

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

**at**

**Island Packet Yachts (IPY)  
Largo, Florida**

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Centers for Disease Control and Prevention  
National Institute for Occupational Safety and Health  
Division of Applied Research and Technology  
Engineering and Physical Hazards Branch  
4676 Columbia Parkway, Mail Stop R-5  
Cincinnati, Ohio 45226-1998**

SITE SURVEYED:

Island Packet Yachts  
Largo, Florida

SIC CODE:

3732 (Boat Manufacturing  
And Repair)

SURVEY DATE:

October 14, 2005

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## **DISCLAIMER**

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.

## **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 1971 by the Occupational Safety and Health (OSH) Act of 1970, 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 October 14, 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 Island Packet Yachts, in Largo, 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.

## **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, which evaporates 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 approximately 30 to 35 percent styrene by weight. The percent styrene in the gelcoat is 27 to 28 percent.

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.<sup>1</sup> 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,<sup>2,3,4</sup> optic,<sup>5,6</sup> and irritant<sup>7</sup> effects when occupational exposures to styrene vapors in air were measured at concentrations 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.<sup>8</sup> 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.<sup>9,10</sup> Styrene has been shown to be a potent ototoxicant by itself, and can have a synergistic effect when presented together with noise or ethanol.<sup>11,12,13,14</sup>

The primary sources of environmental evaluation standards and guidelines for the workplace are: (1) the OSHA Permissible Exposure Limits (PELs);<sup>15</sup> (2) The NIOSH Recommended Exposure Limits (RELs);<sup>16</sup> and (3) the American Conference of Governmental Industrial Hygienists (ACGIH<sup>®</sup>) Threshold Limit Values (TLVs<sup>®</sup>).<sup>17</sup> 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.<sup>17</sup> 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.<sup>18</sup> 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<sup>®</sup>) in 1997, and recommends styrene be controlled to 20 ppm for an 8-hour TWA exposure with a 40 ppm, 15-minute STEL.<sup>19</sup>

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.<sup>20</sup>

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.

**General Facility Information**

Island Packet Yachts is a small sailing yacht manufacturing company employing approximately 150 to 175 employees and is located in Largo, Florida. The facility is on nine acres of land and split on two sides of a street. One contains buildings with 42,000 square feet of space and the other building with 64,000 square feet, for a total building space of approximately 110,000 square feet. The yachts manufactured range in size from 37 to 50 feet. Yacht production is approximately 1.5 yachts per week during a five-day week with one shift daily from 7:00 AM to 3:30 PM. A unique aspect of sailing yachts is the keel cavity that is deeper in sailboats than most other FRP boats. This keel is problematic during manufacturing potentially causing high exposures when laminating or assembling.

**Process Description**

The main process used to manufacture sailing yachts at IPY is open molding. A closed-molding process known as Vacuum Infusion Molding (VIM) is currently in the research and development stage at this company. This process is used to make some small parts such as water tanks and holding tanks.

**Open Molding**

In open molding, fiberglass boat parts are built from the outside in accordance with the process outlined below.

1. The mold is sprayed with a layer of gel coat, which is pigmented polyester resin that hardens and becomes the smooth outside surface of the part.
2. The inside of the hardened gelcoat layer is coated with a "skin coat" of chopped glass fibers and polyester resin.
3. Additional layers of fiberglass cloth or chopped glass fibers saturated with resin are added until the part attains final desired thickness. These layers are compressed by rolling the surface by hand.

Styrene exposures occur at all three steps of the open molding process mentioned above. Both the gelcoat and the polyester resins contain a substantial percentage of styrene. The proportions (by weight) of styrene in resins and gelcoats used for the open-molding process are displayed in Table 1. The tooling and production resins vary depending on the color of the gelcoat and other manufacturing environmental factors.

<b>Resin or Gelcoat Type</b>	<b>% Styrene</b>
Black Tooling Gel	15-40
Vinylester for skin coats, tooling	34.1
Lite Ivory and Camel Gelcoat	28
Production Resin	30-35

**Table 1:** Percentage of Styrene in Gelcoats and Resins

### ***Hull Lamination***

Resin is not sprayed during lamination. The resin is released through perforated rollers attached to a long hollow stick-rolling apparatus. (See Figure 1). A handle is used to control the flow through the roller. A catalyzed pump mixer is attached to the device which activates the resin when the catalyst is introduced. This mobile device allows for close proximity to the hull surface while keeping the styrene vapor in the air to a minimum and the worker's breathing-zone as far away from the hull surface as possible.



**Figure 1:** NIOSH researcher taking styrene detector-tube sample during hull lamination

### ***Assembly of Internal Glass Unit (IGU)***

A unique feature of sailing yachts is their deep hull and keel structure. The way in which yachts are manufactured is in some way different from the more traditional recreational power boat. The amounts of fiberglass and resin used per hull are significant. For example, a 51-foot boat weighs approximately 45,000 pounds. It should be noted that, sailboats typically have a lead and/ or iron ballast that make up approximately 40% of its total weight. The assembly process begins with the hull, followed by the Internal Glass Unit (IGU), and floor timber. The IGU which is built upside down has floor timbers bonded to it on the mold. (See Figure 2.) Once the structure is demolded it is turned right side up. Subsequently, the structure is bonded into the hull to form the completed IGU. Each section is bonded using fiberglass fabric pieces laid out on a piece of cardboard and soaked with resin using a low flow gun. These pieces are then passed to another worker

and placed on the working area. Pieces of wood are inserted throughout the internal glass unit for ease of attachment of interior furniture or flooring at a later time. Gloves, safety glasses, and Tyvek® suiting are worn by all laminators. There are approximately six employees working on this part at one time.



**Figure 2:** Photo of assembled Internal Glass Unit (IGU), upside down

### ***Ventilation during Lamination***

A series of three industrial duty air circulator fans (Dayton, model no. 3C218G) were directed to the hull supplying air from behind. (See Figure 3.) These fans were positioned approximately 20 feet from the edge of the hull. The fan specifications are:  $\frac{1}{4}$  hp, 1725 revolutions per minute (RPM), 24-inch diameter, and 3 in parallel. As seen in Figure 3, the worker's breathing zone is far from the laminate surface.





**Figure 3: A series of industrial fans carefully oriented to remove styrene vapor from worker's breathing-zone**

### ***Ventilation in Glass Shop***

The glass shop houses the primary exhaust route in the entire building. Two sets of fans and stacks exhaust 35,000 cfm of air each and are located in the northeast and northwest booths. A heater with a fan is used for make-up air. Systems installed in this building are adjusted for weather conditions, mainly heat and humidity. The exhaust fans and booths were installed by Collins Myers located in the St. Petersburg/ Clearwater, Florida area, but the heaters and makeup air fans were installed by C&C Enterprises in Kissimmee, FL.

### **Hearing Conservation Program**

A hearing Conservation program is implemented at this facility. At the time of the NIOSH survey different job classifications recently had undergone hearing audits. As a result, hearing protection is required for finishers, grinding (abrasive grinding), and personnel who use portable power tools. All hearing tests (audiometric exams) are contracted out. Continuous noise was produced in the grinding booth; as a result, ear muffs were worn by all workers in the grinding area.

### **Results**

#### ***Styrene***

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-containing products. The range of detection of the tubes used was 10 to 250 ppm. Results are given in Table 2.

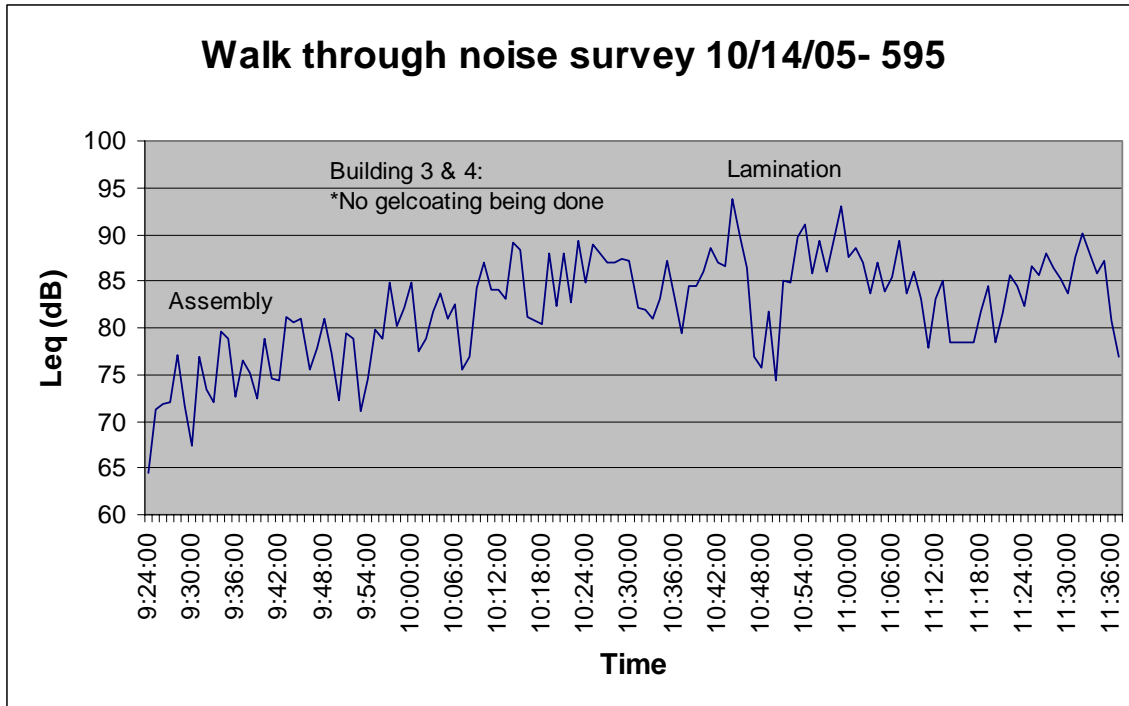
More samples were not taken due to a lay-off during our visit to this plant caused by general market conditions and Hurricane Katrina. The gelcoating booths were closed on our visit as well.

<b>Table 2: Results of Styrene Detector Tube Samples taken throughout Walk-through Survey at Island Packet Yachts in Largo, Florida</b>	
<b>Description</b>	<b>Detected concentration</b>
Lamination of Hulls	10
IGU Glassing and Assembly	25-30

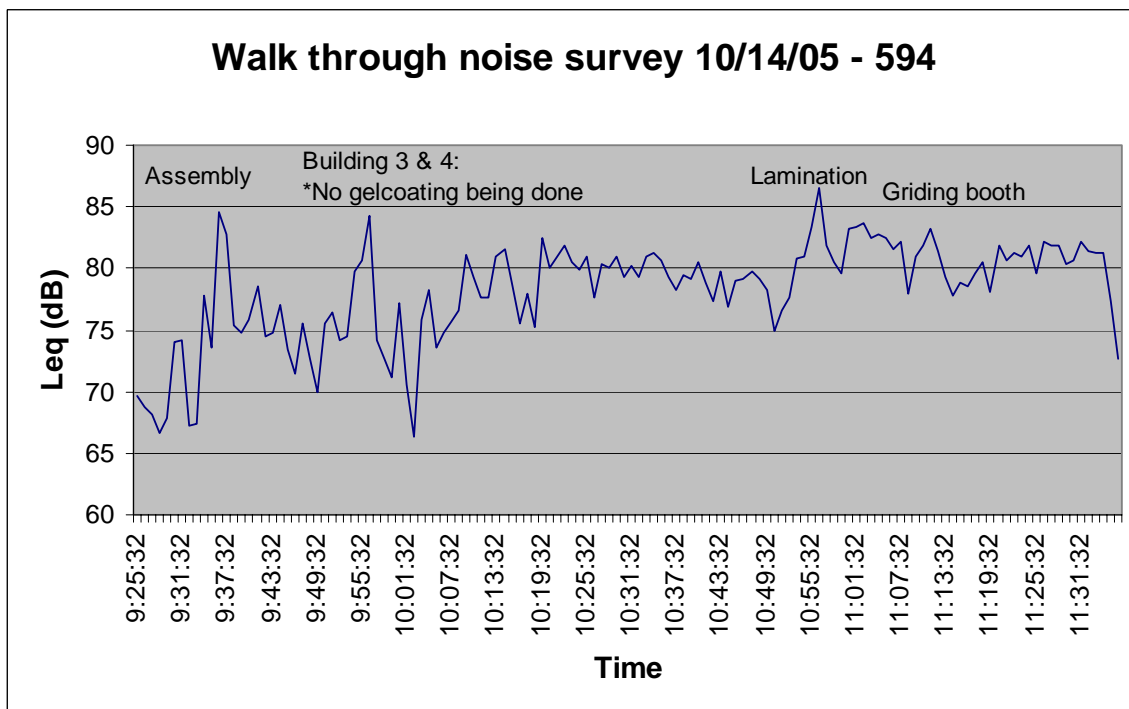
### *Noise Measurements*

In addition to measurements of styrene exposure, noise levels were also measured. Noise level measurements were collected using two Larson-Davis 706 Type 2 dosimeters. For the purposes of this preliminary assessment, the dosimeters were worn by two NIOSH researchers as they conducted the walk-through survey of the facility. Each dosimeter was capable of collecting noise data in one-second increments. The dosimeters were set to simultaneously measure the OSHA PEL and the NIOSH REL. The dosimeters conformed to the American National Standards Institute (ANSI) specifications.<sup>21</sup> Dosimeters were set to “SLOW” response and A-weighting frequency filter. The equipment was calibrated by the manufacturer before the study. The dosimeters were calibrated before and after the surveys. Data from the dosimeters were downloaded to a personal computer and analyzed using the Larson-Davis Blaze™ software.

The results are illustrated in Figures 3 and 4. These results only indicate noise levels in dB(A) of certain tasks observed during the walk-through and cannot be used for calculations of time-weighted noise exposure or dose during a work day.



**Figure 3: Noise dosimeter measurement results—Dosimeter 1**



**Figure 4: Noise dosimeter measurement results—Dosimeter 2**

### **Preliminary Conclusions and Recommendations**

According to an environmental health and safety (EHS) representative, the highest styrene exposure zones occur while making the hulls, decks, and internal glass units (IGU). Due to the shape and configuration of sailing yachts, it is believed that the worker's breathing-zone is near the laminating surface more when compared to traditional recreational-boat manufacturing. According to the few samples taken, the approximate styrene-vapor concentration in the hull laminating was only 10 ppm. The lamination and rolling steps in boat manufacturing are historically known for having the highest styrene vapor in air. It can be concluded that simple precautions like the three directed fans in parallel can be taken to ensure a low styrene-vapor environment. It is up to the plant manager to ensure that the ventilation system is properly balanced. A further investigation of this plant still needs to be discussed with NIOSH researchers.

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