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TECHNICAL REPORT

Extent of Exposure to Styrene in the Reinforced Plastic Boat Making Industry

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

EXTENT OF EXPOSURE TO STYRENE IN THE REINFORCED PLASTIC BOAT MAKING INDUSTRY

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ABSTRACT

Industrial hygiene surveys were conducted in seven fiberglass reinforced plastic boat fabrication plants. This study was designed to quantitate worker exposure patterns to styrene monomer. Exposure to acetone was also measured. There were 464 personal air samples collected in all (results of 96 of these are in excess of the OSHA eight-hour time weighted average standard of 100 parts per million). Statistical analyses were conducted to assess the comparability of certain job categories among the seven plants and within each plant.

Results show that there are differences in exposure among the job categories which may be indicative of resin use patterns. Also, plants with similar ventilation efficiency (as indicated by overall plant styrene levels) showed job category exposure similarities interplant. Dilution ventilation is indicated as being an adequate control measure in some plants. Control technology discussion proposes that in conjunction with general ventilation, the use of local ventilation, styrene-suppressed resins and work practice guidelines can be effective control methods in those plants with over-exposure problems.

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INTRODUCTION

This is a report on an industrial hygiene study undertaken by the National Institute for Occupational Safety and Health (NIOSH) to document worker exposure to styrene monomer in fiberglass reinforced plastic (FRP) boat plants. This study was in conjunction with an epidemiologic study to determine any chronic health problems related to this exposure. It was expected that any ill-health effects would be more readily identified in a group of workers with a history of relatively high exposure to styrene monomer (the word styrene used throughout this report refers to the monomer). The reinforced plastics industry was chosen for study since it offered the highest potential for worker exposure to styrene due to the type of process used and the labor intensive nature of this process. The manufacture of boats is one of the oldest and most extensive uses of styrene diluted polyester resins.

Preliminary industrial hygiene and record assessment evaluations were conducted at fifteen FRP boat manufacturing facilities. Two of these facilities were identified as appropriate for the mortality study. The selection criteria were length of operation, completeness of records and number of employees. Five additional plants were chosen for the industrial hygiene characterization to obtain a broader data base with which any health effects found may be compared. Parameters used for selection of additional plants were production rate, number of employees and environmental controls used.

This report will describe the compounds to which exposure was quantitated and known health effects associated with exposure, the process involved in FRP boat fabrication, the plants surveyed, and survey methods and results. Statistical analyses will be used to determine how the plants involved compare with respect to control of exposure. A discussion of control technology applicable to this industry is included.

POTENTIAL EXPOSURES

Exposure to styrene is directly related to the use of thermoset polyester resins. The polyester resin system used in the FRP boat industry is a mixture of styrene monomer, glycols (propylene glycol or diethylene glycol), saturated acid (phthalic anhydride or isophthalic anhydride), maleic anhydride and inhibitors. The handling of resins after manufacture does not involve exposure to these chemicals other than at trace levels, since they are substantially converted to polyester (1). The styrene content in the resin is approximately forty percent (by weight) (1, 2). It is both a reactant and a diluting solvent. During manual spray-up and lay-up operations, ten to fifteen percent of the styrene can evaporate into the work place air (1, 3). The remainder is consumed in the chemical reaction. The hardening system used may contain a cobalt salt (cobalt haphthenate) as an initiator and a hydroperoxide (methylethylketone peroxide (MEKO) or benzoyl peroxide) as a catalyst (1, 2). An attempt was made to determine exposure levels to MEKO. The analytical results were inconclusive, and the significance of exposure to this substance was not determined. Acetone is the only other compound likely to be present in large concentrations in the vapor phase. Its copious use as a solvent for cleaning laminating tools, spraying equipment and workers' hands warranted documentation of exposure levels. Its high vapor pressure (226.3 mm Hg @ 25^{o}C) causes it to readily evaporate into ambient air from open containers. The presence of fiberglass dust was virtually nonexistant in the laminating areas and therefore was not quantitated.

CHEMICAL AND PHYSICAL PROPERTIES

Styrene ($C6H5CH - CH_2$) is a volatile liquid with an odor threshold reported to be less than one part per million (PPM) (4, 5). It is soluble in many organic solvents and its solubility in water is about 3.1 mg/ml. Some properties of styrene are given in Table I (7-10). Monomeric styrene production peaked at 7.2 billion pounds in 1979 (11). Approximately 500 million pounds of this were used in the production of polyester resins (12).

Acetone (CH3COCH3) is a colorless, highly volatile, flammable liquid with a burning taste and aromatic odor. It is the simplest but most commercially important ketone. Important properties of acetone are presented in Table II (13, 14).

TABLE I

PROPERTIES OF STYRENE

Synonymns	Cinnamene, cinnamol, cinnamenol, vinyl benzene, phenylethylene, phenethylene, stryol
Molecular formula	C6H 5CH=CH2
Formula Weight	104.1
Boiling Point (760 mm Hg)	145 C (292.4 F)
Melting point	-30.6 C (-23.1 F)
Vapor density	3.6 (air = 1)
Density	0.9021 g/cu cm (25 C)
Solubility	0.31 g/100 ml water at 25 C; soluble in ethyl ether, benzene, heptane, ethanol, acetone
Flammable (explosive) limits	1.5 to 6.7% by volume in air
Flash Point	24-98 F 31 C (88F) Tag closed cup 37 C (98F) Tag open cup
Fire Point	99F
Autoignition temperature	490 C (914 F)
Critical temperature	362 C (684 F)
Critical pressure	37.8 atm
Vapor pressure	see below

Vapor pressure:

Temp F	Temp C	mm Hg
50	10	2.34
68	20	4.50
86	30	8.21
104	40	14.30

Concentration in saturated air	5,700 ppm (15 C)
Conversion factors, (25 C, 760 mm Hg)	1 ppm = 4.26 mg/cu m 1 mg/cu m = .235 ppm

TABLE 2

PROPERTIES OF ACETONE

Synonyms	2-Propanone, dimethylketal, dimethyl ketone, beta-ketoacopane, methyl ketone, pyroacetic ether, pyroacetic spirit
Molecular formula	C3H60 CH_3 C=0 CH_3
Formula Weight	48.08
Boiling point	56.1 C (133 F)
Melting Point	-95.6 C (-140 F)
Density	0.7911 gm/cu m (20 C)
Flammable limits	2.15 to 13% by volume in air
Critical Temperature	188 C (370 F)
Critical pressure	57.1 atm
Vapor pressure	226.3 mm Hg at 25 C
Conversion factors (25C, 760 mm Hg)	1 ppm - 24.0 mg/cu m 1 mg/cu m - 0.417 ppm

ROUTES OF EXPOSURE

Styrene is readily absorbed by each of the practical routes; namely, by inhalation, ingestion and skin absorption. Retention rates of from 60 to 75 percent have been reported subsequent to inhalation of styrene (15, 16). Styrene vapor can also penetrate the skin although less efficiently than the liquid (17). Liquid styrene is readily absorbed through the intact skin at rates between 9-15 $mg/cm^2/hr$, while the rates for aqueous solutions were 40-80 $mg/cm^2/L$ for mean concentrations of 66.5-269 mg/l (18). In a Swedish study of human styrene exposure in a reinforced plastics fabrication facility, Gotell, et al, judged the skin absorption to be fairly low (19). Brooks et al in a more recent (1980) study of reinforced plastics workers found that wearing gloves/protective clothing with a respiratory protection device did not offer more protection than the use of respiratory protection alone. Thus, while there are reports that styrene is readily absorbed through the skin and that this represents a potential route of exposure, their investigation failed to demonstrate any significant contribution of percutaneous absorption to the body burden of styrene among workers in the reinforced plastics industry (20). Absorbed styrene is excreted mostly in the urine as metabolites, but some lung excretion occurs (20).

Inhalation absorption of acetone vapor by humans is reported to be directly proportional to the magnitude of the exposure, and that physical activity increased the absorption rate. Absorption is related to the minute volume of air breathed. It was found that acetone can accumulate in the body, which suggests that long periods of exposure ($>$ 4 hours) are more likely to produce toxicity. It was demonstrated that acetone concentrations in the blood were not increased after nude volunteers were exposed to acetone vapor at unspecified concentrations for 20 to 30 minutes. However, it was shown that acetone was absorbed percutaneously when applied to the skin of the subject for 30 minutes and the subject remained in a chamber for an additional 1.5 hours. This was demonstrated by levels of acetone found in the blood and urine (13). It appears that the skin absorption of acetone depends on the extent of exposure.

Ingestion of either styrene or acetone would not contribute significantly to the body burden in this industry except by accident.

HEALTH EFFECTS

(A) Styrene

(i) Irritant Effects

Irritation of the eyes, skin and of the respiratory tract of humans has occurred due to exposure to styrene. Due to the fat-solvent properties of styrene, it has caused dermatitis, including rash and chapped skin, in workers handling the liquid (21, 22). At 100 ppm, human subjects developed eye, nose and throat irritation within 20 minutes of exposure (16). Workers in plastics applications exposed to styrene for several years complained of eye and respiratory tract irritation but were able to tolerate exposure in excess of 500 ppm for several hours at a time (23). Workers exposed for almost four years at 45-550 ppm complained of eye, nose and throat irritation, and about half of them complained of shortness of breath (24). In a factory where reinforced plastics were made, workers exposed at concentrations greater than 100 ppm had eye irritation and 30 to 50 percent of them had upper respiratory tract irritation (21). In another plant, workers exposed to styrene at 25 to 75 ppm for about one year complained of cough and inflammation of the upper respiratory tract (25).

(ii) Effects on the Nervous System

Experimental exposures of humans and workers exposed to styrene have demonstrated that styrene causes acute central nervous system (CNS) depression. At concentrations of 100 ppm or greater, CNS effects have been observed in human subjects exposed for as little as 30 minutes. Effects such as impaired performance of Romberg tests, decreased manual dexterity and coordination, and increased reaction time were observed. There were also headaches, fatigue, malaise, difficulty in concentrating, a feeling of intoxication and a feeling of tension (16, 26). Workers exposed to styrene for up to twelve years at concentrations frequently greater than 100 ppm for varying periods of time had increased tendon reflexes and increased reaction times, headache, fatigue, malaise, tension and dizziness (21, 23, 24, 27). Abnormal EEG's have been found in some of the workers exposed for an average of five years at a level estimated to be above 30 ppm for most workers, but at or below 30 ppm in the case of a few (28). At concentrations believed to be greater than 30 ppm as a time-weighted average TWA, abnormal EEG's were more frequent, and decrements in visuomotor performance were greater with increasing exposure (29). In workers exposed at an average concentration of about 80 ppm, there was poorer performance in psychomotor tests (20).

(iii) Mutagenicity

In vitro tests of mutagenicity have indicated that styrene has little or no mutagenic activity, but that styrene oxide, believed to be an intermediate in the metabolic pathway for styrene, is mutagenic. This had been found with S typhimurium strains TA 98, 100, 1535, 1537 and 1538 (30, 31, 32). Mice treated with styrene oxide, but not those treated with styrene, had an elevated incidence of aberrations in chromosomes from bone marrow cells removed 24 hours after administration (33). On the other hand, chromosomal changes were found to be more frequent in styrene-exposed workers than among controls in two European plants (34, 35, 36, 37).

(iv) Carcinogenicity

The possible carcinogenicity of styrene has been investigated by long term administration to rodents. One study, which involved vapor exposure to rats, resulted in an increase in a combined incidence of leukemia and lymphosarcoma that was not statistically significant (38). In another study, Ponomarkov and Tomatis administered styrene in olive oil by stomach tube to both sexes of one strain of rats and of two strains of mice. There was a statistically significant increase in lung adenomas and adenocarcinomas only in female mice of the strain. The authors suggested that their data provided weak evidence of carcinogenicity of styrene (39). In an NCI investigation there was an increase in lung adenomas and adenocarcinomas in male B6C3F1 mice when compared with matched controls, but not in female mice or in Fischer 344 rats. NCI concluded that the data provided suggestive but not convincing evidence of the carcinogenicity of styrene (40).

Mortality studies of styrene workers have not shown an excess of cancer mortality, although there have been suggestions of an excess of leukemia. Nicholson et. al. studied the mortality experience in one U.S. plant manufacturing styrene and polystyrene. The investigators found two cases of leukemia and one of lymphoma in the study group. After examining 361 death certificates of other workers employed at least six months, they found five additional cases of leukemia and four of lymphoma. They anticipated an excess of leukemia because of previous exposure to benzene of many of these workers (41). In another U. S. plant, Ott et. al. studied styrene workers who had been exposed to low levels of styrene for most of their employment (TWA$\sim$10ppm). These styrene workers had lower total mortality and cancer mortality when compared to the U.S. white male population and to mortality experience from that company. However, there was a significant excess of leukemia deaths when compared to the other company employees, although the excess was not significant when compared to the U.S. population. Most of the excess was due to lymphatic leukemia. Some workers had been exposed years previously to high levels of benzene (42). No excess of cancer was seen in a German plant of employees exposed to styrene. The incidence of death from cancer was compared to the German population and a control group within the plant (43).

From the experimental animal investigations and from the epidemiologic studies, there seems no basis to conclude that styrene is carcinogenic.

(B) Acetone

(i) Irritant effects

Acetone has been reported to produce irritation of the eyes, skin and upper respiratory tract. Adverse effects on skin include intracellular edema and disruption of the cells of the keratin layer; this due to the lipid-solvent properties of acetone. This defatting ability suggests that liquid acetone may cause dermatitis. Eye nose and throat irritation were reported in a small group of workers exposed to acetone vapor for eight hours at an average concentration of 1000 ppm. Another group of subjects exposed to concentration of 500 and 1000 ppm had eye, nose and throat irritation (13).

(ii) Effects on the Nervous System

Acetone has been reported to cause narcosis or signs of CNS depression. Acute intoxication of a ten-year-old boy with acetone resulted in collapse, stupor and incoherance. Eight workers exposed to acetone at a concentration greater than 12,000 ppm felt dizzy, lightheaded and reported weakness of the legs. Another study noted lightheadedness and headache in workers exposed for eight hours at an average 1000 ppm. CNS disturbances, such as, dizziness, inebriation, somnolence and headache were reported among workers in a cellulose acetate fibers production plant. Exposures ranged from 307 to 918 ppm. The authors attributed these effects to accumulation of acetone in the body resulting from repeated exposures (13).

(iii) Mutagenisis and Carcinogenisis

No reports that implicated acetone as a mutagen or carcinogen were found.

(C) Summary

Exposure to liquid styrene and liquid acetone can cause dermatitis due to fat-solvent properties of both liquids. Both vapors have shown to be irritants to the eyes and upper respiratory tract. Inhalation of styrene vapor at 50 ppm and higher can cause CNS depression leading to poorer psychomotor performance. Exposure to acetone vapor at 310 ppm and greater can also cause CNS disturbances. It is not unlikely that these acute effects may be additive at concentrations found in a reinforced plastics manufacturing plant. Such effects could lead to serious consequences in the workplace.

Presently available information does not indicate that either styrene or acetone are carcinogenic.

STANDARDS

The Occupational Safety and Health Administration (OSHA) standard for Styrene is 100 ppm (420 mg/m^3) for an eight-hour TWA, 200 ppm (840 mg/m^3) for a ceiling concentration and 600 ppm (2520 mg/m^3) for five minutes in any three-hour time period (44). The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's)[(R)] for styrene are presently 100 ppm (420 mg/m^3) for an eight-hour TWA and 125 ppm (525 mg/m^3) for a Short Term Exposure Limit (STEL) (The maximum exposure concentration for a continuous 15-minute period). They propose to change these values to a 50 (215 mg/m^3) ppm TLV-TWA and a 100 ppm (425 mg/m^3) TLV-STEL in their Notice of Intended Changes for 1980 (45).

The OSHA Standard for acetone is 1000 ppm (2400 mg/m^3) for an eight-hour TWA (44). NIOSH recommends a 250 ppm (590 mg/m^3) exposure limit for up to a ten-hour work-shift for acetone (13). The present ACGIH TLV-TWA for acetone is 1000 ppm (2400 mg/m^3) for an eight-hour exposure and the present TLV-STEL is 1250 ppm (3000 mg/m^3). They propose a change to 750 ppm (1780 mg/m^3) for a TWA and to 1000 ppm (2375 mg/m^3) for a STEL in their Notice of Intended Change for 1980.

PROCESS DESCRIPTION

The method used in manufacturing FRP boats is called contact molding and is a zero pressure molding method in which only one side contacts the mold surface. There are two principal techniques, hand lay-up and spray-up. Materials used in contact molding are polyester resin, gel coat (pigmented resin), split-strand glass fiber roving which is used for chopping in the spray-up operation, chopped-strand mat (made by chopping split-strand glass fibers, mixing with a binder and pressing into a mat) which is used in hand lay-up, and woven roving (a heavy cloth made from strand roving in a square weave pattern) whose greatest use is to provide a structural backbone in the hand lay-up operation.

Hand lay-up: Mat or mat-and-woven roving layers are wetted out with resin and manually laid-up on the gel coated mold. Resin is applied to the mold, using a brush on smaller pieces or an airless sprayer system on larger ones, and mat is laid on top of the resin. The preferred practice uses alternate layers of mat and woven roving.

Spray-up: A mechanism attached to the sprayer system used for wet out in hand-lay-up allows for chopping split-strand roving and "throwing" the chopped fibers onto the mold surface while at the same time spraying polyester resin. This tool is called a chopper-gun. In this manner a structure can be built up layer by layer in a mat-like style. Following deposition of fiber and resin, it is necessary to roll-out the structure (compacting the resin and glass) with a special rolling wheel. Spray-up is often used in combination with hand lay-up techniques.

The boat making process begins with polishing the surface of an FRP mold having the converse shape of the part being made, and the application of a releasing agent (usually a wax) in preparation for the initial layer of gel coat.

The pigments in gel coat are used for color, since this layer will appear as the outside surface of the boat, and for resistance to ultraviolet deterioration. The name gel coat stems from the fact that when the coat reaches a gel state, the remainder of the laminate is applied.

Methods of contact molding, or lamination, varied between companies. Plants 2, 5, and 6 used only hand lay-up techniques. That is, the parts were constructed of alternating layers of chopped strand mat and woven roving, with each layer being wetted with resin. Plant 4 used spray-up to manufacture some of the smaller pieces but the process was extensively hand lay-up. Plants 1, 3 and 7 used a combination of hand lay-up and spray-up. These parts were constructed of alternating layers of chopped fiberglass from a chopper gun and woven roving. The chopped glass layer is, of course simultaneously mixed with resin as it is applied. The woven roving layer requires wet-out which is done using only the spraying mode of the chopper-gun. The chopped layer requires roll-out to compact the fiberglass and resin. The other layers, whether chopped-strand mat or woven roving, are usually squeegeed to insure saturation and to remove excess resin. A reason given, aside from any economic considerations, for choosing chopped-strand mat over spray-up, was the layer uniformity that this technique offers, resulting in uniform strength and flexibility of the piece.

Following lamination, structural support is necessary on certain parts. Plywood and end grain balsa wood are two materials used for this support. The wood is positioned and then overlayed with fiberglass and resin to secure it in place. Chopped fiberglass, either from a gun or in mat form is generally used for this.

The following discussion addresses the factors affecting exposures in the lamination jobs.

Gel coat is applied in a ventilated booth using an airless sprayer system, except in the case of stationary molds which are coated in place. Generally only large hull and deck molds are stationary and at plants using this system the gel coating was performed on an off-shift so that exposure was experienced by the gel coater only. Plants 5 and 6 had this arrangement. In all plants surveyed, the gel coaters were the best protected from exposure. In addition to booth ventilation, protective clothing was commonplace on the gel coater. Coveralls, hoods and respirators were almost always worn during the gel coating operation.

The rest of the jobs are performed in a large area in the plant designated as the lamination area. Invisible boundaries usually segregate one section from the other (i.e., the hull lamination from deck lamination), with the entire environment being controlled by a central dilution ventilation system consisting of exhaust fans and tempered make-up air. The exception is Plant 6 which used natural ventilation exclusively. In some instances, the ventilation system was aided by the use of circular fans which developed directional air flow patterns. Aside from the effectiveness of the particular ventilation system, exposure potential is affected by the amount of resin used, the size and configuration of the part, and the protective equipment used.

The hull has the largest surface area over which catalyzed resin is applied resulting in greater exposure potential for these workers because of styrene evaporation. Since the hull has a somewhat concave shape its positioning affects exposure. On the mobile mold frame, the hull is turned on a longitudinal axis to access both halves for lamination. Laminating on this type mold is somewhat confining; however, if proper air movement is present styrene vapor does not accumulate. If a stationary hull mold is used, it is always in an upright position and the worker must perform his job inside this mold. Because styrene is more dense than air it will accumulate when the mold is in this position and exposure potential is greater.

Those working in deck and other large parts (flying bridges and aft decks) lamination also use a great deal of resin. Surface area of these parts is not as great but is proportional to the hull size. The frame generally holds these pieces flat or upright and there is no configuration type problem. Directional fans are used to limit accumulation of vapor.

In small parts lamination, the number of pieces being laid-up will affect exposure potential. The molds are laid on a table top instead of being mounted on a frame. There are no configuration problems with these pieces.

Acetone exposure in all instances will depend on the frequency of use as well as location of dispensing cans.

In the lamination jobs the protective equipment provided included half-face cartridge respirators and in some plants aprons and gloves. In plants 1, 3, 4, and 6, no formal policy existed governing respirator (or other protective equipment) use. The other plants had programs with varying enforcement policies.

PLANT DESCRIPTIONS

From June 1978 to March 1979, environmental monitoring was conducted at seven FRP boat manufacturing facilities. Plants 1 and 2 were the ones included in the mortality study. Following is a brief description of these plants:

PLANT 1

Plant 1 produces approximately 400 power boats per year in the seventeen to twenty-eight foot range. Production began in 1952. The plant is located in Southwestern Washington and had around thirty-five people working in lamination during the survey, most of them women. Environmental control consisted of exhaust ventilation through the gelcoat booth and make up air from natural sources (open windows and doors). No tempering was provided. Mobile fans were used for directing air flow.

PLANT 2

Plant 2 manufactured power and sailing boats from twenty-six to forty-two feet in length at a rate of around 350 per year. They also produced eighteen to fifty-six foot vessels under contract with the U. S. Navy. The plant was located in Northwestern Washington. There were approximately fifty laminators working during the survey. At peak production periods they employed close to ninety workers in lamination. The ventilation system included exhaust from the gel coat booth and two large (4 foot diameter) exhaust fans in the lower wall of the laminating area. A number of mobile fans were used for directing air flow. Make up air was provided from natural sources. This plant was destroyed by fire in 1980.

PLANT 3

Plant 3 makes approximately twenty-five different boat models ranging from fourteen to thirty-four feet. At the time of the survey, production was at fifteen per day with nearly thirty workers in the lamination areas. Plant 3 is located in East Central Washington and they started production in 1957. Exhaust ventilation was provided by eleven fans at floor level located on three sides of the lamination area (six on the south wall, four on the north wall and one on the east wall). The north and south wall fans were paired and shared a common plenum with a filtering medium over the entrance. The east wall fan arrangement was similar. Make-up air was provided from duct work near the ceiling (~30 feet) running the length of the building (130' x 260'). In principle the system was not bad, however, poor maintenance of a ventilation system in FRP operations can destroy the purpose of good design. The filtering media used was clogged with a hardened resin/fiberglass/dust composite which limited performance and a few fans were not in operation. Mobile fans were used for directing air flow. This system was reported to provide five air changes per hour optimally. Plans were underway for a new system at the time of the survey.

PLANT 4

Plant 4 is located in Central Texas. It produces small power boats ranging from fourteen to twenty-five feet and sailing boats from thirteen to twenty-six feet. Fifty-six employees were working in lamination at the time of the survey with total production at twenty-five units per day. Forty units per day was common during peak production periods. The ventilation system here comprised exhaust through four gelcoat booths and the painting and grinding booths. These booths were placed some distance from the general laminating areas, so that the effectiveness depended on mobile fans moving the contaminants in the proper direction. Tempered make-up air was supplied from overhead ducts throughout the production area. This system was reported to provide eleven air changes per hour optimally.

PLANT 5

Plant 5, located in Central North Carolina, produces six lines of power yachts in the thirty-seven to fifty-three foot class. Production started in 1959 and was around 400 units per year at the time of the survey. There were fifty laminators in production on two shifts. The ventilation system at Plant 5 consisted of twelve large exhaust ducts, placed at worker level throughout the lamination area and designed to move 15,000 cubic feet per minute (CFM) of air, with three tempered make-up air ducts rated at 60,000 CFM. However, at the time of the survey two of the twelve exhaust ducts were not functioning. Air velocity indicated that the system may have been in a lower mode of operation. Production rate and energy conservation factors may have been involved. Another feature was the placement of circular fans to direct air to the exhaust hoods. Fans were placed aft of the mold. It should be noted here that the hull molds were stationed in pits such that the complete structure was below grade level. In this fashion, the styrene vapor is trapped in the hull until moved toward the exhaust port via the fan air movement. This probably helps to keep general area styrene levels lower than they might be otherwise. Unless the fans are positioned properly, however, the hull lamination workers are exposed to greatly increased levels. It was noticed that the air movement varied from line to line. Stationary, properly aimed fans might be a solution to this problem.

PLANT 6

Production at Plant 6 began in 1960 and it presently makes power yachts ranging from twenty-eight to fifty-eight feet. Seventy laminators worked three shifts at the time of the survey. This plant is located in Southern Florida. Production was at four yachts per day. The ventilation system at Plant 6 consists of exhausted gel coat booths, a number of exhaust fans in the west end of both lamination buildings, some circulating fans and natural ventilation provided by the prevailing winds through the buildings. Weather conditions at this plant location allow for the buildings to be open year round. The flow through the gel coat booths is reported to be between 130-160 cubic feet per minute.

PLANT 7

Plant 7, located in Northcentral Minnesota, produces power boats in the fifteen to twenty-five foot range. This plant opened in 1955 and made fifteen boats a day using around thirty laminators on one shift at the time of the survey. During peak periods, production reached seventy-five units per day. The ventilation system at this plant was comprised of exhaust ventilation through the five gelcoat booths and four ceiling exhaust fans in the lamination areas (rated at 30 cubic ft/minute each), with tempered make-up air coming from ceiling duct work. Due to weather conditions in this region, seasonal exposures can differ greatly. During warmer months, the use of natural ventilation increases, augmenting existing controls, leading to lower exposure potential.

Plants 4, 5, 6, and 7 had medical programs requiring preemployment physicals. Plant 7 required a follow-up physical every two years. Plants 1, 2, and 3 had no medical program. Every plant had a safety program with safety equipment being supplied, but not always required. This generally included safety glasses, proper respiratory protection and gloves. Industrial hygiene monitoring was available to all plants from a variety of sources. Plants 4, 5, and 6 had industrial hygiene support provided by corporate personnel. The other plants were monitored, as needed, by state programs or insurance carriers. All of the facilities monitored in this study were enclosed structures and general dilution ventilation was provided with varying degrees of natural ventilation.

DESCRIPTION OF SURVEY METHODS

Charcoal tube sampling is considered a most reliable and effective method for determining levels of organic chemical vapors and was the method used to collect all styrene and acetone samples. The sampling train used to collect the TWA personal and area samples included an MDA Accuhaler[R] Model 808 sampling pump connected to a charcoal tube with Tygon tubing. The sampling flow rates were determined by using 20, 50, and 100 cc/min. limiting orifices. The charcoal tubes used contained 150 mg of activated coconut shell carbon divided into a 100-mg front section and a 50-mg back-up section separated by a two-mm portion of urethane foam. The charcoal tube was attached to the collar or lapel in the worker's breathing zone. The workshift at Plant 1 was divided into three sampling periods using the 50 cc/min and 100 cc/min flow rates. At Plant 2 the workshift was divided into two sampling periods, again using the 50 cc/min and 100 cc/min flow rates. During the remaining five surveys, single sample full shift monitoring at 20 cc/min was used. Sampling times for all surveys averaged seven and one-half hours per shift.

Analysis of the charcoal tube samples was conducted in accordance with NIOSH analytical method number P&CAM 127, for organic solvents in air (46). This is a gas chromatographic method using carbon disulfide as desorbent and a flame ionization detector. Each sample was analyzed for styrene and acetone. The lower limits of detection were 0.01 mg/sample for styrene and 0.02 mg/sample for acetone.

After analysis, it was found that 198 of 464 (42.2%) personal samples collected had acetone breakthrough (defined as greater than one-third of the total sample contained in the back-up section charcoal). This condition was prevalent in Plants 2, 3, 4, 5, and 7. However, since the last five surveys were conducted in a two-and-one half month period and no sample results were available before the surveys had been completed, a correction in methodology was not possible. There was no styrene breakthrough.

STUDY RESULTS

Descriptive Surey Results

There were 500 air samples collected from the seven plant surveys conducted. Of these 464 were full shift personal TWA samples. These sampling results are listed by plant and job in Appendix A. For each entry the styrene and acetone exposure concentrations are given as well as an indicator of the combined exposure (combined TLV® = $\frac{C_{styrene}}{TLV_{styrene}} + \frac{C_{acetone}}{TLV_{acetone}}$: when the sum of these fractions exceeds unity the Threshold Limit Value for the mixture is considered as being exceeded). There were 23 different jobs present among the plants surveyed. A job dictionary is provided in Appendix B.

Prior to any data analysis the distribution of the data was tested using the Univariate procedure from the Statistical Analysis System (SAS), and found to be non-normally distributed (47). Therefore, a log-normal distribution was assumed as is frequently done in industrial hygiene applications (48). The SAS Means procedure was then used on the log-transformed data to generate the descriptive statistics presented for each plant by job, and for the plants overall. In Appendix C, the geometric mean, coefficient of variation and exposure ranges for styrene and acetone are tabulated.

The substantial variability of exposure to styrene in the FRP boat fabrication industry can be seen in Table 3. Values range from 2 to 183 ppm among all plants. An important observation is that 96 of these personal exposures (20.6%) exceeded the 100 ppm, eight-hour TWA standard. Acetone exposures were also widely variable with exposures in a few instances near 400 ppm (Table 4), which is well below the eight-hour TWA standard of 1000 ppm.

TABLE 3

DISTRIBUTION OF STYRENE EXPOSURE BY PLANT

PLANT	RANGE OF EXPOSURE (PPM) 2-50	50-100	100-183	TOTAL
1	34	19	0	53
2	26	21	20	67
3	13	8	17	38
4	5	39	25	69
5	25	27	10	62
6	94	21	1	116
7	12	24	23	59
ALL	209	159	96*	464

*20.6% over 100 ppm

TABLE 4

DISTRIBUTION OF ACETONE EXPOSURE BY PLANT

PLANT	RANGE OF EXPOSURE (PPM) 0-100	100-200	200-400	TOTAL
1	40	12	1	53
2	56	8	3	67
3	25	12	1	38
4	42	20	7	69
5	55	6	1	62
6	95	16	5	116
7	53	6	0	59
ALL	366	80	18	464

A frequency distribution for all jobs, by plant, is shown in Table 5. Corresponding exposure averages for these jobs are presented for styrene in Table 6, and for acetone in Table 7. It can be seen from the overall plant averages that control of styrene exposure was different from plant to plant. Some were adequate; others were not.

Average exposure to styrene for each job in Plant 1 were kept below 50 ppm (the model development single exposure sample is not considered as an average). Plant 6 mean exposures were controlled to below 40 ppm in all but one job. Both of these plants exhibited that exposures in all jobs can be adequately controlled using dilution ventilation techniques. The importance of the model development should be mentioned. Workers in this category build the prototypes from a wooden model, or plug. The surface of the plug is coated with several layers of fiberglass and resin. The exposure results are of interest in an historical sense, since they most likely depict the exposures experienced by those first using styrene diluted resins in this industry. Early resin use was limited to coating wooden boats to make them more durable. This practice evolved into making the entire boat of FRP using present techniques. If the coated plug tests satisfactorily a mold is made from the plug.

Plant 2 exposure means were kept below 45 ppm in all jobs not related to hull lamination. Stinger installation is a special hull lay-up task. Stingers are longitudinal support pieces which reinforce the hull bottom. During this survey a large hull (>50 feet) was being made requiring work in a stationary upright mold. No attempt was made to move fresh air through the space during the work and resulted in the high exposures.

Plant 5 experienced similar problems with hull lamination exposures. Attempts were made, using moveable fans, to move the air through the hull

TABLE 5

JOB FREQUENCY DISTRIBUTION BY PLANT

JOB	PLANT 1	2	3	4	5	6	7	TOTAL
Hull Chopper	2	0	2	0	0	0	6	10
Hull Hand Lay-up	16	27	7	27	15	46	12	150
Deck Chopper	0	0	2	0	0	0	9	11
Deck Hand Lay-up	11	12	7	26	13	22	12	103
Small Parts Chopper	0	3	2	2	0	0	0	7
Small Parts Hand Lay-up	15	5	2	0	12	13	0	47
Gelcoat	4	2	5	12	5	9	8	45
Stringer Installation	0	8	0	0	0	0	0	8
Stringer Lamination	0	0	0	0	2	0	6	8
Aft Deck Lay-up	0	0	0	0	7	0	0	7
Fly Bridge Lay-up	0	0	0	0	3	7	0	10
Hard Top Lay-up	0	0	0	0	0	4	0	4
Fueltank Lay-up	0	0	0	0	3	5	0	8
Sole Lay-up	0	0	0	0	0	10	0	10
Moldwork	4	0	8	0	0	0	0	12
Model Development	1	4	0	2	0	0	0	7
Overlay	0	6	0	0	0	0	0	6
Foam and Chop	0	0	0	0	0	0	5	5
Forklift	0	0	2	0	0	0	0	2
Clean-up	0	0	1	0	0	0	0	1
Sander	0	0	0	0	1	0	0	1
Paste Mixer	0	0	0	0	1	0	0	1
Mold Masking	0	0	0	0	0	0	1	1
Area	5	0	2	3	9	9	8	36
TOTAL	58	67	40	72	71	125	67	500

TABLE 6

GEOMETRIC MEAN STYRENE EXPOSURES BY JOB WITHIN ALL PLANTS

JOB	PLANT 1	2	3	4	5	6	7
Hull Chopper	37.1		129				83.0
Hull Hand Lay-up	48.5	88.2	106	99.3	92.3	27.4	109
Deck Chopper			124				60.5
Deck Hand Lay-up	33.5	43.4	118	92.5	62.4	34.6	117
Small Parts Chopper		35.0	74.3	65.1			
Small Parts Hand Lay-up	42.6	31.6	117		42.4	31.1	
Gelcoat	33.1	29.0	61.4	59.7	41.2	11.2	61.6
Stringer Installation		94.6					
Stringer Lamination					54.1		58.6
Aft Deck Lay-up					51.6		
Fly Bridge Lay-up					46.0	34.5	
Hardtop Lay-up						30.9	
Fueltank Lay-up					51.8	18.8	
Sole Lay-up						41.2	
Moldwork	10.9		33.5				
Model Develop.	53.7	75.6		46.2			
Overlay		26.2					
Foam & Chop							28.5
Forklift			19.4				
Clean-up			30.4				
Sander				77.3			
Paste Mixer				21.4			
Mold Masking							15.0
ALL	37.3	59.8	70.3	85.5	57.8	28.1	73.8

TABLE 7

GEOMETRIC MEAN ACETONE EXPOSURES BY JOB WITHIN ALL PLANTS

JOB	PLANT 1	2	3	4	5	6	7
Hull Chopper	9.3		139				45.9
Hull Hand Lay-up	24.3	64.1	86.8	77.9	58.3	41.1	73.2
Deck Chopper			98.6				47.2
Deck Hand Lay-up	69.7	70.7	77.9	153	30.4	25.7	90.6
Small Parts Chopper		38.5	89.1	45.1			
Small Parts Hand Lay-up	125	59.1	164		81.8	40.7	
Gelcoat	62.5	18.9	50.2	63.9	12.3	13.4	84.5
Stringer Installation		32.9					
Stringer Lamination					34.3		50.2
Aft Deck Lay-up					69.1		
Fly Bridge Lay-up					42.8	27.4	
Hard Top Lay-up						17.0	
Fueltank Lay-up					95.9	18.4	
Sole Lay-up						34.3	
Moldwork	34.3		30.6				
Model Development	14.4	36.2		79.0			
Overlay		61.1					
Foam and Chop							36.2
Forklift			12.2				
Clean-up			25.3				
Sander					54.0		
Paste Mixer					20.5		
Mold Masking							21.4
ALL	50.6	54.3	59.3	95.6	47.6	31.0	61.7

pits (the hulls molds were stationary and positioned below grade level). However, positioning of these fans was critical and worker movement in the area caused the fans to be moved and maintaining proper air flow patterns was difficult. The fans should have had fixed positions (a technique used in Plant 6). The deck lamination area of this plant also experienced some stagnant air flow. Otherwise, for a survey conducted in the winter, the ventilation system engineered for Plant 5 kept exposure averages below 55 ppm (the single sample collected on the sander is not considered an average).

Plants 3, 4, and 7 each exhibited inadequate control of exposure to styrene. These surveys were all conducted in the winter, in regions of the country where little plant leakage (or ability for natural ventilation) is allowed. These are most likely worst case situations, however, there is no justification for allowing average exposures at or exceeding 100 ppm. Evaluation and redesign of present ventilation systems are required.

By looking at exposures by job across all plants a couple of interesting observations can be made. Firstly, in general, the hull jobs receive the highest exposures to styrene, followed by the deck, small parts and gel-coat jobs. In Plants 1 and 6, the exposures are somewhat homogeneous and this trend is not as obvious. These data seems to support the common sense notion that exposure to styrene vapor emitted from catalysed resin is proportional to resin consumption. That is, the larger parts require more resin and these workers receive the higher exposures. The low ranking of the gel-coat job reflects, in part, the fact that this job is usually performed in a ventilated spray painting type booth, or is performed on an off-shift when dilution systems are more adequate. Secondly, the difference in exposure experienced between chopper and hand lay-up counter parts of hull, deck and small parts lamination jobs varies from plant to plant. This may be indicative of whether the tasks are completely separate between the two jobs or whether the tasks are shared between the two jobs. In Plants 1 and 7 the choppers took no part in the hand lay-up. In Plant 3, the chopper participated in the hand lay-up procedure.

There seemed to be no trend to acetone exposures. Extreme exposures were experienced in a number of jobs. Exposure to acetone results from the use of this solvent for clean-up purposes. Exposure potential is a function of the frequency of cleaning tools and other work habits of the individuals.

Because of the percentage (43%) of samples reported in the previous section as having breakthrough of the acetone, these data will be excluded from further statistical analysis, the value of which would be doubtful.

Statistical Methods

As the first step in approaching the problem of styrene exposure control for this industry, certain statistical comparisons are useful. In order to do the appropriate analysis it was logical to combine the 23 jobs into eight more manageable job categories. This was logical because:

1. The categories combine jobs whose tasks involve no direct exposure to styrene and acetone (that is non-resin-use jobs) into a no exposure category;

2. Those jobs whose tasks involve frequent but not constant direct exposure into a low exposure category;

3. The remaining jobs are categorized by the part being made, or the similarity of parts being made, and all involve constant direct exposure tasks.

There were two reasons for doing this:

1. Not all jobs existed in all plants and many involved small sample sizes, especially among the low and no exposure groupings;

2. Ease of interplant comparison.

The job categories are shown in Table 8 with contributing jobs. Table 9 is a frequency distribution by plant for the job categories.

As was similarly done to the job data, descriptive statistics were generated for the job categories using the SAS Means procedure on the log-transformed data. Since the data were imbalanced with respect to the number of entries for each job category the SAS General Linear Models (GLM) procedure was used to perform various single-factor and two-factor analyses of variance (ANOVA). A t-test which compares the means of the independent variables in the ANOVA is provided by the GLM procedure along with corresponding significance levels (p-values).

Single-factor ANOVA's were conducted to assess the variation of certain jobs and all job categories on styrene exposure within each plant, and to assess the variation of plant on styrene exposure within each job category. A two-factor ANOVA was then performed to assess the effect of both job category and plant, including a term for their interaction, upon the exposure to styrene. This was conducted using only the job categories present in all plants; hull, deck, small parts and gelcoat. Due to interaction effects seen, and noticed relationships, subsequent two factor ANOVA's were run on subsets of these data.

Statistical Results

Table 10 presents the means and coefficient of variation (CV) for all eight job categories among all seven plants. Table 11 presents the p-values for the single-factor ANOVA comparing job categories within the plants. A p-value $\leq$ to 0.05 is considered significant. From these two tables the following observations among the four major job categories are made:

1. Within Plant 1 the greatest difference amont the major job categories is between hull and deck with borderline significance, P=0.0528;

TABLE 8

JOB CATEGORY GROUPINGS

Category	Job
Hull	Hullchopper Hull Hand Lay-up Stringer Installation
Deck	Deck Chopper Deck Hand Lay-up
Small Parts	Small Parts Chopper Small Parts Hand Lay-up Stringer Lamination Fueltank
Gelcoat	Gelcoat
Large Parts	Aft Deck Lay-up Fly Bridge Lay-up Hardtop Lay-up Sole Lay-up
Low Exposure	Overlay Foam & Chop Paste Mixer
No Exposure	Mold Work Paste Mixer Clean-up Sander Mold Masking
Model Development	Model Development

TABLE 9

JOB CATEGORY SAMPLING FREQUENCY DISTRIBUTION BY PLANT

JOB CATEGORY	PLANT 1	2	3	4	5	6	7	TOTAL
Hull	18	35	9	27	15	46	18	168
Deck	11	12	9	26	13	22	21	114
Small Parts	15	8	4	2	17	18	6	70
Gelcoat	4	2	5	12	5	9	8	45
Large Parts					10	21		31
Low Exposure		6			1		5	12
No Exposure	4		11		1		1	17
Model Development	1	4		2				7
TOTAL	53	67	38	69	62	116	59	464

2. Within Plant 2 the exposures are relatively homogeneous except for the hull category whose mean is highly different from the rest, P=0.0005 or less;

3. Within Plant 3 the gelcoat mean is different from both the hull and deck categories, P=0.0132 and 0.0058 respectively;

4. Within Plant 4 both hull and deck are different from gelcoat at the P=0.0001 level, and the hull category is also significantly different from the small parts, P=0.0392;

5. Within Plant 5 the hull category mean is significantly higher than all others (at least at P=0.0226) with relative homogeneity among the other jobs;

6. Within Plant 7, the gelcoat category mean is significantly lower than the others ($P \leq 0.001$);

7. Within Plant 7 the only two similarities are between hull and deck, P=0.2514, and small parts and gelcoat, P=0.7722.

Table 12 presents the P values for comparisons of the chopper and hand lay-up jobs within the plants that have this job breakdown. No significant differences exist between the means in Plants 1 and 3 while the opposite is true in Plants 2 and 7. In Plants 1 and 7 the lay-up jobs have the higher mean exposure and in Plants 2 and 3 the chopper job tends to be higher (Table 6).

The P-values from the ANOVA comparing plants within job categories are in Table 13. By using Tables 10 and 13 together the following observations are made:

1. Except within the hull category (P=0.0001) Plants 1 and 2 are similar;

2. Plant comparisons 3 vs. 4, 3 vs. 7 and 4 vs. 7 appear homogeneous across all four major job categories;

3. Plant comparison 4 vs. 5 and 5 vs. 7 appear to be similar except in the deck job category.

Tables 14 through 17 display the statistics from the interplant two-factor ANOVA's performed. As the degrees of freedom were reduced in Tables 15 and 16 there was a slight lessening of the significance of the independent

TABLE 10

JOB CATEGORY DESCRIPTIVE STATISTICS BY PLANT

JOB CATEGORY	PLANT 1	2	3	4	5	6	7
<u>Hull</u>							
Geo. Mean (ppm)	47.1	89.6	111	99.3	92.4	27.4	99.5
CV (%)	(11.0)	(7.6)	(17.7)	(4.6)	(3.1)	(12.0)	(5.0)
<u>Deck</u>							
Geo. Mean (ppm)	33.5	43.4	120	92.5	62.3	34.6	88.4
CV (%)	(15.4)	(7.6)	(10.4)	(4.7)	(20.0)	(9.7)	(8.9)
<u>Small Parts</u>							
Geo. Mean (ppm)	42.6	32.8	93.4	65.1	45.2	27.0	58.6
CV (%)	(10.4)	(8.5)	(16.9)	(14.6)	(7.5)	(11.4)	(8.6)
<u>Gelcoat</u>							
Geo. Mean (ppm)	33.1	29.0	61.4	59.8	41.2	11.3	61.6
CV (%)	(14.8)	(1.2)	(13.9)	(11.6)	(21.1)	(13.8)	(13.0)
<u>Large Parts</u>							
Geo. Mean (ppm)					49.8	36.8	
CV (%)					(14.5)	(11.4)	
<u>Low Exposure</u>							
Geo. Mean (ppm)		26.2			21.4		28.5
CV (%)		(27.1)			-		(51.5)
<u>No Exposure</u>							
Geo. Mean (ppm)	10.9		30.1		77.3		15.0
CV (%)	(21.5)		(12.3)		-		-
<u>Model Development</u>							
Geo. Mean (ppm)	53.7	75.6		46.1			
CV (%)	-	(9.0)		(2.5)			
<u>ALL</u>							
Geo. Mean (ppm)	37.3	59.8	70.3	85.5	57.8	28.1	73.8
CV (%)	(7.8)	(7.6)	(11.4)	(4.1)	(6.7)	(6.4)	(6.7)

TABLE 11

P-Values for Job Category Comparisons Within Plants+

Job Category Comparison	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
Hull vs. Deck*	0.0528	0.0001	0.6495	0.3499	0.0226	0.0594	0.2514
Hull vs. Small Parts*	0.5288	0.0001	0.4835	0.0392	0.0001	0.9379	0.0009
Hull vs. Gelcoat*	0.1616	0.0005	0.0132	0.0001	0.0008	0.0002	0.0008
Hull vs. Large Parts					0.0012	0.0821	
Hull vs. Low Exposure		0.0001			0.0023		0.0001
Hull vs. No Exposure	0.0001		0.0001		0.6980		0.0001
Hull vs. Model Develop	0.7809	0.4409		0.0002			
Deck vs. Small Parts*	0.1815	0.1526	0.3154	0.0849	0.0531	0.2237	0.0073
Deck vs. Gelcoat*	0.9648	0.2179	0.0058	0.0001	0.0803	0.0001	0.0085
Deck vs. Large Parts					0.2337	0.7564	
Deck vs. Low Exposure		0.0203			0.0234		0.0001
Deck vs. No Exposure	0.0001		0.0001		0.6412		0.0001
Deck vs. Model Develop	0.3294	0.0231		0.0007			
Small Parts vs. Gelcoat*	0.3211	0.7153	0.1326	0.6806	0.6825	0.0010	0.7722
Small Parts vs. Large Parts					0.5799	0.1349	
Small Parts vs. Low Exp.		0.3287			0.1059		0.0004
Small Parts vs. No Exp.	0.0001		0.0001		0.2429		0.0002
Small Parts vs. Model Dev.	0.6279	0.0016		0.2025			
Gelcoat vs. Large Parts					0.4346	0.0001	
Gelcoat vs. Low Exposure					0.1815		0.0001
Gelcoat vs. No Exposure	0.0010		0.0026		0.1991		0.0001
Gelcoat vs. Model Develop.	0.3503	0.0096		0.2107			
Large Parts vs. Low Exp.					0.0735		
Large Parts vs. No Exp.					0.3480		
Large Parts vs. Model Dev.							
Low Exp. vs. No Exposure					0.0446		0.0702
Low Exp. vs. Model Develop.		0.002					
No Exp. vs. Model Dev.	0.0031						
ALL	0.001	0.001	0.001	0.001	0.002	0.001	0.001

*Indicates Major Job Category Comparisons

+Significance is indicated for $p < 0.05$

TABLE 12

P-Values for Chopper and Hand Lay-up Job Comparisons Within Plants *

Job Comparison	PLANT 1	2	3	7
Hull Chopper Vs. Hull Hand Lay-Up	0.4246		0.5530	0.0247
Deck Chopper vs. Deck Hand Lay-up			0.8800	0.0001
Smallparts Chop. vs. Small Parts Lay-up		0.0007	0.2723	

* Significance is indicated for $P \leq 0.05$

TABLE 13

P-Values for Plant Comparisons Within Job Categories*

Plant Comparison	Hull	Deck	Small Parts	Gelcoat	Large Parts	Low Exposure	No Exposure	Model Development
1 vs. 2	0.0001	0.1494	0.1144	0.6959				0.1220
1 vs. 3	0.001	0.001	0.004	0.0219			0.0010	
1 vs. 4	0.001	0.001	0.1356	0.0114				0.4731
1 vs. 5	0.004	0.0006	0.6592	0.4023			0.0010	
1 vs. 6	0.003	0.8362	0.0009	0.0001				
1 vs. 7	0.001	0.0001	0.0814	0.0120			0.5060	
2 vs. 3	0.2807	0.0001	0.0001	0.0255				
2 vs. 4	0.4494	0.0001	0.0233	0.0187				0.0219
2 vs. 5	0.8533	0.0361	0.0497	0.2840		0.7158		
2 vs. 6	0.0001	0.1429	0.2260	0.0032				
2 vs. 7	0.4980	0.0001	0.0054	0.0179		0.7880		
3 vs. 4	0.5856	0.1214	0.2691	0.8976				
3 vs. 5	0.4113	0.0006	0.0009	0.1096			0.0474	
3 vs. 6	0.0001	0.0001	0.0001	0.0001				
3 vs. 7	0.6127	0.0770	0.0577	0.9843			0.1301	
4 vs. 5	0.6710	0.0076	0.1942	0.0771				
4 vs. 6	0.0001	0.0001	0.0024	0.0001				
4 vs. 7	0.9915	0.7148	0.7305	0.8613				
5 vs. 6	0.0001	0.0001	0.0001	0.0001	0.1261			
5 vs. 7	0.6888	0.0225	0.1463	0.0740		0.6132	0.0147	
6 vs. 7	0.0001	0.0001	0.0001	0.0001				
ALL	0.0001	0.0001	0.0001	0.0001	0.1261	0.8671	0.0017	0.0473

* Significance indicated for $P \leq 0.05$

variables on the model. The interaction terms in Table 15 did not lose significance, possibly, due to the large difference between the hull and deck means for Plant 2. The same can be said for the difference between the small parts and gelcoat means for Plants 3 and 6 in their influence on Table 16 statistics. The ANOVA for Table 17 was run to verify findings from the previous single factor test indicating a similarity among Plants 3, 4, and 7, with the resulting negation of the interaction effect due to exclusion of the rest of the plants. This indicates that these Plants 3, 4 and 7 are indeed similar in relative exposure among job categories.

TABLE 14

Interplant Styrene ANOVA Statistics for the Hull, Deck, Smallparts and Gelcoat Job Categories+

Source	DF	SS	F-Value	P
Job Category	3	14.8	23.15	0.0001
Plant	6	63.2	49.35	0.0001
Job Category*Plant	18	12.5	3.26	0.0001

Df = Degrees of Freedom
SS = Sum of Squares

TABLE 15

Interplant Styrene ANOVA Statistics for the Hull and Deck Job Categories +

Source	DF	SS	F-Value	P
Job Category	1	2.0	8.56	0.0037
Plant	6	59.2	41.06	0.0001
Job Category * Plant	6	6.1	4.24	0.0004

+ Significance indicated for $P \leq 0.05$

TABLE 16

Interplant Styrene ANOVA Statistics for the
Smallparts and Gelcoat Job Categories

Source	DF	SS	F Value	P
Job Category	1	1.2	8.45	0.0045
Plant	6	23.9	27.86	0.0001
Job Category * Plant	6	2.7	3.17	0.0068

TABLE 17

Interplant Styrene ANOVA Statistics for Plants 3, 4, and 7

Source	DF	SS	F Value	P
Job Category	3	5.17	16192	0.0001
Plant	2	0.76	3.74	0.0263
Job Category * Plant	6	0.42	0.69	0.6613

DISCUSSION

Industrial hygiene surveys were conducted in seven fiberglass reinforced plastic boat fabrication plants. From this standpoint the problem in this industry is in the control of worker exposure to styrene. The exposures across all plants were substantially variable, ranging from two to 183 ppm. Over 20 percent of the personal TWA exposures were over the 100 ppm eight-hour standard. Most of these predominated in a few plants.

An important trend was identified in the survey results and verified in the statistical analysis. It was shown that the mean exposures for the major job categories of hull, deck, small parts and gelcoat, were different from each other and that the magnitude of these averages followed resin consumption patterns. Styrene exposure is proportional to the amount of catalysed resin used in the job. When the chopper and hand lay-up counterparts in the hull, deck and small parts categories were compared the results were mixed. Exposures were not consistently higher for either task, and seemed to be related to the division of labor between them in the particular plant.

It was demonstrated in the survey results that for some plants dilution ventilation techniques can adequately control exposure to styrene. It has also been shown that plants with similar ventilation efficicney (implied by the overall plant styrene averages) have somewhat homogeneous exposures within job categories. This information has potential use for purposes of control. A technique that adequately controls a high exposure taks in one plant hopefully may be applied with equal effectiveness in a similar plant. A case in point would be Plants 2 and 5 using the method of fixed fans on the large hull molds for maintaining dilution air flow as is successfully done in Plant 6. Application of local exhaust ventilation in Plants 2 and 5 may also work if practical.

There were a few plants identified in this study as being homogeneous with respect to all job category exposures. These same plants exhibited overall inadequate control of exposure to styrene, which is in line with plants having similar ventilation efficiencies having similar exposures among the job categories. While they should individually be evaluated to identify unique plant specific problems, ventilation system redesign is most likely necessary for these plants.

CONTROL TECHNOLOGY

There are undesireable acute health effects caused from exposure to styrene and perhaps some chronic effects as yet unknown. It has been demonstrated that in the fiberglass reinforced plastic boat industry there are frequent worker exposures to styrene which are over current standards. Standards, however, should not be considered as dividing lines between safety and danger. It is generally more significant that when limits have been exceeded by a small amount there has been a failure of control than that one or more individuals have exceeded an agreed exposure.

There are two distinct conditions of exposure to be considered:

i) in which the source of exposure is not subject to control;

ii) in which occurrence of the exposure is foreseen and can be limited by control of the source and by development of satisfactory work practices.

In the FRP boat industry, condition "i" has been the prevailing one for years; condition "ii" is the one which, if a safe and healthy workplace is the goal, should be the aim of those in this industry now and in the future.

If a standard approach to control is looked for in this industry it would be dilution ventilation. In some instances it is shown that this is a satisfactory method of exposure control. This will always be an important feature in any control strategy employed for FRP processes, however, in the general case it will need to be merged with other control features. From experience gained during the surveys in this study, the following areas are recommended for future research and development to control styrene exposures in the FRP industry:

i) local ventilation;

ii) styrene suppressed resins;

iii) work practice guidelines.

<u>Local Ventilation</u>

Localized ventilation in general has the advantage of being more effective in removal of contaminants from the workplace. In operations where pieces are fabricated at fixed stations local exhaust in the form of hoods or booths is practical. However, the shapes and sizes of the pieces needing this type of control (hull molds in particular) have not lended themselves practically to application. An added factor is the mobile nature of most processes. The mold is moved from preparation, to gelcoat, to lay-up and then to a removal station.

There is one source of over-exposure that may be fitted with local ventilation. That is the stationary hull mold, as used in Plants 2, 5 and 6. In fact, since the survey was conducted at Plant 5, they have been experimenting with a local system for this purpose. The design includes an exhaust hood over the aft portion with fixed fans at the bow. The effect is a push-pull system sweeping air from bow to stern, while workers proceed to laminate counter current to airflow.

The major drawback to local ventilation is the retro-fitting into existing operations. The unique problems from plant to plant and the variety of operations and sizes of parts creates the difficulties inherent in the non-general solution to the problem.

<u>Styrene-suppressed Resins</u>

Recently the introduction of environmental resins, called styrene-suppressed resins, has been cause for optimism. The manufacturers claim less styrene evolution from these than from their general purpose resins. The mechanism which produces this effect is an additive which migrates to the surface of the resin after catalyst is added and forms a barrier preventing the evaporation of styrene (1).

Schumacher et al conducted laboratory and in-plant testing of two styrene-suppressed resins. In the laboratory tests one resin showed a reduction of about 30 percent of styrene in the vapor phase. The plant test showed no difference in employee exposure to styrene using another type of styrene-suppressed resin (49). Plant 5 has also reported testing of these types of resins subsequent to the NIOSH survey (50). Some results of this in plant testing have indicated reductions in styrene exposure of nearly fifty percent.

As with many innovations there are problems to be solved in regard to the use of styrene-supressed resins. Primarily there may be differences in the mechanical properties of finished plastic, such as reduced inter-laminar adhesion (1,50). Most agree that the development of a satisfactory resin of this type is a long way off.

Work Practice Guidelines

If properly conceived and implemented work practices can be very effective in exposure control, it is an opportunity for the workers to become directly involved. There are always choices to be made when performing job tasks, and education in the right choice at the right time can have an effect. Examples are things like spraying resin away from fellow workers and toward ventilation when possible; being certain that solvent containers are closed when appropriate; and minimizing overspray on to floors and walls. Other advantages to work practices are better house-keeping and more efficient operations.

A strategy for validating work practices in the reinforced plastics indsutry was applied by Conrad et al from the University of Kansas under a NIOSH contract (51). In this study the indices of personal exposures decreased by up to 74 percent following training for workers with the greatest exposures, and potentially the most control over their exposures.

The only drawback to work practice guidelines is that they are only as effective as the training program provided to teach them.

In summary, there is area for improvement in exposure control in most plants making reinforced plastic boats. In some cases the use of dilution ventilation is adequate. In general, however, improvement in present plant environments will be seen if dilution ventilation is augmented by one of or a combination of local ventilation, styrene-suppressed resins and work practices guidelines. Research in these areas can lead to optimal use of each of these features.

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A P P E N D I X   A

(SAMPLING RESULTS)

JOB CODE

Hullchop - Hull Chopper

Hullam - Hull Lay-up

Deckchop - Deck Chopper

Decklam - Deck Lay-up

Smptchop - Small Parts Chopper

Smptlam - Small Parts Lay-up

Gelcoat - Gelcoat

Strinst - Stringer Installation

Strilam - Stringer Lamination

Aftdeck - Aft Deck Lay-up

Flybridg - Fly Bridge Lay-up

Hardtop - Hard Top Lay-up

Fueltank - Fueltank Lay-up

Solelam - Sole Lay-up

Moldwork - Moldwork

ModelDev - Model Development

Overlay - Overlay

Foamchop - Foam & Chop

Forklift - Forklift

Cleanup - Clean up

Sander - Sander

Pastemix - Paste Mixer

Moldmask - Mold Masking

Area

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=1 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
1	1	34.00	8.22	0.348	HULLCHOP
2	1	40.30	10.60	0.414	HULLCHOP
3	2	50.00	12.10	0.512	HULLAM
4	2	50.90	14.40	0.522	HULLAM
5	2	61.30	18.10	0.630	HULLAM
6	2	29.80	16.90	0.315	HULLAM
7	2	59.20	12.00	0.604	HULLAM
8	2	67.00	48.00	0.718	HULLAM
9	2	61.00	25.60	0.636	HULLAM
10	2	65.80	33.20	0.691	HULLAM
11	2	65.30	48.00	0.701	HULLAM
12	2	54.80	17.10	0.565	HULLAM
13	2	47.70	67.80	0.544	HULLAM
14	2	23.20	29.00	0.261	HULLAM
15	2	82.70	23.50	0.851	HULLAM
16	2	65.90	16.40	0.675	HULLAM
17	2	49.00	19.80	0.509	HULLAM
18	2	12.00	45.00	0.165	HULLAM
19	4	28.70	68.60	0.355	DECKLAM
20	4	30.80	64.20	0.372	DECKLAM
21	4	53.60	93.40	0.629	DECKLAM
22	4	66.20	102.00	0.763	DECKLAM
23	4	46.50	42.30	0.507	DECKLAM
24	4	46.80	56.80	0.534	DECKLAM
25	4	44.20	126.00	0.568	DECKLAM
26	4	22.40	77.70	0.302	DECKLAM
27	4	12.30	43.80	0.167	DECKLAM
28	4	39.90	76.00	0.474	DECKLAM
29	4	18.00	57.00	0.237	DECKLAM
30	6	50.20	90.30	0.592	SMPTLAM
31	6	33.30	107.00	0.437	SMPTLAM
32	6	33.50	114.00	0.449	SMPTLAM
33	6	59.70	62.70	0.659	SMPTLAM
34	6	84.70	133.00	0.979	SMPTLAM
35	6	41.20	120.00	0.532	SMPTLAM
36	6	39.20	199.00	0.590	SMPTLAM
37	6	40.50	132.00	0.537	SMPTLAM
38	6	38.20	174.00	0.556	SMPTLAM
39	6	44.40	108.00	0.552	SMPTLAM
40	6	71.30	396.00	1.109	SMPTLAM
41	6	20.10	79.20	0.280	SMPTLAM
42	6	20.20	81.70	0.289	SMPTLAM
43	6	52.00	164.00	0.683	SMPTLAM
44	6	58.90	125.00	0.714	SMPTLAM
45	7	31.50	97.80	0.412	GELCOAT
46	7	44.90	56.90	0.506	GELCOAT
47	7	22.50	55.60	0.280	GELCOAT
48	7	37.80	49.30	0.427	GELCOAT
49	15	7.34	16.90	0.090	MOLDWORK
50	15	8.38	23.50	0.106	MOLDWORK
51	15	19.10	65.40	0.256	MOLDWORK
52	15	12.20	53.50	0.176	MOLDWORK

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=1 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
53	16	53.70	14.40	0.551	MODELDEV
54	24	8.62	3.09	0.086	AREA
55	24	35.10	3.95	0.355	AREA
56	24	31.70	3.74	0.320	AREA
57	24	25.90	11.70	0.270	AREA
58	24	30.10	10.40	0.311	AREA

------------------------------ PLANT=2 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
59	2	47.9	90.0	0.569	HULLAM
60	2	47.2	60.8	0.533	HULLAM
61	2	50.8	54.2	0.564	HULLAM
62	2	51.8	52.9	0.571	HULLAM
63	2	100.0	116.0	1.116	HULLAM
64	2	94.6	113.0	1.059	HULLAM
65	2	70.6	54.3	0.760	HULLAM
66	2	60.0	79.8	0.680	HULLAM
67	2	59.1	67.5	0.659	HULLAM
68	2	87.7	60.8	0.938	HULLAM
69	2	89.7	73.6	0.971	HULLAM
70	2	117.0	109.0	1.279	HULLAM
71	2	175.0	110.0	1.861	HULLAM
72	2	60.3	18.0	0.621	HULLAM
73	2	56.2	18.0	0.578	HULLAM
74	2	109.0	54.3	1.144	HULLAM
75	2	104.0	53.3	1.093	HULLAM
76	2	183.0	64.2	1.894	HULLAM
77	2	172.0	64.8	1.785	HULLAM
78	2	140.0	66.0	1.466	HULLAM
79	2	143.0	63.5	1.494	HULLAM
80	2	105.0	98.2	1.148	HULLAM
81	2	106.0	102.0	1.162	HULLAM
82	2	61.7	45.4	0.662	HULLAM
83	2	60.6	40.1	0.646	HULLAM
84	2	121.0	78.9	1.289	HULLAM
85	2	121.0	78.7	1.289	HULLAM
86	4	38.2	55.8	0.438	DECKLAM
87	4	40.0	59.0	0.459	DECKLAM
88	4	54.7	86.5	0.633	DECKLAM
89	4	24.3	36.0	0.279	DECKLAM
90	4	50.5	42.4	0.547	DECKLAM
91	4	52.0	55.7	0.576	DECKLAM
92	4	58.3	252.0	0.835	DECKLAM
93	4	31.4	31.0	0.345	DECKLAM
94	4	36.7	30.0	0.397	DECKLAM
95	4	48.7	112.0	0.599	DECKLAM
96	4	48.1	116.0	0.597	DECKLAM
97	4	53.1	212.0	0.743	DECKLAM
98	5	23.7	29.0	0.266	SMPTCHOP

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=2 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
99	5	46.8	71.1	0.539	SMPTCHOP
100	5	38.6	27.6	0.414	SMPTCHOP
101	6	30.7	70.8	0.378	SMPTLAM
102	6	25.5	53.0	0.308	SMPTLAM
103	6	27.6	55.3	0.331	SMPTLAM
104	6	39.7	81.1	0.478	SMPTLAM
105	6	36.7	42.9	0.410	SMPTLAM
106	7	29.4	17.3	0.311	GELCOAT
107	7	28.7	20.6	0.308	GELCOAT
108	8	33.6	45.6	0.382	STRINST
109	8	45.5	30.2	0.485	STRINST
110	8	156.0	37.4	1.597	STRINST
111	8	160.0	42.0	1.642	STRINST
112	8	108.0	23.5	1.104	STRINST
113	8	120.0	34.7	1.235	STRINST
114	8	111.0	23.6	1.134	STRINST
115	8	117.0	33.2	1.203	STRINST
116	16	63.1	31.1	0.622	MODELDEV
117	16	66.6	27.2	0.693	MODELDEV
118	16	88.5	45.2	0.930	MODELDEV
119	16	88.1	45.1	0.926	MODELDEV
120	17	27.4	210.0	0.484	OVERLAY
121	17	29.6	105.0	0.411	OVERLAY
122	17	10.4	23.7	0.132	OVERLAY
123	17	14.5	55.8	0.199	OVERLAY
124	17	43.4	61.8	0.496	OVERLAY
125	17	61.3	28.8	0.642	OVERLAY

------------------------------ PLANT=3 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
126	1	136.0	156.00	1.520	HULLCHOP
127	1	123.0	123.00	1.910	HULLCHOP
128	2	119.0	95.00	1.280	HULLAM
129	2	156.0	152.00	1.710	HULLAM
130	2	34.0	13.20	0.353	HULLAM
131	2	142.0	198.00	1.620	HULLAM
132	2	63.4	64.40	0.698	HULLAM
133	2	179.0	117.00	1.910	HULLAM
134	2	150.0	131.00	1.630	HULLAM
135	3	121.0	86.80	1.300	DECKCHOP
136	3	128.0	112.00	1.390	DECKCHOP
137	4	151.0	114.00	1.620	DECKLAM
138	4	146.0	95.40	1.560	DECKLAM
139	4	134.0	91.70	1.430	DECKLAM
140	4	114.0	69.40	1.210	DECKLAM
141	4	135.0	112.00	1.460	DECKLAM
142	4	133.0	89.30	1.420	DECKLAM
143	4	53.9	25.10	0.564	DECKLAM
144	5	58.6	63.00	0.649	SMPTCHOP

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

PLANT=3

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
145	5	94.1	126.00	1.170	SMPTCHOP
146	6	130.0	209.00	1.510	SMPTLAM
147	6	106.0	128.00	1.190	SMPTLAM
148	7	94.5	34.20	0.979	GELCOAT
149	7	72.6	79.80	0.806	GELCOAT
150	7	46.2	126.00	0.588	GELCOAT
151	7	60.6	29.50	0.636	GELCOAT
152	7	45.3	31.60	0.485	GELCOAT
153	15	49.0	23.90	0.514	MOLDWORK
154	15	40.0	18.50	0.418	MOLDWORK
155	15	37.1	27.80	0.399	MOLDWORK
156	15	19.2	20.40	0.212	MOLDWORK
157	15	18.2	40.00	0.222	MOLDWORK
158	15	27.4	32.00	0.306	MOLDWORK
159	15	43.6	56.30	0.492	MOLDWORK
160	15	52.6	42.60	0.569	MOLDWORK
161	19	18.8	9.77	0.286	FORKLIFT
162	19	20.1	15.20	0.216	FORKLIFT
163	20	30.4	25.30	0.329	CLEANUP
164	24	39.3	17.50	0.411	AREA
165	24	25.3	13.80	0.267	AREA

PLANT=4

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
166	2	80.5	57.7	0.863	HULLAM
167	2	116.0	74.7	1.240	HULLAM
168	2	114.0	79.0	1.220	HULLAM
169	2	99.4	86.9	1.080	HULLAM
170	2	78.7	50.4	0.837	HULLAM
171	2	102.0	62.7	1.080	HULLAM
172	2	80.3	71.8	0.875	HULLAM
173	2	96.4	148.0	1.110	HULLAM
174	2	71.4	87.3	0.801	HULLAM
175	2	74.8	81.3	0.829	HULLAM
176	2	87.6	98.8	0.975	HULLAM
177	2	146.0	95.7	1.560	HULLAM
178	2	124.0	84.9	1.320	HULLAM
179	2	89.4	63.1	0.957	HULLAM
180	2	106.0	75.8	1.140	HULLAM
181	2	102.0	54.4	1.070	HULLAM
182	2	53.8	81.0	0.619	HULLAM
183	2	93.4	71.1	1.000	HULLAM
184	2	153.0	91.6	1.620	HULLAM
185	2	142.0	80.4	1.500	HULLAM
186	2	126.0	81.9	1.340	HULLAM
187	2	138.0	87.4	1.470	HULLAM
188	2	85.9	51.0	0.910	HULLAM
189	2	88.7	83.4	0.970	HULLAM
190	2	99.4	90.2	1.080	HULLAM

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------- PLANT=4 --------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
191	2	108.0	91.7	1.170	HULLAM
192	2	98.9	76.2	1.060	HULLAM
193	4	88.2	146.0	1.040	DECKLAM
194	4	73.3	143.0	0.876	DECKLAM
195	4	74.2	94.3	0.846	DECKLAM
196	4	87.9	105.0	0.984	DECKLAM
197	4	126.0	181.0	1.440	DECKLAM
198	4	88.1	145.0	1.020	DECKLAM
199	4	105.0	121.0	1.170	DECKLAM
200	4	111.0	162.0	1.270	DECKLAM
201	4	57.9	105.0	0.684	DECKLAM
202	4	88.2	170.0	1.050	DECKLAM
203	4	79.4	165.0	0.959	DECKLAM
204	4	73.2	205.0	0.937	DECKLAM
205	4	94.3	147.0	1.090	DECKLAM
206	4	69.2	125.0	0.813	DECKLAM
207	4	88.5	127.0	1.010	DECKLAM
208	4	92.0	169.0	1.320	DECKLAM
209	4	118.0	135.0	1.320	DECKLAM
210	4	109.0	180.0	1.270	DECKLAM
211	4	100.0	237.0	1.240	DECKLAM
212	4	105.0	266.0	1.320	DECKLAM
213	4	71.8	102.0	0.820	DECKLAM
214	4	102.0	166.0	1.190	DECKLAM
215	4	158.0	227.0	1.810	DECKLAM
216	4	117.0	161.0	1.330	DECKLAM
217	4	63.8	76.0	0.714	DECKLAM
218	4	132.0	357.0	1.680	DECKLAM
219	5	66.1	46.1	0.707	SMPTCHOP
220	5	64.2	44.1	0.686	SMPTCHOP
221	7	103.0	81.5	1.110	GELCOAT
222	7	84.0	206.0	1.050	GELCOAT
223	7	58.0	219.0	0.799	GELCOAT
224	7	29.5	16.5	0.311	GELCOAT
225	7	57.7	62.6	0.640	GELCOAT
226	7	60.9	57.2	0.666	GELCOAT
227	7	51.0	46.2	0.556	GELCOAT
228	7	32.3	38.5	0.361	GELCOAT
229	7	66.1	49.8	0.711	GELCOAT
230	7	78.9	53.7	0.843	GELCOAT
231	7	102.0	70.7	1.090	GELCOAT
232	7	45.5	64.2	0.519	GELCOAT
233	16	45.0	86.6	0.537	MODELDEV
234	16	47.3	72.2	0.545	MODELDEV
235	24	60.0	83.6	0.684	AREA
236	24	60.5	66.7	0.672	AREA
237	24	47.4	76.1	0.550	AREA

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=5 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
238	2	77.0	46.00	0.816	HULLAM
239	2	84.9	60.30	0.909	HULLAM
240	2	101.0	83.50	1.090	HULLAM
241	2	91.0	75.30	0.985	HULLAM
242	2	96.6	67.40	1.030	HULLAM
243	2	75.0	31.70	0.782	HULLAM
244	2	111.0	45.00	1.150	HULLAM
245	2	91.3	76.40	0.989	HULLAM
246	2	94.1	45.00	0.986	HULLAM
247	2	90.6	92.90	0.999	HULLAM
248	2	103.0	79.00	1.110	HULLAM
249	2	78.1	48.40	0.829	HULLAM
250	2	104.0	42.50	1.080	HULLAM
251	2	106.0	64.60	1.120	HULLAM
252	2	91.0	54.30	0.964	HULLAM
253	4	19.6	7.02	0.203	DECKLAM
254	4	38.0	38.20	0.418	DECKLAM
255	4	53.6	39.70	0.576	DECKLAM
256	4	39.7	31.00	0.428	DECKLAM
257	4	120.0	24.80	1.220	DECKLAM
258	4	100.0	33.60	1.030	DECKLAM
259	4	154.0	26.30	1.550	DECKLAM
260	4	148.0	24.70	1.500	DECKLAM
261	4	64.8	49.80	0.698	DECKLAM
262	4	109.0	76.50	1.170	DECKLAM
263	4	46.2	43.10	0.505	DECKLAM
264	4	89.0	62.00	0.952	DECKLAM
265	4	17.1	10.70	0.182	DECKLAM
266	6	41.4	66.40	0.480	SMPTLAM
267	6	41.2	140.00	0.522	SMPTLAM
268	6	33.0	62.80	0.393	SMPTLAM
269	6	52.9	112.00	0.641	SMPTLAM
270	6	35.2	75.80	0.428	SMPTLAM
271	6	77.0	111.00	0.881	SMPTLAM
272	6	24.2	87.00	0.329	SMPTLAM
273	6	49.2	70.00	0.562	SMPTLAM
274	6	39.3	120.00	0.513	SMPTLAM
275	6	35.9	104.00	0.363	SMPTLAM
276	6	45.8	60.00	0.518	SMPTLAM
277	6	54.0	36.10	0.576	SMPTLAM
278	7	42.8	11.70	0.440	GELCOAT
279	7	41.1	16.20	0.427	GELCOAT
280	7	18.9	8.14	0.270	GELCOAT
281	7	61.9	26.20	0.645	GELCOAT
282	7	57.7	6.90	0.583	GELCOAT
283	9	40.3	14.90	0.418	STRILAM
284	9	72.6	79.10	0.805	STRILAM
285	10	45.4	53.10	0.507	AFTDECK
286	10	98.3	126.00	1.110	AFTDECK
287	10	66.4	74.50	0.783	AFTDECK
288	10	67.2	60.20	0.732	AFTDECK
289	10	25.9	54.20	0.313	AFTDECK

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=5 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
290	10	75.40	92.90	0.847	AFTDECK
291	10	25.00	49.80	0.300	AFTDECK
292	11	52.20	37.60	0.560	FLYBRIDG
293	11	55.40	45.00	0.599	FLYBRIDG
294	11	33.70	46.30	0.383	FLYBRIDG
295	13	76.20	214.00	0.976	FUELTANK
296	13	37.90	85.60	0.435	FUELTANK
297	13	48.30	48.10	0.531	FUELTANK
298	21	77.30	54.00	0.827	SANDER
299	22	21.40	20.50	0.234	PASTEMIX
300	24	4.05	4.09	0.044	AREA
301	24	35.30	80.20	0.433	AREA
302	24	66.00	60.00	0.666	AREA
303	24	9.90	21.30	0.120	AREA
304	24	12.80	11.90	0.140	AREA
305	24	20.40	31.10	0.235	AREA
306	24	2.14	2.30	0.023	AREA
307	24	22.10	34.90	0.256	AREA
308	24	12.50	38.00	0.163	AREA

------------------------------ PLANT=6 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
309	2	60.30	108.00	0.711	HULLAM
310	2	33.60	85.30	0.421	HULLAM
311	2	49.30	198.00	0.577	HULLAM
312	2	49.50	167.00	0.693	HULLAM
313	2	67.80	89.90	0.768	HULLAM
314	2	51.20	77.80	0.590	HULLAM
315	2	45.60	270.00	0.726	HULLAM
316	2	63.00	113.00	0.743	HULLAM
317	2	9.64	81.50	0.178	HULLAM
318	2	62.20	183.00	0.805	HULLAM
319	2	32.00	91.30	0.411	HULLAM
320	2	25.10	116.00	0.367	HULLAM
321	2	33.80	74.30	0.412	HULLAM
322	2	75.80	214.00	0.972	HULLAM
323	2	32.30	101.00	0.424	HULLAM
324	2	34.60	84.10	0.430	HULLAM
325	2	25.80	49.70	0.308	HULLAM
326	2	27.20	12.70	0.285	HULLAM
327	2	33.60	2.32	0.338	HULLAM
328	2	40.10	21.60	0.423	HULLAM
329	2	57.10	18.30	0.589	HULLAM
330	2	32.80	9.56	0.338	HULLAM
331	2	22.80	38.20	0.266	HULLAM
332	2	34.20	19.00	0.361	HULLAM
333	2	15.40	7.62	0.162	HULLAM
334	2	72.80	113.00	0.841	HULLAM
335	2	121.00	288.00	1.500	HULLAM

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=6 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
336	2	14.40	40.80	0.185	HULLAM
337	2	42.10	31.60	0.453	HULLAM
338	2	34.20	53.20	0.395	HULLAM
339	2	12.80	11.40	0.128	HULLAM
340	2	18.00	103.00	0.283	HULLAM
341	2	6.89	2.75	0.692	HULLAM
342	2	48.40	93.70	0.578	HULLAM
343	2	1.56	2.00	0.018	HULLAM
344	2	23.40	18.20	0.252	HULLAM
345	2	12.90	231.00	0.360	HULLAM
346	2	18.50	18.80	0.204	HULLAM
347	2	29.80	53.50	0.252	HULLAM
348	2	15.90	43.30	0.202	HULLAM
349	2	23.30	369.00	0.602	HULLAM
350	2	43.70	35.30	0.472	HULLAM
351	2	23.00	18.90	0.249	HULLAM
352	2	3.02	0.54	0.030	HULLAM
353	2	18.70	24.30	0.211	HULLAM
354	2	12.80	5.22	0.133	HULLAM
355	4	73.70	110.00	0.847	DECKLAM
356	4	51.70	96.60	0.614	DECKLAM
357	4	43.30	60.80	0.494	DECKLAM
358	4	21.70	66.40	0.283	DECKLAM
359	4	53.20	33.20	0.565	DECKLAM
360	4	37.50	19.50	0.395	DECKLAM
361	4	37.10	49.90	0.421	DECKLAM
362	4	53.50	8.72	0.544	DECKLAM
363	4	31.70	28.40	0.345	DECKLAM
364	4	32.30	24.00	0.347	DECKLAM
365	4	78.90	33.70	0.823	DECKLAM
366	4	52.00	9.51	0.520	DECKLAM
367	4	22.40	9.43	0.233	DECKLAM
368	4	34.10	36.70	0.378	DECKLAM
369	4	43.50	24.80	0.460	DECKLAM
370	4	17.70	9.78	0.187	DECKLAM
371	4	20.20	12.70	0.215	DECKLAM
372	4	15.20	10.10	0.162	DECKLAM
373	4	27.40	8.79	0.283	DECKLAM
374	4	42.00	41.20	0.461	DECKLAM
375	4	30.30	21.00	0.324	DECKLAM
376	4	19.50	49.10	0.245	DECKLAM
377	6	31.70	77.60	0.395	SMPTLAM
378	6	43.40	144.00	0.578	SMPTLAM
379	6	40.30	116.00	0.519	SMPTLAM
380	6	38.40	44.80	0.429	SMPTLAM
381	6	37.10	29.50	0.371	SMPTLAM
382	6	39.00	58.30	0.448	SMPTLAM
383	6	45.90	72.00	0.531	SMPTLAM
384	6	16.40	16.00	0.180	SMPTLAM
385	6	30.20	41.20	0.343	SMPTLAM
386	6	26.00	51.20	0.311	SMPTLAM
387	6	35.90	25.30	0.384	SMPTLAM

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=6 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
388	6	27.90	22.60	0.302	SMPTLAM
389	6	14.00	6.11	0.146	SMPTLAM
390	7	11.80	30.10	0.148	GELCOAT
391	7	20.40	1.22	0.204	GELCOAT
392	7	13.50	13.60	0.148	GELCOAT
393	7	12.20	10.90	0.133	GELCOAT
394	7	8.82	22.40	0.121	GELCOAT
395	7	7.23	177.00	0.249	GELCOAT
396	7	14.30	5.13	0.148	GELCOAT
397	7	5.30	10.90	0.000	GELCOAT
398	7	15.20	11.40	0.163	GELCOAT
399	11	75.60	82.40	0.838	FLYBRIDG
400	11	27.40	23.90	0.298	FLYBRIDG
401	11	16.80	47.30	0.215	FLYBRIDG
402	11	50.20	90.00	0.592	FLYBRIDG
403	11	64.70	16.90	0.664	FLYBRIDG
404	11	10.40	3.89	0.143	FLYBRIDG
405	11	49.40	21.20	0.515	FLYBRIDG
406	12	19.70	49.90	0.247	HARDTOP
407	12	31.60	34.80	0.351	HARDTOP
408	12	43.50	2.22	0.435	HARDTOP
409	12	33.70	21.90	0.359	HARDTOP
410	13	11.70	26.80	0.144	FUELTANK
411	13	43.20	67.70	0.500	FUELTANK
412	13	21.60	13.40	0.229	FUELTANK
413	13	23.20	46.60	0.279	FUELTANK
414	13	9.27	1.85	0.093	FUELTANK
415	14	62.90	78.00	0.707	SOLELAM
416	14	57.50	124.00	0.699	SOLELAM
417	14	54.80	113.00	0.661	SOLELAM
418	14	43.60	110.00	0.546	SOLELAM
419	14	79.70	39.70	0.797	SOLELAM
420	14	29.50	12.50	0.307	SOLELAM
421	14	34.20	18.40	0.360	SOLELAM
422	14	34.80	11.50	0.360	SOLELAM
423	14	22.80	12.00	0.240	SOLELAM
424	14	25.60	15.00	0.271	SOLELAM
425	24	11.20	39.80	0.190	AREA
426	24	2.72	0.41	0.272	AREA
427	24	14.90	0.67	0.149	AREA
428	24	7.69	3.45	0.080	AREA
429	24	7.49	5.97	0.081	AREA
430	24	7.15	27.80	0.100	AREA
431	24	9.56	9.17	0.105	AREA
432	24	3.19	0.50	0.319	AREA
433	24	9.78	35.10	0.000	AREA

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=7 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
434	1	72.2	31.6	0.754	HULLCHOP
435	1	73.9	44.2	0.783	HULLCHOP
436	1	84.2	52.5	0.894	HULLCHOP
437	1	106.0	41.8	1.130	HULLCHOP
438	1	105.0	92.6	0.699	HULLCHOP
439	1	65.6	33.0	0.689	HULLCHOP
440	2	105.0	81.3	1.130	HULLAM
441	2	125.0	101.0	1.350	HULLAM
442	2	126.0	70.5	1.330	HULLAM
443	2	120.0	88.2	1.290	HULLAM
444	2	85.9	69.3	0.928	HULLAM
445	2	97.7	53.4	1.030	HULLAM
446	2	103.0	70.8	1.100	HULLAM
447	2	84.9	62.5	0.911	HULLAM
448	2	109.0	87.7	1.180	HULLAM
449	2	127.0	36.4	1.310	HULLAM
450	2	136.0	95.2	1.460	HULLAM
451	2	101.0	94.6	1.100	HULLAM
452	3	54.6	53.1	0.599	DECKCHOP
453	3	69.2	30.6	0.723	DECKCHOP
454	3	52.5	58.4	0.583	DECKCHOP
455	3	68.5	69.7	0.755	DECKCHOP
456	3	36.0	25.8	0.386	DECKCHOP
457	3	48.5	41.4	0.526	DECKCHOP
458	3	51.0	49.8	0.560	DECKCHOP
459	3	103.0	63.3	1.090	DECKCHOP
460	3	87.2	52.1	0.924	DECKCHOP
461	4	113.0	97.5	1.230	DECKLAM
462	4	101.0	90.4	1.100	DECKLAM
463	4	125.0	123.0	1.370	DECKLAM
464	4	107.0	93.7	1.160	DECKLAM
465	4	119.0	82.9	1.270	DECKLAM
466	4	114.0	89.2	1.230	DECKLAM
467	4	85.6	58.0	0.914	DECKLAM
468	4	111.0	112.0	1.220	DECKLAM
469	4	130.0	98.5	1.400	DECKLAM
470	4	131.0	79.9	1.390	DECKLAM
471	4	160.0	101.0	1.700	DECKLAM
472	4	128.0	79.4	1.360	DECKLAM
473	7	38.8	40.7	0.429	GELCOAT
474	7	64.7	71.3	0.718	GELCOAT
475	7	87.1	122.0	0.993	GELCOAT
476	7	35.2	77.6	0.430	GELCOAT
477	7	55.5	68.6	0.624	GELCOAT
478	7	60.6	92.6	0.699	GELCOAT
479	7	94.5	187.0	1.130	GELCOAT
480	7	85.1	79.6	0.931	GELCOAT
481	9	76.0	61.6	0.822	STRILAM
482	9	48.9	48.2	0.537	STRILAM
483	9	66.6	51.2	0.717	STRILAM
484	9	46.7	62.8	0.530	STRILAM
485	9	69.6	38.6	0.735	STRILAM

APPENDIX A
FIBERGLASS REINFORCED PLASTIC BOAT PLANT
SURVEY DATA

------------------------------ PLANT=7 ------------------------------

OBS	JOB	STYRENE	ACETONE	COMBTLV	NAME
486	9	50.5	43.50	0.549	STRILAM
487	18	26.8	18.40	0.286	FOAMCHOP
488	18	30.1	32.90	0.334	FOAMCHOP
489	18	33.5	55.10	0.390	FOAMCHOP
490	18	29.0	44.10	0.334	FOAMCHOP
491	18	24.1	42.20	0.283	FOAMCHOP
492	23	15.0	21.40	0.172	MOLDMASK
493	24	0.4	7.09	0.011	AREA
494	24	28.0	32.20	0.312	AREA
495	24	45.4	37.10	0.491	AREA
496	24	57.4	41.20	0.615	AREA
497	24	67.0	74.60	0.745	AREA
498	24	70.0	32.80	0.803	AREA
499	24	62.0	61.80	0.686	AREA
500	24	53.8	33.00	0.571	AREA

A P P E N D I X   B

(JOB DICTIONARY)

APPENDIX B

Job Dictionary

1. Hull Chopper - A job whose main task involves the application of a catalyzed resin, chopped fiberglass mixture to the hull mold using a chopper gun.

2. Hull Lay-up - A job whose tasks involve hand manipulation of resin, fiberglass and their composite on the hull mold, including squeegeeing and roll-out.

3. Deck Chopper - A job whose main task involves the application of a catalyzed resin, chopper fiberglass mixture to the deck mold using a chopper-gun.

4. Deck Lay-up - A job whose main tasks involve hand manipulation of resin, fiberglass and their composite on the deck mold, including squeegeeing, and roll-out.

5. Smallparts Chopper - A job whose main taks involves the application of a catalyzed resin, chopper fiberglass mixture to various small parts molds using a chopper-gun.

6. Smallparts Lay-up - A job whose tasks involve hand manipulation of catalyzed resin, fiberglass and their composite on various small parts molds, including squeeging and roll-out.

7. Gelcoat - A job whose taks involves the applications of gelcoat, a pigmented polyester resin, to all molds as a first step in the fabrication procedure.

8. Stringer Installation - A job involving the fixing of longitudinal supports to the bottom of a hull with resin and fiberglass composite.

9. Stringer Lamination - A job involving the fabrication of hull stringers from resin and fiberglass composite.

10. Aft Deck Lay-up - A job involving the hand manipulation of catalyzed resin, fiberglass and other composite on the aft deck mold, including squeegeeing and roll-out.

11. Fly Bridge Lay-Up - A job involving the hand manipulation of catalyzed resin, fiberglass and their composite on the flying bridge mold, including squeegeeing and roll-out.

12. Hardtop Lay-up - A job involving the hand manipulation of catalyzed resin, fiberglass and their composite on the hardtop mold, including squeegeeing and roll-out.

13. Fueltank Lay-up - A job involving the hand manipulation of catalyzed resin, fiberglass and their composite on the Fueltank Mold, including squeegeeing and roll-out.

14. Sole Lay-up - A job involving the hand manipulation of catalyzed resin, fiberglass and their composite on the sole lay-up mold, including squeegeeing and roll-out.

15. Moldwork - A job involving preparation of various molds for lamination by polishing and waxing. May do some repair work.

16. Model Development - A job which involves the hand lay-up of catalyzed resin and fiberglass over a wooden model.

17. Overlay - A job involving the attachment of various support and structural pieces to the boat during assembly.

18. Foam and Chop - A job involving the attachment of a false bottom using chopped fiberglass and resin, drilling holes in this falsebottom, and pouring a methylene bisphenyl isocyanate (MDI) foam beneath it.

19. Forklift - Forklift driver

20. Clean-up - A janitorial job.

21. Sander - A job involving the smoothing of edges on finished small parts.

22. Paste Mixer - A job involving the compounding of chopped fiberglass and catalyzed resin into a paste, used for stringer installation.

23. Mold Masking - The application of masking tape to the waxed hull mold for detailing the gelcoat.

A P P E N D I X C
(Descriptive Statistics)

TABLE C-1

Plant 1

Job Styrene and Acetone Descriptive Statistics

		Styrene			Acetone			Combined TLV		
JOB	N	Geometric Mean (ppm)	CV(%)	Range (ppm)	Geometric Mean (ppm)	CV(%)	Range (ppm)	Mean (ppm)	CV(%)	Range (ppm)
Hull Chopper	2	37.0	8.5	34.0-40.3	9.3	12.7	8.2-10.6	.38	.05	.35-.41
Hull Lay-Up	16	48.5	12.2	12.0-82.7	24.3	13.4	12.0-67.8	.56	.18	.16-.85
Deck Lay-up	11	33.5	15.4	12.3-66.2	69.7	10.2	42.3-126	.45	.18	.17-.76
Small Parts Chopper	15	42.6	10.4	20.1-84.7	125	11.5	67.2-396	.60	.22	.28-1.1
Gelcoat	4	33.1	14.8	22.5-44.9	62.5	15.2	49.3-97.8	.41	.09	.28-.51
Moldwork	4	10.9	21.5	7.3-19.1	34.3	32.4	16.9-65.4	.16	.08	.09-.26
Model Development	1	53.7	--	---	14.4	--	---	.55	--	---
ALL	53	37.3	7.8	7.3-84.7	50.6	12.0	8.2-396	.50	.21	.09-1.1

TABLE C-2

Plant 2

Job Styrene and Acetone Descriptive Statistics

		Styrene			Acetone			Combined TLV		
JOB	N	Geometric Mean (ppm)	CV(%)	Range (ppm)	Geometric Mean (ppm)	CV(%)	Range (ppm)	Mean (ppm)	CV(%)	Range (ppm)
Hull Lay-up	27	88.2	8.1	47.2-183	64.1	9.0	18.0-116	1.0	.42	.53-1.9
Deck Lay-up	12	43.4	7.6	24.3-58.3	70.7	20.6	30.0-252	.54	.16	.28- .84
Small Parts Chopper	3	35.0	20.2	23.7-46.8	38.5	30.8	27.6-71.1	.41	.14	.27- .54
Small Parts Lay-up	5	31.6	8.4	25.5-39.7	59.1	11.2	42.9-81.1	.38	.07	.31- .48
Gelcoat	2	29.0	12.0	28.7-29.4	18.9	8.7	17.3-20.6	.31	.00	---
Stringer Installation	8	94.6	20.2	33.6-160	32.9	8.6	23.5-45.6	1.1	.46	.38-1.6
Model Development	4	75.6	9.0	63.1-88.5	36.2	13.0	27.2-45.2	.79	.16	.62- .93
Overlay	6	26.2	27.1	10.4-61.3	61.1	33.1	23.7-210	.39	.19	.13- .64
All	67	59.8	7.6	10.4-183	53.3	7.2	17.3-252	.78	.43	.13-1.9

TABLE C-3

Plant 3

Job Styrene and Acetone Descriptive Statistics

JOB	N	Styrene Geometric Mean (ppm)	Styrene CV(%)	Styrene Range (ppm)	Acetone Geometric Mean (ppm)	Acetone CV(%)	Acetone Range (ppm)	Combined TLV Mean (ppm)	Combined TLV CV(%)	Combined TLV Range (ppm)
Hull Chopper	2	129	5.0	123-136	139	11.9	123-156	1.7	.28	1.5-1.9
Hull Lay-up	7	106	22.9	34.0-179	86.8	34.1	13.2-198	1.3	.58	.35-1.9
Deck Chopper	2	124	2.8	121-128	98.6	12.7	86.8-112	1.3	.06	1.3-1.4
Deck Lay-up	7	118	13.5	53.9-151	77.9	20.0	25.1-114	1.3	.36	.56-1.6
Small Parts Chopper	2	74.3	23.7	58.6-94.1	89.1	34.6	63.0-126	.911	.37	.65-1.2
Small Parts Lay-up	2	117	10.2	106-130	164	24.5	128-209	1.4	.23	1.2-1.5
Gelcoat	5	61.4	13.9	45.3-94.5	50.2	29.2	29.5-126	.70	.19	.48-.98
Moldwork	8	33.5	14.5	18.2-52.6	30.6	13.6	18.5-56.3	.39	.13	.21-.57
Forklift	2	19.4	3.3	18.8-20.1	12.2	22.1	9.8-15.2	.25	.05	.22-.29
Cleanup	1	30.4	--	---	25.3	--	---	.33	--	---
All	38	70.3	11.4	18.2-179	59.3	13.4	9.8-209	.96	.55	.21-1.9

TABLE C-4

Plant 4

Job Styrene and Acetone Descriptive Statistics

JOB	N	Styrene Geometric Mean (ppm)	Styrene CV(%)	Styrene Range (ppm)	Acetone Geometric Mean (ppm)	Acetone CV(%)	Acetone Range (ppm)	Combined TLV Mean (ppm)	Combined TLV CV(%)	Combined TLV Range (ppm)
Hull Lay-up	27	99.3	4.6	53.8-153	77.9	4.4	50.4-148	1.1	.25	.62-1.6
Deck Lay-up	26	92.5	4.7	57.9-158	153	6.7	76-357	1.1	.28	.68-1.8
Small Parts Chopper	2	65.1	1.4	64.2-66.1	45.1	2.2	44.1-46.1	.70	.02	.69- .71
Gelcoat	12	59.7	11.6	29.5-103	63.9	20.0	16.5-219	.72	.27	.31-1.1
Model Development	2	46.2	2.5	45.0-47.3	79.0	9.1	72.2-86.6	.54	.00	---
All	69	85.5	29.5-158		95.6	6.4	16.5-357	1.0	.31	.31-1.8

TABLE C- 5

Plant 5

Job Styrene and Acetone Descriptive Statistics

		Styrene			Acetone			Combined TLV		
JOB	N	Geometric Mean (ppm)	CV(%)	Range (ppm)	Geometric Mean (ppm)	CV(%)	Range (ppm)	Mean (ppm)	CV(%)	Range (ppm)
Hull Lay-up	15	92.3	13.1	75.0-111	58.3	7.9	31.7-92.9	.99	.11	.78-1.2
Deck Lay-up	13	62.4	20.0	17.1-154	30.4	18.3	7.0-76.5	.80	.47	.18-1.6
Small Parts Lay-up	12	42.4	8.4	24.2-77.0	81.8	11.0	36.1-140	.52	.15	.33- .88
Gelcoat	5	41.2	21.1	18.9-61.9	12.3	24.0	6.9-26.2	.47	.15	.27- .64
Stringer Lamination	2	54.1	29.4	40.3-72.6	34.3	83.5	14.9-79.1	.61	.27	.42- .80
Aft Deck Lay-up	7	51.6	20.2	25.0-98.3	69.1	13.0	49.8-126	.66	.30	.30-1.1
Fly Bridge Lay-up	3	46.0	15.7	33.7-55.4	42.8	6.5	37.6-46.3	.51	.12	.38- .60
Fueltank Lay-up	3	51.8	20.5	37.9-76.2	95.9	43.5	48.1-218	.65	.29	.44- .98
Sander	1	77.3	--	---	54.0	--	---	.83	--	---
Paste Mixer	1	21.4	--	---	20.5	--	---	.23	--	---
All	62	57.8	6.7	17.1-154	47.6	9.2	6.8-214	.71	.32	.18-1.6

TABLE C-6

Plant 6

Job Styrene and Acetone Descriptive Statistics

JOB	N	Styrene Geometric Mean (ppm)	Styrene CV(%)	Styrene Range (ppm)	Acetone Geometric Mean (ppm)	Acetone CV(%)	Acetone Range (ppm)	Combined TLV Mean (ppm)	Combined TLV CV(%)	Combined TLV Range (ppm)
Hull Lay-up	46	27.4	12.0	1.6-121	41.1	21.3	.5-369	.44	.28	.02-1.5
Deck Lay-up	22	34.6	9.7	15.2-78.9	25.7	17.2	8.7-110	.42	.18	.16-.85
Small Parts Lay-up	13	31.1	10.0	14.0-45.9	40.7	23.7	6.1-144	.38	.13	.15-.58
Gelcoat	9	11.2	13.8	5.3-20.4	13.4	44.6	1.2-177	.15	.07	.00-.25
Fly Bridge Lay-up	7	34.5	28.0	10.4-75.6	27.4	41.0	3.9-90.0	.47	.26	.14-.84
Hard Top Lay-up	4	30.9	16.5	19.7-43.5	17.0	70.0	2.2-49.9	.35	.08	.25-.44
Fuel Tank Lay-up	5	18.8	27.2	9.3-43.2	18.4	63.6	1.8-67.7	.25	.16	.09-.50
Sole Lay-up	10	41.2	13.2	22.8-79.7	34.3	32.5	11.5-124	.14	.10	.00-.32
All	116	28.1	6.4	1.6-121	31.0	11.5	.5-369	.40	.23	.00-1.5

TABLE C-7

Plant 7

Job Styrene and Acetone Descriptive Statistics

JOB	N	Styrene Geometric Mean (ppm)	Styrene CV(%)	Styrene Range (ppm)	Acetone Geometric Mean (ppm)	Acetone CV(%)	Acetone Range (ppm)	Combined TLV Mean (ppm)	Combined TLV CV(%)	Combined TLV Range (ppm)
Hull Chopper	6	83.0	8.2	65.6-106	45.9	16.0	31.6-92.6	.83	.17	.69-1.1
Hull Lay-up	12	109	4.5	84.9-136	73.2	8.4	36.4-101	1.2	.17	.91-1.5
Deck Chopper	9	60.5	10.7	36.0-103	47.2	11.0	25.8-69.7	.68	.22	.39-1.1
Deck Lay-up	12	117	4.5	85.6-160	90.6	5.5	58.0-123	1.3	.19	.91-1.7
Gelcoat	8	61.6	13.0	35.2-94.5	84.5	15.8	40.7-187	.74	.26	.43-1.1
Stringer Lamination	6	58.6	46.7-76.0		50.2	7.8	38.6-62.8	.65	.12	.53- .82
Foam & Chop	5	28.5	5.5	24.1-33.5	36.2	18.8	18.4-55.1	.32	.04	.28- .39
Mold Masking	1	15.0	--	---	21.4	--	---	.17	--	---
All	59	73.8	15.0-160		61.7	6.0	18.4-187	.88	.36	.17-1.7

TABLE C- 8

Job Styrene and Acetone Descriptive Statistics

		Styrene			Acetone			Combined TLV		
PLANT	N	Geometric Mean (ppm)	CV(%)	Range (ppm)	Geometric Mean (ppm)	CV(%)	Range (ppm)	Mean (ppm)	CV(%)	Range (ppm)
1	53	37.3	7.8	7.3-84.7	50.6	12.0	8.2-396	.50	.21	.09-1.1
2	67	59.8	7.6	10.4-183	54.3	7.2	17.3-252	.78	.43	.13-1.9
3	38	70.3	11.4	18.2-179	59.3	13.4	9.8-209	.96	.55	.21-1.9
4	69	85.5	4.1	29.5-158	95.6	6.4	16.5-357	1.0	.31	.31-1.8
5	62	57.8	6.7	17.1-154	47.6	9.2	6.9-214	.71	.32	.18-1.6
6	116	28.1	6.4	1.6-121	31.0	11.5	.5-369	.40	.23	.00-1.5
7	59	73.8	6.7	15.0-160	61.7	6.0	18.4-187	.88	.36	.17-1.7
All	464	51.3	3.3	1.6-183	51.2	4.2	.5-396	.71	.41	.00-1.9

TABLE C- 9

Area Sample Descriptive Statistics By Plant

PLANT	N.	Styrene: Geometric Mean (ppm)	Styrene: CV(%)	Styrene: Range (ppm)	Acetone: Geometric Mean (ppm)	Acetone: CV(%)	Acetone: Range (ppm)	Combined TLV: Mean (ppm)	Combined TLV: CV(%)	Combined TLV: Range (ppm)
1	5	23.7	25.8	8.6-35.1	5.6	28.0	3.1-11.7	.27	.11	.09- .36
3	2	31.5	22.0	25.3-39.3	15.5	11.9	13.8-17.5	.34	.10	.27- .41
4	9	55.6	8.0	47.4-60.5	75.1	6.5	66.7-83.6	.64	.07	.55- .68
5.	9	13.4	35.0	2.1-66.0	19.8	40.0	2.3-80.2	.23	.20	.02- .67
6	9	7.2	18.7	2.7-14.9	4.6	61.4	.4-39.8	.14	.10	.00- .32
7	8	28.7	61.9	.4-70.0	33.9	24.9	7.1-74.6	.53	.26	.01- .80

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