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6260
Ser IH25/0173
APR 14 2014

From: Commanding Officer, Navy and Marine Corps Public Health Center
To: Director, Strategic Systems Programs

Subj: ASSESSMENT OF CARBON MONOXIDE, HYDROGEN AND VOLATILE ORGANIC COMPOUNDS (VOCs) INSIDE D5 MISSILES ONBOARD USS RHODE ISLAND (SSBN 740)

Ref: (a) SSP E-Mail SP273 of 20 May 2013

Encl: (1) Report of Carbon Monoxide, Hydrogen and Volatile Organic Compounds (VOCs) Inside D5 Missiles Onboard SSBN 740

1. As per reference (a), Strategic Systems Programs (SSP) requested Navy and Marine Corps Public Health Center (NMCPHC) assistance in identifying volatile organic chemicals (VOCs) and gases present inside D5 missiles, determining their concentrations and potential for overexposure of personnel performing work inside the D5 missile. The survey report is provided as enclosure (1).

2. The point of contact is Mr. Dan C. Brunick. He may be reached at (757) 953-0743, DSN 377-0743 or via e-mail: Dan.Brunick@med.navy.mil.

D. D. HAGEN
By direction

REPORT OF CARBON MONOXIDE, HYDROGEN AND VOLATILE ORGANIC COMPOUNDS (VOCs), INSIDE D5 MISSILES ONBOARD SSBN 740

31 January 2014

Conducted by

Navy and Marine Corps Public Health Center
Portsmouth, VA

TABLE OF CONTENTS

Executive Summary

1. Background. At the request of the Strategic Systems Programs (SSP), industrial hygiene personnel from the Navy and Marine Corps Public Health Center, Portsmouth, VA (NMCPHC) conducted air monitoring aboard USS Rhode Island (SSBN 740). Air samples were collected inside D5 missiles, during 3-4 Sep 2013, for volatile organic compounds (VOCs), carbon monoxide (CO) and hydrogen (H_2) as part of a Special Weapons Test (SWT). The purpose was to verify the presence of benzene and CO and determine whether H_2 was creating erroneously high CO readings. The concentrations measured were compared to the Submarine Atmosphere Control Limits (SACLs) and to the American Conference of Governmental Hygienists (ACGIH) Threshold Limit Values (TLVs), as appropriate, to determine the potential for exposure of personnel. Acceptable concentration profiles were those with 95th percentile exposures that did not exceed the Occupational Exposure Limit more than 5% of the time, per the Navy Industrial Hygiene Field Operations Manual.

2. Conclusions. Based on observations during the survey and interpretation of the data collected, the following major conclusions were reached. Detailed discussion is provided in the body of the report.

a. Carbon monoxide (CO) concentrations are not expected to create an overexposure to the OELs considered.

b. CO concentrations inside D5 missiles, as measured by the PHD-6 direct-reading multi-gas meter, overestimate the true concentration about half the time.

c. Hydrogen (H_2) concentrations inside D5 missiles, although present in significant concentrations, could not by themselves explain the difference between CO concentrations measured by the PHD-6 meter and laboratory analysis.

d. The difference between CO concentrations measured by PHD-6 and laboratory analysis may be caused by response of the PHD-6's electrochemical sensor to a combination of gases.

e. Benzene was present in all sections of D5 missiles sampled with no apparent difference between the three sections.

f. Without mitigation, e.g., exhaust ventilation, personnel working inside D5 missiles for more than seven minutes will be exposed to benzene above the 15-minute STEL-TLV.

g. Without mitigation, e.g., exhaust ventilation, personnel working inside D5 missiles for more than one hour may be exposed to benzene above the 8-hour TWA-TLV.

h. Although not zero, the potential for vinylidene chloride, methyl chloroform and toluene to cause an overexposure to the OELs considered is very low.

i. There was negligible risk of personnel overexposure with respect to the OELs considered from any of the two gases and 57 VOCs for which air samples were taken in the missile compartment before and after the work of opening missiles was conducted.

3. Recommendations. The following recommendations are based on the conclusions contained in this report:

a. Institute mitigation procedures to reduce and control benzene exposures to below all applicable OELs. Such procedures should control exposures to the other VOCs measured.

b. Comply with all applicable Navy and federal regulations concerning benzene exposure.

REPORT OF
CARBON MONOXIDE, HYDROGEN AND
VOLATILE ORGANIC COMPOUNDS (VOCs),
INSIDE D5 MISSILES ONBOARD SSBN 740

Ref: (a) SSP E-Mail SP273 of 20 May 2013
(b) *A Strategy for Assessing and Managing Occupational Exposures*, Third Edition, American Industrial Hygiene Association, 2006
(c) Industrial Hygiene Field Operations Manual, Navy and Marine Corps Public Health Center Technical Manual TM-6290.01-2 Rev B with continual maintenance updates through September 2013
(d) 2013 Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati
(e) NAVSEA S9510-AB-ATM-010, Volume 1, Revision 5 of 15 Mar 2012

1. Introduction

a. Request Per reference (a), Strategic Systems Programs (SSP) requested Navy and Marine Corps Public Health Center (NMCPHC) assistance in identifying the volatile organic chemicals (VOCs) and gases present inside D5 missiles, determining their concentrations and determining their potential for overexposure of personnel performing work inside the D5 missile.

b. Description of the Problem. Missile Technicians (MTs) periodically enter various stages of D5 missiles for varying periods of time to perform maintenance and modifications. Previous air sampling had identified the presence of benzene and other VOC vapors and carbon monoxide (CO) gas in the air inside the missiles at concentrations that exceeded Occupational Exposure Limits (OELs). A variety of sampling and analytical methods were used in the several sampling campaigns reported requiring a definitive study to confirm what was present and at what concentration.

c. Objectives. The objectives of this study were as follows:

(1) Confirm that benzene vapor was present,

(2) Quantify the concentration of benzene, if present,

(3) Identify what other common VOCs are present, their concentration and whether they represent an occupational health hazard,

(4) Confirm that CO was present,

(5) Determine if CO measurements by direct-reading meters were consistent with definitive laboratory analysis, and

(6) Determine if hydrogen (H_2) gas was responsible for any differences between CO

concentrations measured by direct-reading meter and laboratory analysis.

d. Response. A survey team composed of CAPT Donald D. Hagen, MSC, USN and Mr. Leighton K. Turner, Certified Industrial Hygienists (CIH) and Mr. Dan C. Brunick, Industrial Hygienist from the Navy and Marine Corps Public Health Center, Portsmouth, VA (NMCPHC) directed air sampling onboard USS Rhode Island (SSBN 740) from 3 - 4 Sep 2013 inside D5 missiles. Air samples were collected by Lockheed-Martin personnel using equipment provided by NMCPHC concurrently with parallel air sampling by the Lockheed-Martin personnel with their own and different equipment to duplicate air sampling inside D5 missiles performed a year prior on the USS Wyoming (SSBN 742).

e. Missile Compartment Overview. The missile compartment is divided into four levels designated Upper Level (UL), Second Level (2L), Third Level (3L) and Lower Level (LL) as described below. The missile tubes pass through all four levels of the missile compartment but the deck at each level is not sealed around the missile tubes. Access between the four levels is provided at the extreme forward and after ends of the missile compartment via ladderways between each level.

(1) The Upper Level contains support equipment for the missiles and overflow berthing at deckplate level. Access to the missile Equipment Section (ES) and umbilical is available from this level.

(2) The Second Level contains support equipment for the missiles and the missile tube vents, one per missile tube, through which the gas used to pressurize the missile tubes, i.e., Missile Gas (MG), is released from the missile tubes prior to entry. This level also contains a fan room for the output of the air purification system and the supply air duct coming out of this fan room has a Continuous Air Monitoring System (CAMS) station installed. Additionally, this level contains Sick Bay, the Weapons Office, the Missile Drying and Dehumidification (MDD) equipment room, some work centers and overflow berthing at deckplate level. Access to the missile Interstage (IS) is available from this level.

(3) The Third Level contains a number of 9-man bunkrooms, wash room and water closet spaces, crew's computer room, the Engineering Logroom, other offices and workcenters. Those spaces are port and starboard of the single centerline fore and aft passageway. This is the level with the highest concentration of personnel for extended periods of time. The only ambient compartment air CAMS station in the missile compartment is installed at a height of about six feet outside the Engineering Logroom and just Port of the centerline passageway. No access to the missile is available from this level.

(4) The Lower Level contains support equipment for the missiles, work spaces and overflow berthing at deckplate level. This level also houses the two fan rooms for the missile compartment, one along the port side and one along the starboard side. Although there is continuous access fore and aft on the port and starboard sides, one would have to transit through the fan room to do so. The primary fore and aft passageway is centerline and travel there is unimpeded. Access to the missile Eject Chamber (EC) is available from this level.

f. Missile Compartment Ventilation. The missile compartment is provided ducted supply air from the two fan rooms on the LL primarily supplied to the UL, 2L and 3L of the compartment. The entire missile compartment is used as a return air plenum with the air supplied to the upper three levels moving downward through the two ladderways at each end of the compartment and through the openings between the missile tubes and deckplates and other deck penetrations to reenter the fan rooms through their deck level intakes on the LL. Of note is that each bunk in the 9-man bunkrooms has a dedicated supply air diffuser.

2. Methods

a. Air Sample Collection. Air sample collection methods were selected to collect samples representative of the initial concentration of gases and VOCs when a missile is first opened and to have a negligible impact on the Lockheed-Martin personnel collecting the samples since these samples were added to a previously agreed scope of work. The methods are described below.

(1) Carbon Monoxide (CO) and Hydrogen (H_2) Sample Collection Methods. One and four tenths (1.4) liter SUMMA canisters were used to collect general area air samples for CO and H_2. The SUMMA canisters were cleaned and evacuated to a high vacuum in the laboratory. When the canister sampling valve is opened, air enters the canister until it is full or the valve is closed. Samples were collected virtually instantaneously using a #0 airflow restriction orifice that allowed unimpeded air flow. SUMMA canisters and flow restrictors were those manufactured by Entech Instruments, Inc., 2207 Agate Court, Simi Valley, CA 93065, (805) 527-5939. No air sampling pump was required for SUMMA canisters.

(2) VOC Sample Collection Methods. One and four tenths (1.4) liter SUMMA canisters and one liter amber glass bottles were used to collect general area air samples. The SUMMA canisters were cleaned and evacuated to a high vacuum in the laboratory. When the canister sampling valve is opened, air enters the canister until it is full or the valve is closed. Samples were collected virtually instantaneously using a #0 airflow restriction orifice that allowed unimpeded air flow. SUMMA canisters and flow restrictors were those manufactured by Entech Instruments, Inc., 2207 Agate Court, Simi Valley, CA 93065, (805) 527-5939. No air sampling pump was required for SUMMA canisters.

b. Air Sample Analysis. Air sample analytical methods are described below.

(1) Carbon Monoxide (CO) and Hydrogen (H_2) Analytical Methods and Laboratory.

(a) Samples collected in SUMMA canisters for CO were analyzed using Occupational Safety and Health Administration's (OSHA) Method ID-210. That method uses gas chromatography with a discharge ionization detector (GC-DID). The result obtained by GC-DID was confirmed by infrared spectroscopy. That analysis was performed by Airborne Laboratories International (ALI), 22 World's Fair DR, Somerset, NJ 08873, (732) 302-1950.

(b) Samples collected in SUMMA canisters for CO were also analyzed for H_2 by GC-DID. That analysis was also performed by Airborne Laboratories International (ALI), 22 World's Fair DR, Somerset, NJ 08873, (732) 302-1950.

(2) VOC Analytical Methods and Laboratories. Samples collected in SUMMA canisters and evacuated glass bottles for VOCs were analyzed using U.S. Environmental Protection Agency's (EPA) Method TO-15. TO-15 analysis is done by gas chromatography with mass spectrometry detection (GC-MS) that provides the most definitive identification of each VOC, the lowest detection limit and the widest measurement range. That analysis was performed by the ALS Environmental Laboratory, 960 Levoy Dr, Salt Lake City, UT 84123, (801) 266-7700. ALS Environmental Laboratory is accredited by the American Industrial Hygiene Association (AIHA).

c. Summary of Sample Collection and Analytical Methods. Sample collection and analytical methods are summarized in Table I.

Table I
Summary of Air Sample Collection and Analytical Methods

Analyte	Sample Collection Method	Analytical Method	Sample Type	Duration
CO	SUMMA Canister	OSHA ID-210, air samples collected then lab analysis for CO with confirmation by infrared spectroscopy	Area	Instantaneous
H_2	SUMMA Canister	Gas chromatography with Discharge Ionization Detector (GC-DID)	Area	Instantaneous
VOCs	SUMMA Canister	EPA TO-15, air samples collected then lab analysis for VOCs	Area	Instantaneous

d. Data Analysis

(1) Similar Exposure Groups (SEGs). Statistical analysis of the air sampling data requires that samples be separated into Similar Exposure Groups or SEGs. This process is outlined in reference (b) which has been adopted by the U.S. Navy in reference (c). The SEGs are described below and summarized in Table II.

(a) D5 SEG. The concentrations reported for air samples taken inside the D5 missiles are considered a SEG. This SEG can be subdivided, if statistical analysis indicates it should, into three SEGs that correspond to samples taken in each of the three D5 missile sections, i.e., ES, IS or EC.

(b) MC SEG. The concentrations reported for air samples taken inside the missile compartment to document pre-work and post-work ambient air quality are considered a SEG. These samples were not taken in or near any open D5 missiles. This SEG has too few samples to be subdivided based on the four levels of the missile compartment.

Table II
Summary of Similar Exposure Groups

Similar Exposure Group		Number of Samples
Code	Description	
D5	Inside D5 missiles, any section	9
MC	Inside missile compartment on any level but not inside or near an open D5 missile, i.e., pre-work or post-work	4

(2) Statistical Distribution of Air Sampling Data. Air sampling data is recognized to be essentially log-normally distributed. That means that the logarithms of the air concentrations approximate a normal distribution. Recognizing this allows one to use available sampling data to predict the parameters of the parent log-normal distribution that it comes from and, thereby, predict the frequency of occurrence of airborne concentrations of any desired value. The more sampling data available the closer the predicted distribution comes to the true distribution. Reference (b) asserts that six to ten samples allow for reasonable description of the parent distribution. Some underlying assumptions of this statistical treatment are that the exposures are stable over time, i.e., not increasing or decreasing, and that the samples collected are as random as possible.

(3) Using the Exposure Profile of Air Sampling Results to Predict the Frequency of Overexposures. References (b) and (c) point out that traditional air sampling data analysis that compares each sample result individually to the appropriate OEL or "snapshot" decision-making often wrongly determines whether a person is overexposed or not to a chemical substance. Instead, the best analysis of air sampling data is to recognize that all samples taken on persons who belong to a SEG are samples from the statistical distribution that describes all exposures for members of that SEG. That being the case, one can use the air sampling results to estimate the statistical parameters that describe the distribution of all possible exposures in the SEG. That distribution is called the Exposure Profile. Once that exposure profile is determined the next step is to calculate the 95th percentile (95th%ile) exposure of the Exposure Profile. The 95th percentile exposure is the concentration that is greater than 95% of all the concentrations in the Exposure Profile. Since one is most interested in whether the highest exposures are above the OEL, not whether the few we have sampled are individually above the OEL, analysis of air sampling data should focus on whether the 95th%ile exposure is greater than the OEL. To determine how confident one is in the estimate of the 95th%ile, the 95% upper confidence level (referred to as the Upper Tolerance Level (UTL)) is determined. Using those parameters one can calculate the % of exposures in the Exposure Profile that are expected to exceed the OEL, i.e., Exceedance Fraction. To be in acceptable control, exposures must not exceed the OEL more than 5% of the time. In other words, one is accepting the risk of 5% overexposure. OELs have been

traditionally set to ensure that 95% of the healthy working population will be protected.

(4) Calculating the Parameters of the Exposure Profile. Statistical analysis of the air sampling data and calculation of the essential parameters of the Exposure Profile was performed with the IHSTAT Excel spreadsheet distributed by the American Industrial Hygiene Association with reference (b). Unfortunately, this Excel spreadsheet does not handle datasets larger than 50 values nor does it optimally analyze censored data. Therefore, when datasets exceeded 50 values, contained censored values and/or when necessary to process all similar data using the same statistical tools the analysis was performed using Industrial Hygiene Data Analyst software from Exposure Assessment Solutions, Inc., Morgantown, WV.

(5) Other Statistical Data Analysis. Other statistical tests of air sampling data were performed using other software. Excel 2007 was used for performing Analysis of Variance. In some cases, Minitab Version 14 (Minitab, Inc., Quality Plaza, 1829 Pine Hall RD, State College, PA 16801-3008, Telephone 814-238-3280) was used for performing Analysis of Variance, Analysis of Means and other common statistical tasks.

3. Findings and Discussion

a. Limitations of the Data. The data presented reflects the operations conducted and environmental conditions existing on the dates of sampling.

b. Occupational Exposure Limits (OELs).

(1) OELs Used. Analytical results for all contaminants were compared to OELs of the following types from the following sources and are listed in Table V. Note that some gases and VOCs measured do not have an OEL. Blank cells in Table V indicate that no OEL of that type exists.

(a) Threshold Limit Values (TLVs), in reference (d), that are established by the American Conference of Governmental Industrial Hygienists. These guidelines are considered to represent the most current scientific knowledge about occupational exposure limits. There are three types of TLVs as described below.

1. TLV-Time-Weighted Average (TLV-TWA) which ACGIH defines as, "The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect."

2. TLV-Short-Term Exposure Limit (TLV-STEL) which ACGIH defines as, "A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA up to the TLV-STEL, should be less than 15 minutes, should occur no more than four times per day, and there should be at least 60 minutes between successive exposures in this range."

3. TLV-Ceiling (TLV-C) which ACGIH defines as, "The concentration that should

not be exceeded during any part of the working exposure." The time-averaging period for TLV-Cs is instantaneous. Among the two gases and 57 VOCs monitored in this study, only Freon 11, to protect against cardiac sensitization, and 1,2,4-trichloroethene, to protect against eye and respiratory irritation, have a TLV-C. In the following tables where OELs are listed, TLV-Cs are listed in the TLV-STEL column with the OEL concentration preceded by a "C".

(b) Submarine Atmosphere Control Limits (SACLs) established by the Naval Sea Systems Command in Section 3.3 of reference (e). Reference (e) is considered to be the definitive authority on contaminants in submarines while underway. Since SACLs are set to achieve a balance between safety and health and the demanding operational realities of the submerged submarine environment, they may be higher than the corresponding TLVs. Two types of SACLs were considered as described below.

1. 90-day SACLs were considered because they represented the lowest SACL concentration for a given gas or VOC.

2. 24-hour SACLs were considered because their time averaging period came closest to the 8 to 10 hour work shift a Missile Technician might work.

Table V
Monitored Gases and VOCs and Their Corresponding OELs

Chemical Name	CASRN	Occupational Exposure Limit (ppm)			
		8-Hour TWA-TLV	15-Minute STEL-TLV	90-Day SACL	24-Hour SACL
Gases					
Carbon monoxide	630-08-0	25		20	50
Hydrogen	1333-74-0				
Volatile Organic Compounds (VOCs)					
Dichlorodifluoromethane (Freon 12)	75-71-8	1,000		100	1,000
Methyl chloride (Chloromethane)	74-87-3	50	100		
Freon 114 (Dichlorotetr5afluoroethane)	76-14-2	1,000		100	1,000
Vinyl chloride	75-01-4	1			
1,3-Butadiene	106-99-0	2			
Bromomethane	74-83-9	1			
Ethyl chloride	75-00-3	100			
Freon 11 (Trichlorofluoromethane)	75-69-4		C 1,000	5	20
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	76-13-1	1,000	1,250		
1,1-Dichloroethene (Vinylidene chloride)	75-35-4	5		0.15	10
Acetone	67-64-1	500	750	200	1,000
Carbon disulfide	75-15-0	1			
Methylene chloride (Dichloromethane)	75-09-2	50			
trans-1,2-Dichloroethene	156-60-5	200			
Methyl t-butyl ether	1634-04-4	50			
Vinyl acetate	108-05-4	10	15		
Methyl ethyl ketone (2-Butanone)	78-93-3	200	300		
cis-1,2-Dichloroethene	156-59-2	200			
1,1-Dichloroethane	75-34-3	100			
Ethyl acetate	141-78-6	400			
n-Hexane	110-54-3	50			
Chloroform	67-66-3	10			

Chemical Name	CASRN	Occupational Exposure Limit (ppm)			
		8-Hour TWA-TLV	15-Minute STEL-TLV	90-Day SACL	24-Hour SACL
Tetrahydrofuran	109-99-9	50	100		
1,2-Dichloroethane (Ethylene dichloride)	107-06-2	10			
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	350	450	2.5	10
Carbon tetrachloride	56-23-5	5	10		
Benzene	71-43-2	0.5	2.5	1	2
Cyclohexane	110-82-7	100			
Trichloroethene	79-01-6	10	25		10
1,2-Dichloropropane (Propylene dichloride)	78-87-5	10			
Bromodichloromethane	75-27-4				
Heptane	142-82-5	400	500		
cis-1,3-Dichloropropene	10061-01-5	1			
Methyl isobutyl ketone (4-Methyl-2-pentanone)	108-10-1	20	75		
trans-1,3-Dichloropropene	10061-02-6				
1,1,2-Trichloroethane	79-00-5	10			
Toluene	108-88-3	20		20	100
2-Hexanone (Methyl n-butyl ketone)	591-78-6	5	10		
Tetrachloroethene	127-18-4	25	100		
Dibromochloromethane	124-48-1				
1,2-Dibromoethane (Ethylene dibromide)	106-93-4				
Chlorobenzene	108-90-7	10			
Ethyl benzene	100-41-4	20			
m,p-Xylene	179601-23-1	100	150	50	100
o-Xylene	95-47-6	100	150	50	100
Styrene	100-42-5	20	40		
Bromoform	75-25-2	0.5			
1,1,2,2-Tetrachloroethane	79-34-5	1			
4-Ethyl toluene	622-96-8				
1,3,5-Trimethylbenzene	108-67-8				
1,2,4-Trimethylbenzene	95-63-6				
1,3-Dichlorobenzene	541-73-1				
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	10			
Benzyl chloride	100-44-7	1			
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	25	50		
1,2,4-Trichlorobenzene	120-82-1		C 5		
Hexachloro-1,3-butadiene	87-68-3	0.02			

NOTE: Blank cells indicate that there was no OEL of that type established.
CASRN – Chemical Abstracts Service Registry Number
ppm – parts of VOC per million parts of air
SACL – Submarine Atmosphere Control Limit
STEL-TLV – 15-Minute Short-Term Exposure Limit Threshold Limit Value
TWA-TLV – 8-Hour Time-Weighted Average Threshold Limit Value
VOC – Volatile Organic Compound

(2) OEL Time Averaging Periods. All OELs have a time averaging period stated and it is important to recognize that air sampling results can only be strictly compared to an OEL if the averaging periods of both are the same. All the data collected for this study were instantaneous samples and can only be rigorously compared to Ceiling TLVs (TLV-C). However, comparison to OELs with different time averaging periods can be useful as long as consideration is given to the effect that higher or lower concentrations of the gas or VOC may have on the total concentration during the remainder of the appropriate time averaging period. For example, "instantaneous" SUMMA canister results, since they are taken soon after a missile compartment is opened, probably represent the highest concentration that would be measured during a longer

sampling period. In other words, a 15-minute or 8-hour sample would be expected to result in a lower concentration. That may not be true if off-gassing of a gas or VOC continues or increases after the missile is opened.

c. Air Contaminants Inside D5 Missiles.

(1) Air Contaminants Measured. CO, H_2 and 57 VOCs were measured as potential occupational exposure problems. The 57 VOCs included all the VOCs previously measured and reported in earlier studies of air contaminants inside D5 missiles. The concentrations of these gases and VOCs reported by the two laboratories are listed in Table VI. Orange colored cells in Table VI indicate that the VOC was not detected in the sample at concentrations greater than the analytical method's minimum detection limit (MDL). In other words, the laboratory could not measure any of that VOC in the air sample.

(2) Air Contaminants Detected. In addition to the two gases, only 34 VOCs were actually detected by the laboratory at concentrations greater than the analytical method's minimum detection limit (MDL). The analytical method's MDL is either 0.003 parts of contaminant per million parts of air (ppm) or 0.0015 ppm, depending on the VOC measured.

(3) Air Contaminants Having Potential for Occupational Overexposure. The following process was used to select air contaminants that had a potential for occupational overexposure, From the two gases and 57 VOCs in Table VI, hydrogen and seven VOCs, none of which had an OEL, were removed from consideration. An additional 18 VOCs were eliminated because they were not detected and their MDL was less than 10% of their lowest OEL and, in one case, 15% of its lowest OEL. This left only CO and 32 VOCs. Then all gases and VOCs for which their maximum concentration was less than 10% of their lowest OEL were removed from consideration. That left CO, vinylidene chloride, methyl chloroform, benzene and toluene as having a potential for an occupational overexposure. In the following contaminant by contaminant discussions, remember that the sampling results are instantaneous and that all of the OELs have longer time averaging periods ranging from 15 minutes to 90 days so comparisons are very conservative because the concentration is expected to decrease over time after the missile is opened. Also, it was observed that the air sample attributed to the Eject Chamber of Missile Tube 10 and analyzed for VOCs was noticeably different in concentrations from the other inside the missile samples and more closely resembled an ambient air sample. The source of that discrepancy is unknown; however, when interpreting the VOC data inside D5 missiles that sample was excluded.

(4) Carbon Monoxide. The results of laboratory analysis for CO are presented in Figure 1 accompanied by laboratory results for H_2 and direct-reading instrument, i.e., PHD-6 meter, measurements of CO by electrochemical sensor as part of the Lockheed-Martin protocol.

(a) One-to-One Comparison of Laboratory CO Results to the OELs. Only one of the nine results obtained by laboratory analysis of SUMMA canister samples exceeded any of the OELs. That gives a non-parametric Exceedance Fraction of 11%, i.e., 1/9. That result was a 26 ppm concentration that exceeded the TLV-TWA (8-hour) and SACL (90-day).

Table VI
Concentrations of Gases and VOCs Analyzed for Inside D5 Missiles 3-4 Sep 2013 Onboard SSBN 740

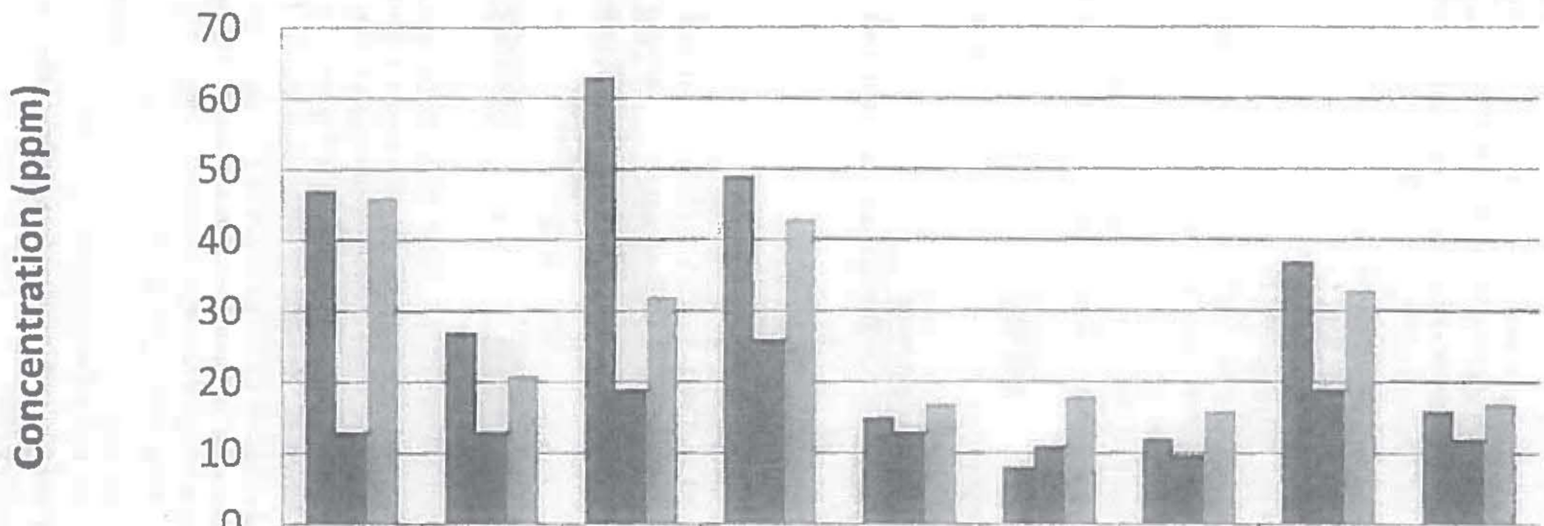
Chemical Name	Occupational Exposure Limit (OEL)				Missile Section								
	8-hr TWA TLV (ppm)	15-min STEL TLV (ppm)	90-dy SACL (ppm)	24-hr SACL (ppm)	Equipment Section (ES)			Interstage (IS)			Eject Chamber (EC)		
					Missile Tube Number								
					10	21	15	15	23	21	10	15	23
					Results (ppm)								
Gases													
					ALI Laboratory Sample Number 13-0923-X								
					3	4	7	12	5	1	11	9	6
Carbon monoxide	25		20	50	13	13	19	26	13	11	9.7	19	12
Hydrogen					46	18	32	43	17	18	28	33	17
Volatile Organic Compounds (VOCs)													
					ALS Laboratory Sample Number 132601XXXX								
					7002	7003	7004	7005	7006	7008	7010	7011	7012
Dichlorodifluoromethane (Freon 12)	1000		100	1,000	0.35	0.13	0.13	1.8	0.76	2.1	0.1	0.75	0.5
Methyl chloride (Chloromethane)	50	100			0.031	0.026	0.019	0.032	0.036	0.023	0.0029	0.02	0.024
Freon 114 (Dichlorotetr5afluoroethane)	1000		100	1,000	0.81	0.65	0.36	0.63	0.76	0.55	0.052	0.44	0.53
Vinyl chloride	1				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,3-Butadiene	2				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Bromomethane	1				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Ethyl chloride	100				0.0089	0.0074	0.0015	0.0048	0.0039	0.0045	0.0015	0.0044	0.0071
Freon 11 (Trichlorofluoromethane)		1000	5	20	0.0065	0.0087	0.0051	0.006	0.0037	0.0075	0.0015	0.0065	0.0075
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	1000	1250			0.0073	0.0077	0.0015	0.0015	0.0066	0.007	0.0015	0.0015	0.0072
1,1-Dichloroethene (Vinylidene chloride)	5		0.15	10	0.18	0.21	0.0042	0.0015	0.22	0.2	0.013	0.0015	0.21
Acetone	500	750	200	1000	3.2	4.6	4.5	4.6	3.7	4.3	0.26	4.9	4.2
Carbon disulfide	1				0.022	0.027	0.03	0.028	0.044	0.031	0.0027	0.041	0.031
Methylene chloride (Dichloromethane)	50				0.13	0.12	0.044	0.064	0.12	0.12	0.012	0.057	0.12
trans-1,2-Dichloroethene	200				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Methyl t-butyl ether	50				0.011	0.023	0.011	0.017	0.012	0.021	0.0015	0.013	0.021
Vinyl acetate	10	15			0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Methyl ethyl ketone (2-Butanone)	200	300			2.2	2.1	3.1	3.7	2.7	2	0.22	3.8	2.2
cis-1,2-Dichloroethene	200				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,1-Dichloroethane	100				0.0043	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Ethyl acetate	400				0.0015	0.0015	0.0022	0.0038	0.0015	0.0015	0.0015	0.0015	0.0015
n-Hexane	50				0.028	0.025	0.016	0.024	0.026	0.024	0.0035	0.028	0.033
Chloroform	10				0.0018	0.003	0.0015	0.0017	0.0017	0.0032	0.0015	0.0015	0.0033
Tetrahydrofuran	50	100			0.01	0.02	0.021	0.032	0.024	0.019	0.0015	0.025	0.021
1,2-Dichloroethane (Ethylene dichloride)	10				0.0015	0.0021	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,1,1-Trichloroethane (Methyl chloroform)	350	450	2.5	10	6.1	5.9	0.25	0.34	5.1	5.8	1.1	0.31	5.2

Chemical Name	Occupational Exposure Limit (OEL)				Missile Section								
					Equipment Section (ES)			Interstage (IS)			Eject Chamber (EC)		
	8-hr TWA TLV (ppm)	15-min STEL TLV (ppm)	90-dy SACL (ppm)	24-hr SACL (ppm)	Missile Tube Number								
					10	21	15	15	23	21	10	15	23
					Results (ppm)								
Carbon tetrachloride	5	10			0.0015	0.0033	0.0016	0.0027	0.0015	0.0015	0.0015	0.0015	0.0015
Benzene	0.5	2.5	1	2	3.5	4	4.2	4.5	3.5	4.1	0.34	4.9	3.7
Cyclohexane	100				0.0094	0.0094	0.016	0.025	0.0082	0.0093	0.0015	0.022	0.0099
Trichloroethene	10	25		10	0.0023	0.0022	0.0022	0.0015	0.0084	0.0025	0.0015	0.0029	0.0025
1,2-Dichloropropane (Propylene dichloride)	10				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Bromodichloromethane					0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Heptane	400	500			0.0053	0.01	0.032	0.048	0.0081	0.011	0.0015	0.042	0.011
cis-1,3-Dichloropropene	1				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Methyl isobutyl ketone (4-Methyl-2-pentanone)	20	75			0.077	0.085	0.13	0.17	0.14	0.086	0.0015	0.18	0.091
trans-1,3-Dichloropropene					0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,1,2-Trichloroethane	10				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Toluene	20		20	100	1.1	3.1	2.8	3	1.6	2.9	0.13	3.1	3.1
2-Hexanone (Methyl n-butyl ketone)	5	10			0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Tetrachloroethene	25	100			0.002	0.0021	0.0021	0.0029	0.021	0.0023	0.0015	0.0026	0.0025
Dibromochloromethane					0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,2-Dibromoethane (Ethylene dibromide)					0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Chlorobenzene	10				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Ethyl benzene	20				0.069	0.029	0.11	0.15	0.085	0.028	0.0027	0.13	0.031
m,p-Xylene	100	150	50	100	0.25	0.095	0.25	0.31	0.29	0.093	0.011	0.29	0.11
o-Xylene	100	150	50	100	0.079	0.045	0.096	0.11	0.16	0.044	0.0032	0.11	0.048
Styrene	20	40			0.014	0.0047	0.013	0.016	0.0045	0.0051	0.0015	0.016	0.0063
Bromoform	0.5				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,1,2,2-Tetrachloroethane	1				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
4-Ethyl toluene					0.013	0.017	0.022	0.024	0.021	0.016	0.0015	0.025	0.022
1,3,5-Trimethylbenzene					0.019	0.022	0.025	0.03	0.037	0.026	0.0015	0.034	0.028
1,2,4-Trimethylbenzene					0.046	0.061	0.063	0.075	0.11	0.079	0.0028	0.081	0.08
1,3-Dichlorobenzene					0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
1,4-Dichlorobenzene (p-Dichlorobenzene)	10				0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Benzyl chloride	1				0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1,2-Dichlorobenzene (o-Dichlorobenzene)	25	50			0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1,2,4-Trichlorobenzene		5			0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Hexachloro-1,3-butadiene	0.02				0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

NOTE: Orange colored cells indicate the listed concentration, if present, was below the minimum detection limit, i.e., none was detected.

CASRN – Chemical Abstracts Service Registry Number
ppm – parts of VOC per million parts of air
SACL – Submarine Atmosphere Control Limit
STEL-TLV – 15-Minute Short-Term Exposure Limit Threshold Limit Value
TWA-TLV – 8-Hour Time-Weighted Average Threshold Limit Value
VOC – Volatile Organic Compound

Figure 1 – CO and H_2 Inside D5 Missile Sections
3-4 Sep 2013 – SSBN 740



	ES Tube 10	ES Tube 21	ES Tube 15	IS Tube 15	IS Tube 23	IS Tube 21	EC Tube 10	EC Tube 15	EC Tube 23
CO by PHD6	47	27	63	49	15	8	12	37	16
CO by Lab	13	13	19	26	13	11	9.7	19	12
H2 by Lab	46	21	32	43	17	18	16	33	17

(b) Statistical Comparison of the 95th Percentile Concentration of the Lognormal Exposure Distribution to the OELs. The IHSTAT spreadsheet was used to calculate the statistical parameters of the laboratory CO results from SUMMA canister samples. That provides an estimation of the Exceedance Fraction for a specific OEL. One compares that to the previously cited criteria of less than five percent to decide if the exposure profile is acceptable. The essential results of the statistical calculations are listed in Table VII. All exposures come from a single distribution with data from all missile sections combined. This exposure profile is acceptable when compared to the TLV-TWA and SACL 24-hour but not to the SACL 90-day.

(c) Summary Assessment of the Exposure Profile. There is a reasonable expectation that 8-hour, 24-hour and 90-day exposures will be significantly less given that no personnel are expected to be exposed to concentration near the initial concentration of CO for those time periods. Due to the conservative comparison of an instantaneous exposure profile to OELs with much longer averaging times, i.e., 8 hours to 90 days, and assuming that the laboratory analysis results are the most accurate CO measurements; it is probable that CO exposures are acceptable.

Table VII
Statistical Prediction of Acceptability of the Carbon Monoxide Exposure Profile

Air Contaminant	Carbon monoxide			
Sample Location	Inside D5 missiles all sections combined			
Number of Samples	9			
Geometric Standard Deviation	1.371			
Pass W-test for Lognormality?	Yes			
Upper Tolerance Level 95,95	37.4 ppm			
	TLV-TWA (8-hour)	**TLV-STEL (15-minute)**	**SACL (90-day)**	**SACL (24-hour)**
OEL	25 ppm	None	20 ppm	50 ppm
95th Percentile Estimate	24.2 ppm			
Estimated % > OEL	4.0	N/A	14.8	0.0
Acceptable Exposure Profile?	Yes	N/A	No	Yes

(d) Do Direct-Reading Measurements of CO Agree with Laboratory Analysis of CO? Laboratory analysis of CO is considered to be more specific and accurate than direct-reading meters because electrochemical sensors have some cross-sensitivities to other gases. Direct-reading measurements of CO with a PHD-6 meter are reported in Figure 1 in direct comparison to the laboratory reported CO concentrations. In eight of nine instances, the PHD-6 reported more CO than the laboratory, with a range of 115% to 362% of the laboratory concentration. In four instances (including the one where the laboratory reported more CO than the PHD-6) the difference was four ppm or less which borders on what might be explained by the errors inherent in both methods. However, in five of nine instances, the PHD-6 reported significantly greater CO concentrations than reported by laboratory analysis, with a range of 188% to 362%. That is most likely due to a positive interference of other contaminants with the CO electrochemical sensor. Hydrogen gas, known to be present in the submarine environment, is a common positive interference with CO electrochemical sensors.

(c) Can H_2 Concentrations Explain the Difference Between Direct-Reading and Laboratory CO Concentrations? In Figure 1, laboratory reported concentrations of H_2 are listed. Significant H_2 concentrations were reported by the laboratory in every D5 missile samples, with a range from 16 ppm to 46 ppm. It is significant to note that the four D5 missiles where there was no significant difference between the direct-reading and laboratory CO concentrations also had the lowest concentrations of H2 reported, with a range from 16 ppm to 18 ppm. That suggests that there might be a threshold below which H_2 has no positive interference with the PHD-6's electrochemical CO sensor. The data was analyzed to determine if there was mathematical relationship between the H_2 concentrations reported by the laboratory and the difference between the PHD-6 CO concentrations minus the laboratory CO concentrations. That analysis focused on the five samples where there was a significant difference between direct-reading and laboratory CO results. Various relationships were investigated and subtracting the suspected threshold of 18 ppm H_2 was considered. No mathematical relationship was found that could explain the difference in CO concentration between the two measurement methods as a function of H_2 concentration. That suggests that there may be other interferences and the cause is more complex. The small data set may also have masked the existence of a relationship.

(5) Vinylidene Chloride. Concentrations of vinylidene chloride are presented in Figure 2.

(a) One to One Comparison to the OELs. Five of the eight results exceeded a single OEL. That was the SACL (90-day). That gives a non-parametric Exceedance Fraction of 62.5%, i.e., 5/8.

(b) Statistical Comparison of the 95th Percentile Concentration of the Lognormal Exposure Distribution to the OELs. The IHSTAT spreadsheet was used to calculate the statistical parameters of the vinylidene chloride sampling results. That provides an estimation of the Exceedance Fraction for a specific OEL. One compares that to the previously cited criteria of less than five percent to decide if the exposure profile is acceptable. The essential results of the statistical calculations are listed in Table VIII. All exposures did not come from a single distribution with data from all missile sections combined. There were five missiles that had significantly higher concentrations of vinylidene chloride than the other three. Since there was one low concentration missile in each of the three sections tested, i.e., ES, IS, EC, it could not be concluded that the differences in concentration were related to the missile section. The low concentration results would produce an acceptable exposure profile for all the OELs. Therefore, statistical analysis was performed for the five high concentration results as a SEG. This exposure profile is acceptable when compared to the TLV-TWA and SACL 24-hour but not to the SACL 90-day.

(c) Summary Assessment of the Exposure Profile. Due to the conservative comparison of an instantaneous exposure profile to OELs with much longer averaging time, i.e., 90 days, it is probable that vinylidene chloride exposures are acceptable. There is a reasonable expectation that 90-day exposures will be significantly less given that no personnel are expected to be exposed to concentrations near the initial concentration of vinylidene chloride continuously for 90 days. The marked difference in concentration between the two groups of missiles could be interpreted as an indication of the presence of vinylidene chloride being due to an external source, e.g., accidental introduction during legitimate missile work, and not something originating from the missile. However, the data is insufficient to prove that. The data parallels the data for methyl chloroform.

Figure 2 - Vinylidene Chloride Inside D5 Missile Sections 3-4 Sep 2013 – SSBN 740

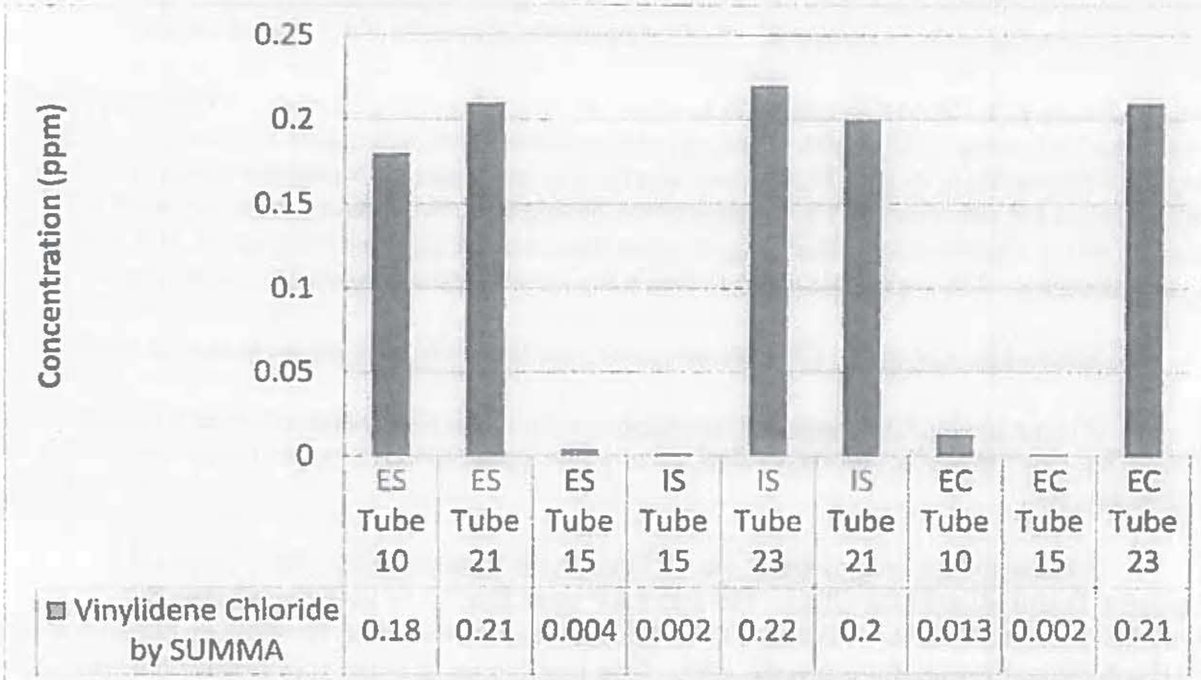
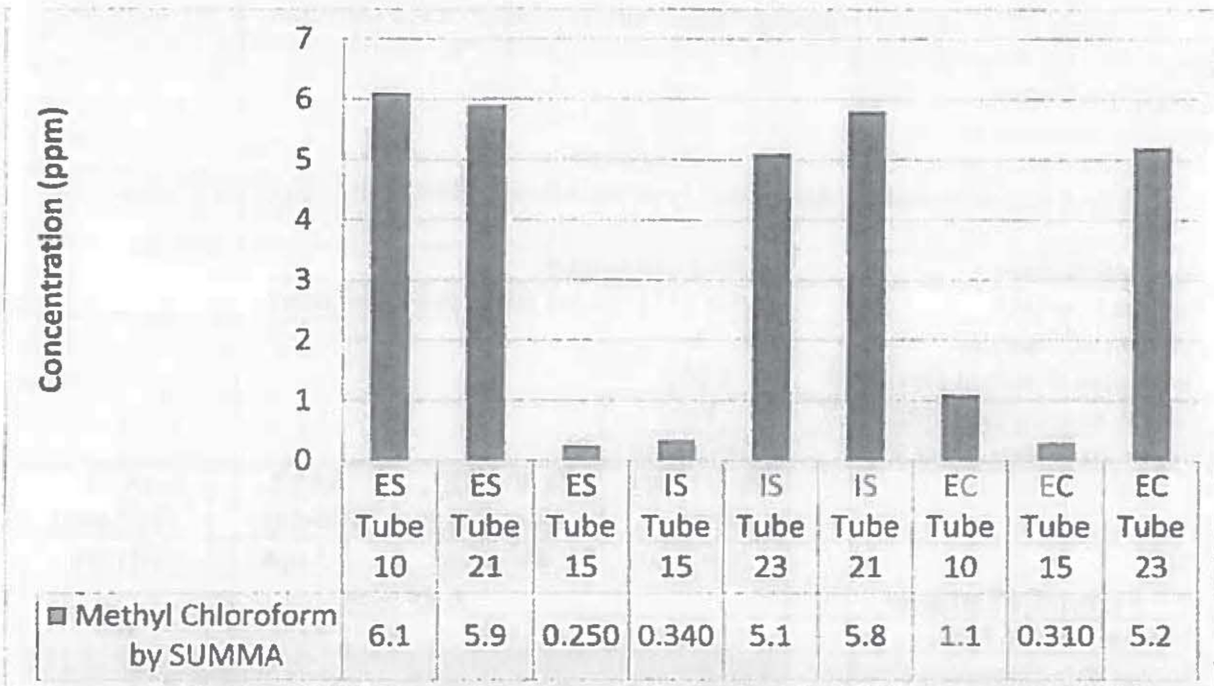


Table VIII
Statistical Prediction of Acceptability of the Vinlylidene Chloride Exposure Profile

Air Contaminant	Vinylidene chloride			
Sample Location	Inside D5 missiles all sections combined			
Number of Samples	5			
Geometric Standard Deviation	1.080			
Pass W-test for Lognormality?	Yes			
Upper Tolerance Level 95,95	0.281 ppm			
	TLV-TWA (8-hour)	**TLV-STEL (15-minute)**	**SACL (90-day)**	**SACL (24-hour)**
OEL	5 ppm	None	0.15 ppm	10 ppm
95th Percentile Estimate	0.231 ppm			
Estimated % > OEL	0.0	N/A	100.0	0.0
Acceptable Exposure Profile?	Yes	N/A	No	Yes

(6) <u>Methyl Chloroform</u>. Concentrations of methyl chloroform are presented in Figure 3.

Figure 3 - Methyl Chloroform Inside D5 Missile Sections 3-4 Sep 2013 – SSBN 740



(a) One to One Comparison to the OELs. Five of the eight results exceeded a single OEL. That was the SACL (90-day). That gives a non-parametric Exceedance Fraction of 62.5%, i.e., 5/8.

(b) Statistical Comparison of the 95th Percentile Concentration of the Lognormal Exposure Distribution to the OELs. The IHSTAT spreadsheet was used to calculate the statistical parameters of the methyl chloroform sampling results. That provides an estimation of the Exceedance Fraction for a specific OEL. One compares that to the previously cited criteria of less than five percent to decide if the exposure profile is acceptable. The essential results of the statistical calculations are listed in Table IX. All exposures did not come from a single distribution with data from all missile sections combined. There were five missiles that had significantly higher concentrations of methyl chloroform than the other three. Since there was one low concentration missile in each of the three sections tested, i.e., ES, IS, EC, it could not be concluded that the differences in concentration were related to the missile section. The low concentration results would produce an acceptable exposure profile for all the OELs. Therefore, statistical analysis was performed for the five high concentration results as a SEG. This exposure profile is acceptable when compared to the TLV-TWA, TLV-STEL and SACL 24-hour but not to the SACL 90-day.

(c) Summary Assessment of the Exposure Profile. Due to the conservative comparison of an instantaneous exposure profile to OELs with much longer averaging time, i.e., 90 days, it is probable that methyl chloroform exposures are acceptable. There is a reasonable expectation that 90-day exposures will be significantly less given that no personnel are expected to be exposed to concentrations near the initial concentration of methyl chloroform continuously for 90 days. The marked difference in concentration between the two groups of missiles could be interpreted as an indication of the presence of methyl chloroform being due to an external source, e.g., accidental introduction during legitimate missile work, and not something originating from the missile. However, the data is insufficient to prove that. The data parallels the data for vinylidene chloride.

Table IX

Statistical Prediction of Acceptability of the Methyl Chloroform Exposure Profile

Air Contaminant	Methyl chloroform			
Sample Location	Inside D5 missiles all sections combined			
Number of Samples	5			
Geometric Standard Deviation	1.083			
Pass W-test for Lognormality?	Yes			
Upper Tolerance Level 95,95	7.841 ppm			
	TLV-TWA (8-hour)	**TLV-STEL (15-minute)**	**SACL (90-day)**	**SACL (24-hour)**
OEL	350 ppm	450 ppm	2.5 ppm	10 ppm
95th Percentile Estimate	6.39 ppm			
Estimated % > OEL	0.0	0.0	99.9	0.0
Acceptable Exposure Profile?	Yes	Yes	No	Yes

(7) Benzene. Concentrations of benzene are presented in Figure 4.

(a) One to One Comparison to the OELs. All of the nine results exceeded all of the OELs. That gives a non-parametric Exceedance Fraction of 100%, i.e., 9/9. Although not as certain, there is a reasonable probability that a person might exceed the TLV-TWA if they spend substantial time working inside a missile without mitigation. On the other hand, it is virtually certain that, without mitigation, personnel working inside D5 missiles will be exposed to benzene above the TLV-STEL.

(b) Statistical Comparison of the 95th Percentile Concentration of the Lognormal Exposure Distribution to the OELs. The IHSTAT spreadsheet was used to calculate the statistical parameters of the benzene sampling results. That provides an estimation of the Exceedance Fraction for a specific OEL. One compares that to the previously cited criteria of less than five percent to decide if the exposure profile is acceptable. The essential results of the statistical calculations are listed in Table X. All exposures come from a single distribution with data from all missile sections combined. This exposure profile is not acceptable when compared to the TLV-TWA, TLV-STEL, SACL 90 day and SACL 24-hour.

(c) Do SUMMA Canister and Charcoal Tube Benzene Concentrations Agree? In Figure 4, benzene results from 30-minute TWA charcoal tube samples taken by Lockheed-Martin personnel were available for comparison to SUMMA canister samples for seven of the nine

SUMMA samples. One of those sample pairs could not be compared because the SUMMA sample was suspect as previously discussed. Statistical comparison of the two data sets using Analysis of Variance (ANOVA), while not absolutely appropriate due to slightly different averaging periods, indicated no significant difference ($p=0.7172$). Removal of the pair with the most extreme 30-minute TWA, i.e., 10 ppm, to reduce the variance still resulted in an indication of no significant difference ($p=0.0715$).

Figure 4 - Benzene Inside D5 Missile Sections
3-4 Sep 2013 – SSBN 740

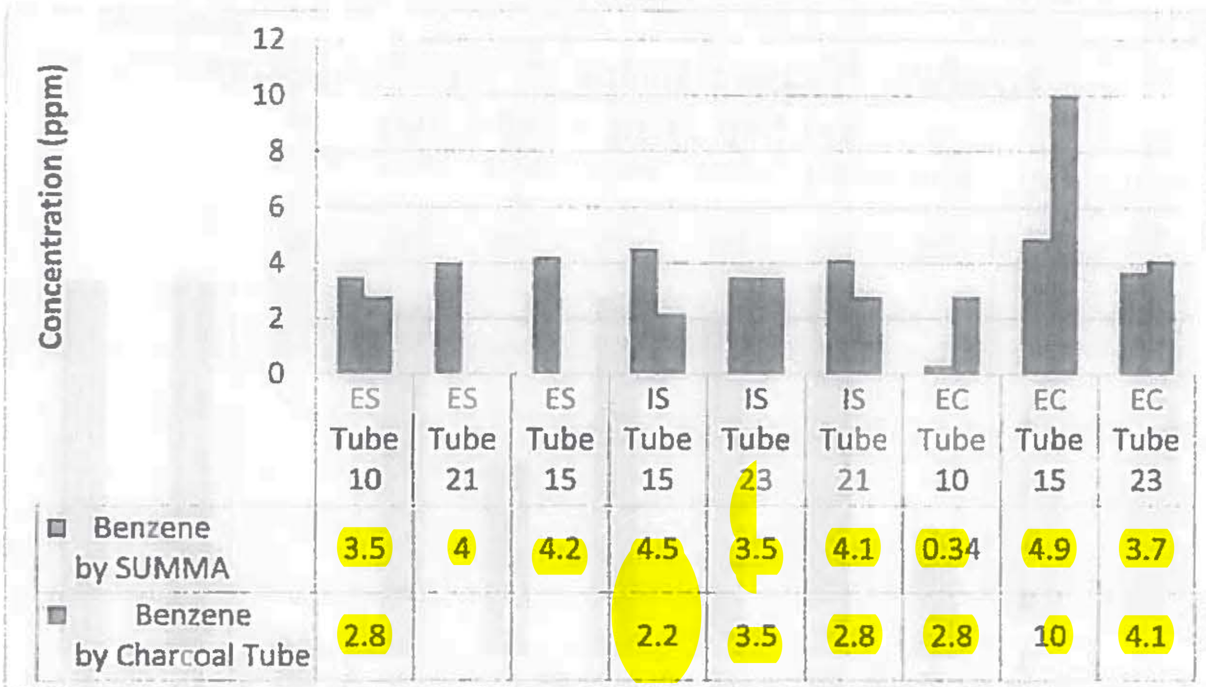


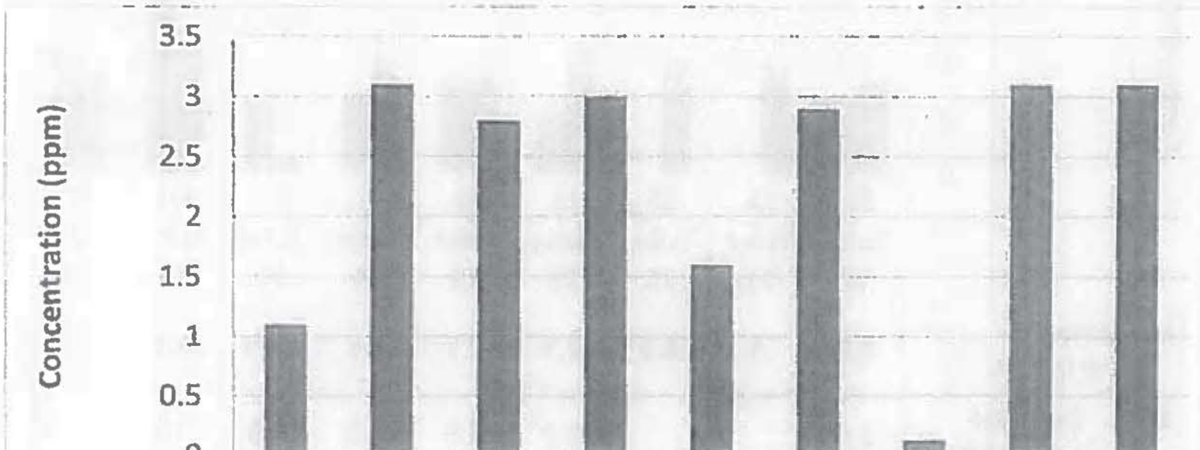
Table X
Statistical Prediction of Acceptability of the Benzene Exposure Profile

Air Contaminant	Benzene			
Sample Location	Inside D5 missiles all sections combined			
Number of Samples	9			
Geometric Standard Deviation	1.127			
Pass W-test for Lognormality?	Yes			
Upper Tolerance Level 95,95	5.89 ppm			
	TLV-TWA (8-hour)	**TLV-STEL (15-minute)**	**SACL (90-day)**	**SACL (24-hour)**
OEL	0.5 ppm	2.5 ppm	1 ppm	2 ppm
95th Percentile Estimate	4.90 ppm			
Estimated % > OEL	100.0	99.9	100.0	100.0
Acceptable Exposure Profile?	No	No	No	No

(d) Summary Assessment of the Exposure Profile. Due to the conservative comparison of an instantaneous exposure profile to OELs with much longer averaging times. There is a reasonable expectation that 24-hour and 90-day exposures will be significantly less given that no personnel are expected to be exposed to a concentration near the initial concentration of benzene for those time periods. Although not as certain, there is a reasonable probability that a person might exceed the TLV-TWA if they spend substantial time working inside a missile without mitigation. On the other hand, it is virtually certain that, without mitigation, personnel working inside D5 missiles will be exposed to benzene above the TLV-STEL.

(7) Toluene. Concentrations of toluene are presented in Figure 5.

Figure 5 - Toluene Inside D5 Missile Sections
3-4 Sep 2013 – SSBN 740



	ES Tube 10	ES Tube 21	ES Tube 15	IS Tube 15	IS Tube 23	IS Tube 21	EC Tube 10	EC Tube 15	EC Tube 23
Toluene by SUMMA	1.1	3.1	2.8	3	1.6	2.9	0.13	3.1	3.1

(a) One to One Comparison to the OELs. None of the eight results exceeded any OEL. That gives a non-parametric Exceedance Fraction of 0.0%, i.e., 0/8.

(b) Statistical Comparison of the 95th Percentile Concentration of the Lognormal Exposure Distribution to the OELs. The IHSTAT spreadsheet was used to calculate the statistical parameters of the toluene sampling results. That provides an estimation of the Exceedance Fraction for a specific OEL. One compares that to the previously cited criteria of less than five percent to decide if the exposure profile is acceptable. The essential results of the statistical calculations are listed in Table XI. All exposures did not come from a single distribution with data from all missile sections combined. There were six missiles that had significantly higher concentrations of toluene than the other two. Since there was one low concentration missile in each of the three sections tested (that includes the EC sample that was previously excluded as atypical), i.e., ES, IS, EC, it could not be concluded that the differences in concentration were related to the missile section. The low concentration results would produce an acceptable exposure profile for all the OELs. Therefore, statistical analysis was performed for the six high concentration results as a SEG. This exposure profile is acceptable when compared to all of the OELs.

(c) Summary Assessment of the Exposure Profile. Even without considering effect of the conservative comparison of an instantaneous exposure profile to OELs with much longer averaging times toluene exposures are acceptable when compared to any of the OELs. The marked difference in concentration between the two groups of missiles could be interpreted as an indication of the presence of toluene being due to an external source, e.g., accidental introduction during legitimate missile work, and not something originating from the missile. However, the data is insufficient to prove that. The data parallels the data for vinylidene chloride and methyl chloroform.

Table XI
Statistical Prediction of Acceptability of the Toluene Exposure Profile

Air Contaminant	Toluene			
Sample Location	Inside D5 missiles all sections combined			
Number of Samples	6			
Geometric Standard Deviation	1.044			
Pass W-test for Lognormality?	Yes			
Upper Tolerance Level 95,95	3.51 ppm			
	TLV-TWA (8-hour)	**TLV-STEL (15-minute)**	**SACL (90-day)**	**SACL (24-hour)**
OEL	20 ppm	None	20 ppm	100 ppm
95th Percentile Estimate	3.22 ppm			
Estimated % > OEL	0.0	N/A	0.0	0.0
Acceptable Exposure Profile?	Yes	N/A	Yes	Yes

d. Air Contaminants In the Missile Compartment. Each day two SUMMA canister samples (one for gases and one for VOCs) at a single location to characterize the pre-work ambient air quality and two at a single location to document post-work ambient air quality. These samples were collected at different locations on some level in the missile compartment to cover as many locations as possible with four samples. The objective was twofold: 1) determine if any of the gases or VOCs detected inside D5 missiles were present at significant concentration in the missile compartment and might be a source of contaminants detected inside the missiles and 2) determine if opening the D5 missiles significantly raised their concentration in the missile compartment,

(1) Air Contaminants Measured. The VOCs measured were the same two gases and 57 VOCs for which samples collected inside D5 missiles were analyzed. The concentrations of

these gases and VOCs reported by the two laboratories are listed in Table XII. Orange colored cells in Table XII indicate that the VOC was not detected in the sample at concentrations greater than the analytical method's minimum detection limit (MDL). In other words, the laboratory could not measure any of that VOC in the air sample.

(2) Air Contaminants Detected. In addition to the two gases, only 23 VOCs were actually detected by the laboratory at concentrations greater than the analytical method's minimum detection limit (MDL). The analytical method's MDL is 0.00015 ppm, 0.0003 ppm (only one sample was analyzed with these MDLs), 0.0015 ppm or 0.003 ppm depending on the instrument parameters for the analysis and on the VOC analyzed.

Table XII
Concentrations of VOCs Measured In Missile Compartment Ambient Air Pre-Work and Post Work on 3-4 Sep 2013 Onboard SSBN 740

Chemical Name	Occupational Exposure Limit (OEL)				Sample Purpose/Level/Closest Tube			
	8-hr TWA TLV (ppm)	15-min STEL TLV (ppm)	90-dy SACL (ppm)	24-hr SACL (ppm)	Pre-Work UL / STBD of 7	Post-Work 2L / PORT of 16	Pre-Work LL CL Btwn 11/12	Post-Work 2L STBD Btwn 21/23
					Result (ppm)			
Gases								
					ALI Lab Sample # 13-0923-X			
					2	10	8	N/A
Carbon Monoxide	25		20	50	1	Trace	1	N/A
Hydrogen					3	1	1	N/A
Volatile Organic Compounds (VOCs)								
					ALS Lab Sample # 132601XXXX			
					7001	7007	7009	70013
Dichlorodifluoromethane (Freon 12)	1,000		100	1,000	0.0024	0.014	3.4	1
Methyl chloride (Chloromethane)	50	100			0.00067	0.0015	0.023	0.0015
Freon 114 (Dichlorotetr5afluoroethane)	1000		100	1,000	0.031	0.041	0.095	0.075
Vinyl chloride	1				0.00015	0.0015	0.0015	0.0015
1,3-Butadiene	2				0.00015	0.0015	0.0015	0.0015
Bromomethane	1				0.00015	0.0015	0.0015	0.0015
Ethyl chloride	100				0.00015	0.0015	0.0015	0.0015
Freon 11 (Trichlorofluoromethane)		1000	5	20	0.00027	0.0015	0.0015	0.0015
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	1000	1250			0.00015	0.0015	0.0015	0.0015
1,1-Dichloroethene (Vinylidene chloride)	5		0.15	10	0.00015	0.0015	0.0015	0.0015
Acetone	500	750	200	1000	0.025	0.056	0.061	0.13
Carbon disulfide	1				0.00061	0.0015	0.0015	0.0015
Methylene chloride (Dichloromethane)	50				0.00022	0.0015	0.0015	0.0015
trans-1,2-Dichloroethene	200				0.00015	0.0015	0.0015	0.0015
Methyl t-butyl ether	50				0.00015	0.0015	0.0015	0.0015
Vinyl acetate	10	15			0.00015	0.0015	0.0015	0.0015
Methyl ethyl ketone (2-Butanone)	200	300			0.00015	0.0015	0.0015	0.064
cis-1,2-Dichloroethene	200				0.00015	0.0015	0.0015	0.0015
1,1-Dichloroethane	100				0.00015	0.0015	0.0015	0.0015
Ethyl acetate	400				0.0067	0.0015	0.0015	0.0015
n-Hexane	50				0.0015	0.0015	0.0015	0.029
Chloroform	10				0.00015	0.0015	0.0015	0.0015
Tetrahydrofuran	50	100			0.00015	0.0015	0.0015	0.0015
1,2-Dichloroethane (Ethylene dichloride)	10				0.00015	0.0015	0.0015	0.0015

Chemical Name	Occupational Exposure Limit (OEL)				Sample Purpose/Level/Closest Tube			
	8-hr TWA TLV (ppm)	15-min STEL TLV (ppm)	90-dy SACL (ppm)	24-hr SACL (ppm)	Pre-Work UL / STBD of 7	Post-Work 2L / PORT of 16	Pre-Work LL CL Btwn 11/12	Post-Work 2L STBD Btwn 21/23
					Result (ppm)			
Gases								
1,1,1-Trichloroethane (Methyl chloroform)	350	450	2.5	10	0.0009	0.027	0.031	0.059
Carbon tetrachloride	5	10			0.00015	0.0015	0.0033	0.0015
Benzene	0.5	2.5	1	2	0.0039	0.016	0.019	0.035
Cyclohexane	100				0.00034	0.0015	0.0015	0.0015
Trichloroethene	10	25		10	0.00015	0.0015	0.0015	0.0015
1,2-Dichloropropane (Propylene dichloride)	10				0.00015	0.0015	0.0015	0.0015
Bromodichloromethane					0.00015	0.0015	0.0015	0.0015
Heptane	400	500			0.00018	0.0015	0.0015	0.0015
cis-1,3-Dichloropropene	1				0.00015	0.0015	0.0015	0.0015
Methyl isobutyl ketone (4-Methyl-2-pentanone)	20	75			0.00015	0.0015	0.0015	0.0015
trans-1,3-Dichloropropene					0.00015	0.0015	0.0015	0.0015
1,1,2-Trichloroethane	10				0.00015	0.0015	0.0015	0.0015
Toluene	20		20	100	0.027	0.012	0.013	0.042
2-Hexanone (Methyl n-butyl ketone)	5	10			0.0003	0.003	0.003	0.003
Tetrachloroethene	25	100			0.00015	0.0015	0.0015	0.0015
Dibromochloromethane					0.00015	0.0015	0.0015	0.0015
1,2-Dibromoethane (Ethylene dibromide)					0.00015	0.0015	0.0015	0.0015
Chlorobenzene	10				0.00015	0.0015	0.0015	0.0015
Ethyl benzene	20				0.00033	0.0015	0.0015	0.017
m,p-Xylene	100	150	50	100	0.0016	0.0085	0.0015	0.075
o-Xylene	100	150	50	100	0.00075	0.0058	0.0015	0.07
Styrene	20	40			0.00015	0.0015	0.0015	0.0028
Bromoform	0.5				0.00015	0.0015	0.0015	0.0015
1,1,2,2-Tetrachloroethane	1				0.00015	0.0015	0.0015	0.0015
4-Ethyl toluene					0.0014	0.022	0.0025	0.52
1,3,5-Trimethylbenzene					0.0014	0.025	0.0029	0.51
1,2,4-Trimethylbenzene					0.0054	0.095	0.012	1.6
1,3-Dichlorobenzene					0.00015	0.0015	0.0015	0.0015
1,4-Dichlorobenzene (p-Dichlorobenzene)	10				0.00015	0.0015	0.0015	0.0015
Benzyl chloride	1				0.0003	0.003	0.003	0.003
1,2-Dichlorobenzene (o-Dichlorobenzene)	25	50			0.0003	0.003	0.003	0.003
1,2,4-Trichlorobenzene		5			0.0003	0.003	0.003	0.003
Hexachloro-1,3-butadiene	0.02				0.0003	0.003	0.003	0.003

NOTE: Orange colored cells indicate the listed concentration was below the minimum detection limit, i.e., none was detected.
CASRN – Chemical Abstracts Service Registry Number
ppm – parts of VOC per million parts of air
SACL – Submarine Atmosphere Control Limit
STEL-TLV – 15-Minute Short-Term Exposure Limit Threshold Limit Value
TWA-TLV – 8-Hour Time-Weighted Average Threshold Limit Value
VOC – Volatile Organic Compound

(3) Air Contaminants Having Potential for Occupational Overexposure. The following process was used to select air contaminants that had a potential for occupational overexposure. From the two gases and 57 VOCs in Table XII, hydrogen and seven VOCs, none of which had an OEL, were removed from consideration. An additional 30 VOCs were eliminated because they were not detected and their MDL was less than 10% of their lowest OEL and, in one case,

15% of its lowest OEL. This left only CO and 20 VOCs. Then all gases and VOCs for which their maximum concentration was less than 10% of their lowest OEL were removed from consideration. That left no gas or VOC as having a potential for an occupational overexposure in the ambient air of the missile compartment. Although benzene was detected in all four samples its highest concentration was 7% of its lowest OEL.

4. Conclusions

The following conclusions are based on observations during the survey and interpretation of the data collected during the survey. All conclusions are conservative because the instantaneous sample results represent a "worst case" when compared to Occupational Exposure Limits (OELs) that have time-weighted averaging periods of 15minutes to 90 days.

a. Carbon monoxide (CO) concentrations are not expected to create an overexposure to the OELs considered.

b. CO concentrations inside D5 missiles, as measured by the PHD-6 direct-reading multi-gas meter, overestimate the true concentration about half the time.

c. Hydrogen (H_2) concentrations inside D5 missiles, although present in significant concentrations, could not by themselves explain the difference between CO concentrations measured by the PHD-6 meter and laboratory analysis.

d. The difference between CO concentrations measured by PHD-6 and laboratory analysis may be caused by response of the PHD-6's electrochemical sensor to a combination of gases.

e. Benzene was present in all sections of D5 missiles sampled with no apparent difference between the three sections.

f. Without mitigation, e.g., exhaust ventilation, personnel working inside D5 missiles for more than seven minutes will be exposed to benzene above the 15-minute STEL-TLV.

g. Without mitigation, e.g., exhaust ventilation, personnel working inside D5 missiles for more than one hour may be exposed to benzene above the 8-hour TWA-TLV.

h. Although not zero, the potential for vinylidene chloride, methyl chloroform and toluene to cause an overexposure to the OELs considered is very low.

i. There was negligible risk of personnel overexposure with respect to the OELs considered from any of the two gases and 57 VOCs for which air samples were taken in the missile compartment before and after the work of opening missiles was conducted.

5. Recommendations

The following recommendations are based on the conclusions contained in this report: