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

at

CENTURY BOAT COMPANY, INC.
Panama City, Florida

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Centers for Disease Control and Prevention
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Engineering and Physical Hazards Branch
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SITE SURVEYED:	Century Boat Company, Inc. Panama City, Florida
SIC CODE:	3732 (Boat Manufacturing And Repair)
SURVEY DATE:	August 25, 2005
SURVEY CONDUCTED BY:	Rebecca M. Valladares NIOSH, Cincinnati, OH Leo M. Blade 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 U.S. 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 U.S. 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 measures for controlling occupational exposures to potential chemical and physical hazards.

On August 25, 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 Century Boat Company, Inc., in Panama City, Florida. The primary purpose of this walk-through was to learn more about the fiberglass-reinforced plastic (FRP) boat manufacturing industry and to assess the suitability of this facility for an in-depth survey. The main goals for the walk-through survey included performing a preliminary assessment of the occupational exposures to styrene vapor in air, and observing the effectiveness of engineering exposure-control measures during the FRP boat-manufacturing operations. A secondary objective was to perform a preliminary assessment of the noise exposures occurring during these operations.

The FRP boat manufacturing process mainly used at Century Boats is known as the open molding process. The facility is divided into six buildings which occupy a total of 123,822 square feet (ft^2). Of this area, 113,058 ft^2 is dedicated to manufacturing. Century Boats has 16 boat models ranging in size from 17 to 32 feet (ft.) in length. The facility operates one shift, working Monday through Thursday from 7:00 AM to 5:30 PM, and producing 1500 to 1700 boats per year. There are approximately 300 employees at this facility.

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 an emission evaporating from resins, gel coats, solvents, and surface coatings used in the manufacturing process. The thermo-set polyester production resin used at this plant is compliant with the U.S. Environmental Protection Agency (EPA) requirements for Maximum Achievable Control Technology (MACT) and contains 31.64 percent styrene 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. This produces a solid resin material 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 a part is formed from the polymer.

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 kidneys 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 vapors in air 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% to 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 loss of 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®). 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 vapor in air is 50 ppm for a 10-hour time-weighted average (TWA) (meaning the limit applies to the average exposure during 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 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, the Styrene Information and Research Center (SIRC) and three other styrene industry trade associations (American Composites Manufacturers Association, National Marine Manufacturers 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 zones.

Description of Facilities and Operations

Century Boats Inc. is located in Panama City, Florida. The facility is divided into six buildings which occupy a total of 123,822 ft^2. Of this area, 113,058 ft^2 are dedicated to manufacturing, 3,914 ft^2 to office space, and 6,850 ft^2 to other purposes. The manufacturing portion is split into two buildings (See Figures 1 and 2). Larger boats, ranging from 22 to 32 ft, are produced in Plant 4, while boats smaller than 22 ft. are produced in Plant 2. Century Boats has approximately 300 employees, of which 200 are directly involved in production activities. The facility operates one shift, working Monday through Thursday from 7:00 AM to 5:30 PM. They produce 1500 to 1700 boats per year. In 1998, the company invested $4 million in a ventilation system designed and installed by Frees, Inc. Century Boats Inc. spends approximately $120,000 to $125,000 on personal protective equipment (PPE) per year.

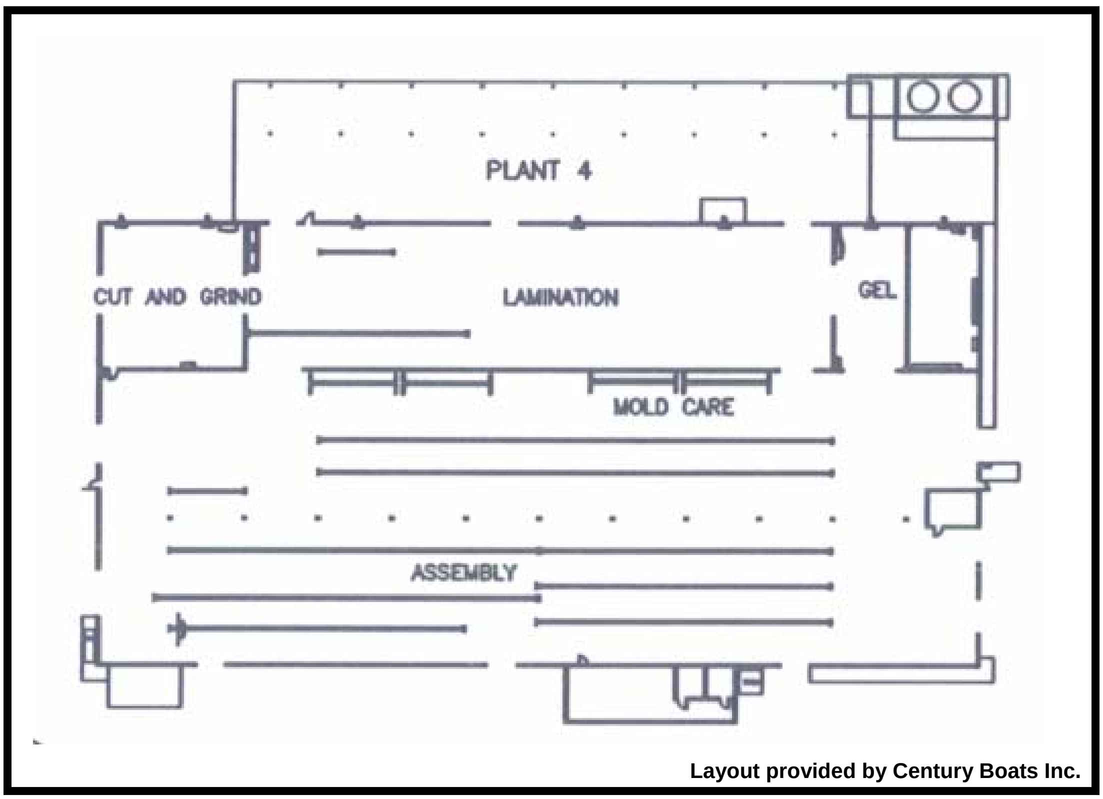

Figure 1: Layout of Plant 4-- Production of boats in size range of 22 to 32 feet

In Building 4, the only areas where potential styrene vapor exposures occur are in the gelcoat booth and lamination bays. In Building 2, both of the gelcoating booths, lamination, and lamination of small parts have potential styrene vapor exposures. Other tasks performed in Building 2 include: mold maintenance, spray-on waxing, polymer release agent, and any other repairs. The approximate concentrations of styrene vapor measured in these areas are reported in the *Results* section of this report. All exhaust air filters in the aforementioned areas are changed when the magnehelic gauge indicates a resistance of the filter to the flow of air of 0.20 inches of water when the velocity is 100 feet per minute (FPM). The resistance of the filter to the flow of air is negative pressure. Area supervisors read the magnehelic gage to the Frees Air Makeup System at the end of each day and determine if filter change is required.

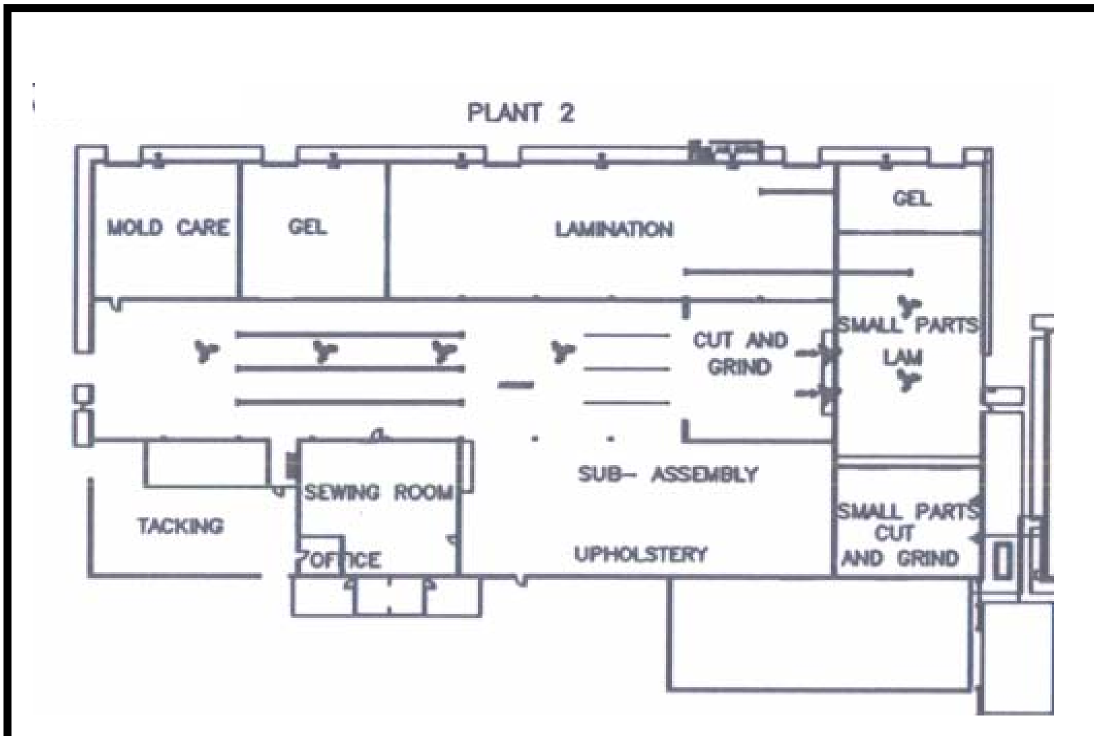

Figure 2: Layout of Plant 2-- Production of boats in size range of 17 to 22 feet

Century Boats Inc. provides a 10-year warranty protection against expense of repairs that are a result of defects in material and workmanship. The warranty includes the hull, deck, liners, stringers, transom, and all deck and hull joints. Tooling, warranty, and mold detail tasks are done in Plant 6, located at the far rear of the facility (not pictured in this report). Most tooling (molds) used for production are made by Century Boats Inc. Boat designs are built in wood plugs prior to production. From the wood design a plug, glass master, and production mold are made sequentially. In a separate bay within Building 6, the molds are laminated using a FIT (Fluid Impingement Technology) non-atomizing spray gun. These guns give higher transfer efficiency, better styrene emission control, and reduction of overspray. Tyvek clothing, half-face respirators (3M Organic Vapor respirators model no. 6001), and safety glasses are worn by all molding laminators.

Gelcoaters wear full-face respirators along with Tyvek clothing and safety goggles. Standard gelcoat spray guns are used by gelcoaters in the spray booth. Gelcoaters stand approximately three feet away from the surface while gelcoating hulls (See Figure 3).

Figure 3: Gelcoater spraying a production hull

Description of the FRP-Manufacturing Process

The FRP boat manufacturing process mainly used at Century Boats is known as the open molding process. Fiberglass boats are built from glass-fiber reinforcements laid in a mold and “wetted-out” with a polyester plastic resin. The plastic resin hardens to form a rigid plastic part reinforced with the fiberglass.

Gelcoating

The gelcoating process starts when the mold is sprayed with a layer of gel coat, which is essentially a pigmented polyester resin that hardens and becomes the smooth outside surface of the part. A noticeable amount of air is supplied to this process area and exhausted downwind of the gelcoating area. Tooling gelcoats range from 18.2 to 37 percent styrene. Pigmented gelcoats used for production range from 20.50 to 32.32 percent styrene.

Lamination

The lamination process begins with the application of a skin-coat applied using a non-atomizing chop-fiberglass gun followed by resin application. This process prevents the structured fiberglass applied immediately after the skin-coat from penetrating through the surface. The fiberglass mat used is stretched and woven to allow resin penetration within the fiberglass structure of the mat during resin saturation (rolling process). All hull molds were rotated sideways which enables the air to pass through the hull area and then be pulled from behind into the exhaust system. The laminators worked approximately 36 inches (using extension handles) from the mold. When decks are laminated, the working area is horizontally oriented. The orientation of the deck is horizontal due to the nature of the process and the detailed crevices in the decks of the boat. For parts horizontally oriented during lamination, a long duct tube connected to the supply was used to disperse air into the stringer installation of the hulls and is exhausted behind the hull (See Figure 4 below).

Figure 4: Extension of supply air into the Aft-end of the hull

MACT-compliant chopper guns are used for small parts, liners, hull and deck lining, and between layers of structural glass mats. The hand-laid fiberglass mats and chopped fiberglass pieces are saturated with resin by a gunner using a MACT–compliant, low-flow, non-atomizing gun. The saturated resin is then hand-rolled and compressed by the rollers. The production resin used is MACT compliant and contains 31.64 percent styrene by weight. Once the fiberglass mats and resin are applied and the desired thickness has been achieved, deck bulking occurs. Deck bulking is the application of structural glass, coring material, and urethane blocks into the deck. All workers in the deck bulking area wear half face respirators when working downwind and safety glasses. Floors and stingers are also added once the hull has completed the bulking process.

Resin Storage Area

Resins are stored in two 5,000 gallon tanks located outside of Building 4. The tanks are enclosed in a separate block building. The storage temperature is maintained between 75-80 degrees Fahrenheit. The temperature is controlled by water through a shell-and-tube heat exchanger.

Results

Styrene detector tubes (Drager Tube model no. 67 33 141) were used to estimate concentrations of styrene vapor in the air in areas where NIOSH researchers observed a high use of styrene-containing products. The range of detection of the tubes used was 10 to 250 ppm. Results are given in Table 1. Representatives from Century Boats Inc. also took their own measurements of styrene vapor in air using a Sensidyne (Tube no. 158S) styrene detector tube with a sampling range of 2.5 to 300 ppm. Results from these measurements are presented in Table 1.

Table 1: Results of Styrene Detector Tube Samples taken throughout the Century Boats Facility in Panama City, Florida

		Approximate Concentration [ppm]		
Plant	**Description**	**NIOSH detected concentration**	**Century Boats Inc. detected concentration**	**Mandatory Respirator Use**
4	Skinning	20	20-21	downwind
4	Deck Bulking	25-30	25-30	downwind
4	Floor and Stringers	50-55	50-55	yes
4	Gelcoating	30-35*	18-20	yes
2	Deck Skinning	30	25-25	downwind
2	Hull Bulk	30-35	35-40	downwind
2	Gelcoating small boats	50-60*	25-30	yes
2	Gelcoating small parts	20-25	15-20	yes
2	Lamination small parts	30	50	yes

***NOTE**: NIOSH research was standing downwind of gelcoater, thus high concentration

Preliminary Conclusions and Recommendations

The highest concentration detected in Plant 2 occurred while gelcoating small boats. The concentration was approximately 50-60 ppm. The NIOSH representative taking this sample was standing downwind of the gelcoater increasing the concentration detected by the styrene detector tube.

The gelcoating of small parts is a difficult task to keep ventilated. The small areas and detailing of the small part causes the contaminated styrene air to remain entrapped in the depths of the mold. Likewise in small parts lamination, the worker is positioned in an area where styrene vapors are trapped within the nooks and crevices that make up the detail of the design of the boat. Longer-handled rolling tools used in Plants 2 and 4 during lamination bulking should be considered in areas where tactile functions are not critical to keep the workers' breathing zones further away from the surface where resin is being rolled. The continued use of the organic-vapor charcoal-filter respirators is recommended especially for those workers involved in the rolling process on hulls oriented horizontally. Styrene emissions seemed to be reasonably well controlled in the remainder of the plant where styrene is being used. The ventilation systems installed seem to be working properly. A further investigation of this plant still needs to be discussed among the NIOSH researchers.

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