IN-DEPTH SURVEY REPORT:

STYRENE EXPOSURES DURING FIBER REINFORCED WIND BLADE MANUFACTURING

at

LM Glasfiber
Grand Forks, ND

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SITE SURVEYED:	LM Glasfiber Grand Forks, North Dakota
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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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ABSTRACT

In December 2007, NIOSH researchers conducted an in-depth survey at LM Glasfiber in Grand Forks, ND and sampled for styrene, noise, and total particulate. LM Glasfiber manufactures wind blades for utility scale wind energy applications and had previously requested to participate in the NIOSH engineering control research project related to controlling occupational exposures to styrene. Sampling results from the in-depth survey indicated that personal breathing zone samples were higher than the IDLH value for styrene during one process where workers entered the wind blade to wipe the glue that was pressed out when the two half blades were joined together. Sampling results also indicated that personal breathing zone samples were higher than the ceiling limit for styrene during the gelcoating process. Following the NIOSH in-depth survey, LM Glasfiber initiated several efforts to reduce the styrene concentrations inside of the wind blade specifically focusing on the glue wipe process. In March 2008, NIOSH researchers conducted a follow up survey at LM Glasfiber to evaluate personal breathing zone concentrations for styrene for a design change to the molds that eliminated the need for workers to enter the IDLH atmosphere during the glue wipe operation. Although the design change prevented workers from entering the IDLH atmosphere inside of the wind blade, several workers still performed operations near the opening to the blade. Personal breathing zone samples collected from workers near the opening to the wind blade during the follow-up NIOSH evaluation of the glue wipe process indicated that all styrene concentrations were below IDLH and all but one concentration was below the ceiling limit for styrene. Sampling results also indicated potential for overexposures to dust and noise during the cut and trim process. This report describes the methods and results from the in-depth and follow-up evaluations at LM Glasfiber and provides recommendations for reducing occupational exposures to styrene, noise, and dust during the wind blade manufacturing process.

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.

In the early 1980s, NIOSH researchers conducted an engineering control technology assessment of styrene exposures in the fiberglass reinforced plastic (FRP) boat manufacturing industry [NIOSH 1983]. The study focused mainly on ventilation systems and work practices used in the open molding production of large FRP boats and yachts. In 2004, NIOSH researchers from the Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology (DART) began a follow-up assessment to evaluate worker exposures from new processes that have been introduced since the previous NIOSH study. Several of the technologies include processes that use low styrene resins, non-atomizing spray equipment, pressure driven rollers, improved ventilation, and closed molding.

In September 2007, environmental health and safety representatives from LM Glasfiber, a major wind blade manufacturer, contacted NIOSH researchers to request participation in the research study about occupational exposures to styrene. The LM Glasfiber facility uses styrene-based resins to manufacture large FRP blades for the rapidly growing utility scale wind energy industry. Due to similar styrene-based resins and manufacturing processes, NIOSH researchers agreed that workers in a wind blade manufacturing plant might have similar potential for styrene exposures as workers in boat manufacturing.

On October 19, 2007, researchers from NIOSH conducted a walk-through survey at LM Glasfiber, in Grand Forks, North Dakota. The purpose of the walk-through survey was to learn more about the FRP wind blade manufacturing industry and to assess the suitability of the LM Glasfiber facility for an in-depth survey. During the walk-through survey, NIOSH researchers were able to obtain preliminary information about styrene concentrations in the plant and to observe the engineering exposure control measures used during the wind blade manufacturing process.

Following the walk-through survey, an in-depth survey was conducted on December 12-14, 2007. NIOSH researchers collected personal and area samples for styrene, noise, and total particulate. Personal and area samples for styrene and noise were collected in the L and M Buildings from multiple processes including gelcoating, closed molding, chequer plate, and glue wipe operations. The gelcoat contains styrene and is sprayed the mold to serve as the outer painted surface of the part. Closed molding is a process where styrene resin is injected in between a rigid half mold and a flexible film under a vacuum to be infused with the glass mat. The chequer plate is a safety platform shaped like a donut that is installed after the two half blades have been joined together. Glue wipe refers to a process where workers entered the wind blade to wipe the styrene based glue that is pressed out when the two half blades join together. These processes will be described in more detail in a later section of this report. Personal breathing zone and general area samples for total particulate were collected at the cut and trim area of the M Building.

Prior to the NIOSH surveys, OSHA conducted a compliance inspection at LM Glasfiber on April 17, 2007. This resulted in several citations, including serious violations of the permit-required confined space standard [29 CFR 1910.146 (2002)]. Additional OSHA sampling on June 27, 2007 resulted in a serious violation of airborne concentrations of total particulate [29 CFR 1910.1000(a)(2)(2002)]. As stated in the OSHA citation and notification of penalties, the permit-required confined space violations were corrected during the inspection and the violation of total particulate was given an abatement date of November 01, 2007. The OSHA compliance inspection conducted on April 17, 2007 did not sample workers from the glue wipe operation and did not show any overexposures to styrene from air sampling. Another inspection conducted by OSHA after the NIOSH December 2007 survey evaluated styrene exposures during the glue wipe process. Results from the OSHA and NIOSH styrene sampling of workers during the glue wipe process showed similarly high worker exposures to styrene. To abate the OSHA violations for overexposures to styrene, LM Glasfiber installed controls to provide ventilation to the space inside of the wind blade. However, the ventilation did not achieve the desired reduction in air styrene concentrations inside of the wind blade. In March 2008, LM Glasfiber developed new molds designed to prevent the workers from entering the blades during the glue wipe process. Later in March 2008, NIOSH researchers returned to LM Glasfiber to collect personal breathing zone and general area air styrene samples for workers and areas surrounding this design change. The purpose of this report is to explain the study methods, results, and provide recommendations from the December 2007 and March 2008 NIOSH surveys at LM Glasfiber.

Styrene Usage

The major chemical component of concern in terms of occupational exposures in the FRP process is styrene. Styrene is a fugitive emission that evaporates from resins, gelcoats, solvents, and surface coatings used in the manufacturing process. The polyester resins used at the LM Glasfiber plant contain between 36 and 42 percent styrene. 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 and primary chemical bonds. Since styrene is consumed as part of this reaction, there is no need for removal of the diluents after the part is formed. However, if the process is not controlled properly, vapors from the application and curing process may pose an inhalation exposure hazard for workers near the process.

Exposure Hazards of Styrene and Noise

Humans exposed to styrene for short periods of time through inhalation may exhibit irritation of the eyes and mucous membranes, and gastrointestinal effects [40 CFR 63 (2000)]. 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. Several studies have shown that styrene exposures were linked to central and peripheral neurologic [Mutti et al. 1984; Tsai et al. 1996; Fung et al. 1999], optic [Triebig et al. 2001; Gong et al. 2002], and irritant [Minamoto et al. 2002] 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 [ACGIH® 2001]. 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 [Campo et al. 2001; Lataye et al. 2003]. Styrene has been shown to be a potent ototoxicant by itself, and can have a synergistic effect when presented together with noise or ethanol [Lataye et al. 2000; Morata et al. 2002; Makitie et al. 2003; Sliwinska-Kowalska et al. 2003].

Evaluation Criteria

In evaluating the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OELs) for specific chemical, physical, and biological agents. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy) to the specific hazardous substance. In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, thus contributing to the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values where there are health effects from higher exposures over the short-term. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time, even instantaneously.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are mandatory, legal limits; others are recommendations. The U.S. Department of Labor OSHA PELs [29 CFR 1910 (general industry); 29 CFR 1917 (maritime industry); and 29 CFR 1926 (construction industry)] are legal limits that are enforceable in workplaces covered under the OSH Act. NIOSH recommended exposure limits (RELs) are recommendations that are made based on a critical review of the scientific and technical information available on the prevalence of hazards, health effects data, and the adequacy of methods to identify and control the hazards. Recommendations made through 1992 are available in a single compendium [NIOSH 1992]; more recent recommendations are available on the NIOSH Web site (http://www.cdc.gov/niosh). NIOSH also recommends preventive measures (e.g., engineering controls, safe work practices, personal protective equipment (PPE), and environmental and medical monitoring) for reducing or eliminating the adverse health effects of these hazards. The NIOSH Recommendations have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the threshold limit values (TLVs®) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH® 2007]. ACGIH® TLVs® are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace environmental exposure levels (WEELs) are recommended OELs developed by American Industrial Hygiene Association (AIHA), another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

Employers should understand that not all hazardous chemicals have specific OSHA PELs and for many agents, the legal and recommended limits mentioned above may not reflect the most current health-based information. However, an employer is still required by OSHA to protect their employees from hazards even in the absence of a specific OSHA PEL. In particular, OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

The NIOSH REL for styrene is 50 ppm as a 10-hour TWA, with a 15 minute STEL of 100 ppm [NIOSH 2004]. These recommendations are based upon reported central nervous system effects, eye irritation, and respiratory irritation effects. The NIOSH immediately dangerous to life or health (IDLH) value for styrene of 700 ppm is based on acute inhalation toxicity in humans. The OSHA PEL for styrene is 100 ppm TWA with a ceiling limit of 200 ppm. ACGIH® revised its TLV® in 1997, and recommends styrene be controlled to 20 ppm TWA with a 40 ppm STEL [ACGIH® 2004]. The TLV® is based on a number of health effects of low styrene exposure such as ototoxicity, central and peripheral neurologic, optic, and irritant actions in humans [ACGIH® 2001]. The ACGIH® also recommends Biological Exposure Indices (BEI®) for end of shift and prior to next shift values for worker exposure to styrene by measuring mandelic acid in urine, phenylglyoxylic acid in urine, and styrene in venous blood [ACGIH® 2001].

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 that was later vacated by court order. OSHA announced the voluntary agreement in a 1996 newsletter [OSHA 1996]. 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 [SIRC, 1996].

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

Particulate Not Otherwise Regulated, Total

Often, the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate is now "particulates, not otherwise classified (p.n.o.c.)," [or "not otherwise regulated" (p.n.o.r.) for the OSHA PEL]. The OSHA PEL for total particulate, p.n.o.r., is 15.0 mg/m^3 and 5.0 mg/m^3 for the respirable fraction, determined as 8-hour averages. The ACGIH® recommended TLV® for exposure to a particulate, p.n.o.c., is 10.0 mg/m^3 (total dust, 8-hour TWA). Such exposure criteria can be applied only to particulates that are known to produce no irritation, irreversible affects, or pulmonary disease.

Noise

The OSHA standard for occupational noise exposure, 29 CFR 1910.95, specifies a maximum PEL of 90 decibels, A-weighted (dBA), averaged over an 8-hour time period. The OSHA standard states that exposure to impulse noise (e.g., firearms) should not exceed 140 dB sound pressure level (SPL) [29 CFR 1910.95(2002)]. The regulation uses a 5-dB exchange rate trading relationship. For example, if a person is exposed to average noise levels of 95 dBA, the amount of time allowed at this exposure level must be cut in half (i.e., 4 hours) in order to be within OSHA's PEL. Conversely, a person exposed to 85 dBA is allowed twice as much time at this level (i.e., 16 hours) and is within the daily PEL. The OSHA regulation has an additional action level (AL) of 85 dBA, which stipulates that an employer shall administer a continuing, effective hearing conservation program when the 8-hour TWA exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and record keeping requirements. The standard also states that when workers are exposed to noise levels in excess of OSHA's PEL of 90 dBA, feasible engineering or administrative controls shall be implemented to reduce workers' exposure levels.

The NIOSH REL and ACGIH® TLV® for noise is 85 dBA (8-hour TWA) using 3-dB exchange rate trading relationship [NIOSH 1998; ACGIH® 2007]. NIOSH and ACGIH® also recommend that no impulse exposure be allowed above 140 dB peak SPL.

Facility Description

LM Glasfiber is a Danish-owned company that operates on a global basis with at least twelve locations worldwide. It is the world's largest supplier of wind blades for utility scale wind turbines. At the time of the survey, the LM Glasfiber facility in North Dakota was operating two types of shifts, a 4-day 10 hour shift and a 3-day 12 hour shift. Workers at the plant did not typically work more than 40 hours per week. At the time of the survey, shifts were being scheduled to support manufacturing operations 24 hours per day, 365 days per year. Approximately 600 of the plant's 940 employees worked in areas where there was potential for exposure to styrene vapor. The manufacturing operations took place in two buildings on the approximately 50,000 m^2 (12.4 acre) property referred to as the "L" and "M" buildings (Figures 1 and 2, respectively).

Figure 1: L Building Layout

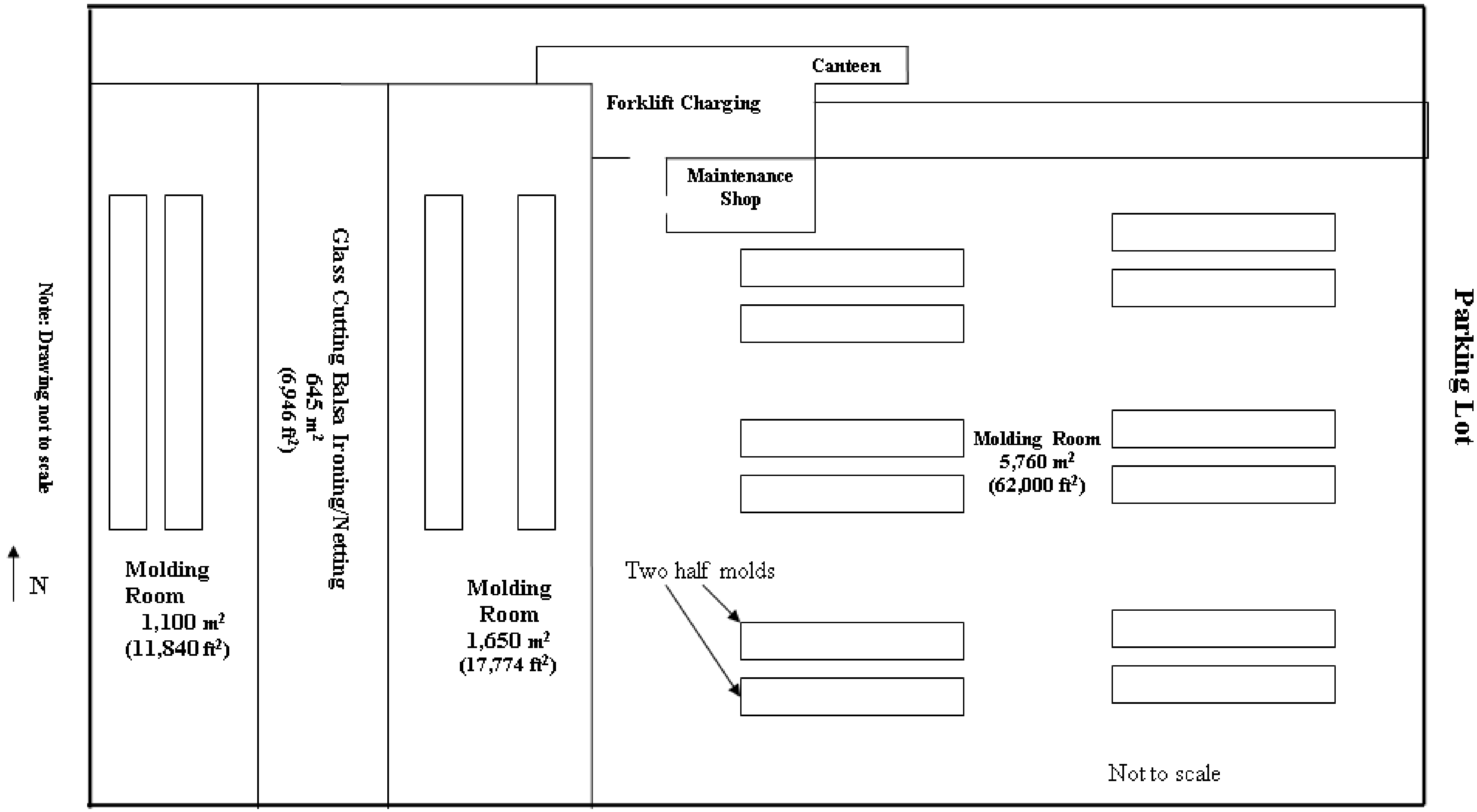
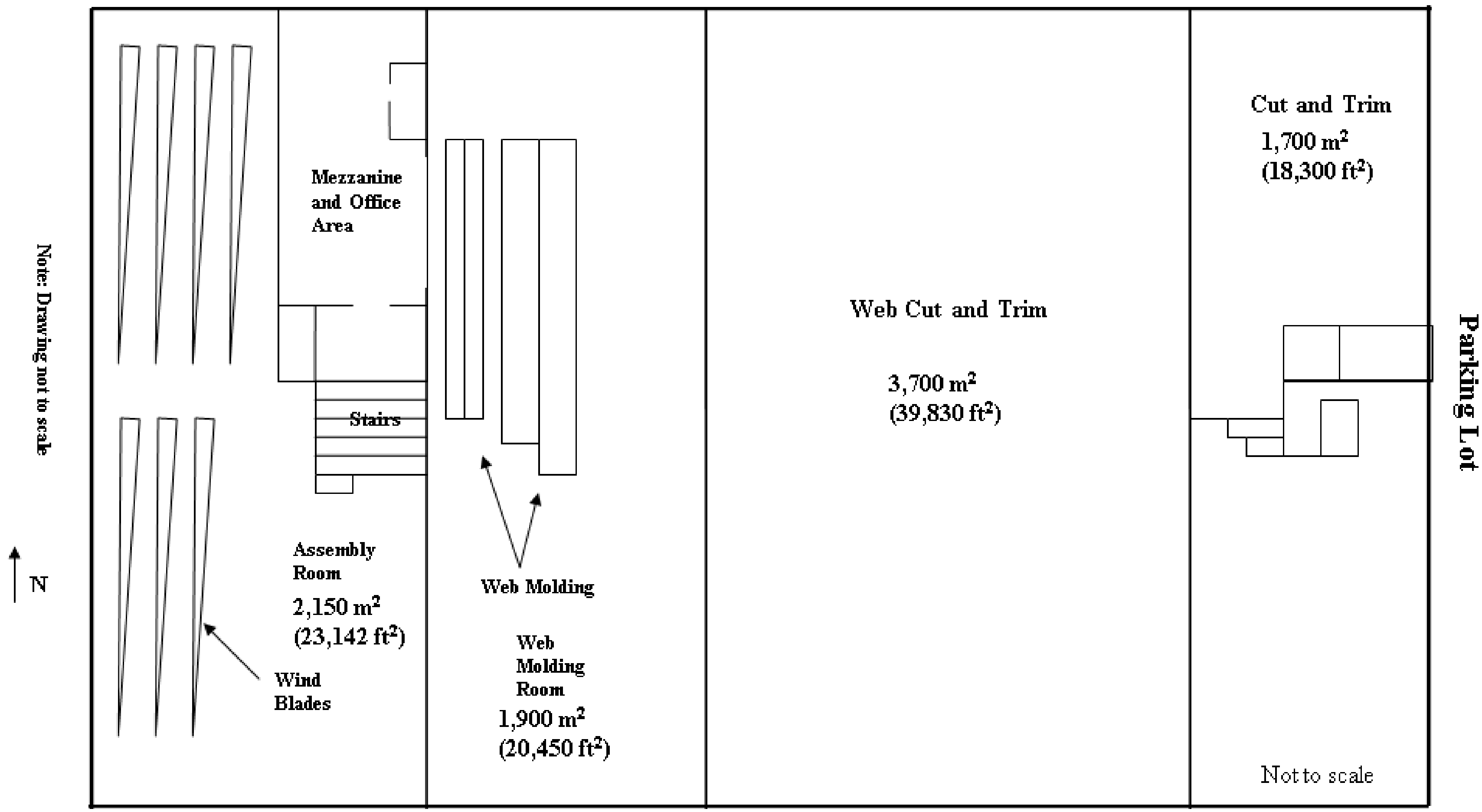


Figure 2: M Building Layout



The supply air flow rates from the four air handling units (AHUs) in each of the buildings were provided by facility representatives and are shown in Tables 1 and 2 (in cubic meter of air volume per second or m^3/s).

Table 1. Supply air flow rates for air handling units in the L Building

AHU #	Air Flow Rate
1	24 m^3/s (50,000 cfm)
2	12 m^3/s (25,000 cfm)
3	25 m^3/s (52,000 cfm)
4	26 m^3/s (55,000 cfm)

Table 2. Supply air flow rates for air handling units in the M Building

AHU #	Air Flow Rate
5	26 m^3/s (55,000 cfm)
6	26 m^3/s (55,000 cfm)
7	21 m^3/s (44,000 cfm)
8	21 m^3/s (44,000 cfm)

The general ventilation supply air for the manufacturing space in both buildings consisted of fabric sock air distribution systems such as what is shown in Figure 3 for the M Building. The L Building was split into several sections. AHUs 1, 2, and 3 were located in the large open space on the east side of the L Building which served the largest molding room. AHU 4 was hard ducted and served the remaining portions of the L Building including office areas. The four air handling units in the M Building served the assembly area on the west side of the building and web cut and trim on the east side of the building. The exhaust ventilation system in the cut and trim side of the M Building is shown in Figure 4 and was located on the opposite sides of the blades from the supply. Exhaust vents in the L Building were located in the floor and are shown in Figure 5. The exhaust vents in Figure 5 were originally located to be at the ends of the blades; however, as product demands required longer wind blades, the ends of the blades extend beyond the location of the vents. Additional exhaust ventilation was located along the south side of the L Building. Each exhaust air system corresponded to the supply-air systems. According to plant representatives, the supply-air flow rate for each system was greater than that of the exhaust air to keep the plant under positive pressure. The supply-air system delivered 100% outside air, heated or cooled, as needed, so there was no recirculation. In both buildings, most of the exhaust systems only provided dilution ventilation. Local exhaust was used only during cutting, grinding, and sanding operations to control dust.

Figure 3: General ventilation supply in the M Building web cut and trim area

Figure 4: Exhaust ventilation in the web cut and trim area of the M Building

Figure 5: In-floor exhaust ventilation in the L Building

Process Description

The production of wind blades at LM Glasfiber begins with design software. The software uses finite-element analysis to calculate proper aerodynamic and structural requirements before determining the optimal placement of fiber and core materials in the blade. The basic manufacturing process uses two glass-fiber shells attached to two rigid beams. The rigid beams are called the web, which increases the strength of the blade through proper placement. The blades are built from the outside towards the center. Once the mold is prepared, the manufacturing process continues in the following order [LM Glasfiber 2007]:

1. Mold prepared
2. Gelcoat sprayed into the mold--creating the protective surface of the blade
3. Glass fiber laid out (supporting layer)
4. Bushings installed
5. Balsa/foam installed (core materials)
6. Glass fiber laid out over the balsa and bushings
7. Vacuum film placed over glass fiber and balsa
8. Resin infused
9. Vacuum film removed
10. Sandwich web installed
11. Lightning conductor installed
12. Glue applied to edges of the shells and to the webs
13. Shells are bonded and glue is wiped
14. Blade removed from mold and given final finish (cutting and grinding).

The fiberglass blades are built from glass-fiber reinforcements placed in a mold and saturated with a polyester resin. The resin hardens to form a rigid part reinforced with the glassfiber. The gelcoating process starts when the mold is sprayed with a layer of gelcoat, which is a pigmented polyester resin that hardens and produces a smooth outer surface. During the gelcoating process, the worker walks along the concave side of the mold while spraying the gelcoat. After the gelcoat cures, the lamination process begins with the placement of the fibers and core material. The mold is covered with a vacuum film and resin saturates and bonds the fiber and core material. The blades are laminated in two shells before the sandwich web is installed. Glue is applied to the edges of the shell and web, and one shell is moved and fixed to the other half to assemble the blade. After the two shells are pressed together, workers enter the blade to wipe any excess glue that is pressed out. The blade is then removed from the mold for cutting, grinding, and sanding of the outside edge to provide a smooth finish.

Closed molding

Closed molding typically refers to a manufacturing process that uses (1) two rigid half molds (male and female) or (2) a solid mold (female) and a flexible film. Variations of closed molding include the use of two flexible molds, or a flexible mold and flexible film.

There are two closed molding core technologies that are used in manufacturing FRP: resin transfer molding (RTM) and vacuum infusion processing (VIP). RTM is a pressure-driven process, whereby resin is injected into a closed-mold cavity at higher than atmospheric pressure. VIP is a vacuum driven process where resin is pulled into the mold cavity that is lower than atmospheric pressure. There are a number of variations and combinations of these core technologies. For example, pressure injection RTM can be combined with vacuum assist in a process known as VARTM. Likewise, the vacuum infusion process can use low pressure injection assist and is known as pressure assisted vacuum infusion processing. The technology used at LM Glasfiber is VARTM. Compared to open molding, closed molding technology should significantly reduce environmental emissions and worker exposure to styrene. However, the gelcoating portion of most closed molding processes is still performed in an open mold and represents a potential source of exposure [Hammond, Carlo et al. 2007].

METHODS

<u>Air Sampling for Styrene</u>

Personal breathing zone and general area air samples for styrene were collected and analyzed in accordance with NIOSH Method 1501 [NIOSH 1994]. Samples were collected on SKC sorbent tubes (Model number 226-01, Anasorb CSC, Coconut Charcoal, Lot #2000). The tubes were 7 centimeters (cm) long with a 6 millimeter (mm) outer diameter and a 4-mm inner diameter. The ends were flame-sealed, and contained two sections of activated coconut shell charcoal, 100 milligrams (mg) in front and 50 mg in back, separated by a 2-mm urethane foam plug. A glass wool plug precedes the front section, and a 3-mm urethane foam plug follows the back section. After breaking the sealed ends, each tube was connected to a Gilian low flow pump or an SKC Pocket Pump set at a nominal flow rate. The pumps' actual flow rates were calibrated before and after sampling. For personal breathing zone air samples, the air inlet of the sampling apparatus was secured in each worker's breathing zone with a lapel clip, and the battery-powered pump clipped to the worker's belt. In addition, field blank samples were created each day to ensure that the sample media was not contaminated and to account for any variance in sample preparation.

The analyses of the charcoal tube samples for styrene were performed by Bureau Veritas North America, Inc., in Novi, Michigan. The samples were analyzed by removing the individual sections of the charcoal tube and placing them into separate vials. The glass wool and the foam plugs that divide the sections of charcoal were discarded. The individual sections were chemically desorbed by using 1 milliliter (mL) of carbon disulfide. The samples were placed on a mechanical shaker for a minimum of 30 minutes before being analyzed by gas chromatography with flame ionization detection (GC/FID) in accordance with NIOSH Method 1501 [NIOSH 1994]. The limit of detection (LOD) and limit of quantification (LOQ) for styrene for this sample set was 0.33 ppm and 2.93 ppm, respectively.

General area air samples were collected to better understand the effectiveness of the installed engineering controls using the same type of sampling apparatus as used for the personal air sampling. These samples were placed in stationary locations to determine how well the ventilation system was performing throughout the plant, and to assess the spread of the styrene vapor throughout the facility. Area samples were placed upwind and downwind of the gelcoating process, adjacent to the molds for the chequer plate, VARTM and glue wipe processes, and near the exhaust ventilation for the particulate sampling.

Once the sample results were received from the analytical laboratory, the styrene breathing zone concentrations and general area concentrations were calculated using Equation 1. The concentration in milligrams per meter cubed (mg/m^3) was converted to ppm.

$$C = \frac{m}{V \times 4.26} \qquad (1)$$

Where,
C = styrene concentration, ppm
m = mass of styrene per sample, µg
V = volume of air sample, L
Note: 4.26 is the constant used for styrene to convert from µg/L (mg/m^3) to ppm obtained from: NIOSH Manual of Analytical Methods (NMAM) [NIOSH 1994].

Air Sampling for Total Particulate

The analyses of the PVC filters for total particulate were performed by Bureau Veritas North America, Inc., in Novi, Michigan. Personal breathing zone and general area air samples were analyzed for total particulate according to NIOSH 0500 (NMAM, 4th Edition). The PVC filters were allowed to equilibrate for a minimum of two hours before weighing. A static neutralizer was placed in front of the balance and each filter was passed over this device before weighing. The filters were weighed on a Mettler balance, model number AT201. The laboratory-established LOD and LOQ were determined using laboratory media blanks for this filter type. The LOD is equal to three times the pooled standard deviation of the media blank weight differences. The LOQ is 3.33 times the LOD. The pooled standard deviation of the PVC media blank weights was 9.26 µg.

LOD for PVC filters: 30 µg/sample
LOQ for PVC filters: 93 µg/sample
Analytical range: 30 µg to 200 mg

Noise Measurements

In addition to evaluation of plant ventilation, styrene and dust exposure, noise exposures were also measured. Eight-hour personal and area noise level measurements were collected using five Quest NoisePro dosimeters and five Larson-Davis 705+ and 706 Type 2 dosimeters. A total of 33 personal full-shift measurements were collected during the survey from 20 workers who were also exposed to styrene. 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 S1.25-1997) specifications [ANSI 1997]. Dosimeters were set to “SLOW” response and A-weighting frequency filter. The equipment was calibrated by the manufacturer before the study. Field calibration checks were conducted before and after measurements using a Quest QC-10 and Larson-Davis CAL150 calibrator. Data from the dosimeters were downloaded to a personal computer and analyzed using the Quest Suite Professional II software for the NoisePro dosimeters, or the Larson-Davis Blaze™ software for the 705+ and 706 Type 2 dosimeters.

RESULTS

Sample identification, job or area description, sample mass, sample time, and concentration in ppm for the styrene air samples collected during the three day survey in December 2007 are shown in Appendix I. Sample identification, job or area description, sample mass, sample time, and concentration from the styrene air sampling of the glue wipe process conducted in March 2008 are shown in Appendix II. Sample identification, sample mass, sample time, and concentration from the total particulate sampling of the cut and trim process conducted in December 2007 are shown in Appendix III. Geometric mean, geometric standard deviation, 95% confidence limits, and sample size for comparison of personal breathing zone and general area air styrene samples are included in Table 3 for the December 2007 NIOSH survey. Geometric mean, geometric standard deviation, 95% confidence limits, and sample size for comparison of personal breathing zone and general area air styrene samples are included in Table 4 for the March 2008 NIOSH survey following changes to the glue wipe process. Geometric mean, geometric standard deviation, 95% confidence limits, and sample size for personal breathing zone and general area total particulate samples are included in Table 5.

Table 3: Personal and area sample statistical results for styrene vapor from the December 2007 NIOSH survey

Job Description	Sample Type	Geometric Mean (ppm)	Geometric Standard Deviation	Geometric Upper 95% Confidence Limit	Geometric Lower 95% Confidence Limit	n
Chequer Plate	Personal	68	4.3	410	11	5
Gelcoat Machine	Personal	87	2.0	**	0.2	2
Gelcoat	Personal	65	2.6	100	42	19
Glue Wipe	Personal	340	2.0	510	230	14
Glue Wipe adjusted*	Personal	970	2.4	1600	580	14
Infuser (VARTM)	Personal	1.8	1.5	2.2	1.5	21
Miller	Personal	150	1.4	220	100	6
Glue Wipe	Area	18	1.3	37	8.6	3
Chequer Plate	Area	4.2	1.5	11	1.6	3
Gelcoat	Area	46	2.4	90	24	9
Infusion (VARTM)	Area	1.5	1.1	2.5	0.9	6

*The adjusted glue wipe values were calculated with the assumption that air styrene concentrations were 20 ppm for the time that workers spent outside of the wind blade. The Glue Wipe description in the following section provides a more detailed explanation.
**No meaningful confidence limit due to small sample size and high variation

Table 4: Personal and area sample statistical results for styrene vapor sampling of the glue wipe process March 2008 after changes to the glue wipe process

Job Description	Sample Type	Geometric Mean (ppm)	Geometric Standard Deviation	Geometric Upper 95% Confidence Limit	Geometric Lower 95% Confidence Limit	n
Glue Wipe	Personal	31	3.2	65	14	12
Glue Wipe	Area	11	1.6	17	9.1	8

Table 5: Personal and area sample statistical results for total particulate

Sample Type	Mean (mg/m^3)	Standard Deviation	Upper 95% Confidence Limit	Lower 95% Confidence Limit	n
Personal	48.73	65.09	87.19	10.26	11
Area	5.29	1.42	6.68	3.90	4

Glue Wipe (December 2007 Results)

The personal breathing zone samples for styrene from workers performing the glue wipe tasks inside the wind blade were higher than any other process in the plant with a geometric mean concentration of 340 ppm. The geometric mean air styrene concentration from area samples collected outside of the wind blade during the glue wipe process was 18 ppm. Most of the personal sampling pumps ran longer than the 15 minute timed glue wipe process because workers were performing tasks outside of the wind blade or had to put on or remove PPE. Therefore, NIOSH researchers calculated an adjusted value shown in Table 3 that accounts for time workers spent outside of the blade. A more detailed explanation of the adjusted value for the glue wipe process is provided in the discussion section of this report. When the personal breathing zone samples for the glue wipe process were adjusted for time that workers spent outside of the blade, several of the sample results were much higher than the IDLH value for styrene of 700 ppm.

Glue Wipe (March 2008 Results)

The geometric mean of personal breathing zone samples from the glue wipe process collected during the March 2008 survey was 31 ppm which is approximately an order of magnitude lower than the results from the previous NIOSH evaluation. The primary difference between the two surveys was the design change that eliminated the need for workers to enter the space inside of the blade while performing the glue wipe job function. The workers that were sampled included the same workers that would have otherwise been working inside of the wind blade, but instead were performing some glue wiping while standing outside of the blade and reaching inside of the blade with a long handled tool. The geometric means of the general area styrene air samples for both surveys were below 20 ppm.

Infusion - VARTM Results

The lowest personal breathing zone sampling results for styrene were measured among the 21 workers performing the infusion process. All personal breathing zone and general area styrene air samples measured during the infusion process were below 5 ppm, which is well below all regulatory and recommended exposure limits for occupational exposure to styrene in air. The infusion process at LM Glasfiber appears to effectively control occupational exposures to styrene compared to traditional open mold lamination methods for the manufacture of fiberglass reinforced plastics.

Gelcoating Results

Personal breathing zone and general area styrene air samples measured among workers performing gelcoating tasks were much higher than infusion. Six of the nineteen personal breathing zone samples measured from gelcoaters were above 100 ppm and two were also above the 200 ppm ceiling limit for styrene when sampled over the process time. Personal breathing zone samples were also measured from six workers performing the job tasks of miller and two performing job tasks of gelcoat machine operator during the gelcoating process. The gelcoat machine operator stands next to the mold that the gelcoater is spraying and operates the equipment that supplies the gelcoat to the gelcoater. The miller also works next to the mold and makes sure the gelcoating equipment moves at the same rate as the gelcoater. Both the gelcoat machine operator and the miller walk along the side of the mold as the gelcoater walks on the mold while spraying takes place. All six personal breathing zone samples measured from the millers were higher than 100 ppm and one was higher than 200 ppm. One of the two measurements from the gelcoat machine operators was higher than 100 ppm. Actual worker exposures were likely much lower than measured concentrations since at the time of the NIOSH survey, all gelcoaters, millers, and gelcoat machine operators wore either half-mask or powered air purifying respirators with organic vapor cartridges. Under the NIOSH Respirator Decision Logic, any air-purifying half mask respirator equipped with appropriate gas/vapor cartridges has an assigned protection factor of 10 [NIOSH 1987]. Any powered air-purifying respirator with a loose-fitting hood or helmet equipped with appropriate gas/vapor cartridges has an assigned protection factor of 25.

Chequer Plate Results

After the two half shells have been bonded together and the glue has cured, the assembled wind blade is moved from the molding area in the L Building to the cut and trim area in the M Building. A chequer plate, which is a safety platform in the shape of a donut, is then glued to the inside wall of the wind blade near the root. Five personal breathing zone samples for styrene were measured from chequer plate workers. Three of the five air samples were measured from workers inside the safety platform, and two from workers outside the safety platform. For the process time sampled, the three personal breathing zone samples measured inside the safety platform were 92 ppm, 156 ppm, and 316 ppm, while both personal air styrene samples measured outside the safety platform were below 50 ppm. Actual exposures were much lower since workers wore full face respirators with organic vapor cartridges. Company policy is to follow confined space procedures during the chequer plate installation.

Total Particulate Sampling Results

Personal and area sample statistical results for total particulate are shown in Table 5. Eleven personal breathing zone and four general area samples for total particulate were collected from workers performing the cut and trim operation. The mean of the personal breathing zone and general area total particulate samples were 48 mg/m^3 and 5 mg/m^3 respectively. Actual exposures were much lower since workers wore full face respirators with P100 cartridges.

Noise Exposure Results

Summaries of the personal noise dosimetry measurements are shown in Table 6. The table shows the range of the results of the measurements based on the NIOSH and OSHA criteria for different job tasks.

Table 6: Personal and Area Noise Dosimetry Results

Job Description	Mean Styrene Level (personal sample) (ppm)	NIOSH		OSHA	
		Noise TWA (dBA)	Noise Dose (%)	Noise TWA (dBA)	Noise Dose (%)
Chequer Plate	123.6	90.2-91.9	334-496	84.6-89.3	47-91
Cut & Trim	Not sampled	91.5-99.2	455-2659	90.3-97.3	105-277
Gelcoat	89.1	82-88.3	50-218	78.1-85.2	19-51.8
Glue Wipe	411.7	84.1-88.2	82-211	79.4-83.9	23-43
Infuser	1.85	76.9-89.6	17-291	66.3-78	4-19
Miller	160	73.9-75.4	60-76	57.8-64.7	8-23

The highest noise exposures occurred for the Chequer Plate and Cut&Trim operations. Most workers, except for the Millers, exceeded the NIOSH TWA of 85 dBA REL. The Cut&Trim workers exceeded both the NIOSH REL and OSHA PEL.

DISCUSSION

Since workers moved between different processes during their shift, NIOSH researchers decided to conduct process sampling instead of full shift sampling. This decision was based on preliminary data provided that indicated several of the processes produced dramatically different exposures. Although this type of sampling was not useful in determining average worker exposure over the entire shift, it provided information on which processes could benefit most from introducing controls. Process sampling also revealed that the ceiling limit and IDLH values for styrene may have been exceeded during certain tasks such as glue wipe. But even sampling the glue wipe process presented some difficulties in attempting to measure concentrations only during the process time. The glue wipe process inside of the wind blade took 15 minutes. However, NIOSH researchers were not able to start and stop samples immediately when workers entered and exited the wind blades due to the need for workers to put on or take off PPE or perform additional tasks outside the blade while sample pumps were still operating. Therefore, the results for the glue wipe personal breathing zone samples for styrene in Appendix I include the 15 minutes each worker spent inside the blade along with the time spent outside the blade. The results shown in Appendix IV are adjusted to approximate each workers exposure for only the 15 minute glue wipe task. The adjusted values were calculated by assuming worker exposures during the glue wipe process were 20 ppm for the portion of the sample time that exceeded 15 minutes. The value of 20 ppm was used since the three area samples collected outside of the wind blade were in the range of 20 ppm. After adjustment, the geometric mean styrene personal breathing zone concentration was calculated at 970 ppm.

Glue wipe personal breathing zone samples for styrene before adjustment indicated several samples were either approaching or higher than 700 ppm. The adjusted personal breathing zone results in Appendix IV indicated that twelve of the fourteen values were higher than 700 ppm and two values were higher than 2,000 ppm. These values are higher than the established NIOSH IDLH exposure level for styrene of 700 ppm.

When the data from the glue wipe task was adjusted for time spent outside the wind blade, 11 of the 14 adjusted values were also above 10% of the lower explosive limit (LEL) for styrene. OSHA Compliance Assistance Guidelines for Confined and Enclosed Spaces and Other Dangerous Atmospheres [29 CFR 1915.12(b)(3)] considers that atmospheres with a "concentration of flammable vapors at or above 10 percent of the LEL are considered hazardous when located in confined spaces." The LEL for styrene is 0.9% or 9,000 ppm. Concentrations should be lower than 900 ppm in order to remain below 10% of the LEL.

<u>NIOSH Respirator Decision Logic for IDLH Conditions</u>

During the December 2007 NIOSH evaluation, workers performing glue wipe tasks wore powered air purifying respirators which is not consistent with NIOSH respirator decision logic for IDLH atmospheres. The current NIOSH definition for an IDLH condition, as given in the <u>NIOSH Respirator Decision Logic</u>, is "an exposure condition that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment." NIOSH has established an IDLH exposure level for styrene of 700 ppm. The IDLH is considered a maximum level above which only a highly reliable breathing apparatus providing maximum worker protection is permitted. Any appropriate approved respirator may be used to its maximum use concentration up to the IDLH concentration. Under the <u>NIOSH Respirator Decision Logic</u>, only "highly reliable" respirators (i.e., the most protective respirators) would be selected for IDLH conditions [NIOSH 1987]. These "highly reliable" respirators include a pressure-demand, full-face piece self-contained breathing apparatus (SCBA) or a pressure demand, full-face piece supplied-air respirator (SAR) in combination with an auxiliary pressure demand, full-face piece SCBA. The auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted. An auxiliary unit means that the SAR unit includes a separate air bottle to provide a reserve source of air should the airline become damaged. The auxiliary unit shares the same mask and regulator, and enables the SAR to function as an SCBA if needed. When NIOSH returned to LM Glasfiber in March 2008 to conduct sampling of the glue wipe process following design changes, workers were wearing PPE that was consistent with NIOSH respirator decision logic since they were no longer entering the IDLH atmosphere.

Discussion/ Noise

Regarding the group of workers who are considered to be exposed to styrene and noise (at levels that would trigger their inclusion in a hearing conservation program), results indicated that both exposures can exceed recommended limits. However, workers wore PPE to protect against styrene and noise exposures. If the workers in this group develop a hearing loss that cannot be explained by their noise exposure, they should be referred to their physician for further examination, and their styrene exposure should be taken into account when determining causation of the hearing losses.

Noise measurement results showed large differences when calculations for time-weighted averages and dose were done using either the OSHA exchange-rate of 5 dB or NIOSH's rate of 3 dB. NIOSH has found that scientific evidence supports the use of a 3-dB exchange rate for the calculation of a TWA for noise. The premise behind the 3-dB exchange rate is that equal amounts of sound energy will produce equal amounts of hearing impairment regardless of how the sound energy is distributed in time.

These workers whose noise exposure measurements were obtained are already in the company's hearing conservation program. Their noise exposures are quite different by job title and task, indicating different needs regarding hearing loss prevention. Another approach to be considered should be the use of administrative or engineering controls. Workers who are exposed to lower noise levels do not need as much attenuation. In their case, the concern should be to avoid over-attenuation, because it might discouraged the workers from wearing the hearing protection. Details on how to select appropriate hearing protection and on other phases of an effective hearing conservation program can be found in the NIOSH criteria document [NIOSH 1998] or part (a) of the OSHA noise exposure standard [OSHA 1992].

Discussion/Chequer Plate

Since the time of the NIOSH evaluation, LM Glasfiber initiated a chemical substitution to eliminate styrene exposures during the installation of the chequer plate. A product called Sika Flex replaced the styrene resin used to secure the plate inside of the wind blade. Although the new adhesive does not contain styrene, the new Sika Flex product contains xylene. Sampling for xylene vapor should be conducted to make sure it does not replace one hazard with another and present an exposure hazard for workers. The OSHA PEL for xylene is 100 ppm. The NIOSH recommended STEL for xylene is 150 ppm. Sampling for xylene vapor should consider the STEL in addition to the PEL. A picture of the chequer plate installation with the new adhesive is shown in Figure 6.

Figure 6: Installation of the chequer plate using Sika Flex.

RECOMMENDATIONS

The following recommendations are provided to further reduce occupational exposures to styrene and provide a safer and healthier working environment.

Glue Wipe Recommendations

At the time of the NIOSH follow-up evaluation conducted during March 2008, the design changes to the molds eliminated the need for workers to enter the wind blade during the glue wipe process. This change was very important since it dramatically reduced exposures to styrene for workers that were previously entering the wind blade. Management should routinely check to ensure that workers do not enter the wind blade during the glue wipe process.

Although the new process for glue wipe dramatically reduced worker exposures to styrene, some workers were observed standing outside of the wind blade while leaning in with a pole to wipe glue near the opening. The pole used by the worker was flimsy which increased the likelihood that the worker would lean in and cross the plane of the confined space while wiping glue.

Better tools should be provided to the glue wipe workers along with training to keep their breathing zone out of the confined space during the process. The continued use of the organic-vapor charcoal-filter respirators is highly recommended for the glue wipe process.

Gelcoating Recommendations

During the time of the December 2007 NIOSH survey, LM Glasfiber was using respiratory protection combined with an administrative control to reduce average styrene exposures of workers during the gelcoating process. The administrative control required workers to leave the room and take a break after the process was finished and return when area concentrations for styrene decreased below 20 ppm. This administrative control effort should continue and all workers in the gelcoating area should be monitored and encouraged to leave the room and take advantage of the control measure. The continued use of the organic-vapor charcoal-filter respirators is highly recommended for the gelcoating process.

Although the respiratory protection and administrative control served to reduce average styrene exposures among workers in the gelcoating area, several short term personal breathing zone styrene concentrations were higher than the ceiling limit for styrene for the gelcoating process time sampled. Due to the size of the part, limitations may exist in designing effective local exhaust ventilation over the entire process for each of the wind blades. However, management along with plant engineers should consider pneumatic conveying air systems that follow the gelcoater along the process. The traveling or moving air system could possibly be tied into existing conveying systems over each mold. Since the NIOSH survey, LM Glasfiber began contacting ventilation companies to pursue local exhaust options. These options should be investigated to further reduce personal breathing zone concentrations of styrene below the ceiling limit and other applicable exposure criteria.

Dust Control Recommendations

Although workers wore full face respirators, some of the workers also wore Tyvek or other protective clothing stuffed under the seal of the respirator that would likely compromise a proper fit. Training should be implemented to ensure that workers understand the importance of maintaining a proper seal between the respirator and face. Additionally, workers in the cut and trim area not involved in grinding operations should also wear respirators to protect against inhalation of particulates.

In addition to the proper wear of respirators, local exhaust on tooling can help reduce occupational exposures to particulate during grinding and cutting operations. Local exhaust and vacuum hoses were installed in the cut and trim area, and connected to a central dust collection unit. However, the local exhaust may not have been functioning properly at the time of the survey. According to health and safety management at LM Glasfiber, improvements to the local exhaust system have been made since the NIOSH evaluation. Health and safety from LM Glasfiber also reported that OSHA evaluated the improvements and found nearly an 80%

reduction in exposures. LM Glasfiber plans to make additional improvements until exposures are below the PEL. Efforts should be made to ensure that local exhaust on tooling continues functioning properly and is being used for all cutting and grinding operations. Research and development efforts should be initiated focusing on design or manufacturing changes to reduce the need for grinding and sanding of the wind blades.

Noise Control Recommendations

The use of hearing protection is recommended whenever exposure levels reach or exceed 85 dBA, even if the exposures last less than 8 hours [NIOSH 1998]. When considering engineering controls to improve work conditions and reduce styrene exposures, noise exposures also need to be taken into account.

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APPENDIX I

Sample identification, job or area description, sample mass, sample time, and concentration from the NIOSH styrene air sampling at LM Glasfiber conducted in December 2007.

Sample ID	Personal or Area Sample	Job or Area Description	Sample Mass (µg/sample)	Sample Time (min)	Concentration (ppm)
55	Area	(Area) Glue Wipe	240	24	24.00
61	Area	(Area) Glue Wipe	290	38	17.95
62	Area	(Area) Glue Wipe	220	39	13.30
64	Area	Area (Chequer Plate)	37	29	5.00
65	Area	Area (Chequer Plate)	41	29	5.57
67	Area	Area (Chequer Plate)	21	31	2.67
15	Area	Area (gelcoat)	220	142	12.08
16	Area	Area (gelcoat)	890	141	50.00
17	Area	Area (gelcoat)	390	139	22.26
18	Area	Area (gelcoat)	530	134	31.58
19	Area	Area (gelcoat)	400	134	22.97
20	Area	Area (gelcoat)	990	131	59.04
92	Area	Area (Gelcoat)	1500	40	144.68
97	Area	Area (Gelcoat)	1000	28	139.47
100	Area	Area (Gelcoat)	660	29	88.77
84	Area	Area (infusion)	0	263	0.00
85	Area	Area (infusion)	130	277	1.81
86	Area	Area (infusion)	110	270	1.59
34	Area	Area (VARTM)	72	194	1.46
35	Area	Area (VARTM)	69	191	1.42
36	Area	Area (VARTM)	77	195	1.66
21		BLANK	0	0	0.00
22		BLANK	0	0	0.00
24		BLANK	0	0	0.00
25		BLANK	0	0	0.00
49		BLANK	0	0	0.00
50		BLANK	0	0	0.00
51		BLANK	0	0	0.00
74		BLANK	0	0	0.00
81		BLANK	0	0	0.00
82		BLANK	0	0	0.00
105		BLANK	0	0	0.00
106		BLANK	0	0	0.00
107		BLANK	0	0	0.00
66	Personal	Chequer Plate (inside)	2200	55	156.44
68	Personal	Chequer Plate (outside)	770	66	45.66
69	Personal	Chequer Plate (outside)	94	53	6.92
71	Personal	Chequer Plate (inside)	3000	37	316.64
72	Personal	Chequer Plate (inside)	1400	59	92.58
8	Personal	Gelcoat Machine	440	65	53.35

10	Personal	Gelcoat Machine	1200	66	142.79
1	Personal	Gelcoater	400	66	46.42
5	Personal	Gelcoater	1400	65	168.64
6	Personal	Gelcoater	420	79	41.31
9	Personal	Gelcoater	390	59	52.15
11	Personal	Gelcoater	930	67	110.47
12	Personal	Gelcoater	580	71	63.40
13	Personal	Gelcoater	1000	71	109.33
89	Personal	Gelcoater	430	37	45.14
90	Personal	Gelcoater	590	41	56.08
91	Personal	Gelcoater	2700	42	249.66
93	Personal	Gelcoater	330	41	31.15
94	Personal	Gelcoater	1000	43	91.42
95	Personal	Gelcoater	35	41	3.31
96	Personal	Gelcoater	1400	38	143.14
98	Personal	Gelcoater	2700	45	234.37
101	Personal	Gelcoater	550	35	61.02
102	Personal	Gelcoater	380	36	40.78
103	Personal	Gelcoater	740	35	81.97
104	Personal	Gelcoater	700	43	63.95
41	Personal	Glue Wipe	7400	29	603.49
43	Personal	Glue Wipe	17000	63	638.09
44	Personal	Glue Wipe	1600	26	144.70
45	Personal	Glue Wipe	7000	49	338.17
46	Personal	Glue Wipe	14000	67	493.57
47	Personal	Glue Wipe	4900	58	201.25
48	Personal	Glue Wipe	8500	67	299.38
52	Personal	Glue Wipe	640	23	66.05
53	Personal	Glue Wipe	8500	29	694.32
54	Personal	Glue Wipe	9100	37	582.55
56	Personal	Glue Wipe	8200	25	780.25
57	Personal	Glue Wipe	11000	129	200.81
59	Personal	Glue Wipe	6600	50	312.12
60	Personal	Glue Wipe	9200	53	409.71
23	Personal	Infuser	47	107	1.72
26	Personal	Infuser	39	152	1.01
27	Personal	Infuser	100	175	2.22
28	Personal	Infuser	35	157	0.88
29	Personal	Infuser	57	173	1.30
31	Personal	Infuser	61	197	1.21
32	Personal	Infuser	110	207	2.08
33	Personal	Infuser	85	121	2.75
37	Personal	Infuser	100	227	1.73
38	Personal	Infuser	75	180	1.63
39	Personal	Infuser	130	224	2.27
40	Personal	Infuser	64	200	1.25
63	Personal	Infuser	27	67	1.57
75	Personal	Infuser	44	160	1.06

76	Personal	Infuser	0	151	0.00
77	Personal	Infuser	120	150	3.11
78	Personal	Infuser	130	241	2.10
79	Personal	Infuser	160	158	3.95
80	Personal	Infuser	65	125	2.02
83	Personal	Infuser	94	135	2.73
87	Personal	Infuser	150	257	2.27
2	Personal	Miller	810	57	112.58
3	Personal	Miller	1500	68	172.43
4	Personal	Miller	2400	67	279.96
7	Personal	Miller	1100	58	150.35
14	Personal	Miller	740	53	109.49
99	Personal	Miller	1400	40	135.18

APPENDIX II

Sample identification, job or area description, sample mass, sample time, and concentration from the NIOSH styrene air sampling at LM Glasfiber conducted in March 2008.

Sample ID	Personal or Area Sample	Job or Area Description	Sample Mass (µg/sample)	Sample Time (min)	Concentration (ppm)
365	Area	glue wipe area mold 15	220	44	11.60
366	Area	glue wipe area mold 3	120	20	13.96
367	Area	glue wipe area mold 3	130	20	15.32
369	Area	glue wipe area mold 15	200	46	10.12
391	Area	glue wipe area mold 24	170	41	9.78
394	Area	glue wipe area mold 24	340	43	18.40
397	Area	glue wipe area mold 2	41	31	3.12
399	Area	glue wipe area mold 2	260	30	20.16
361		BLANK	0	0	0.00
362		BLANK	0	0	0.00
363		BLANK	0	0	0.00
364		BLANK	0	0	0.00
376		BLANK	0	0	0.00
382		BLANK	0	0	0.00
389		BLANK	0	0	0.00
368	Personal	glue wipe mold 3	190	24	18.55
370	Personal	glue wipe mold 3	36	22	4.27
372	Personal	glue wipe mold 3	470	28	39.59
373	Personal	glue wipe mold 15	1200	63	50.33
374	Personal	glue wipe mold 15	440	66	15.69
375	Personal	glue wipe mold 15	2400	63	89.85
392	Personal	glue wipe mold 2	140	37	8.83
393	Personal	glue wipe mold 24	1100	42	61.52
395	Personal	glue wipe mold 24	590	41	33.87
396	Personal	glue wipe mold 24	2000	45	102.18
398	Personal	glue wipe mold 2	3300	36	212.63
400	Personal	glue wipe mold 2	120	37	7.61

APPENDIX III

Sample identification, sample mass, sample time, and concentration from the total particulate sampling of the cut and trim process conducted in December 2007

Sample ID	Personal or Area sample	Sample Mass (µg/sample)	Sample Time (min)	Concentration (mg/m^3)
PN12030797	Personal	370	91.5	2.0
PN120307109	Personal	15000	78.5	95.5
PN120307110	Area	910	79	5.8
PN120307116	Area	510	79.5	3.2
PN120307118	Personal	3300	76.5	21.6
PN120307120	Personal	3400	57.5	29.6
PN120307121	Personal	770	71	5.4
PN120307122	Personal	6700	98	34.2
PN120307125	Blank	0	0	0.0
PN120307126	Blank	0	0	0.0
PN120307127	Area	800	69	5.8
PN120307131	Area	920	72	6.4
PN120307134	Personal	13000	78.5	82.8
PN120307135	Personal	32000	72.5	220.7
PN120307137	Personal	690	81	4.3
PN120307141	Personal	750	71.5	5.2
PN120307144	Personal	5100	73.5	34.7

APPENDIX IV

Sample identification, sample mass, sample time, and concentration from the styrene sampling of the glue wipe process conducted in December 2007 with adjustment for time workers spent outside of the wind blade.

Sample ID	Personal or Area Sample	Job or Area	Sample Mass (ug/sample)	Sample Time (min)	Concentration (ppm)
41	Personal	Glue Wipe	7400	29	1148
43	Personal	Glue Wipe	17000	63	2615
44	Personal	Glue Wipe	1600	26	236
45	Personal	Glue Wipe	7000	49	1059
46	Personal	Glue Wipe	14000	67	2135
47	Personal	Glue Wipe	4900	58	720
48	Personal	Glue Wipe	8500	67	1267
52	Personal	Glue Wipe	640	23	90
53	Personal	Glue Wipe	8500	29	1323
54	Personal	Glue Wipe	9100	37	1407
56	Personal	Glue Wipe	8200	25	1287
57	Personal	Glue Wipe	11000	129	1574
59	Personal	Glue Wipe	6600	50	993
60	Personal	Glue Wipe	9200	53	1396