WALK-THROUGH SURVEY REPORT: STYRENE AND NOISE EXPOSURES DURING FIBER REINFORCED PLASTIC BOAT MANUFACTURING

at

U.S. MARINE INCORPORATED
Arlington, Washington

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SITE SURVEYED:	U.S. Marine Arlington, Washington
SIC CODE:	3732 (Boat Manufacturing And Repair)
SURVEY DATE:	June 9, 2005
SURVEY CONDUCTED BY:	Rebecca M. Valladares Leo M. Blade All mentioned above: NIOSH, Cincinnati, OH
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Introduction

The National Institute for Occupational Safety and Health (NIOSH) is part of the Centers for Disease Control and Prevention (CDC) in the Department of Health and Human Services (DHHS). NIOSH was established in 1970 by the Occupational Safety and Health (OSH) Act, at the same time that the Occupational Safety and Health Administration (OSHA) was created in the Department of Labor (DOL). The OSH Act mandated NIOSH to conduct research and education programs separate from the standard-setting and enforcement functions conducted by OSHA. An important area of NIOSH research involves controlling occupational exposure to potential chemical and physical hazards.

On June 9, 2005, researchers from the Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology (DART) conducted a walk-through survey at a U.S. Marine facility in Arlington, Washington. The primary purpose of this walk-through was to learn more about the fiberglass reinforced plastic (FRP) boat industry and to assess the suitability of this facility for an in-depth survey. The main goals for the walk-through survey involved evaluating the occupational exposures of styrene vapor in air and observing the effectiveness of engineering exposure-control measures during FRP boat manufacturing operations. A secondary objective was to perform a preliminary assessment of the noise exposures occurring during these operations.

The U.S. Marine plant in Arlington, Washington, manufactures Meridian Yachts mainly using the open mold process. The closed molding process is used for building small hatch covers. U.S. Marine Corporation has 2600 total employees nationwide. The Arlington facility employs approximately 1050 people and runs three different shops: manufacturing, research and development, and administration. Their time and efforts are spent between manufacturing and research and development (engineering and documentation for all boat lines sold by U.S. Marine).

Styrene Usage and the Hazards of Exposure to Styrene and Noise

The major chemical component of concern in terms of occupational exposures in the FRP process is styrene. Styrene is a fugitive emission, a result evaporating from resins, gel coats, solvents, and surface coatings used in the manufacturing process. The thermo set polyesters used at this plant range from 19% (low styrene gelcoat) to 35% (polyester resin/ vinyl ester resin blend containing styrene and fumed silica) styrene content by weight. Styrene is an essential reactive diluent for polyesters because it reduces the viscosity of the polyester mixture making it thinner and more capable of coating fiber reinforcements allowing the reactive sites on the molecules to interact. As an active diluent, styrene will react in the free-radical cross-linking reaction. Cross-linking is the attachment of two chains of polymer molecules by bridges composed of molecular, in this case styrene, and primary chemical bonds. It produces a solid that is impervious to most solvents, petroleum, and other chemicals found in the marine environment. Since styrene is consumed as part of this reaction, there is no need for removal of the diluents after the part is formed; however, due to the volatility of styrene, vapors from the application and curing process may pose an inhalation exposure hazard for workers near the process.

Humans exposed to styrene for short periods of time through inhalation may exhibit irritation of the eyes and mucous membranes, and gastrointestinal effects.[1] Styrene inhalation over longer periods of time may cause central nervous system effects including headache, fatigue, weakness, and depression. Exposure may also damage peripheral nerves and cause changes to the kidney and blood. Numerous studies have shown that styrene exposures were linked to central and peripheral neurologic,[2,3,4] optic,[5,6] and irritant[7] effects when occupational exposures to styrene emissions were greater than 50 parts per million (ppm). There is also evidence concerning the influence of occupational styrene exposure on sensory nerve conduction indicating that 1) 5-10% reductions can occur after exposure at 100 ppm or more, 2) reduced peripheral nerve conduction velocity and sensory amplitude can occur after styrene exposure at 50 to 100 ppm, 3) slowed reaction time appears to begin after exposures as low as 50 ppm and 4) statistically significant reductions in color discrimination (dyschromatopsia) may occur.[8] Some other health effects of low-level styrene exposure include ototoxicity in workers and experimental animals. Styrene exposure can cause permanent and progressive damage to the auditory system in rats even after exposure has ceased.[9,10] Styrene has been shown to be a potent ototoxicant by itself, and can have a synergistic effect when presented together with noise or ethanol.[11,12,13,14]

The primary sources of environmental evaluation standards and guidelines for the workplace are: 1) the OSHA Permissible Exposure Limits (PEL),[15] 2) The NIOSH Recommended Exposure Limits (REL),[16] and 3) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLV®).[19] Employers are mandated by law to follow the OSHA limits; however, employers are encouraged to follow the most protective criteria. The NIOSH REL for styrene is 50 ppm time weighted average (TWA) (meaning the limit is for a work day of up to 10 hours and a work week of up to 40 hours), with a 15-minute short-term exposure limit (STEL) of 100 ppm, limiting average exposures over any 15 minute period during the work day.[17] These recommendations are based upon reported central nervous system effects and eye and respiratory irritation. The OSHA PEL for styrene is 100 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm.[18] The ceiling limit restricts exposures for any portion of the work day. The American Conference of Governmental Industrial Hygienists (ACGIH) revised its Threshold Limit Value (TLV®) in 1997, and recommends styrene to be controlled to 20 ppm for an 8- hour TWA exposure with a 40 ppm, 15-minute short-term exposure limit (STEL).[19]

In February 1996, Styrene Information and Research Center (SIRC) and three other styrene industry trade associations (American Composites Manufacturers Association, National Marine Manufactures Association, and the International Cast Polymer Association) entered into a precedent-setting arrangement with OSHA to voluntarily adhere to the 50-ppm level set by the 1989 update of the OSHA PEL (which was later vacated by the courts). The SIRC encouraged its members to continue to comply with the 50-ppm standard as an appropriate exposure level for styrene, regardless of its regulatory status.[20]

Exhaust ventilation, low styrene-content resin, non-atomizing spray equipment, and personal protective equipment have historically been recommended to limit styrene vapor exposures to workers. Recent developments in specific closed molding technologies, however, may also provide protection by reducing process emissions of styrene, and, in turn, the concentration of styrene in the workers' breathing zone.

<u>Facility and Process Description</u>

The plant facility includes 17 buildings dispersed on 32 acres of land. These include: prototype assembly, lamination shops, office administration buildings, warehouses, wood shops, a mill shop, a weld shop, loading, a plug shop, and windshield installation. Time and efforts are divided between manufacturing and research and development. Plant production time is split into three shifts: shift one is from 6:00 am to 2:30 pm, shift two is from 2:30 pm to 10:00 pm, and shift three is from 10:00 pm to 6:00 am. Eight different boat models are manufactured at this facility, at a rate of approximately 1.5 to 3 boats per day (including production and assembly). The boat size produces ranges from 34 to 58 feet. The pertinent buildings and the operations performed in each will be described in the paragraphs that follow.

5-Axis Mill

Building 12A houses a 5-axis mill used to create a plug. A plug is an original mold used to make production molds (also known as tooling or glass master molds). The plug is made from large high density blocks of Styrofoam. The Styrofoam blocks are machined using a computer-controlled milling machine to approximately half an inch smaller than the desired thickness. The Styrofoam blocks are coarse and roughly shaped, so a high density urethane spray is applied once the undersized plug has been machined. After the spray, the plug is re-machined to obtain a smooth finished surface. While the polystyrene foam is being shaped large particulates are released into the air. Upon completion, the plug is gelcoated and a Mold-A is made and later waxed in building 2 (*See lamination of tooling below*). In cases where small volume quantities, one to three boats, are going to be made, tooling or production molds are made directly from the plug. However, in many cases a mold known as Mold-A and a glass master are made for high volume production. The glass master is identical to the plug.

Plug Shop

The plug shop is located in the southwest corner of Building 12 directly south of the 5-axis mill. It is supplied with a re-circulating air ventilation system. All of the small detailing that the mill cannot complete is performed here. The air pockets from the foam are removed and Bondo containing styrene is applied. The final production and detail of the plugs occur in the south end of the plug shop. Two coatings of Duratec containing styrene are applied to the plugs to give them their finished appearance. Any imperfections that may be present in the plug are fixed by sanding and applying a styrene based putty to the hole and sanding again. The resin is stored near the boat sanding area (9711 Resin Isosynate). A recirculation particulate filtration air handling unit is installed in the south area. Tyvek body suits and particulate respirators were worn by all employees.

Lamination of tooling

The lamination process occurred in Building 2 which is located in the north area of the facility. Two stage respirators with organic charcoal filters and a pre-filler for particulates (NIOSH 95) are required for all lamination personnel working in this building. Hearing protection is also required for all employees and visitors entering this building. The air exchange rate is 7.5 air volume exchanges per hour with the assumption that 25 employees are working in the north end of the facility. The volumetric flow rate for the north area of the lamination building is 102,000 cubic feet per minute (cfm).

Two types of molds are made in this building. The lamination process begins with the application of the gelcoat to the plug-mold followed by the placement of the fiberglass mats. Once the gelcoat is applied to the plug, fiberglass mats and resin are added to make Mold-A. Mold-A is used to make a tool known as the glass master which is the production mold. The resin fill is sprayed on by a flow coater spray gun (model no. G03, Magnum-Venns Super Pearl Chopper Gun, Kent, Washington). The initiator used in the resin is methyl ethyl ketone peroxide (MEKP) and is mixed in the gun before application. Approximately one to two percent of MEKP is added dependant on the weather and promotion process. Although MEKP is a volatile hazardous chemical it is believed not to have an inhalation exposure potential because the gun used is a flow-coater gun which does not atomize. The tooling resin used in this building contains 40 percent styrene by weight. Gloves are not required for laminators but are provided by the compliance manager. Some laminators prefer and work better without any gloves on. It should be noted that some laminators had resin all over their hands.

Prototype Assembly

Prototype assembly is located in Building 1. A full-scale model of each new boat designed is made out of plywood and cardboard. These are made for the designers to insure that the boat dimensions and the features are exactly the way they expected them to be. All documentations for the yacht are written in this building. This concludes the ending of the research and development portion of the tour which includes the “tooling” of the production molds described in the preceding sections.

<u>Production Buildings</u>

Lamination

Production lamination is completed in Building 3. The lamination process begins with the application of the gelcoat to the mold followed by the placement of the pre-cut fiberglass mats. The production resin used contains 32 to 34 percent styrene by weight. The dry mat used contained the high porosity needed to allow resin penetration within the fiberglass structure of the mat during resin saturation (rolling process). Layers of resin, chopped glass and glass mats were added to the mold by the gunner then rolled and compressed by the rollers. The resin fill is sprayed on by a flow coater spray gun (same as one described above). This low flow gun is MACT compliant. The initiator used in the resin is methyl ethyl ketone peroxide (MEKP) and is mixed in the gun before application. Once the fiberglass mats and resin are applied and the desired thickness has been achieved, a corefoam is installed in the boat for more support. No hearing protection was required in this building except during release from the mold. Gloves are not required to be worn by laminators but are provided by the compliance manager.

Lamination was also preformed in Building 16 which is located in the south region of the plant. Hearing protection is not required in this area. Mostly hulls and large parts are laminated in this building. The resin storage room is located in the northeast side of the building. The resin used is stored in two resin tanks containing 7000 gallons of resin each. No mixing is done in this storage room.

Assembly

Assembly is located in Building 4 in the northeast section of the facility. Hearing protection was required for all personnel entering this building. Most of the work in this building involving styrene emissions is due to patch work (repair) and detail processes. A bonding agent called PatchAid (Composite Products, Kansas City, Kansas) is used to repair cracks in the parts caused by mishandling or from removing the cured fiberglass from the mold. A mixture of PatchAid and gelcoat is used for most repair work. The gelcoat used is 35 percent styrene and the patchaid is 80 percent styrene.

Woodshop and Final Assembly

The woodshop is located in building 8 and the final assembly is located in building 17. Hearing protection is required at all times in both of these buildings. Application of clear coat and staining are done in building 8. Both the clear-coat and staining materials are water based.

Weld shop and Closed Molding Process

The weld shop is located in building 10. Hearing protection is required in this building. Also housed in this building is the closed molding process known as Resin Transfer Molding (RTM). RTM was only used to produce small parts, mainly hatches. The biggest concern in this area is the styrene exposures during gelcoating. RTM is a closed-mold technique which uses two rigid half molds that close before resin injection and curing to form the final part. Prior to the injection of the resin to the closed mold, a gelcoat is applied to the interior surface of both molds to provide a smooth finish on all external surfaces after the cure. Following the gelcoat operation, dry fiber reinforcement is placed into the rigid mold before closing. After the mold is closed, resin and initiator are then transferred into the mold cavity by a pressure pump. The resin curing process takes place while the product is still in the closed-mold. Once the resin has cured, the composite part is demolded and trimmed.

Results

Styrene detector tubes were used to estimate concentrations of styrene vapor in the air in areas where NIOSH researchers observed a high use of styrene based products. The range of detection of the tubes used was 10 to 250 ppm. Results are given in Table 1.

Table 1: Results of Styrene Detector Tube Samples taken throughout the U.S. Marine Inc., Arlington, Washington Facility

Building Number	Description	Approximate Concentration [ppm]
12	Plug Shop, South end	**15**
2	Tooling Lamination, north end	**15-20**
3	Production Lamination	**40-50**
16	Production Lamination, northwest end (down wind of air supply line)	**12**
4	Assembly (near patch and repair work)	**5**

Conclusions

The highest concentration measured was located in the production lamination building. As was expected, most of the styrene exposures are occurring in the lamination buildings. These concentrations are not above the NIOSH REL, but they do exceed the ACGIH TLV of 20 ppm. After speaking with the Risk Manager and observing the ventilation system installed in all of the buildings, we do not see a major problem at this facility. There are many things that can be learned from this plant. Their ventilation system appeared to be well designed and properly placed. Due to time constraints, a ventilation characterization was not completed. It should be noted that the styrene detector tubes used provide only approximate measurements to get a general idea of what the exposures may be. An in-depth survey is recommended not only to assess the exposures, but also to learn how U.S. Marine uses their engineering controls and administrative controls to maintain a low styrene exposure plant.

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