

To quantify this behavior, search imprecision is defined as the number of incorrect positive matches that are returned by the search software. A search that only returns the correct library record has imprecision 0. When two library records are returned but only one of them is correct, the imprecision is 1, etc. The tabulated results for all measurements conducted in the course of this testing are given in Table 4. Note that for one measurement—Ethylenediaminetetraacetic acid in free space—the decision support software did not report a library match or come to a mixture resolution. This null result has no associated imprecision. The remaining 66 cases are reported below. Cumulative percentages are given in the last column, indicating the percent of cases with imprecision equal to or better than the corresponding row imprecision.

Table 4. Summary of Search Precision over All Cases

Imprecision	Cases	Cumulative
0	59	89.4%
1	4	95.5%
2	1	97.0%
3	2	100.0%
Total	66	

One can not take the above cumulative percentages as 'population' estimates. For the testing as presented, in 89.4% of cases zero non-relevant library records were returned in the search.

5. CONCLUSION

The toxic industrial chemical (TIC) detection capability of the Ahura Corporation FirstDefender handheld Raman chemical identification system was tested and confirmed for 31 toxic industrial chemicals and several non-reactive binary mixtures using both the vial chamber and "point-and-shoot" modes. The system correctly identified the chemicals under consideration in 66 of 67 cases tested. The unit was also capable of directly identifying the material contained in amber glass bottles. In summary, given that the instrument is enclosed in a lightweight weather/chemical resistant package that measures approximately 12 in. x 6 in. x 3 in., the instrument can operate over a temperature range of -20 to +40 °C in dry and wet environments, and has been verified to meet military and commercial standards for water sealing, mechanical shock, mechanical vibration, and thermal shock, and the chemical detection performance as tested. The FirstDefender can be a suitable candidate for rapid field detection and identification of toxic industrial liquids and solids

APPENDIX A
AHURA CORPORATION BACKGROUND

Ahura Corporation was founded as a Delaware corporation, in March of 2002 around a team of scientists and engineers to develop innovative cost-effective high-performance optical solutions for a broad array of markets. Ahura is a small business concern that has raised more than \$20M from top tier venture capital firms including ComVentures, ARCH Venture Partners, and Castile Ventures. The Company is focused on developing, manufacturing, and selling Raman based products based on proprietary optical engines and software platforms.

Ahura Corporation is comprised of an innovative team of scientists and engineers in a vertically integrated facility, bringing a cross-disciplinary approach to the challenges facing our society. Ahura is located in a 30,000 square foot facility in Wilmington, Massachusetts. The majority of this space is dedicated to engineering development and manufacturing including: an MOCVD semiconductor laser growth facility, chip fabrication and thin-film development, ultra-compact optical package development lab and production line, electronic system design and test capability, full electrical and optical test infrastructure, reliability and failure analysis room, and highly equipped machine shop. In addition to these facilities, the company has software design tools for lasers, thin-film passive optics, packaging, electronic circuit design, and software algorithm development. The remaining space is used for inventory, shipping and receiving, and office space.

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**APPENDIX B
COMPLIANCE TESTING**

The Table lists the standards from MIL-STD-810F that were met by the FirstDefender Handheld. Transit shock testing is currently in progress. Testing to the military standards was conducted by the company through a third party laboratory; MET Laboratories (Baltimore, MD). A letter of compliance to these standards is given in the Figure for reference. A detailed test report is available from MET Laboratories.

Table. Qualification Tests Passed for the FirstDefender Handheld

Qualification Test	Detail	Condition
Mechanical Shock	MIL-STD-810F (516.5) Procedure I	Ground Equipment, 40 g, 11ms, saw tooth
Vibration	MIL-STD-810F (514.5) Procedure I (Composite Wheeled Vehicle)	1 hr / axis, Category 20 - Composite Wheeled Vibration Exposure
Humidity	MIL-STD-810F (507.4)	5X (48 hr) 60 °C & 95% RH
Sand & Dust	MIL-STD-810F (510.4) Procedure I	Blowing Dust
Water Immersion	MIL-STD-810F (512.4)	1 m for 30 min
Thermal Shock	MIL-STD-810F (503.4) Procedure I	<1 min Transition -30 to +60 °C, 1 day
Low Temperature (Operation)	MIL-STD-810F (502.4) Procedure II	-20 °C 1 day exposure following stabilization (Restrained Glass)
High Temperature (Storage)	MIL-STD-810F (501.4) Procedure I	+60 °C 7 days exposure
Low Temperature (Storage)	MIL-STD-810F (502.4) Procedure I	-30 °C 1 day exposure

The FirstDefender has been designed to be compliant with commercial emissions, laser safety, and product safety regulations. A list is given below: ● **SAFETY:** The product is being designed to comply with UL-61010-1 and CSA C22.2 No. 61010-1 safety standards.

- **LASER SAFETY:** Complies with FDA CDRH 1040.1 & IEC60825
- **EMISSIONS:** FCC Part 15 Subpart B – Unintentional Radiators and ICES-003 Industry Canada Interference-Causing Equipment Standard-Digital Apparatus specifications. Specifically our unit has been tested to comply with 15.107 conducted emissions and 15.109 radiated emissions.



MET Laboratories, Inc.

914 W. Patuxent Ave., Baltimore, MD 21230
410-354-3230, Fax: 410-354-3213, 800-558-2067 www.metlabs.com

June 7, 2005

Alburn Corporation
45 Jonskin Road
Wilmington, MA 01897

Dear Kevin Knapp,

Congratulations! It is our pleasure to inform Alburn Corporation that the First Defender Handheld Identification System (FD-2000), as well as defined in the MET Laboratories' Test Report E5L17000-MIL, has completed the following testing at MET Laboratories, Inc. for MIL-STD-810-F:

Method 501.4 High Temperature

Procedure I - Storage (High Temp) - Complete and Compliant

Procedure II - Operation (High Temp) - Complete and Compliant

Method 502.4 Low Temperature

Procedure I - Storage (Low Temp) - Complete and Compliant

Procedure II - Operation (Low Temp) - Complete and Compliant

Method 503.4 Temperature Shock

Procedure I - Steady State - Complete and Compliant

Method 507.4 Humidity - Complete and Compliant

Method 510.4 Sand and Dust

Procedure I - Blowing Dust - Complete and Compliant

Method 512.4 Immersion

Procedure I - Immersion - Complete and Compliant

Method 514.5 Vibration

Category 20 - Ground Vehicles - Ground Mobile - Complete and Compliant

Method 516.4 Mechanical

Procedure I - Functional Shock - Complete and Compliant

Procedure IV - Transit Drop - Complete and Compliant

Method 516.5 Shock

Procedure I - Functional Shock - Complete and Compliant

For specific details regarding the extent of the testing and the configuration of the product tested, please consult the MET Laboratories' Detailed Test Report. Please contact me with any questions or comments.

Sincerely,

Todd Talbot
Manager, Environmental Simulation Laboratory

The Nation's First Nationally Recognized Testing Laboratory Licensed by OSHA

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Figure. MET Laboratories Letter of MIL-STD-810F Compliance

APPENDIX B