



VENTILATION FOR PAINTING IN ENCLOSED SPACES

Risk Management Panel Project

FINAL REPORT

NSRP Subcontract Agreement No. 2012-456

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EXECUTIVE SUMMARY

The purpose of this research has been to collect new data that is representative of current industry conditions in order to develop a predictive tool to better estimate and establish some ventilation performance metrics for effective control of potential airborne hazards to health during shipyard painting processes. Many physical challenges influence the performance of such ventilation solutions including irregular size and configuration of work areas, distance and obstacles between staging areas for air movers and the painting work and variable composition and application of coating methods, coupled with the technical challenges encountered in the use of effective air sampling and test methods for reactant materials with very low short-term exposure limits.

Field work was completed at four participating shipyard sites between October 2012 and June 2013. BAE Southeast, Huntington Ingalls Newport News Shipbuilding (NNS), NASSCO, and Norfolk Naval Shipyard (NNSY) participated in this evaluation. The Navy and Marine Corps Public Health Center (NMCPHC) also participated in this evaluation, providing data analysis and technical reviews throughout the process.

Observation and testing covered a broad spectrum of shipyard painting processes. This work included surface ships and submarines, brush and spray applications, ships afloat and subsections under construction, work in small tight compartments and in large enclosed blast and paint facilities. Personal breathing zone and area air sampling was conducted for six different air contaminants including solvents, particulates and reactants. Six different coatings were applied during this testing, providing an excellent cross-section of the products currently used in the maritime industry.

The results of this work have shown that the participating shipyards have been able to develop, demonstrate and apply specialized equipment, skills and methods to effectively install and operate both fixed and temporary ventilation systems for painting in enclosed spaces. Due to the many variables which may change job-to-job, this work requires constant attention, adjustment, measurement and repair. Consequently, due to the high number of dynamic variables which could not be controlled on a consistent or predictable basis, it was not possible to produce a simple chart, graph, equation or table that can be effectively applied to predict, with confidence, the exact ventilation system requirements which may apply to any significant amount of anticipated shipyard painting work.

Recommendations for follow up action include ongoing testing of ventilation system performance, a review of methods to maximize the effectiveness and efficiency of current in-place equipment, and ensuring that painters and supervisors understand how to best apply these systems in affected work areas for contaminant control.

INTRODUCTION AND PROJECT OVERVIEW

Shipboard painting is often done in tight and enclosed spaces. This work is difficult to adequately ventilate for the effective control of visibility, flammability and health hazards due to irregular space configurations, limited access and egress, distance between painting work and a satisfactory staging area for fans and blowers, a variety of paint application equipment and methods, and a complex variety of paint formulations and potential airborne contaminants. Clearly, there is a need to summarize the effect of these many variables, under current “real-world” conditions of use. The goal of this project has been to record and apply this information to determine what practical methods may be of the greatest value in the estimation, selection, installation and performance of effective ventilation for painting in enclosed areas during future shipbuilding and repair.

This work will frequently use moveable temporary shipboard ventilation systems. These systems include portable powered air movers placed “topside” on an upper deck, open to the outside air, connected through a manifold to long lengths of flexible corrugated ducting that extend throughout the ship to the affected work space. A representative sample of such a ventilation system is shown in Figure 1.



Figure 1 – Temporary Ventilation Blower

Fully enclosed blast and paint facilities have also been constructed in some shipyards. These facilities can accommodate large subsections of ships under construction or components under repair in a dedicated painting environment designed to control temperature, humidity, and lighting while eliminating the potential overspray and emissions concerns with in-situ spraying within temporary containment structures or within enclosed or confined spaces. Fixed, in-place ventilation systems, designed for the blast and paint facility can provide high volumes of tempered and supply and filtered exhaust air. A representative sample of an enclosed blast and paint facility is shown in Figure 2.



Figure 2 – Enclosed Blast and Paint Facility

(Source: Wheelabrator Group; <http://www.wheelabratorgroup.com/pdf/Surface%20Preparation%20for%20Shipyards.pdf>)

Modern maritime coating products may be applied through brush and roller methods or by spray application. A representative illustration of spray application, and a spray nozzle, is shown as Figure 3 and Figure 4.



Figure 3 – Protective Equipment for Shipyard Painting
(Source: OSHA Shipyard Employment e Tool – Painting and Other Coatings)

Figure 4 – Paint spray gun

Due to the volume of materials released in a space in a given amount of time, spray application requires continuous attention to the control of the work area and airflow volumes. In addition to the solvents and particulates released by spray application, some two-part or multi-component coatings systems may produce reactant materials with very low exposure limits. For example, m-Xylene-a,a'-Diamine (m-XDA) has a Threshold Limit Value (TLV) of 0.1 parts per million of air as a Ceiling Limit, not to be exceeded at any time without appropriate respiratory protection. Understandably, control to applicable exposure limits in these conditions can be especially difficult. With the potential to release such a combination of mists, heavy liquids and solids in air, theoretical calculations simply based on predicted solvent concentrations is not always an adequate method of determining the amount of ventilation needed to control potential exposures to these materials.

Anticipated solvent concentrations for work in a given space may be calculated with some confidence based upon the fixed, static control of variables such as work area volume, temperature, the percentage of a known solvent in the coating and the number of gallons applied. Real life solutions for predicting airborne concentrations of solvents and other compounds produced by this work are not so simple, due to non-uniform work area volumes, exhaust ventilation airflows, spray application rates and inexact knowledge of the amount of coating ingredients present due to the wide range of percentages supplied on Material Safety Data Sheets (MSDS) under Section 2, Hazardous Ingredient Information. An example of the range of percentages shown for ingredients on current MSDS for maritime coatings products is shown as Figure 5.

Material Safety Data Sheet
FORMULA 150 PRIMER GREEN PART A TYPE III

| 3. Composition/information on ingredients | | |
|--|--------------|----------|
| Ingredient | CAS No. | Percent |
| Butanol | 0000071-36-3 | 25 - 50 |
| Titanium dioxide | 0013463-67-7 | 1.0 - 10 |
| FATTY ACIDS, TALL-OIL, REACTION PRODUCTS WITH TETR | 0068953-36-6 | 1.0 - 10 |
| Talc (*non-asbestiform) | 14807-96-6* | 25 - 50 |

Figure 5 – Material Safety Data Sheet example; Percentage Ranges for Ingredients

Compounding the problem is the fact that some of these coatings ingredients, when mixed and applied, may produce unique compounds as reactants, so the relationship of the amount of material available in the air of the space to the actual percentage of component as indicated on the MSDS is unclear. Good sampling information is needed to ensure that respiratory protection is adequate to protect against the broad range of contaminants that may be encountered. This is true even for those spraying operations where personnel wear air-fed respirators and are maintaining

concentrations below 10% of the LEL (or some set lower value), to ensure that the IDLH limit is not exceeded for one of these other contaminants.

This issue is further complicated because the measurement and analysis of some of these airborne coating components is problematic and expensive for individual yards. This industry-wide project was initiated in June 2012 to evaluate and report on this issue. The goal of this project has been to collect and report pertinent observations and representative data that may be used by all shipyards to guide the application of best practices for effective ventilation use in shipboard painting for ongoing health and safety management programs.

Four shipyards participated in this project:

- BAE Southeast, Jacksonville, FL
- Huntington Ingalls Industries Newport News Shipbuilding, Newport News, VA
- NASSCO Shipyard, San Diego, CA
- Norfolk Naval Shipyard, Portsmouth, VA

In addition, the Navy and Marine Corps Public Health Center (NMCPHC) also participated in this evaluation, providing assistance with technical research, data analysis and periodic reviews throughout the completion of this work.

In these field evaluations, the effectiveness of ventilation systems used for shipyard painting was evaluated through a combination of airflow measurement and air sampling for personal and area exposure measurement. This testing was completed during a variety of representative work configurations which are encountered in shipyard operations.

Indeed, the field measurements and observations collected in this study have confirmed that spray painting in enclosed shipboard spaces located several decks below topside poses many challenges. While the portable ventilation blowers are located on the top (open) deck, flexible exhaust ductwork must be lowered to the work area in a manner to provide effective airflow, while not obstructing access in and out of hatches, ladders or walkways.

While the temporary ventilation equipment in use was generally observed to be highly effective, the actual airflow volumes moved by individual blowers were not typically measured on any regular or documented basis. Consequently, performance assessments using baseline data for use in comparisons of airflow volumes, measuring expected versus actual or current job versus previous work were not possible. Additional challenges included excess duct lengths with curves, kinks or coils that reduce the effective ventilation exhaust volumes through friction losses. Cuts, tears or holes in temporary portable ventilation ducts will further reduce system effectiveness. An example of the use of this type of temporary flexible ductwork in limited spaces is shown in Figure 6.

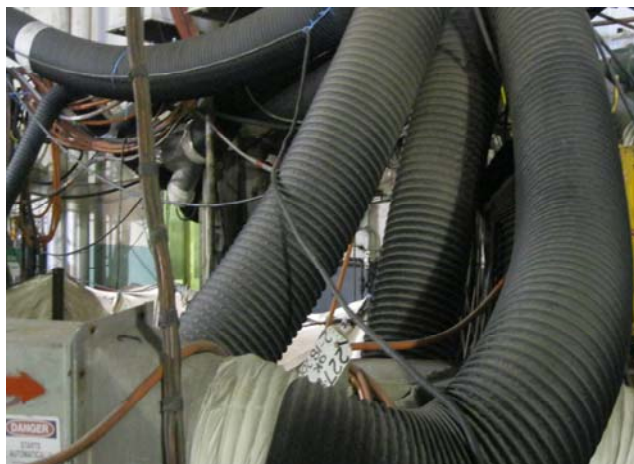


Figure 6 – Flexible Shipboard Ventilation Ductwork

The application of effective ventilation for exposure control to potential health hazards is further complicated through the use of a variety of new and evolving paint systems that include reactant materials with low occupational exposure limits and many of different solvents. These coatings are typically used in accordance with NAVSEA-defined surface preparation, application and inspection procedures for ship construction and repair. These procedures are also modified and updated as needed, to accommodate new coating products, equipment and application methods. As a result of this dynamic working environment, air sampling conducted to evaluate occupational exposure control in past

studies years ago is likely not representative of the coating products, application methods or work area configurations encountered today.

This testing was conducted in typical space and ventilation scenarios defined by the participating shipyards as a means to evaluate and improve their ventilation processes for shipboard painting. The test data in this report, combined with observations and recommendations should provide a valuable tool to better define the methods which are most effective in the use of ventilation for shipyard painting in enclosed spaces.

The goal of this project has been to provide an up to date and comprehensive assessment of the use of ventilation for painting in enclosed spaces in the shipyard environment that effectively:

1. Defines the requirements,
2. Describes current practices in the industry,
3. Measures performance under actual conditions of use, and
4. Provides recommendations for improvement, where possible and where needed.

PROJECT ELEMENTS

The work was divided into three distinct phases, as summarized below:

TASK 1 – BACKGROUND RESEARCH AND INFORMATION REVIEW

Shipyards painting in enclosed areas is not a new industrial process. The use and evaluation of ventilation systems for this work has been an ongoing effort for many years. Several pertinent historical studies and references were reviewed during the initial period of this work to establish a baseline level of information.

Research and Technical Studies

The references reviewed and cited for this work are listed below. Pertinent historical studies and testing data include:

- a. George S Reichenbach Jr. (1953): Ventilation for Ship Construction and Repair, American Industrial Hygiene Association Quarterly, 14:4, 307-311
- b. NSRP (1981): Surface Preparation and Painting of Tanks and Closed Areas, Procedure Handbook
- c. NIOSH (1998) Health Hazard Evaluation Report, General Dynamics Electric Boat Division Groton, Connecticut Publication No. 96-0253-2682
- d. Navy and Marine Corps Public Health Center NOED Database for Industrial Hygiene Data, 1988-2011; Exposure Measurements for butyl alcohol, m-XDA and TiO₂ during painting of ship components.

OSHA and Navy Requirements

Applicable technical references and standards include:

- a. OSHA Maritime Standards, 29 CFR 1915.35, Painting, define ventilation requirements
- b. OSHA Shipyards Employment E Tool – Painting and Other Coating
- c. OSHA, Ventilation in Shipyards Employment (OSHA 3639 -04 2013)
- d. NAVSEA Standard Item 009-07, Sec. 3.7.9, FY-13 (CH-4), Shipboard Temporary Ventilation

While these references provided an important awareness of the methods, materials and principles applied to this issue over the past 60 years, no single source or combination of historical references could meet the current requirements for evaluation of today's coating materials, ship configurations and ventilation equipment under current operating conditions. Consequently, a new evaluation, representative of current materials, methods and work areas provides a needed element to fill this gap in the available information for effective hazard control.

TASK 2 – FIELD WORK AND IN-SHIPYARD TESTING

Based upon the review of historical references and discussions with participating shipyard representatives, a field sampling plan was prepared for Task 2. The work to be completed included a series of air monitoring surveys, ventilation airflow measurements and data collection in the four shipyards. The goal of this data collection and analysis was to fill information gaps in order to prepare some qualified estimation guidelines for ventilation required for effective control of airborne contaminants while shipboard painting in enclosed spaces.

The specific chemical compounds to be tested in air samples collected as part of the scheduled field evaluations were determined based upon a review of paint products planned for use at that time in the selected shipyards.

- Participating yards provided a listing of currently used coatings
- MSDS were obtained and the listing of Hazardous Ingredient Information in Section 2 was reviewed for each coating to determine representative air monitoring priorities,
- Air sampling methods and equipment requirements were defined for the respective chemical compounds selected.

Based upon the information available at the onset of this project, the research team prepared an outline of a technical approach to provide the type of air samples and defined data elements required for the necessary research evaluation. The goal of this testing and data collection was to provide sufficient analytical detail, where needed, to help define practical control measures to maintain effective ventilation and ensure employee protection during painting in enclosed shipboard spaces.

Sampling Plan Elements

1. Collection and Laboratory Analysis of Air Samples
2. Measurement of Ventilation System Airflow – A TSI Velocicalc 9565, Multi-Function Ventilation Meter will be used to evaluate the performance of the systems used to ventilate affected spaces. A description of this instrument is provided as Appendix B.
3. Four specific analyses, offering a broad spectrum of reporting capability, have been proposed as representative of the testing required for this evaluation:
 - a. Solvents
 - b. Reactants
 - c. Metal Particulates
 - d. Total Particulates

A summary of the air sampling methods is provided in **Figure 7**, below.

| Profile | Analytes | Media | Volume | Sampling Rate | Method | Technique |
|----------------------|---|--|---|---------------|--|----------------------------|
| Organic Solvent | Acetone, Benzene, Butyl Acetate, Chlorobenzene, Cyclohexanone, Decane, 1, 2-Dichloroethane, 1, 4-Dioxane, Ethyl Acetate, Ethyl Benzene Heptane, Hexane, Isooctane, Methyl Ethyl Ketone, Methyl Isobutyl Ketone, Methylene Chloride, m-Xylene, n-Propyl Acetate, O | Charcoal Tube, T-01, 226-01 | 3-10 Liters | 0.02-0.1 LPM | OSHA 7M | GC/FID |
| | | 3M 3500/3520, SKC 575-001 | -- | -- | NIOSH 1501M | GC/FID |
| Solids: Diisocyanate | TDI (2,4), TDI (2,6) MDI, HDI, IPDI, HMDI | Open face sampling on treated GFF | Air Vol (L): 15-240 | 1.0 LPM | Mod. OSHA PV2092, Mod. OSHA 42, Mod. OSHA 47 | HPLC/UV. |
| Total Particulates | Nuisance dusts, particulates not otherwise classified | Tared 37mm, 5um PVC filter, open faced | Air Vol (L): 7-133 L at 15 mg/m ³ of air | 1-2 LPM | NIOSH 0500 | Gravimetric Filter Weight. |
| Metal Particulates | TiO ₂ , other metals | 37mm MCE filters Closed Face | 10-960L | 2 LPM | OSHA ID-121 | AA ICP |
| x-MDA | Aromatic amines | 3-pc 37mm cassettes acid-treated glass fiber filters | 15 L | 1 LPM | OSHA 105 | HPLC-UV |

4. Galson Laboratories (<http://www.galsonlabs.com/>) is proposed for the analysis work in this study.
5. The proposed sampling plan includes air sampling evaluations in four shipyards;
 - a. BAE Southeast, Jacksonville, FL
 - b. Huntington Ingalls Industries Newport News Shipbuilding, Newport News, VA
 - c. NASSCO Shipyard, San Diego, CA
 - d. Norfolk Naval Shipyard, Portsmouth, VA
6. Each shipyard evaluation will include two full days of air monitoring and ventilation airflow measurement during painting work, for a total of 8 days of full-shift air sampling.
7. Ventilation airflow measurement and observations will be recorded in accordance with standard methods defined in the Navy Industrial Hygiene Manual, Chapter 6, Ventilation; provided as Attachment 3. Field measurement of ventilation airflows will be in accordance with the Face Velocity Traverse Method described in Section 4a.
8. Each day of air sampling will be prepared to collect air samples of solvent mixtures and air samples of solids mixtures, as available, with total samples collected based upon production schedule and performance.
9. The air sampling evaluation and ventilation testing will be completed in four shipyards, with the goal of including in-shop, on-ship, new construction, overhauls, surface ships and submarines within the scope of the project.
10. The data elements to be collected in the 4 field testing surveys include:
 - a. Description of space or compartment to be painted
 - b. Dimensions and volume of affected area
 - c. Coating systems being applied
 - d. Coating application method
 - e. Number of painters in the affected space
 - f. Description of tools and equipment in use
 - g. Personal protective equipment in use
 - h. Description of ventilation system(s) in use

- i. Airflow velocity (fpm) and volume (cfm) measured in the affected areas being painted
- j. Airborne contaminant measurements, both in laboratory reported units (ppm or mg/m³ of air, etc...) and, where possible, expressed in comparison to applicable Occupational Exposure Limit, such as PEL or TLV.
- k. Other work, activity or conditions in the vicinity of painting that may affect the measurement or later application of these results.

TASK 3 – DATA ANALYSIS AND REPORTING

As described in the field sampling plan developed in Task 2, four shipyard site visits were completed as part of this evaluation. Each visit was three days in length, including a review, observation and testing of the equipment, methods and procedures in use for the effective application of ventilation while painting in enclosed spaces.

A brief summary of the observations from each respective site visit is presented below:

Shipyard 1 –

The interior and exterior of a small tank, of approximately 200 cubic feet with a single top entry, removed from a ship, was to be repainted with brush and roller application in a large, open shop building. The painter applied Formula 150 and Formula 153 epoxy polyamide coatings. Approximately one gallon was applied each two hours of painting. Exhaust ventilation was provided through a single 6-inch diameter flexible duct, inserted through the top hatch, pulling between 500 and 600 cubic feet per minute. One painter completed the work, equipped with full-body clothing and gloves, hardhat, safety glasses and a half-mask respirator. Personal breathing zone and nearby area air samples were collected with 3M 3500 Vapor Badges, analyzed for n-Butyl Alcohol (1-Butanol). The OSHA PEL for 1-Butanol is 100ppm, TWA. The ACGIH TLV is 20ppm, TWA. Personal breathing zone results ranged from 4.3 to 4.9 ppm during the period monitored. Area samples, collected at the edge of the tank, ranged from 8.1 to 13 ppm. The painting work was effectively ventilated with air monitoring results documented to be well below applicable occupational exposure limits.

Shipyard 2 –

Small voids, or enclosed spaces, approximately 150 to 175 cubic feet, were painted with spray application. Three separate work areas were monitored, each with different two-person crews, over three work shifts. For each work area, one painter worked inside the space to spray, while the other remained outside the compartment to provide mixing, tools and assistance, as needed. Two voids were sprayed with FastClad epoxy coating. One void was sprayed with Seaguard 5000 epoxy coating.

The painters working with FastClad wore personal breathing zone monitors for x-MDA, an epoxy reactant compound. The painters were equipped with full-body protective clothing including head covers and a full-face airline respirator worn by the in-tank painter and a dual-cartridge full-face respirator worn by the helper outside the compartment. These spaces were approximately 175 ft³, ventilated with a single 6" round diameter exhaust trunk. The painted space had plenty of beams and ridges, with an estimated painted surface area of 479 ft², at a coating thickness of 24 mils. The Foreman estimated that 10-20 gallons of paint would be used in each compartment. Exhaust airflow measured 106 cfm at 540 fpm face velocity for the first area and 255 cfm at 1300 fpm face velocity for the second space. Each of the painters' m-XDA concentrations slightly exceeded the 0.1ppm 15-minute CEILING limit (ACGIH TLV) for their respective sample periods, with a 0.15ppm reported on the first space and a 0.12ppm reported on the second. In this case, the higher exhaust volume, as measured on the second day of testing, correlated with lower m-XDA exposure.

The painters spray applying Seaguard 5000 in a small (1800 ft³) compartment worked on a different ship. Based upon Sherwin Williams coverage estimates of approximately 100 square feet per gallon at a 10mil coating thickness, this job was estimated to use about five gallons, considering the surface area requiring coverage. The painters wore personal breathing zone monitors for Titanium Dioxide (TiO₂, as airborne particulates, from paint pigment) and n-butyl alcohol (as paint solvent). Again, this work was ventilated by a single exhaust tube, with full-body protective clothing and respiratory protection used, as described above. The TiO₂ results were 7.7 mg/m³ (OSHA PEL of 15 mg/m³, ACGIH TLV of 10mg/m³) for spray work in the compartment, and below detection limits for work outside. The n-butyl alcohol results were 260 ppm for spray work in the compartment and 22 ppm for work outside. Adjusted for an 8-hr Time-Weighted Average, the in-compartment n-butyl alcohol result was 36.3ppm compared to an OSHA PEL of 100ppm and ACGIH TLV of 20ppm. The single-duct temporary ventilation for this job appears effective in maintaining exposures below applicable OSHA limits.

Shipyard 3 –

Large ship subsections, approximately 30 feet high, 40 feet wide and 50 feet long, with a complex array of hatches, bulkheads and deck levels, were spray painted with Intershield 300V coatings in an enclosed, ventilated Blast and Paint Facility. Approximately 200 gallons of this coating were used in each two hour spray application. Graco XTR-7 Airless Spray Guns and Graco Premier pump systems were used, with manual mixing of the paint by a dedicated "mixer" assigned for each shift. The Blast and Paint Facility was approximately 100 feet long, 100 feet wide and 60

feet high (600,000 cubic feet), and maintained under filtered, negative air pressure during all painting work. Powered ventilation supply and filtered exhaust is delivered from elevated corner-mounted manifolds, with entry-side (opposite 80ft-wide powered garage-door opening) supply and opposite end corners (farthest from the entry bay door) providing exhaust drawn to paint spray and vapor Thermal Oxidizer and filtration systems. Ventilation appears to be designed for a push-pull flow of paint spray away from the bay door openings. Paint odors were not detectable outdoors during spray application. Inward air flow velocities were measured across a series of openings during painting work, with an estimated range of 7150 to 9750 cfm of inward fresh air supply. Noticeable, but low velocity air movement was detectable in the paint facility during spraying. No portable hoses or temporary, localized ventilation systems were observed in use.

Six painters were at work. All were protected by full body cotton coveralls and hoods Tyvek coveralls, gloves and full-face respirators with organic vapor cartridges.

Personal breathing zone monitors were worn by painters with analysis for Ethyl benzene, Xylene and Total Particulates. All monitoring results for Ethyl benzene and Total Particulates, adjusted for an 8-hour TWA, were below their respective OSHA PEL. Monitoring results for Xylene were substantially higher, with 6 out of 10 above the OSHA PEL of 100ppm, adjusted for an 8-hour TWA, with a peak TWA of 447ppm. Since the Full Face respirator had an Assigned Protection Factor (APF) of 50, the painters were effectively protected well within the range of the respirator in use. Based upon observation and measurement, some supplemental localized ventilation could have substantially reduced the xylene concentrations. The highest xylene result of 580ppm during the actual sampling period was about 6.4% of the Lower Explosive Limit (LEL) of 900-1100ppm. This is also a significant concern.

Shipyards 4 –

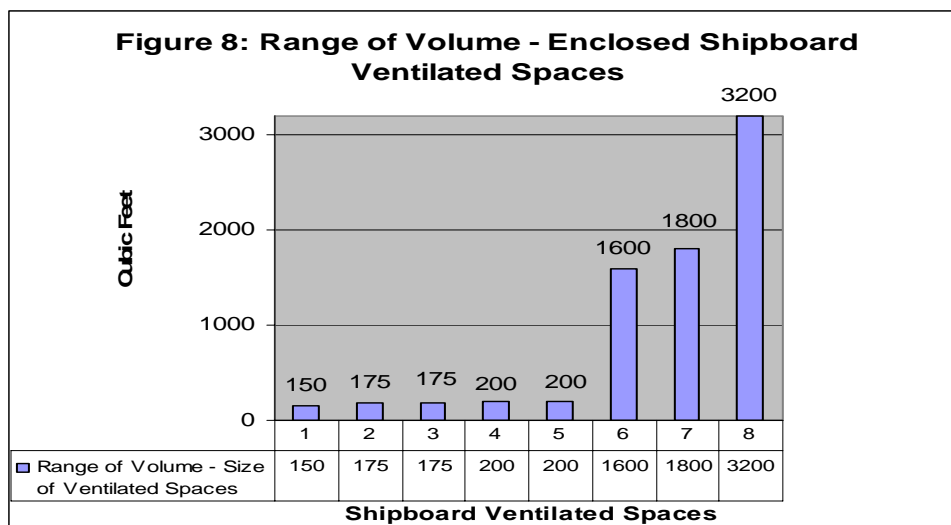
Brush and roller application of Interbond Formula 998 epoxy coating was observed in the lower level Machinery Space on an afloat vessel. Two painters were at work in a space approximately 1600 cubic feet, ventilated by a single 6-inch diameter flexible exhaust hose, drawing approximately 167 cfm. Full-body protective clothing was worn, with half-mask respirators and organic vapor cartridges. Since this work was limited, short-duration touch-up application in a larger, well-ventilated and comparatively open area and unlikely to collect any detectable solvent vapors at or above laboratory detection limits, no air monitoring was conducted on this work.

Work area set up and mobilization was also underway on a vessel afloat, preparing for the spray painting in two lower-level areas including a Plumbing Drain Tank of about 150 ft³ with FastClad epoxy and the spray application of Seaguard 5000 on the decking of a (3200ft³) Sonar space. Each of these work areas was ventilated with a single flexible exhaust hose with airflows ranging from 108 to 165 cfm.

A complete summary of the field testing data collected during the shipyard site visits is provided as **Appendix A**, Field Test Data.

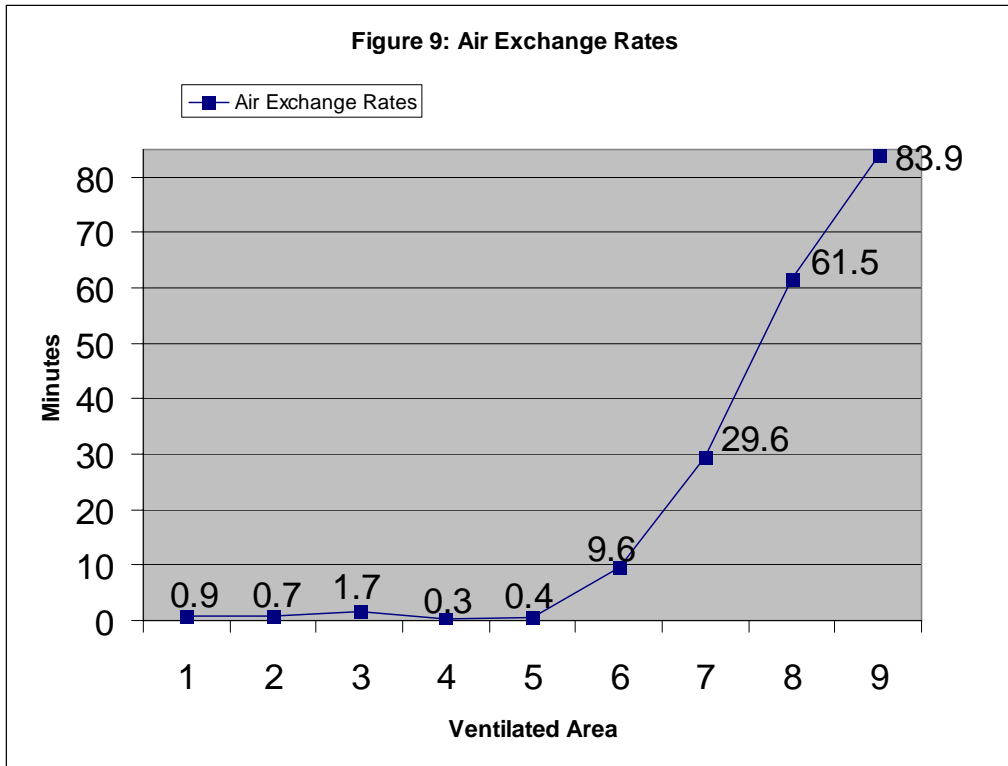
Data Analysis

The size of ventilated enclosed spaces varies widely in shipyard painting work, with a more than 20-fold difference between the largest and smallest spaces observed, as shown in Figure 8, below.



* This excludes the Facility with 600,000cubic feet of ventilated area.

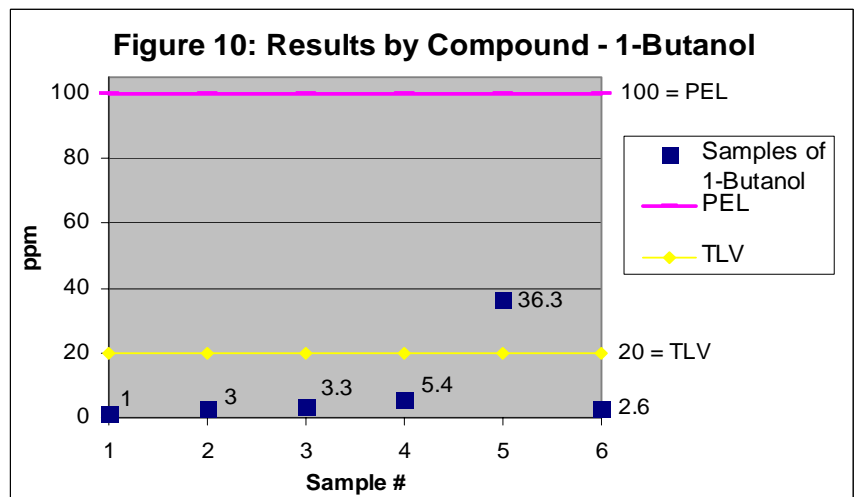
There was also a significant variation in the exhaust airflow provided by the ventilation systems in relation to the size of the affected work area, expressed as air exchange rates in Figure 9, below. This illustrates the time, in minutes, required for the volume of air equivalent to the entire affected enclosed area, to be exhausted and, in theory, replaced through the inward flow of clean replacement air. For example, a small space of 200 cubic feet with an exhaust air flow of 100 cubic feet per minute would require two minutes for the complete air exchange. The exchange rates calculated for these work areas ranged from less than one minute to a high of 83.9 minutes. The higher exchange rates also corresponded to the highest contaminant concentrations measure during air sampling.

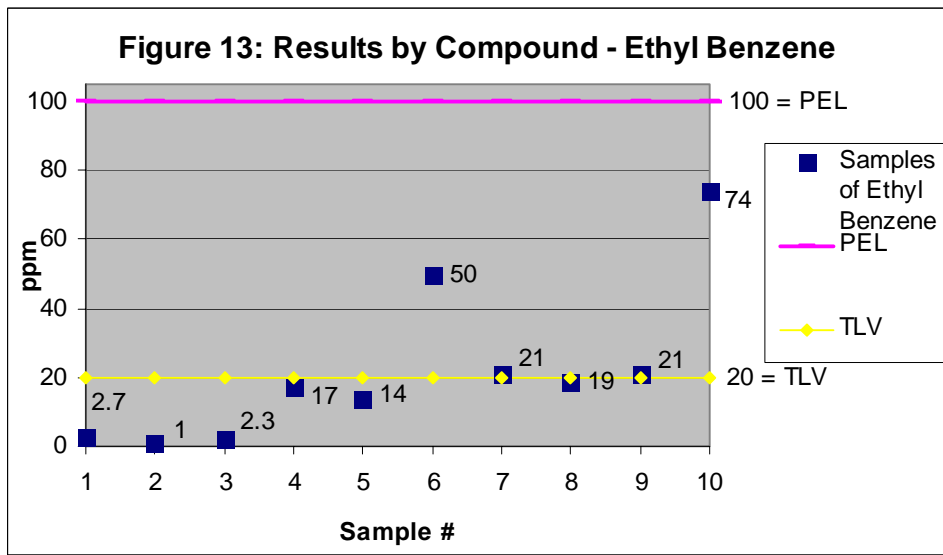
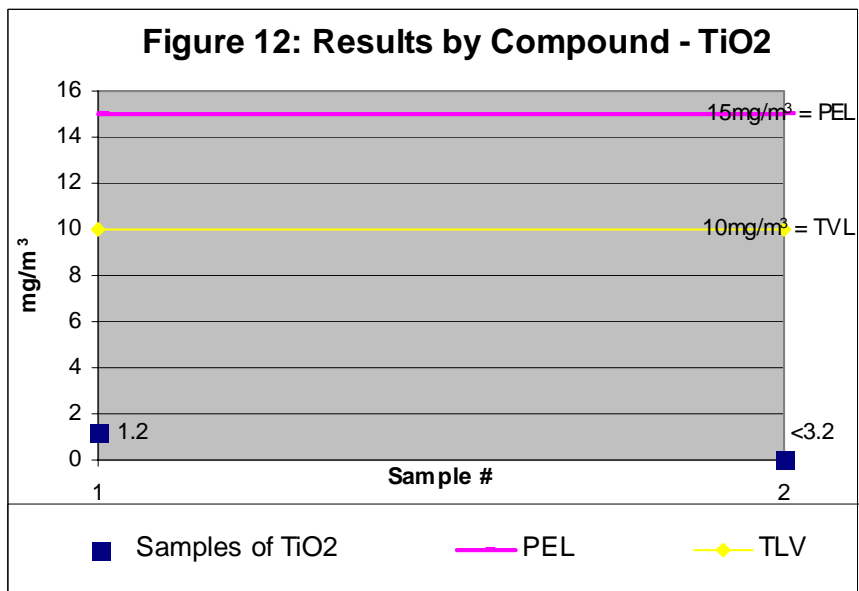
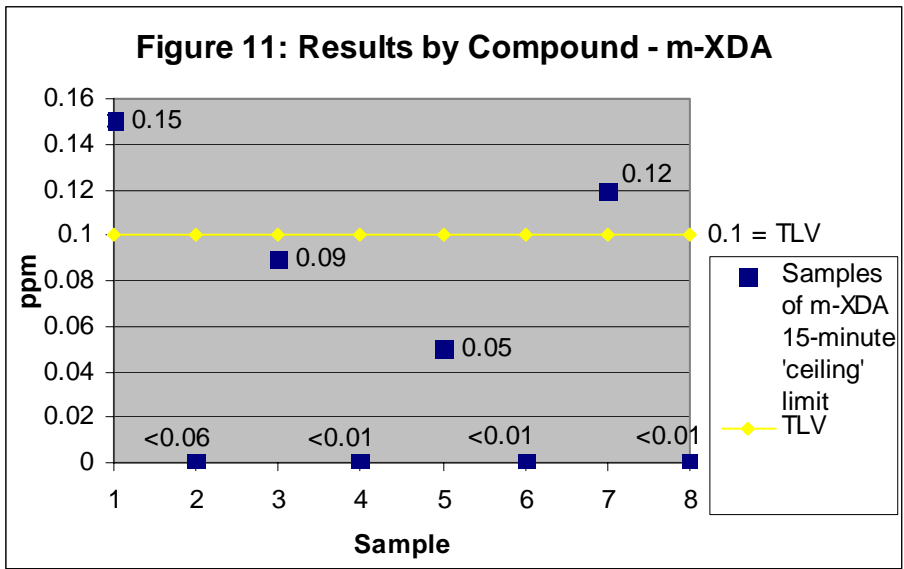


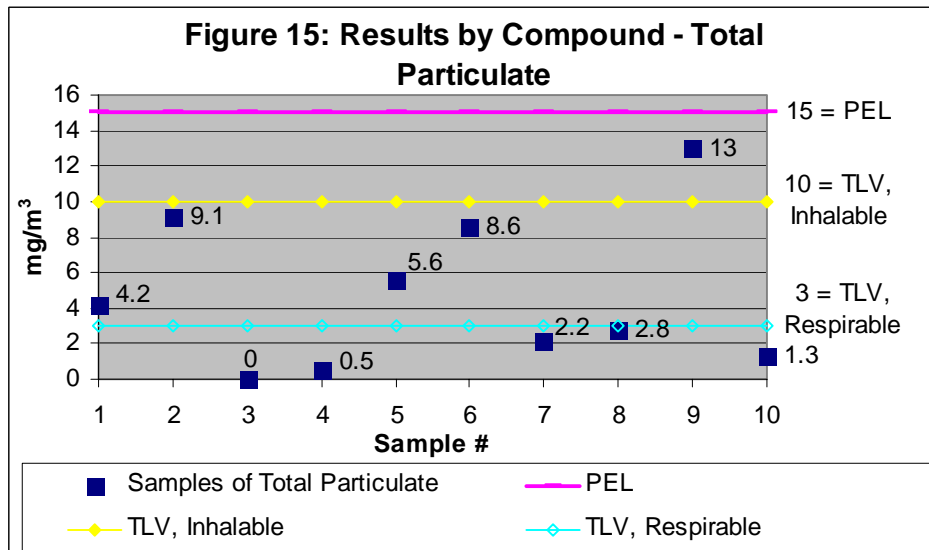
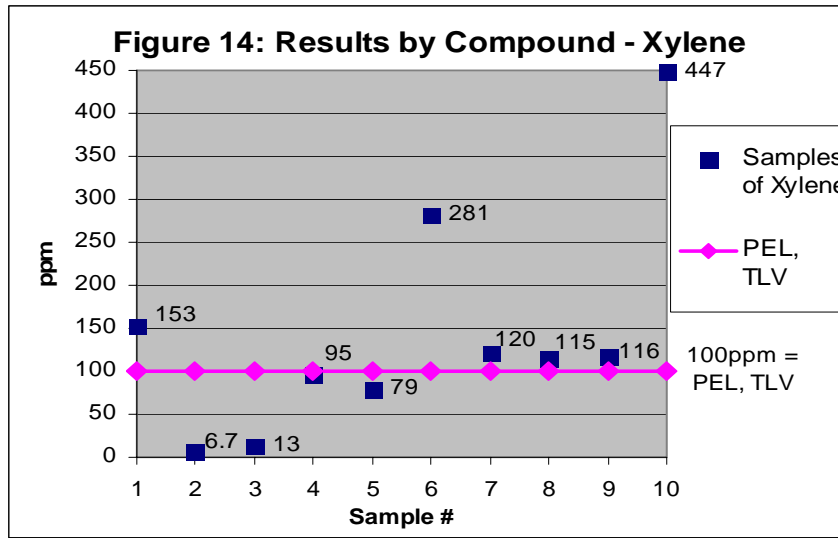
| # | Area ft ³ |
|---|----------------------|
| 1 | 150ft ³ |
| 2 | 175ft ³ |
| 3 | 175ft ³ |
| 4 | 200ft ³ |
| 5 | 200ft ³ |
| 6 | 1600ft ³ |
| 7 | 1800ft ³ |
| 8 | 60000ft ³ |
| 9 | 60000ft ³ |

Air sampling results, by compound are presented in Figures 10-15, below. Over the work evaluated in the four shipyard site visits, air sampling was completed for 1-Butanol, m-XDA, TiO₂, ethyl benzene, xylene and total particulates. Of the compounds tested, only xylene exceeded the applicable OSHA Permissible Exposure Limits (PEL), without considering the use of respiratory protection. This occurred during spray application in a large Blast and Paint enclosure. The painters and the crews working on these jobs were equipped with respiratory protection to effectively reduce this exposure to levels far below applicable limits. Substantially more results exceeded their respective TLV's, where applicable. In all cases, this also occurred during spray application.

Note: Samples 1-4 are from brush and roll
Samples 5-6 are from spray application







Note: 2013 ACGIH TLV, Appendix B, 3mg/m³ Respirable, 10mg/m³ Inhalable. Not compatible with OSHA measurement methods

The air sample results by work area type are presented in Figures 16-21, below. Clearly, the enclosed paint and blast facility shown in Figure 17 presents the greatest challenges in effective exposure control. The remaining work area configurations, where localized exhaust ventilation is applied with temporary flexible ductwork appear to provide much more effective exposure control.

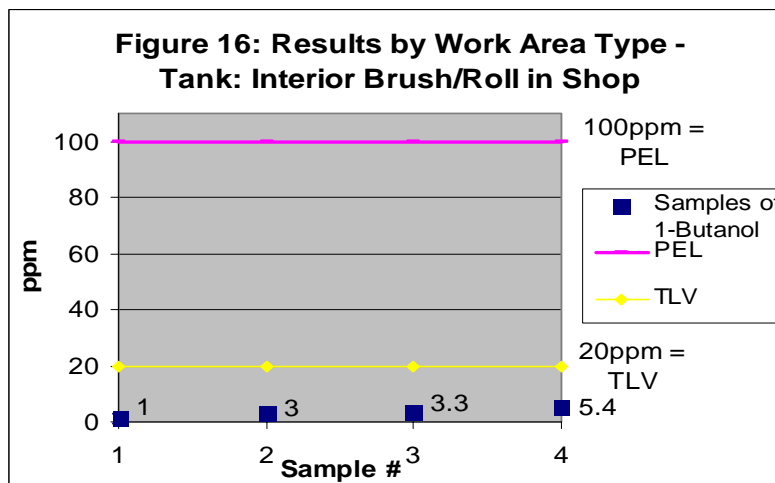


Figure 17: Results by Work Area Type - Ship Subsection: Paint & Blast Facility, Spray Application

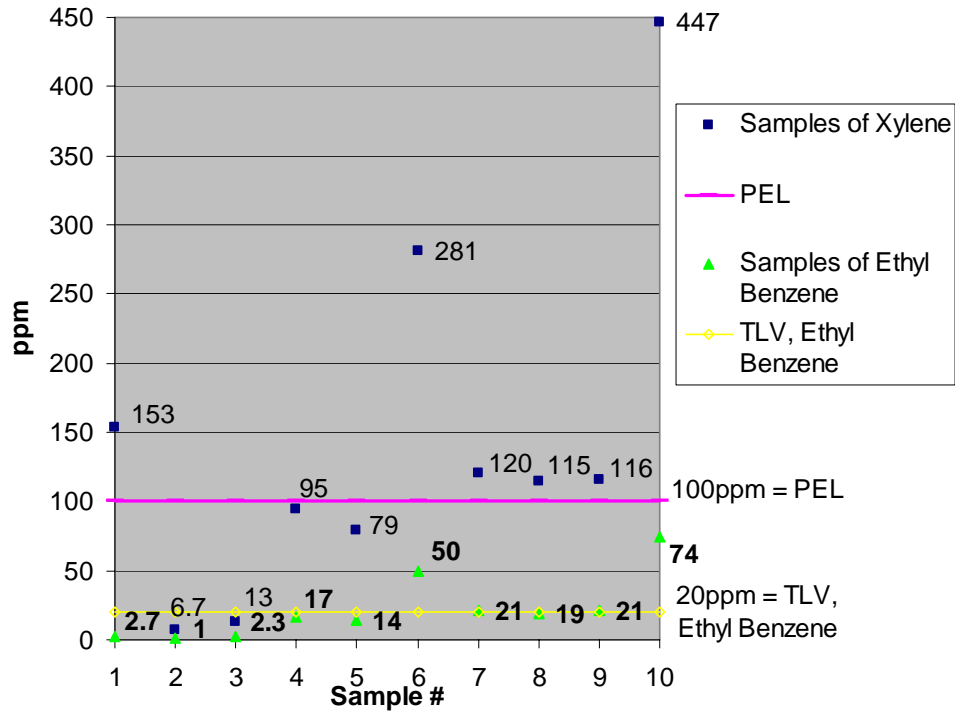


Figure 18: Results by Work Area Type - Ship Subsection: Paint & Blast Facility, Spray Application

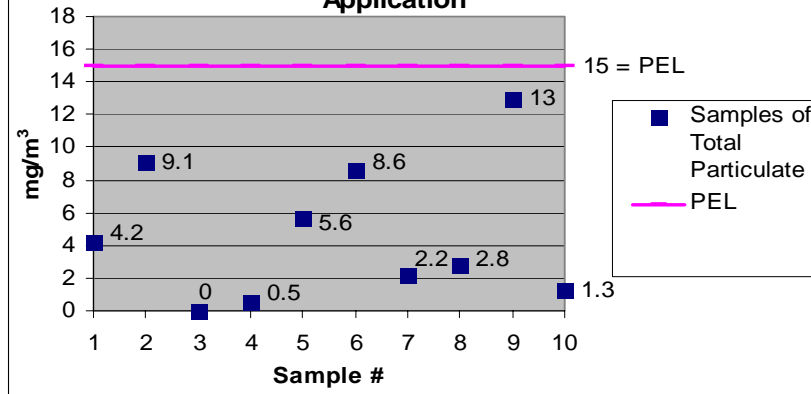
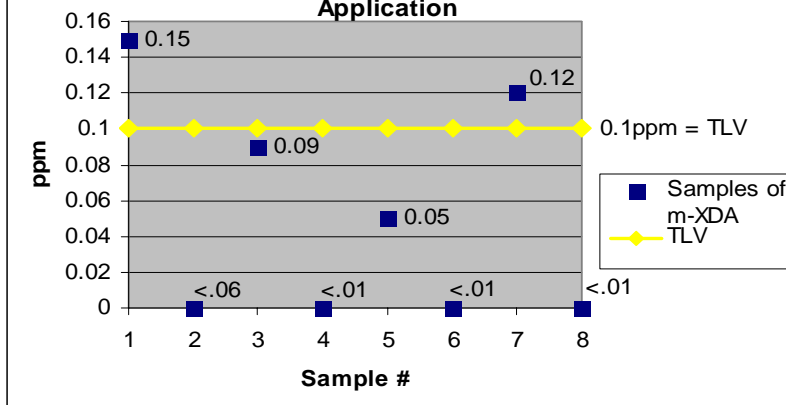
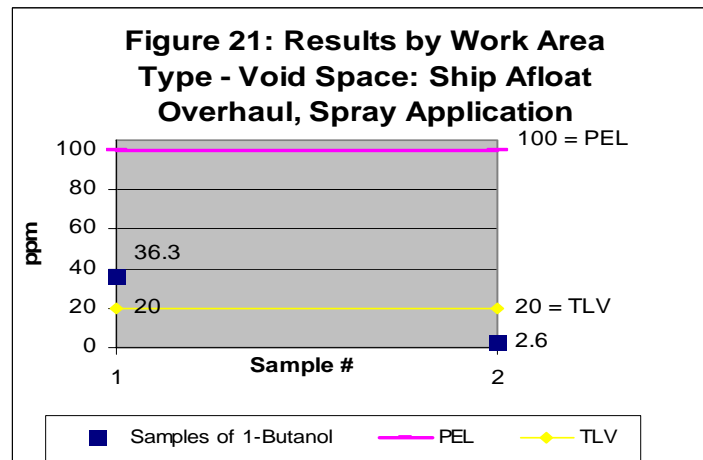
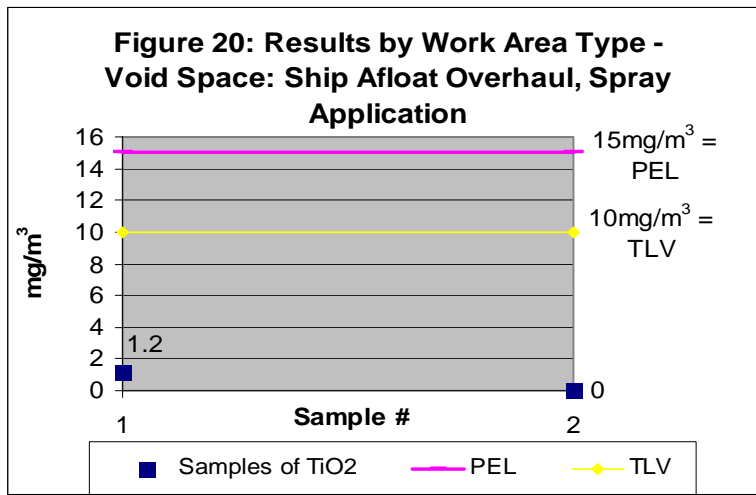


Figure 19: Results by Work Area Type - Void Space: Ship Subsection Outdoors, Spray Application





Summary

The observation and testing covered a broad spectrum of shipyard painting processes. The painting work included surface ships and submarines, brush and spray applications, a combination of established coatings (Formula 150) and newer single-coat epoxies (FastClad), ships afloat and subsections under construction, work in small tight compartments and jobs in large enclosed blast and paint facilities. Personal breathing zone and area air sampling was conducted for six different air contaminants including solvents, particulates and reactants. Six different coatings were applied during this testing, providing an excellent cross-section of the products currently used in the maritime industry.

Across all shipyards, brush and roll application was observed to be effectively ventilated and controlled with exhaust air drawn through flexible ductwork and discharged topside to the outdoors. Spray application was more problematic. While all helpers and support personnel working on the perimeter of the paint application were observed to have airborne contaminant levels for solvent, reactants and particulates effectively controlled below their respective OSHA PELs, some excursions above these limits were observed in the results of painters' breathing zone monitoring from the immediate vicinity of the spraying. In all cases, the painters were observed to be well protected within the assigned protection factors of their respirators, typically with a substantial safety factor. Localized ventilation appears more effective for the control of breathing zone exposure than permanently-installed wall-mounted systems, based upon the observations of this work. This was especially evident in the large Blast and Paint enclosure.

All shipyard painting was observed to be conducted in an environment filled with Supervisors, Superintendents, Inspectors, other trades and customer and Navy representatives. Consequently this work is closely monitored, highly controlled, thoroughly documented and regulated at every step and application interval. This detailed oversight should also contribute to a highly dynamic reinforcement mechanism for ensuring that the work environment is well ventilated for a combination of hazard control, maintaining temperature and humidity limits for coatings performance, timely coatings inspector access and to ensure the ongoing productivity and comfort of surrounding trades.

CONCLUSIONS AND RECOMMENDATIONS

The work completed during this evaluation has met the goal to deliver a complete and comprehensive assessment of ventilation performance for air contaminant control with current shipyard practices for painting in enclosed spaces.

The observation and testing covered a broad spectrum of shipyard painting processes. This work included surface ships and submarines, brush and spray applications, ships afloat and subsections under construction, work in small tight compartments and in large enclosed blast and paint facilities. Personal breathing zone and area air sampling was conducted for six different air contaminants including solvents, particulates and reactants. The six different coatings were applied during this testing provided an excellent cross-section of the products currently used in the maritime industry.

The results of this work have shown that the participating shipyards have been able to develop, demonstrate and apply specialized equipment, skills and methods to effectively install and operate both fixed and temporary ventilation systems for painting in enclosed spaces. While the combination of temporary and fixed ventilation systems were observed to be generally effective, many key performance variables may change on a job to job or day to day basis. In order to respond to these changes, this work requires constant attention, adjustment, measurement and repair. For research and reporting this presents a high number of dynamic variables which could not be controlled on a consistent or predictable basis. Because of these continuous changes, it was not possible to “lock-in” the metrics to produce a simple chart, graph, equation or table that can be effectively applied to predict, with confidence, the exact ventilation system requirements which may apply to any significant amount of anticipated shipyard painting work.

Recommendations for action include:

1. Periodically review and evaluate the performance of ventilation system blowers to ensure continued effectiveness and consistent, predictable airflow volumes
2. Review and update equipment installation and movement procedures, as needed, to determine how and where system performance may be enhanced by:
 - a. Reduction of leaks in ducts and manifold connections. This should include inspection and repair of cuts, tears and holes in connections and duct work prior to installation to enhance system effectiveness.
 - b. Minimizing friction losses caused by excess, broken, pinched or snarled flexible ductwork, and
 - c. Location of exhausts and supply ducts as near as possible to the affected work areas to maximize the effectiveness of contaminant control during painting
3. Ensure that the painters and associated trades who require the ventilation understand and apply basic measures needed to optimize the effectiveness and performance of these systems (just like respirator training and fit testing). This should include discussion of fan and duct placement for maximizing airflow and understanding what type of monitoring may be done to confirm proper contaminant control.
4. Evaluate the need for supplemental ventilation within enclosed Blast and Paint facilities, as needed, to reduce breathing zone exposures.
5. Apply sufficient ventilation to ensure the control of low flash point solvents well below 10% LEL and IDLH limits. In these cases explosion proof equipment must be used.
6. Ensure that the amount of ventilation provided to any location is adequate for number of painters and amount of paint being applied.

APPENDIX A: FIELD TEST DATA

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft3 | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+)or(-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|-------------------------|-------------------------|-----------------------|-------------------|--|-----------|-----------------------|---|---------------------|--------------------------------|----------------|--------------------------------------|-------------------|
| 1 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 59ppm | 219 | 100ppm | 20ppm | 2.7 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 2 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 2.0ppm | 267 | 100ppm | 20ppm | 1 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 3 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 6.5ppm | 169 | 100ppm | 20ppm | 2.3 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 4 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 49ppm | 170 | 100ppm | 20ppm | 17 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 5 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 41ppm | 159 | 100ppm | 20ppm | 14 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 6 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 67ppm | 354 | 100ppm | 20ppm | 50 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 7 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 29ppm | 343 | 100ppm | 20ppm | 21 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 8 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 27ppm | 345 | 100ppm | 20ppm | 19 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 9 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 27ppm | 368 | 100ppm | 20ppm | 21 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Mixer |

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft3 | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+)or(-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|-------------------------|-------------------------|-----------------------|-------------------|--|-----------|-----------------------|---|---------------------|--------------------------------|----------------|--------------------------------------|-------------------|
| 10 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Ethyl Benzene | Personal | 96ppm | 368 | 100ppm | 20ppm | 74 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 11 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 340ppm | 219 | 100ppm | 100ppm | 153 | (+) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 12 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 12ppm | 267 | 100ppm | 100ppm | 6.7 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 13 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 37ppm | 169 | 100ppm | 100ppm | 13 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 14 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 270ppm | 170 | 100ppm | 100ppm | 95 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 15 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 240ppm | 159 | 100ppm | 100ppm | 79 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 16 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 380ppm | 354 | 100ppm | 100ppm | 281 | (+) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 17 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 170ppm | 343 | 100ppm | 100ppm | 120 | (+) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 18 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 160ppm | 345 | 100ppm | 100ppm | 115 | (+) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 19 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 150ppm | 368 | 100ppm | 100ppm | 116 | (+) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Mixer |

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft ³ | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+)or(-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|-------------------------|-------------------------|-----------------------|-------------------|--|-----------|-----------------------|---|---------------------|--------------------------------|----------------|--------------------------------------|-------------------|
| 20 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Xylene | Personal | 580ppm | 368 | 100ppm | 100ppm | 447 | (+) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 21 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 9.1 | 220 | 15mg/m ³ | 1* | 4.2 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 22 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 16 | 275 | 15mg/m ³ | 1* | 9.1 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 23 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | <0.75 (0) | 267 | 15mg/m ³ | 1* | 0 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 24 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 1.4 | 169 | 15mg/m ³ | 1* | 0.5 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Mixer |
| 25 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 16 | 170 | 15mg/m ³ | 1* | 5.6 | (-) | Perimeter Push Pull | NO/Side Walls Only | 7150 | Large, Sealed Blast & Paint Facility | Painter |
| 26 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 11 | 372 | 15mg/m ³ | 1* | 8.6 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 27 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 3.1 | 343 | 15mg/m ³ | 1* | 2.2 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 28 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 3.9 | 345 | 15mg/m ³ | 1* | 2.8 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |
| 29 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 17 | 368 | 15mg/m ³ | 1* | 13 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Painter |

1*: 2013 ACGIH TLV, Appendix B, 3mg/m³ Respirable, 10mg/m³ Inhalable. Not compatible with OSHA measurement methods

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft3 | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+)or(-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|-------------------------|-------------------------|-----------------------|-------------------|--|----------------------|-----------------------|---|---------------------|--------------------------------|----------------|--|-------------------|
| 30 | Ship Subsection | 600,000 | 6 | Spray | Intershield 300V | Total Particulate | Personal | 1.7 | 368 | 15mg/m ³ | 1* | 1.3 | (-) | Perimeter Push Pull | NO/Side Walls Only | 9750 | Large, Sealed Blast & Paint Facility | Mixer |
| 31 | LET Tank | 200 | 1 | Brush/Roll | F150 | 1-Butanol | Personal | 4.3ppm | 110 | 100ppm | 20ppm | 1 | (-) | LEV | 6" FlexDuct | 600 | Open Top, LET Tank, Removed from Ship, Painted in Shop | NR |
| 32 | LET Tank | 200 | 1 | Brush/Roll | F150 | 1-Butanol | Area | 13ppm | 111 | 100ppm | 20ppm | 3 | (-) | LEV | 6" FlexDuct | 600 | Open Top, LET Tank, Removed from Ship, Painted in Shop | NR |
| 33 | LET Tank | 200 | 1 | Brush/Roll | F153 | 1-Butanol | Personal | 4.9ppm | 322 | 100ppm | 20ppm | 3.3 | (-) | LEV | 6" FlexDuct | 510 | Open Top, LET Tank, Removed from Ship, Painted in Shop | NR |
| 34 | LET Tank | 200 | 1 | Brush/Roll | F153 | 1-Butanol | Area | 8.1ppm | 320 | 100ppm | 20ppm | 5.4 | (-) | LEV | 6" FlexDuct | 510 | Open Top, LET Tank, Removed from Ship, Painted in Shop | NR |
| 35 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | 0.15ppm | 17 | none | 0.1ppm Ceiling Limit | *0.15ppm | (+) | LEV | 6" FlexDuct | 106 | New Construction Ship Subsection - IN | Sprayer |
| 36 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | <0.06ppm | 17 | none | 0.1ppm Ceiling Limit | *<0.06 | (-) | LEV | 6" FlexDuct | 106 | New Construction Ship Subsection - OUT | Helper |

1*: 2013 ACGIH TLV, Appendix B, 3mg/m³ Respirable, 10mg/m³ Inhalable. Not compatible with OSHA measurement methods

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft3 | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+)or(-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|----------------------------|-------------------------|-----------------------|-------------------|--|----------------------|-----------------------|---|---------------------|--------------------------------|----------------|--|-------------------|
| 37 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | 0.09ppm | 18 | none | 0.1ppm Ceiling Limit | *0.09 | (-) | LEV | 6" FlexDuct | 106 | New Construction Ship Subsection - IN | Sprayer |
| 38 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | <0.01ppm | 16 | none | 0.1ppm Ceiling Limit | *<0.01 | (-) | LEV | 6" FlexDuct | 106 | New Construction Ship Subsection - OUT | Helper |
| 39 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | 0.05ppm | 17 | none | 0.1ppm Ceiling Limit | *0.05 | (-) | LEV | 6" FlexDuct | 255 | New Construction Ship Subsection - IN | Sprayer |
| 40 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | <0.01ppm | 17 | none | 0.1ppm Ceiling Limit | *<0.01 | (-) | LEV | 6" FlexDuct | 255 | New Construction Ship Subsection - OUT | Helper |
| 41 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | 0.12ppm | 17 | 0.1ppm | 0.1ppm Ceiling Limit | *0.12 | (+) | LEV | 6" FlexDuct | 255 | New Construction Ship Subsection - IN | Sprayer |
| 42 | VOID | 175 | 2 | Spray | FastClad | m-XDA | Personal | <0.01ppm | 17 | 0.1ppm | 0.1ppm Ceiling Limit | *<0.01 | (-) | LEV | 6" FlexDuct | 255 | New Construction Ship Subsection - OUT | Helper |
| 43 | Compartment | 1800 | 2 | Spray | Seaguard 5000 | 1-Butanol | Personal | 260ppm | 67 | 100ppm | 20ppm | 36.3 | (-) | LEV | 6" FlexDuct | NR | Overhaul - Ship Afloat - IN | Sprayer |
| 44 | Compartment | 1800 | 2 | Spray | Seaguard 5000 | 1-Butanol | Personal | 22ppm | 57 | 100ppm | 20ppm | 2.6 | (-) | LEV | 6" FlexDuct | NR | Overhaul - Ship Afloat - OUT | Helper |
| 45 | Compartment | 1800 | 2 | Spray | Seaguard 5000 | TiO2 = 15mg/m ³ | Personal | 7.7 | 73 | 15mg/m ³ | 10mg/m ³ | 1.2 | (-) | LEV | 6" FlexDuct | NR | Overhaul - Ship Afloat - IN | Sprayer |

| Entry No. | Description of Space | Estimated Size or Volume of Affected Space in ft3 | Number of painters | Application method | Coating Products Applied | Exposure Monitoring for | Personal or Area Sample | Air monitoring result | Duration, Minutes | OSHA PEL TWA for each contaminant tested | ACGIH TLV | * = Ceiling Limit TWA | Result above or below PEL (8 hr) (+) or (-) | Ventilation Methods | Air fixture/inlet in work area | Airflow in cfm | Notes and comments | Title Description |
|-----------|----------------------|---|--------------------|--------------------|--------------------------|----------------------------|-------------------------|-----------------------|-------------------|--|---------------------|-----------------------|---|---------------------|--------------------------------|----------------|------------------------------|-------------------|
| 46 | Compartment | 1800 | 2 | Spray | Seaguard 5000 | TiO2 = 15mg/m ³ | Personal | <3.2 | 62 | 15mg/m ³ | 10mg/m ³ | 0 | (-) | LEV | 6" FlexDuct | NR | Overhaul - Ship Afloat - OUT | Helper |
| 47 | Sonar1 | 3200 | 0 | Prep | Seaguard 5000 | none | - | - | - | - | - | - | - | LEV | 6" FlexDuct | 108 | Overhaul - Ship Afloat | Work Area Prep |
| 48 | Tank | 150 | 0 | Prep | FastClad | none | - | - | - | - | - | - | - | LEV | 4" FlexDuct | 165 | Overhaul - Ship Afloat | Work Area Prep |
| 49 | Machinery Space | 1600 | 2 | Brush/ Roll | Formula 998 | none | - | - | - | - | - | - | - | LEV | 6" FlexDuct | 167 | Overhaul - Ship Afloat | Painter (2) |

APPENDIX B: TSI VELOCICALC METER



VELOCICALC MULTI-FUNCTION VENTILATION METER 9565

PRODUCT DETAILS

The VelociCalc® Multi-Function Ventilation Meter 9565 features a menu-driven user interface for easy operation in your local language. On-screen prompts and step-by-step instructions guide the user through instrument setup, operation and field calibration. The 9565 also features an ergonomic, overmolded case design with probe holder and a keypad lockout to prevent tampering during unattended use. The

9565 model includes the Straight Air Velocity Probe 964 and is designed to work with a wide range of plug-in probes.

FEATURES AND BENEFITS

- Straight Air Velocity Probe 964 measure air velocity, temperature and relative humidity
- Includes differential pressure sensor
- Best-in-class air velocity accuracy
- Optional “smart” plug-in probes, including VOC, CO₂, and rotating vane probes
- Accommodates up to two K-alloy thermocouples
- Large graphic display
 - Displays up to five measurements simultaneously
 - On-screen messages and instructions
 - Program for local language
- Intuitive menu structure allows for ease of use and setup
- Multiple data logging formats
- Bluetooth communications for transferring data or remote polling
- Includes TrakPro™ and LogDat2™ downloading software with USB cable

APPLICATIONS

- HVAC testing and balancing
- Clean room testing
- Biological safety cabinet and laboratory fume hood testing
- HVAC commissioning and troubleshooting
- IAQ investigations
- Thermal comfort studies
- Ventilation evaluations
- Process air flow testing

DOWNLOAD SOFTWARE

- To download applicable software and/or firmware, please use the [Software/Firmware Selector](#).

APPENDIX C: NAVY INDUSTRIAL HYGIENE MANUAL, CHAPTER 6, VENTILATION

CHAPTER 6

INDUSTRIAL VENTILATION

1. **GENERAL**. Ventilation is the process of supplying and removing air by natural or mechanical means to or from any space. It is used for heating, cooling, and controlling airborne contaminants which affect employees and the general environment. Industrial ventilation emphasizes the control of toxic and/or flammable contaminants.

2. **DEFINITIONS**.

a. **Baffle** - a surface which provides a barrier to unwanted airflow from the front or sides of a hood.

b. **Biological Safety Cabinet (BSC)** - a specially constructed cabinet that is designed to protect workers and the environment from dangerous agents, especially bacteria and viruses. BSCs are more specifically defined in Reference 6-1.

c. **Blast gate** - a sliding valve used in ducts to create additional pressure loss in the duct and restrict flow.

d. **Capture velocity** - the air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.

e. **Coefficient of entry** - the actual rate of flow caused by a given hood static pressure compared to the theoretical flow which would result if the static pressure could be converted to velocity pressure with 100% efficiency. The ratio of actual to theoretical flow.

f. **Entry loss** - loss in pressure caused by air flowing into a duct or hood.

g. **Fan** - a mechanical device which physically moves air by creating a pressure differential.

h. **Flange** - a surface at and parallel to the hood face which provides a barrier to unwanted air flow from behind the hood.

i. **Hood** - a shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.

j. **Lower explosive limit** - the lower limit of flammability or explosibility of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250° F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility increases with higher temperatures.

k. Plenum - pressure equalizing chamber.

l. Replacement (make-up) air - the volume of outdoor air intentionally supplied to a building to replace air being exhausted.

m. Static pressure - the potential pressure exerted in all directions by a fluid at rest; the tendency to either burst or collapse a pipe. For a fluid in motion, it is measured in a direction normal (perpendicular) to the direction of flow. It is usually expressed in inches of water gauge (" w.g.) and may be positive or negative.

n. Total pressure - the algebraic sum of the velocity pressure and the static pressure. May be positive or negative.

o. Velocity pressure - the kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge, it is always positive.

3. INSTRUMENTATION.

a. Manometer and Pitot tube.

(1) The manometer is an instrument, which is a primary standard, for the measurement of pressure. The simplest type of manometer is the U-tube, partially filled with liquid (usually water, mercury, or light oil). The inclined manometer is more accurate, but more difficult to use. The amount of liquid displaced indicates the amount of pressure exerted on the instrument.

(2) The Pitot tube is a tube within a tube. The inner tube has a port that points directly into the airstream and measures total (impact) pressure. The outer tube has a ring of ports that are perpendicular to the airstream and measures static pressure.

(3) When both tubes of the Pitot Tube are connected to a manometer, the velocity pressure is measured.

(4) The manometer and Pitot tube combination is simple to operate, inexpensive, and the most legally credible air velocity measurement system. The one disadvantage is that it cannot measure velocity less than 600 feet per minute.

b. Thermal (heated wire/element) anemometer.

(1) When air moves across the electrically heated wire/element, the wire cools and the resistance changes. The resistance change provides an electrical signal which is proportional to the air velocity and is displayed on either a digital or analog meter.

(2) The probe can be used directly to measure air velocity in open spaces and at air exhaust and supply openings.

(3) Attachments are available to measure static pressure.

(4) Due to the small diameter of the probe, measurements can be made directly inside ducts using the measurement techniques described for Pitot traverses in sections 4.b. and 4.c. of this chapter.

(5) Battery charging and maintenance are extremely important and the battery voltage must be checked prior to instrument use.

(6) Minimum velocity ranges vary depending on the manufacturer, but are generally 50-100 feet per minute.

(7) Initial and periodic calibration are required.

CAUTION: Thermal anemometers should not be used in explosive atmospheres because they may provide an ignition source.

c. Swinging vane anemometer (velometer).

(1) Indicates air velocity as a function of the pressure exerted by the air stream on a swinging vane which is under tension and calibrated.

(2) Includes a variety of fittings which can be used to measure static pressure and a wide range of linear velocities.

(3) Perform "zero check" prior to use by holding it horizontal and covering both ports so that no air can flow through. If the pointer does not come to rest at zero, the zero ("Z") adjustment must be turned to make the necessary correction.

(4) Dust, moisture, or corrosive material in the atmosphere present a problem since air passes through the meter.

(5) The minimum velocity is 50 feet per minute unless adapted for a lower range.

(6) The instrument requires initial and periodic calibration.

d. Aneroid gauge.

(1) Gauge operates without liquid to measure pressure. The best known type is the "Magnehelic" gauge.

(2) Advantages:

(a) Easy to read;

- (b) Greater range of response than manometers;
- (c) Portable (small and lightweight);
- (d) Less maintenance due to absence of fluid; and
- (e) Can mount and use in any position without loss of accuracy.

(3) Disadvantages:

- (a) Subject to mechanical failure; and
- (b) Requires periodic calibration checks and occasional recalibration.
- (c) Change of mounting position (e.g., from vertical to horizontal) requires rezeroing.

4. **GENERAL METHODS FOR EVALUATION OF INDUSTRIAL VENTILATION SYSTEMS.** See Reference 6-2 for a complete discussion on where to take measurements, the number of readings required, etc.

a. Face velocity traverse method.

- (1) Determine the area of the open face of the booth or hood.
- (2) Measure air velocity at several points across the face of the booth or hood and calculate the average velocity. This should be accomplished by forming a grid of equal area rectangles across the face and taking a velocity measurement in the center of each rectangle.
- (3) Calculate total volumetric flow rate using Equation 6-1.

$$Q = VA$$

Equation 6-1

Where:

- Q = volumetric flow rate (ft³/min)
- V = average air velocity across face (ft/min)
- A = area of booth or hood face (ft²)

b. Pitot tube traverse method for round ducts.

- (1) Make two traverses across the diameter of the duct at right angles to each other.

(a) Holes made for the Pitot tube should be drilled, not punched, to avoid projections or burrs inside the duct which may add to air turbulence and alter readings.

(b) Whenever possible, the traverse should be made $7\frac{1}{2}$ duct diameters or more downstream and $2\frac{1}{2}$ duct diameters or more upstream from any major air disturbance (e.g., elbow, hood, branch entry).

(2) Measure velocity pressure at the center of annular rings of equal area.

(3) For ducts with a diameter less than or equal to 6 inches, at least 6 traverse points should be measured. For ducts with diameters greater than 6 inches, at least 10 traverse points should be used. For very large ducts (approximately 40 inches in diameter or larger) or for ducts with a wide variation in velocity from point to point, 20 traverse points should be used. The location of the traverse points should be documented.

If the minimum distances from disturbances cannot be satisfied, a traverse should be taken at a second location. If the average reading from the two locations agree within 10%, an average of all readings may be used. If variation exceeds 10%, readings should be taken from a third location and average of the two readings in closest agreement may be used.

(4) Convert all velocity pressure measurements to velocity using Equation 6-2.

$$V = 4005\sqrt{VP}$$

Equation 6-2

Where:

V = velocity (ft/min)

VP = velocity pressure (inches of water gauge)

This equation is for dry air at standard temperature (25° C) and pressure (760 mm Hg). Otherwise, corrections must be made for temperature, moisture and pressure. Consult Reference 6-2.

(5) Determine the average duct velocity and calculate the duct volumetric flow rate using Equation 6-1.

c. Pitot traverse method for square or rectangular ducts.

(1) Divide the cross-section into a number of equal area rectangles.

(2) Measure the velocity pressure at the center of each rectangle. Make enough readings so that the greatest distance between the centers is approximately 6 inches. In all cases, at least 16 measurements should be made.

(3) Convert all velocity pressure measurements to velocity using Equation 6-2.

(4) Determine the average duct velocity and calculate the duct volumetric flow rate using Equation 6-1.

d. Static pressure measurements.

(1) The preferred method of measuring static pressure is the use of a manometer and Pitot tube. Static pressure may also be measured by connecting the manometer to an opening in the wall of the duct.

(2) If static pressure is measured at the duct wall, it should be done $7\frac{1}{2}$ duct diameters downstream and $2\frac{1}{2}$ duct diameters upstream of any fittings. If this is not possible, drill (do not punch) four or more holes equally spaced around the duct in the same plane and average the readings.

(3) Measurements of hood static pressure for tapered hoods should be made a distance of one duct diameter from the duct entry. For flanged or plain hoods, measure hood static pressure at 3 duct diameters from the hood.

e. Capture velocity measurements.

(1) Measure air flow at the point of contaminant generation.

(2) Factors affecting capture velocity which should be documented:

(a) Flanges - decrease the required flow rate to achieve a given capture velocity by providing a barrier to unwanted air flow from behind the hood. In most instances, the flange width should equal the square root of the hood area.

(b) Baffles - provide a similar effect by providing a barrier to unwanted air from the front or sides of the hood.

(c) Room currents - may be favorable or unfavorable to capture.

(d) Size of hood - large hoods create a large air mass in motion while small hoods create localized control only.

f. Smoke tubes. Observing generated smoke makes it possible to determine direction of air flow, turbulence and location of dead spots.

CAUTION: Ventilation smoke tubes may contain stannic oxychloride or titanium tetrachloride which produce hydrogen chloride gas, a strong

mucous membrane irritant. Do not direct smoke toward an employee's eyes or breathing zone.

g. Visual inspection. A visual inspection of a ventilation system can detect such things as broken or corroded fan blades, broken or clogged duct work, dirty filters, etc.

5. VENTILATION SURVEYS.

a. The scope of the ventilation survey will primarily depend on whether measurements and/or calculations are intended for screening or baseline information.

(1) Screening. Screening measurements are usually obtained by the industrial hygienist during the periodic walkthrough portion of an industrial hygiene survey. Capture and face velocities are usually all that are measured. These measurements are used to document airflow.

(2) Baseline evaluations. Evaluate ventilation systems in conjunction with the baseline industrial hygiene survey, unless otherwise specified in Navy occupational safety and health (NAVOSH) standards. Documentation should include a comparison of the design specifications to the performance data. If a design specification for a particular ventilation system does not exist, a baseline ventilation survey will serve as the benchmark. When the ventilation system does not control the hazard to within acceptable levels, notify the cognizant activity personnel and conduct another survey after repairs or modifications are completed.

b. Industrial ventilation survey reports. During ventilation surveys, include as much of the following information as possible in the survey report:

(1) Sketches and/or photographs of ventilation systems.

(2) Brief description of ventilation systems, e.g., natural, forced air, dilution, local exhaust or combinations.

(3) Locations and types of ventilation systems, hood face velocities, capture velocities, the appropriateness of the ventilation for the job and range of activities relative to hazard generation.

(4) Adequacy of make-up air. Explain how make-up air is obtained, exhausted or recirculated and whether it is contaminated.

(5) Records of periodic inspections and summaries of previous surveys/inspections. Use previous survey information as much as possible.

(6) Variables that affect ventilation, e.g., doors, windows, openings in building and processes affecting temperature, heating and cooling of the building and/or operation, local cooling fans, and seasonal characteristics.

(7) General comments on the effectiveness of the system and personnel work practices.

(8) Personnel exposure levels when the ventilation systems are operating.

(9) Fan manufacturer, model number, serial number, capacity in ft³/min, static pressure rating in inches of water gauge, and fan pulley diameter in inches.

(10) Fan motor manufacturer, model number, serial number, revolutions per minute, motor pulley diameter in inches and horsepower.

(11) Type, size and capabilities of the dust collector, and the status of filters, cyclones, etc. (e.g., operational, clogged, torn).

(12) Manufacturer, model number, serial number, and calibration date for air velocity meter used.

(13) References and standards upon which any recommendations are based.

(14) Survey date and signature of person performing survey.

c. Shipboard Industrial Ventilation Surveys. Shipboard HVAC and industrial ventilation design criteria is provided in Reference 6-3. Naval Ships Technical Manuals should be consulted first for ventilation requirements. Where Navy standards do not exist, Reference 6-3 authorizes use of Reference 6-2 for industrial ventilation requirements.

(1) For a number of reasons, most shipboard ventilation surveys are best accomplished while the ship is not underway. Major ventilation systems required for propulsion can be secured or operated at various speeds, ship's personnel are more available to assist, and there is easier access to hard-to-reach ducts and openings.

(2) Ventilation systems should be thoroughly traced and sources of replacement air for recirculation systems identified.

(3) On ships which are equipped with a Chemical Protective System (CPS), ventilation surveys should document the status of the CPS during the survey.

(4) Unauthorized ship alterations, such as cardboard vent covers, holes in ducts and cheesecloth dust-catchers, should be noted in the report as discrepancies.

(5) Interim and feasible alternatives to ship alteration corrections must be investigated for ventilation discrepancies.

(6) The industrial hygiene officer should assist the command in preparing 2K and 2L forms for corrective actions. These maintenance forms will be added to the Current Ship's Maintenance Project (CSMP).

d. Biological Safety Cabinet (BSC) Ventilation Measurements. BUMED industrial hygienists are sometimes asked to measure BSC ventilation. Although IH personnel can make measurements that may be useful in identifying potentially malfunctioning BSCs (i.e., troubleshooting), they are usually neither trained nor equipped to “certify” a BSC.

(1) Field Certification of BSCs.

(a) Frequency of Certification. The Centers for Disease Control have recognized expertise in the area of BSCs. CDC’s guidance on BSC certification is stated in References 6-1 and 6-4 as follows: “The operational integrity of a BSC must be validated before it is placed into service and after it has been repaired or relocated. Relocation may break the HEPA filter seals or otherwise damage the filters or the cabinet. Each BSC should be tested and certified at least annually to ensure continued, proper operation.”

(b) Industrial Hygiene Personnel Authorized to Certify a BSC. Industrial Hygiene personnel that certify BSCs shall be certified under the NSF International Field Certification of BSC Program. Details of that certification program can be obtained from NSF International via the internet at www.nsf.org.

(c) Certification Procedures. Field testing of Class II Biological Safety Cabinets (BSCs), Types A1, A2, B1, and B2, must be conducted in compliance with the requirements of Reference 6-5, Annex F, using specialized equipment and procedures. Additional information is available in Reference 6-1, Appendix A.

(d) Contracting versus In-House Certification of BSCs. Due to the cost of the training and required specialized test equipment (e.g., aerosol photometer for filter testing, aerosol generator, etc.) and the ready availability of certified personnel who contract to provide Field Certification of BSCs, it is unlikely to be cost effective for BUMED IH personnel to provide Field Certification of BSCs in CONUS. IH Program Offices that are considering developing the capability for Field Certification of BSCs should consult with their Regional Industrial Hygiene staff before making a commitment.

(2) BSCs Used for Handling Hazardous Drugs and other Pharmacy BSCs. Reference 6-6 establishes requirements for certification of BSCs used for handling Hazardous Drugs. Chapter 21 of Reference 6-7 establishes requirements for certification of pharmacy BSCs in general. Pharmacy BSCs shall be maintained in accordance with those two references and usually require recertification every six months.

(3) Requests for Evaluation of BSCs. Due to their expertise, IHs may be called upon to investigate airflow or filter issues associated with BSCs. If the IH responding to such a request is currently certified by the NSF to perform field certification of BSCs, he/she may act within the scope of that NSF certification. If the IH performing the work is NOT certified by the NSF to perform field certification of BSCs, he/she may comply with the request if the following actions are taken:

(a) Do NOT place any labels or stickers of any type either on the BSC or in the area of the BSC that document the measurements made. This is to prevent such items from being misinterpreted as a “certification” label.

(b) Ensure that the written report of such “troubleshooting” assistance makes it perfectly clear that the work performed was not a “certification” of the BSC.

6. **TROUBLE SHOOTING AN INDUSTRIAL EXHAUST SYSTEM - SOME HELPFUL HINTS.** Most of the following checks can be made by visual observation without the need for extensive measurements.

a. If the air flow is low in hoods:

(1) Check fan rotation. Reversed polarity in a three-phase electrical system will cause the fan to run backwards. A centrifugal fan running backwards may deliver only 30-50 percent of rated flow.

(2) Check fan revolutions per minute (rpm). Note unusual noises. For example, fan "squealing" may indicate belt slippage or loosening.

(3) Check for clogged or corroded fan wheel and casing.

(4) Check for clogged duct work:

(a) A high hood static pressure and low air flow may indicate an obstruction in the ductwork upstream of the hood static pressure measurement point. A low hood static pressure and low air flow may indicate a downstream duct obstruction.

(b) Open clean-out doors and inspect inside of duct.

(5) Check for closed or frozen dampers in ductwork.

(6) Check for clogged collector or air cleaning devices.

(7) Check for weather cap being placed too close to discharge stack. A $\frac{3}{4}$ duct diameter gap should be present between cap and stack. Current ventilation practice recommends NOT using weather caps.

(8) Check for poorly designed duct work:

(a) Short radius elbows ($1\frac{1}{2}$ to $2\frac{1}{2}$ duct diameters radius of curvature recommended).

(b) Branch entries into main duct at sharp angles. A 30° angle of entry with main is recommended. Duct diameter expansions should be provided.

(c) Duct is too small to carry air flow.

(d) Duct velocities excessively higher than the required transport velocity result in unnecessarily high static pressures.

(e) Rectangular duct work is less efficient than round.

(9) Check for high negative pressures as a result of lack of replacement air.

(a) Propeller fan systems are sensitive to even slight negative pressures. This may reduce air flow.

(b) High velocity drafts at door openings and windows usually result from lack of replacement air.

b. If hood air flow is satisfactory, but there is poor contaminant control:

(1) Check for cross drafts from

(a) Process air movement;

(b) Cooling fans, air supply systems; and

(c) Open doors and windows.

(2) Check for poor work practices.

(3) Check for an operation too far from the hood opening to maintain effective capture velocity.

(4) Check for poor hood enclosure (e.g., doors, baffles, or sides of hoods may have been removed).

(5) Check for misapplication of system to contaminant type (i.e., use of canopy hoods for control of toxic contaminants).

7. **CATEGORIES OF VENTILATION STANDARDS**. NAVOSH ventilation standards may cover three general categories: health, fire and explosion, and special conditions. References 6-8 through 6-22 provide specific details.

a. Health-related standards. The standards in this category are intended to control exposures to below Navy OELs for air contaminants. Details are in References 6-15 through 6-19.

(1) Compliance should be achieved with the air flow specifications listed in health related standards.

(2) Ventilation is considered to be sufficient if personnel are not exposed to levels of air contaminants in excess of NAVOSH standards.

(3) In the event that air flow specifications are not achieved, but exposures are adequately controlled, a lower abatement priority or risk assessment code may be assigned to the ventilation system.

b. Fire and explosion related standards. The standards in this category, references 6-20 through 6-22, are intended to prevent fires and explosions. When working with ventilation systems of this type, the industrial hygienist must notify the cognizant gas-free engineer prior to conducting any tests or directing any adjustments.

(1) In the application of fire- and explosion-related ventilation standards, an operation has adequate ventilation when both of the following criteria are met:

(a) The requirement of a specific standard has been met (e.g., NAVOSH, National Fire Protection Association (NFPA)).

(b) The concentration of flammable vapors is 25 percent or less of the lower explosive limit (LEL). Standards which are exceptions to the 25 percent of the LEL rule may be found in References 6-21 and 6-22. These allow no more than 10 percent of the LEL.

(2) To determine the concentration of flammable material, the industrial hygienist must do the following:

(a) Take and evaluate measurements from direct reading instruments (i.e., combustible gas indicators, detector tubes, etc.);

CAUTION: If explosive atmospheres are possible, equipment used must be rated as intrinsically safe for hazardous locations.

(i) If the reading on the combustible gas meter is greater than 25 percent of the LEL, immediate corrective action is necessary and the cognizant gas-free engineer must be immediately notified and consulted concerning such action.

(ii) Direct-reading instruments must also be used to determine if the ventilation system provides enough air to reduce a flammable concentration to 25 percent or less of the LEL to all floor areas, pits or dead-air spots where flammable vapors may collect.

(b) Calculate the air volume required considering evaporation rates, etc., and the amount supplied to ensure that the flammable concentration does not exceed 25 percent of the LEL.

c. Special conditions standards. The standards in this category involve confined space operations and/or high hazard contaminants specifically designated in the standards.

Professional judgment must be exercised in the evaluation of actual or potential hazards due to the high exposure levels which may be encountered in many of the referenced operations. Depending on the circumstances, specific training in “gas-free engineering” may be required to properly address confined space problems. . When working with ventilation systems of this type, the industrial hygienist must notify the cognizant gas-free engineer prior to conducting any tests or directing any adjustments. Factors which may be of assistance in determining whether an actual or potential hazard is present in a confined space operation include:

- (1) The use of an oxygen meter and/or air sampling equipment;
- (2) The size of the enclosure;
- (3) The restriction of airflow;
- (4) The potential for oxygen deficiency (i.e., displacement of air by the contaminant(s), depletion of oxygen caused by the operation, etc.);
- (5) The toxicity of the substances to which the employee may be exposed. For example, the permissible exposure limit for propylene oxide is 20 ppm, the LEL is 2.3% or 23,000 ppm. The immediately dangerous to life and health (IDLH) concentration for propylene oxide is 400 ppm, less than 10% of the LEL;
- (6) Employee interviews;
- (7) Work practices; and
- (8) Tendency of the environment to change (e.g., methane accumulation in sewer manhole).

8. **DESIGN REVIEWS.** Occupational health aspects must be considered, designed, and engineered into all facilities which are acquired or constructed for use by Navy personnel. The cognizant industrial hygienist must participate in the review of plans and specifications for ventilation system construction, renovation and/or repair projects. Consult References 6-2, 6-3 and 6-14 for design criteria.

9. **REFERENCES.**

6-1 Centers for Disease Control and Prevention (CDC): The National Institutes of Health (NIH). Biosafety in Microbiological and Biomedical Laboratories, 5th Edition. Washington, DC: U. S. Government Printing Office, 2007 (or latest edition).

6-2 American Conference of Governmental Industrial Hygienists (ACGIH). *Industrial Ventilation - A Manual of Recommended Practice*. 23rd Edition. Cincinnati: American Conference of Governmental Industrial Hygienists, 1998 (or latest edition).

6-3 NAVSEA 0938-LP-018-0010, *Heating, Ventilation, and Air Conditioning Design Criteria for Surface Ships of the U.S. Navy.*

6-4 Centers for Disease Control and Prevention (CDC): The National Institutes of Health (NIH). *Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets*, 3rd Edition. Washington, DC. U. S. Government Printing Office, 2007 (or latest edition).

6-5 NSF/ANSI 49-2007. *Class II (laminar flow) biosafety cabinetry*. NSF International, Ann Arbor.

6-6 BUMEDINST 6570.3 Series

6-7 Manual of the Medical Department, NAVMED P117

6-8 OPNAVINST 5100.19 Series

6-9 Occupational Safety and Health Administration (OSHA). *Occupational Safety and Health Administration Technical Manual*, Section II, Chapter 3, *Ventilation Investigation*. OSHA Instruction TED 1.15. Washington, D.C.: U.S. Department of Labor. 1995.

6-10 NAVSEA S6470-AA-SAF-010, *Gas Free Engineering Program*.

6-11 Code of Federal Regulations, Title 29, Part 1910.146, *Permit-required Confined Spaces*.

6-12 Code of Federal Regulations, Title 29, Part 1915, Subpart B, *Confined and Enclosed Spaces and Other Dangerous Atmospheres in Shipyard Employment*.

6-13 Naval Ships' Technical Manual, S9086-CH-STM-030, Chapter 074 (Volume 3), *Gas Free Engineering*.

6-14 MIL-HDBK-1003/17 Series, *Military Handbook, Industrial Ventilation Systems*.

6-15 Code of Federal Regulations, Title 29, Part 1910.94, *Ventilation*.

6-16 Code of Federal Regulations, Title 29, Part 1910, Subpart Q, *Welding, Cutting and Brazing*.

6-17 Code of Federal Regulations, Title 29, Part 1926, section 57, *Ventilation*; section 154, *Temporary Heating Devices*; and section 353, *Ventilation and Protection in Welding, Cutting and Heating*.

6-18 Code of Federal Regulations, Title 29, Part 1915, section 32, *Toxic Cleaning Solvents*; and section 51, *Ventilation and Protection in Welding, Cutting and Heating*.

6-19 Code of Federal Regulations, Title 29, Part 1918.93, *Ventilation and Atmospheric Conditions*.

6-20 Code of Federal Regulations, Title 29, Part 1910, section 103, *Hydrogen*; section 104, *Oxygen*; section 106, *Flammable and Combustible Liquids*; section 107, *Spray Finishing Using Flammable and Combustible Materials*; section 108, *Dip Tanks Containing Flammable or Combustible Liquids*; and section 307, *Hazardous (classified) Locations*.

6-21 Code of Federal Regulations, Title 29, Part 1915, section 12, *Precautions and the Order of Testing Before Entering Confined and Enclosed Spaces and Other Dangerous Atmospheres*; section 13, *Cleaning and Other Cold Work*; section 35, *Painting*; and section 36, *Flammable Liquids*.

6-22 Code of Federal Regulations, Title 29, Part 1926.803, *Compressed Air*.

APPENDIX D: OSHA 29CFR 1915.35, SURFACE PREPERATION AND PRESERVATION

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- **Part Number:** 1915
- **Part Title:** Occup. Safety and Health Standards for Shipyard Employment
- **Subpart:** C
- **Subpart Title:** Surface Preparation and Preservation
- **Standard Number:** 1915.35
- **Title:** Painting.

1915.35(a)

Paints mixed with toxic vehicles or solvents.

1915.35(a)(1)

When paints mixed with toxic vehicles or solvents are sprayed, the following conditions shall apply:

1915.35(a)(1)(i)

In confined spaces, employees continuously exposed to such spraying shall be protected by air line respirators in accordance with the requirements of subpart I of this part.

1915.35(a)(1)(ii)

In tanks or compartments, employees continuously exposed to such spraying shall be protected by air line respirators in accordance with the requirements of subpart I. Where mechanical ventilation is provided, employees shall be protected by respirators in accordance with the requirements of subpart I of this part.

1915.35(a)(1)(iii)

In large and well ventilated areas, employees exposed to such spraying shall be protected by respirators in accordance with the requirements of subpart I of this part.

1915.35(a)(2)

Where brush application of paints with toxic solvents is done in confined spaces or in other areas where lack of ventilation creates a hazard, employees shall be protected by filter respirators in accordance with the requirements of subpart I of this part.

1915.35(a)(3)

When flammable paints or vehicles are used, precautions shall be taken in accordance with the requirements of 1915.36.

1915.35(a)(4)

The metallic parts of air moving devices, including fans, blowers, and jet-type air movers, and all duct work shall be electrically bonded to the vessel's structure.

1915.35(b)

Paints and tank coatings dissolved in highly volatile, toxic and flammable solvents. Several organic coatings, adhesives and resins are dissolved in highly toxic, flammable and explosive solvents with flash points below 80 deg. F. Work involving such materials shall be done only when all of the following special precautions have been taken:

1915.35(b)(1)

Sufficient exhaust ventilation shall be provided to keep the concentration of solvent vapors below ten (10) percent of the lower explosive limit. Frequent tests shall be made by a competent person to ascertain the concentration.

1915.35(b)(2)

If the ventilation fails or if the concentration of solvent vapors reaches or exceeds ten (10) percent of the lower explosive limit, painting shall be stopped and the compartment shall be evacuated until the concentration again falls below ten (10) percent of the lower explosive limit. If the concentration does not fall when painting is stopped, additional ventilation to bring the concentration to below ten (10) percent of the lower explosive limit shall be provided.

1915.35(b)(3)

Ventilation shall be continued after the completion of painting until the space or compartment is gas free. The final determination as to whether the space or compartment is gas free shall be made after the ventilating equipment has been shut off for at least 10 minutes.

1915.35(b)(4)

Exhaust ducts shall discharge clear of working areas and away from sources of possible ignition. Periodic tests shall be made to ensure that the exhausted vapors are not accumulating in other areas within or around the vessel or dry dock.

1915.35(b)(5)

All motors and control equipment shall be of the explosion-proof type. Fans shall have nonferrous blades. Portable air ducts shall also be of nonferrous materials. All motors and associated control equipment shall be properly maintained and grounded.

1915.35(b)(6)

Only non-sparking paint buckets, spray guns and tools shall be used. Metal parts of paint brushes and rollers shall be insulated. Staging shall be erected in a manner which ensures that it is non-sparking.

1915.35(b)(7)

Only explosion proof lights, approved by the Underwriters' Laboratories for use in Class I, Group D atmospheres, or approved as permissible by the Mine Safety and Health Administration or the U.S. Coast Guard, shall be used.

1915.35(b)(8)

A competent person shall inspect all power and lighting cables to ensure that the insulation is in excellent condition, free of all cracks and worn spots, that there are no connections within fifty (50) feet of the operation, that lines are not overloaded, and that they are suspended with sufficient slack to prevent undue stress or chafing.

1915.35(b)(9)

The face, eyes, head, hands, and all other exposed parts of the bodies of employees handling such highly volatile paints shall be protected. All footwear shall be non-sparking, such as rubbers, rubber boots or rubber soled shoes without nails. Coveralls or other outer clothing shall be of cotton. Rubber, rather than plastic, gloves shall be used because of the danger of static sparks.

1915.35(b)(10)

No matches, lighted cigarettes, cigars, or pipes, and no cigarette lighters or ferrous articles shall be taken into the area where work is being done.

1915.35(b)(11)

All solvent drums taken into the compartment shall be placed on nonferrous surfaces and shall be grounded to the vessel. Metallic contact shall be maintained between containers and drums when materials are being transferred from one to another.

1915.35(b)(12)

Spray guns, paint pots, and metallic parts of connecting tubing shall be electrically bonded, and the bonded assembly shall be grounded to the vessel.

1915.35(b)(13)

All employees continuously in a compartment in which such painting is being performed shall be protected by air line respirators in accordance with the requirements of Subpart I of this part and by suitable protective clothing. Employees entering such compartments for a limited time shall be protected by filter cartridge type respirators in accordance with the requirements of subpart I of this part.

1915.35(b)(14)

All employees doing exterior paint spraying with such paints shall be protected by suitable filter cartridge type respirators in accordance with the requirements of subpart I of this part and by suitable protective clothing.

[61 FR 26321, May 24, 1996; 67 FR 44541, July 3, 2002]

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