IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR FIBER REINFORCED PLASTICS INDUSTRY

AT

AMF HATTERAS YACHTS, NEW BERN DIVISION
NEW BERN, NORTH CAROLINA

REPORT WRITTEN BY:

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May 25, 1984

REPORT NO. 107-24a

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED: AMF Hatteras Yachts-New Bern Facility
110 North Glenburnie Road,
PO Box 2324
New Bern, North Carolina 28561

SIC CODE: 3079 Miscellaneous Plastics Products

SURVEY DATE: September 9, 1983

SURVEY CONDUCTED BY: William F. Todd, Dennis O'Brien, Alfred Amendola, and Kenneth Martinez, NIOSH, DPSE, ECTB

EMPLOYER REPRESENTATIVES CONTACTED: Mr. Alton Herndon, Operations Manager; Tom Pugliese, Plant Superintendent; Don Farlow, Plant Engineer; Pat Gorden, Safety Coordinator; Bob Looney, General Supervisor; and Russ Norris, Plant Manager Phone (919) 633-3101

EMPLOYEE REPRESENTATIVES CONTACTED: None

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I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH resesearch deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial processes, and specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

This study is being performed to collect information on the effective controls for styrene vapors in small parts manufacture in the fiber reinforced plastics (FRP) industry. Participating firms and the industry will benefit by demonstrating that the industry can and will meet the levels of control required by OSHA. Several plants will be selected which have the best known engineering controls. These plants will be studied in-depth to determine the level of control and the detailed performance of the control system. Work practices, monitoring, and the use of personal protective equipment by plant personnel will be observed.

II. PLANT AND PROCESS DESCRIPTION

Plant Description: Hatteras Yachts began operation in 1959 in High Point, North Carolina. The skilled craftsmen affiliated with the furniture industry proved readily adaptable to producing the fine interiors of luxury yachts and the detailed carpentry for making boat molds and fitting out hulls with bulkheads and bracing. The company expanded to a new production facility in New Bern, North Carolina where large yachts, from 53 feet to 77 feet in length are manufactured. The Highpoint, North Carolina operation produces boats of 32 feet to 50 feet in length. The Hatteras Yachts Company produces 60 to 100 boats per year. The buildings at the New Bern facility are fairly new, the plant having been built in 1969. The small parts department ventilation system was completed in 1982. There are 680 employees at the plant. Seventeen of these employees work in the small parts department, 10 or less in the small parts lamination area. The plant is located on an irregular 95 acre tract. Five and 1/2 of these acres are currently used for the main plant, which measures approximately 400 feet by 600 feet. The long axis of the plant lies along an east west line, with lamination performed at the east end, and fully assembled yachts emerging from the west end. Other buildings on the property are the paint shop, electrical check facility, and the launch and make ready facility.

Process Description: The small parts department in this plant is responsible for the lamination of flying bridges, shower stalls, deck lounges, hatches, fuel tanks, water tanks, battery boxes, pulpits, seat lids, and hull stiffeners. Shower stalls and flying bridges are not laminated in the small parts area; hence they were not included in this study. The molds for these items are evenly distributed thoughout the work area as shown in Figure 1, which, as depicted, is further subdivided into tank and miscellaneous small parts areas. The parts are all prepared by hand lamination with the exception of some resin transfer molding in the southwest corner of the production area. This production area measures 210 feet by 61 feet, has a work area of 10,700 square feet and additional facilities, office and storage area of 2110 square feet. With the 15 foot ceiling, the work area has a volume of 160,560 cubic feet. The small parts production area ventilation system was redesigned in 1982 to increase the effectiveness in removing styrene from the work area. This was done by installing three ventilation booths, which are shown in Figures 2, 3, and 4. The location of these booths is shown in Figure 1.

Potential Hazards: The most serious hazard in a FRP plant is the styrene because of its volatility and the volume of its use. Other materials which may pose hazards to the workers include the methyl ethyl ketone peroxide (MEKP) catalyst, acetone, and Hatteras Cleaner, a solvent containing o-chlorotoluene. The styrene and acetone are primarily absorbed by breathing the vapors although each can be absorbed through the skin upon contact. MEKP can cause skin burns and eye injuries. The exposure to styrene vapors occurs in the lamination area. Exposure to acetone can occur during the purging of the spray nozzles, transferring acetone from drums, or when cleaning roll-out hardware. The exposure to MEKP can occur to those persons mixing resins and to those exposed to the resin spray mist. A summary of the legal and recommended levels for the previously mentioned substances and their health effects appear in Table I.

Table I. Summary of Hazards Associated with the production of small parts in the FRP industry

Materials or Agents	PEL[1] (ppm)	TLV[2] (ppm)	NIOSH[3] Recommended level (ppm)	Major[4] Health Effects
Styrene	100	50	50	Rapid CNS depression from high exposure (10,000 ppm); skin irritation
Methyl ethyl ketone peroxide		0.2*	-	Skin and eye irritation
Hatteras Cleaner		50	-	Toxic details unknown
Acetone	1000	1000	-	Skin defatting, solvent narcosis

* Ceiling limit, no established 8 hour TWA

[1]Permissible Exposure Limit; this is the legally enforceable standard

[2]Threshold Limit Value, 8 hour TWA; this is a voluntary level recommended by the American Conference of Governmental Industrial Hygienists

[3]Criteria for a recommended standard···Occupational exposure to styrene. NIOSH publication 83-119

[4]Sax, Toxicology 1968, Page 1013

III. METHODOLOGY

List of Equipment: The equipment used in the study is listed in Table II.

Table II. Equipment items used in the study

Item	Model	Use
Sampling pumps	MDA Accuhaler	Styrene vapor
Draeger detector tubes	Styrene (low concentration)	Styrene vapor
Hot-wire anemometer	TSI model 1650	Air velocity
Pitot-tube	Dwyer	Air velocity
Rotating vane anemometer	Davis #50400B	Air velocity

Measurement of Control Parameters: Air flow measurements were limited to the determination of total volumetric air flow exhausted from each of the lamination booths and selected traverses of key points in the air supply ductwork. Air flows were determined using either a pitot tube or calibrated hot-wire anemometer according to the procedures outlined in Industrial Ventilation: A Manual of Recommended Practice.

Sampling Procedures: As an index of control, the 8-hour time-weighted average (TWA) concentration of styrene vapor was determined for the gel coat spray gun operator and other selected lamination workers in the small parts work area. The 8-hour TWA concentrations were determined from separate morning and afternoon samples collected outside the respirator (where used). Styrene vapors were collected on 150 mg charcoal tubes with personal air sampling pumps operated at 10 cc/min. Tubes were subsequently desorbed with carbon disulfide and analyzed by gas chromatography. On the second sampling day, one-half hour samples were obtained on three of the lamination workers, while at the same time, the work practices were noted at one minute intervals. This data will be processed separately to attempt to establish some relationship between work practices and styrene exposure.

Styrene concentrations were spot checked with Draeger detector tubes. This was to determine the approximate concentrations of styrene in the vicinity of lamination work in the small parts work area.

IV. CONTROL TECHNOLOGY

Principles of Control: Occupational exposures can be controlled by the application of a number of well-known principles, including engineering, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control both in terms of occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system.

These principles of control apply to all situations, but their optimum application varies from case-to-case. The application of these principles at the Hatteras Yachts New Bern Operation plant is discussed below.

Engineering Controls: The hull lamination and assembly areas of the plant are ventilated by the air make-up units (AMU) and by exhaust blowers at ground level which remove the styrene fumes through the wall ports shown in Figure 5. The small parts department production area, which has three levels, is located along the long axis of the lamination and assembly building as shown in Figure 6. All lamination is done on the first or ground level. The ventilation to the small parts lamination area, which was redesigned in 1982, is provided by three AMU located on the 3rd level, two of which supply a total of 120,800 CFM of air to the first floor lamination area, and a third AMU which supplies 49,000 CFM of air to the 2nd level.

There are three lamination booths in the small parts work area as shown in Figure 1. Air exhausted through the booths is considerably less than the supply air from the AMU. The excess vents into the hull lamination and finishing areas of the plant. Air is delivered to the hull lamination area by fans and the AMU, and is exhausted fom the building by the outside exhaust blowers. The total supply air to this work area is 169,800 CFM. The area served by booths 1 & 2 receives a total of 31,900 CFM. The remainder, 137,900 CFM ventilates the area containing booth 3. This flow arrangement is shown in Figure 7.

The average air flow toward booths 1 & 2 is 37 FPM. This is not enough to overcome the room air turbulance generated by point source supply air inlets and worker comfort fans and probably results in unpredicable air flow patterns in that work area.

A similar situation exists in the work area containing booth 3. This area extends from the restroom to the mixing room. This area receives ample supply air so that most styrene is displaced into the hull lamination area outside of the small parts department.

The face velocity of air entering booth #1 was measured with the vane anemometer. The average face velocity was determined to be 130 FPM. This is considered adequate to contain styrene vapors within the booth. It was noted that although the three ventilation booths were ideal for spray-up and roll-out lamination, the molds were not rotated in and out of the booths to take advantage of this.

Work Practices: The employees in the small parts work area are apparently aware of the need to work up-wind of the resin roll-on operation. By working on the side of the mold away from the booths, the drift of air toward booths #1 and #2 should reduce the exposure to styrene. The fiberglass filters on the exhaust air inlets of the booths occasionally become clogged and require changing. The use of comfort fans in the work area during warm weather generates considerable air turbulence which must have some effect on the styrene exposure of workers and on the effectiveness of the ventilation system.

The gel coat is sprayed on the molds and is done in the open. This operation should be carried out in the booths to limit the contamination of the general work area by styrene vapor, however, this is impractical due to the work flow. Resin for roll-on lamination work, was blended with catalyst in a 5 gallon pail. Stirring was done with a stick. The blending was carried out in the work area. The contribution to styrene exposure from this operation is not known, but it is a short term operation and exposure should not be very high.

Monitoring: The industrial hygiene sampling of Hatteras Yachts facilities is overseen by the industrial hygienist of the parent company, AMF Inc.

Personal protection: The gel coater was observed to always wear a respirator while performing his task. The use of respirators by other workers was not observed but are available to the workers from the Safety Department. Workers in the lamination area wear old clothes provided by the company. The workers are provided with protective gloves and safety glasses. A protective barrier creme, Gel 9 (by Mallard), is made available to the workers to protect skin from irritation by styrene and acetone.

It was reported by the Safety Manager that workers receive periodic refresher instruction in the use of good work practices and the use of personal protective equipment.

V. RESULTS OF SAMPLING

A total of 66 personal samples for styrene were obtained plus an additional 12 area samples. The results for the personal samples are shown in Table III, and the area data in Table IV. The sample data are shown in Appendix A.

A statistical Analysis of Variance (ANOVA) was performed on the half-hour sample data collected on 9/14/83. Only workers A, B, and C were included in this particular sample series. This data includes minute by minute observations of work practices that relate to styrene exposure. Those factors selected were Laminating (L), Other (than laminating) Work (O), Resting (R), Up-wind (U), Down-wind (D), Inside of Booth (I), Near Booth (N), and Far From Booth (F). The Near Booth (N) zone was defined as that area between the face of the booth and the first building support in the up-wind direction, a distance of about 10 feet.

The sampling on the second day was initiated with the understanding that the man cooling fan located near the corridor by the grinding room, would be turned off to avoid interfering with the ventilation system. It was noted on a sampling sheet that this fan was turned on at 2:22 PM. This was not anticipated but it allows a test for the effect of the man-cooling fan on styrene exposure to the three workers being sampled.

In these analyses, the data for each factor analyzed is compared to all other factors in that category. For exemple, in the "Job" category, the 21 instances of laminating and 6 for activities "Other" than laminating would have a fraction-laminating ratio of 21/27 or 0.78. This same concept is applied to the Booth and Up-wind/Down-wind categories. The exposure data for these factors was plotted in the SAS computer printout. A linear regression analysis was performed on each set of data and a correlation coefficient calculated to indicate the degree of fit the data has about the regression line. A correlation coefficient of 1 indicates a perfect fit of the data to the line. The interpretation of the significance of the value of a correlation coefficient is difficult and sometimes inconclusive in that a good correlation may be made a by uncontrolled factors that have lowered the value of the correlation coefficient. The graphs that show the relationship of the ratio of occurance of Lamination, Up-wind/Down-wind to the exposure levels are in Appendix D. The correlation of other factors is not good enough to include the graphs.

The statistical analysis indicates that the correlation coefficient for lamination of workers A and B (0.73 and 0.72) are better than for worker C (0.33) and the coefficient for Up-wind for worker A (-0.79) is higher than for workers B and C (0.38 and 0.47). The same applies for the Down-wind coefficient of worker A (0.84) compared to B and C (-0.15 and -0.46).

The evaluation of the workers actions is highly subjective for factors other than "Lamination". This may account for the poor correlation of other factors, especially in the Up-wind/Down-wind category where the air flow direction was assumed and in fact indicates that the air flow, in the case of workers B and C, was opposite that assumed.

The observations for these workers regarding styrene exposure levels for (I), (N) and (F) in relation to the booth were not indicative of a strong correlation. This may be because: 1). The air turbulence in the room was more a factor in worker exposure than the distance from the booth; 2). other factors such as nearness to the work and actual air flow direction may have affected the results.

The data obtained on the second day had an interesting factor introduced when the man-cooling fan located in the center of the room near the corridor connecting the two ends of the work area was turned on at 2:22 PM. This fan had been turned off at the beginning of the morning shift so as to avoid excessive turbulence in the room air, a decision made to allow an unbiased evaluation of the ventilation system. The data for this analysis for the three workers was separated into two sets, up to 2:22 PM and after 2:22 PM. 33 samples were taken during the first period and 15 samples after the fan had been were turned on. The mean styrene exposure when the man-cooling fan was not running was 37 ppm and 15 ppm for the period when the fan was running.

To perform the analysis on the difference of the means, the data was transformed to natural logarithms and tests for statistical significance of the means were applied. The tests used were the Normal Distribution Test for sample sizes over 30, and the Student's t-Test for small sample sizes. Both of these tests indicated that the differences in the means was significant at the 90% confidence level. The calculations and data are displayed in in Appendix C.

Another factor which might influence the interpretation of this test is the amount of time the worker spent laminating The data was evaluated for the categories (L), (O), and (R), and found to be 58% lamination (L) before 2:22 PM and 50% after 2:22 PM. This is not a difference that should account for the 37 ppm styrene level with the fan off and the 15 ppm level with the fan on. The conclusion is that the added turbulence of the man cooling fan reduces the average styrene exposure in that work area.

Table III. Styrene exposure of workers

DATE	EMPLOYEE	SAMPLE TIME Hours	STYRENE CONC. ppm	STYRENE MEAN CONC. ppm	STANDARD DEVIATION
9/13	Worker A	9.2	8		
9/14*	Group	8.0	18	13	5
9/15	Leader	7.6	14		
9/13	Worker B	9.1	36		
9/14*	Laminator	7.5	42	47**	14
9/15		7.7	62		
9/13	Worker C	3.9	13		
9/14*	Laminator	7.8	22	23	11
9/15		4.2	35		
9/13	Worker D	3.9	12		
9/14	Tank Lam.	7.9	14	14	3
9/15		7.7	17		
9/13	Worker E	0.4	74	-	
9/14	Gel Coater	0.5	63	-	

* Data taken on 9/14, for workers A, B, and C, was for half-hour sample periods, consolidated here to represent a TWA for the workday.

** The high standard deviation for this worker indicates that the exposure might be above the NIOSH recommended TLV of 50 ppm Styrene, 8 hour TWA.

The area data are shown in Table IV.

Table IV. Area sample data for styrene

DATE	SAMPLE TIME hours	SAMPLE LOCATION[3]	STYRENE CONCENTRATION, ppm
9/13	4.3	See footnote 1.	20
9/13	5.9	"	11
9/13	4.1	See footnote 2.	10
9/13	5.9	"	5
9/14	4.2	See footnote 1.	1
9/14	5.6	"	1
9/14	4.3	See footnote 2.	7
9/14	5.5	"	3
9/15	3.6	See footnote 1.	3
9/15	5.5	"	10
9/15	3.6	See footnote 2.	7
9/15	3.3	"	6

1. This sample site is in a doorway near booth #2 and between the small parts area and the hull lamination area.
2. This sample site is on a column in the small parts area and between booths #1 and #2.
3. Sample locations are shown in Figure 1.

VI. CONCLUSIONS AND RECOMMENDATIONS

The ventilation system for the small parts production area of this plant was redesigned and altered in 1982 to improve the working conditions for the employees. The three booths installed would permit the lamination of parts within an enclosed space and would offer better protection from styrene vapor if good work practices are used. The use of the work space does not permit the rotation of molds in and out of the booths. It is apparent from the number of parts that are routinely made in this shop that it would be impractical to move the molds about during lamination and gel coating without disrupting an otherwise orderly procedure. The styrene exposures of the workers indicates that 1 of the 14 sample days was above the NIOSH recommended level of 50 ppm styrene. This, a 62 ppm value for worker B representing 7.7 hours of sample time on 9/15, is valid as an 8 hour TWA. Two 1/2-hour samples on worker E, the Gel Coater (9/13 & 9/14), were not representative of 8-hour TWA exposures. The Gel Coater was observed to wear a respirator during spray-on operations.

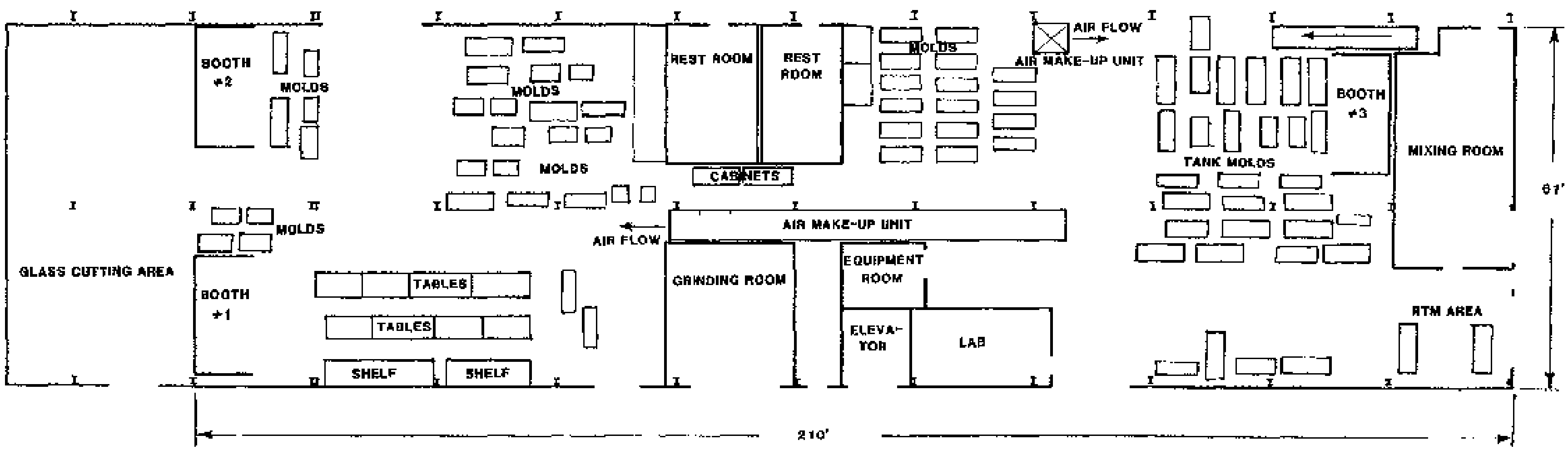
The area samples indicate that the styrene concentration in the two selected areas of the plant did not exceed 20 ppm for a 4 hour period or 16 ppm for an 8-hour workday. Since one sample point was selected to sample air leaving the production area and the other selected to sample air in the middle of the sample area, it is safe to conclude that the styrene concentration in the work area is generally well below the recommended NIOSH 50 ppm 8-hour TWA for styrene. The reason for this low level is probably due to the high air flow rate through the work area. The area containing booths #1 and #2 has the air changed every 2 minutes and the other work area containing booth #3 has the air changed each minute. About 58% of this small parts department supply air vents into the general plant area.

The lamination workers are instructed in good work practices. On September 14, personal samples were taken each half hour, while the workers actions were noted, to obtain some relationship of work practices with styrene exposure. The analyis of the data indicates that worker exposure is a function of time spent laminating and the time spent up-wind and down-wind of the lamination surface. The correlation of the resin application data for up-wind (RU) and down-wind (RD) is reversed for workers B and C as compared to worker A. This is evident from the increase in styrene exposure level as the proportion of time up-wind is increased. This apparently is the result of assuming that the air flow in the room was in the direction of booths #1 and #2 while eddy currents generated by the air supply inlets may have altered the direction of flow. Worker exposure data does not correlate well with the location of the workers in relation to the booths. These locations are noted by, In the booth (I), near the booth (N), and far from the booth (F). This lack of correlation is also apparently due to the air turbulence in the room which overrides the assumed direction of air flow and suggests that there are, at times, points of high concentration of styrene in the work area due to patterns of air currents. The effect of the man cooling fan is to dilute the styrene in the room air by mixing, and results in lower exposure levels of the workers.

The conclusion is that although this plant has achieved good control of styrene exposure in the small parts production area, the exposure could probably be further reduced. For example, if it is assumed that the higher level of exposure of worker B compared to the other laminators is the result of work practices, improved work practices could lower the average styrene exposure.

It is recommended that better use be made of the booths to reduce the exposure of the workers to styrene. This recommendation is made without knowledge of production problems that would result from cycling molds in and out of the booths.

FIGURE 1. PLANT LAY-OUT FOR SMALL PARTS DEPARTMENT



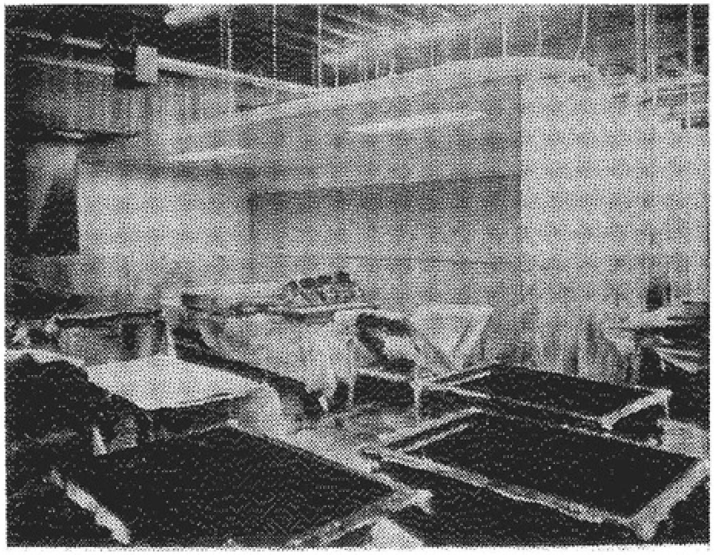


Figure 2. Booth 1, small parts area

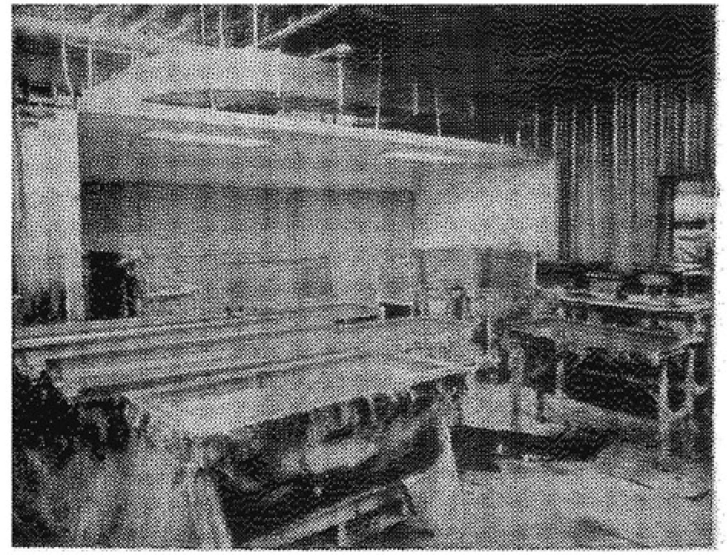


Figure 3. Booth 2, small parts area

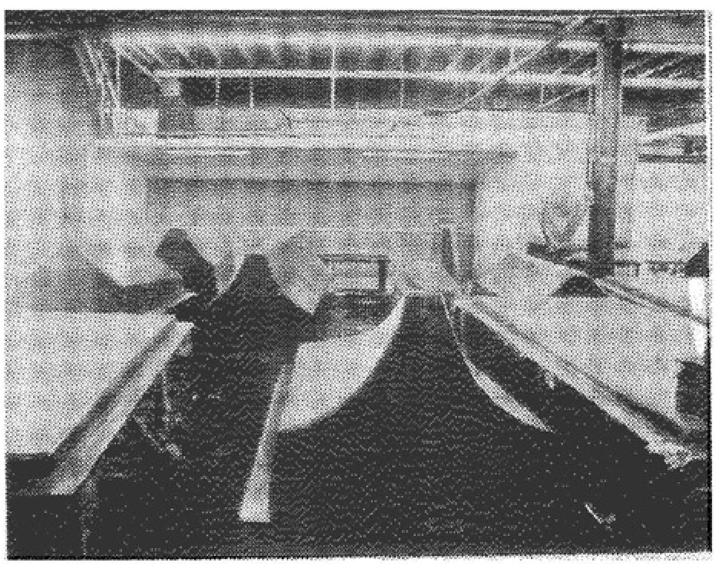


Figure 4. Booth 3, small parts area

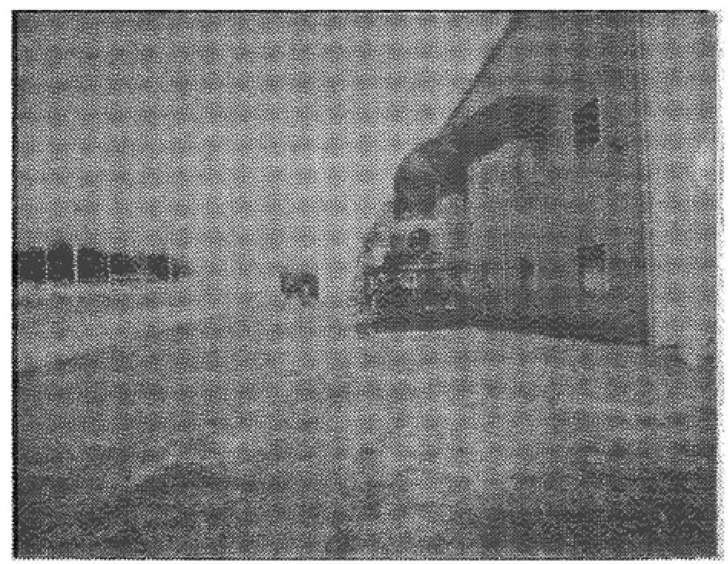


Figure 5. Exhaust blowers from main plant

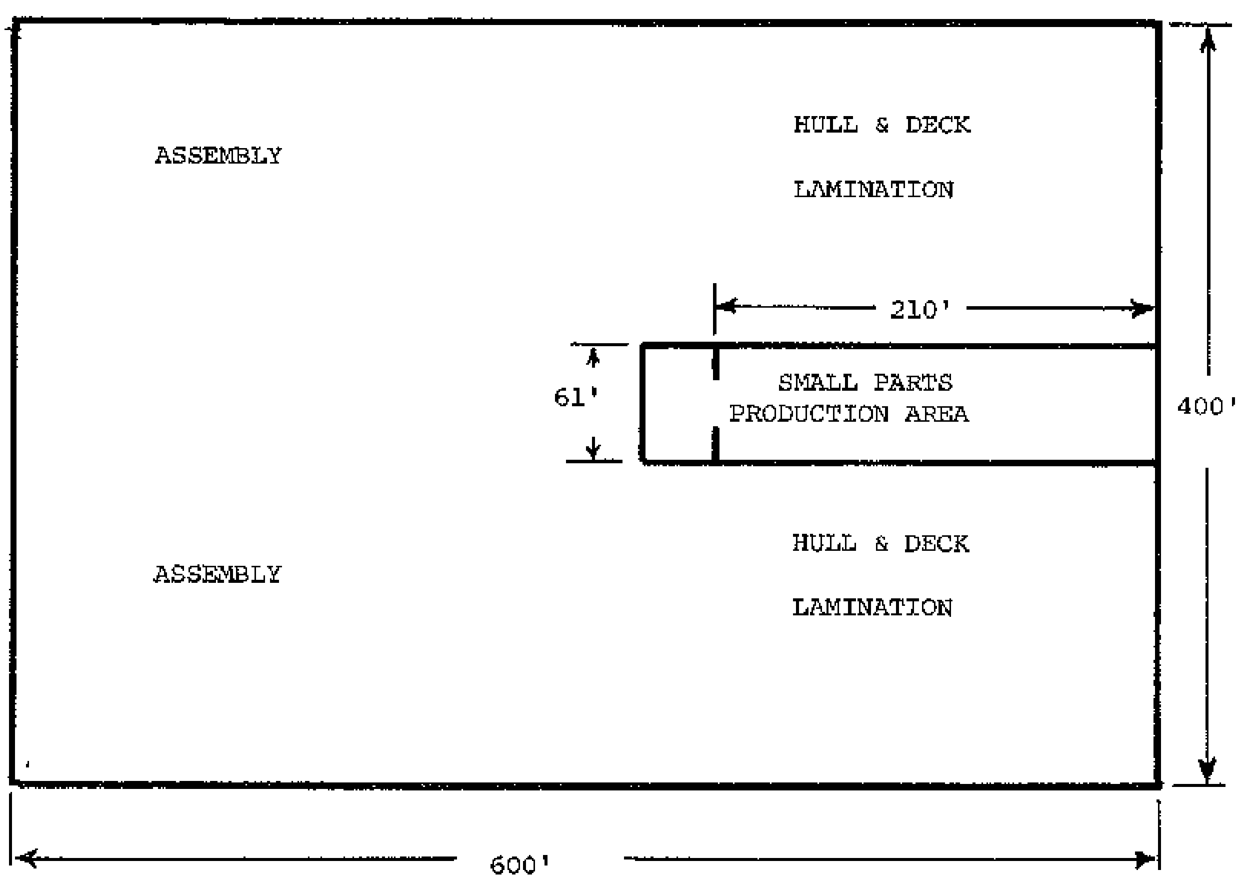
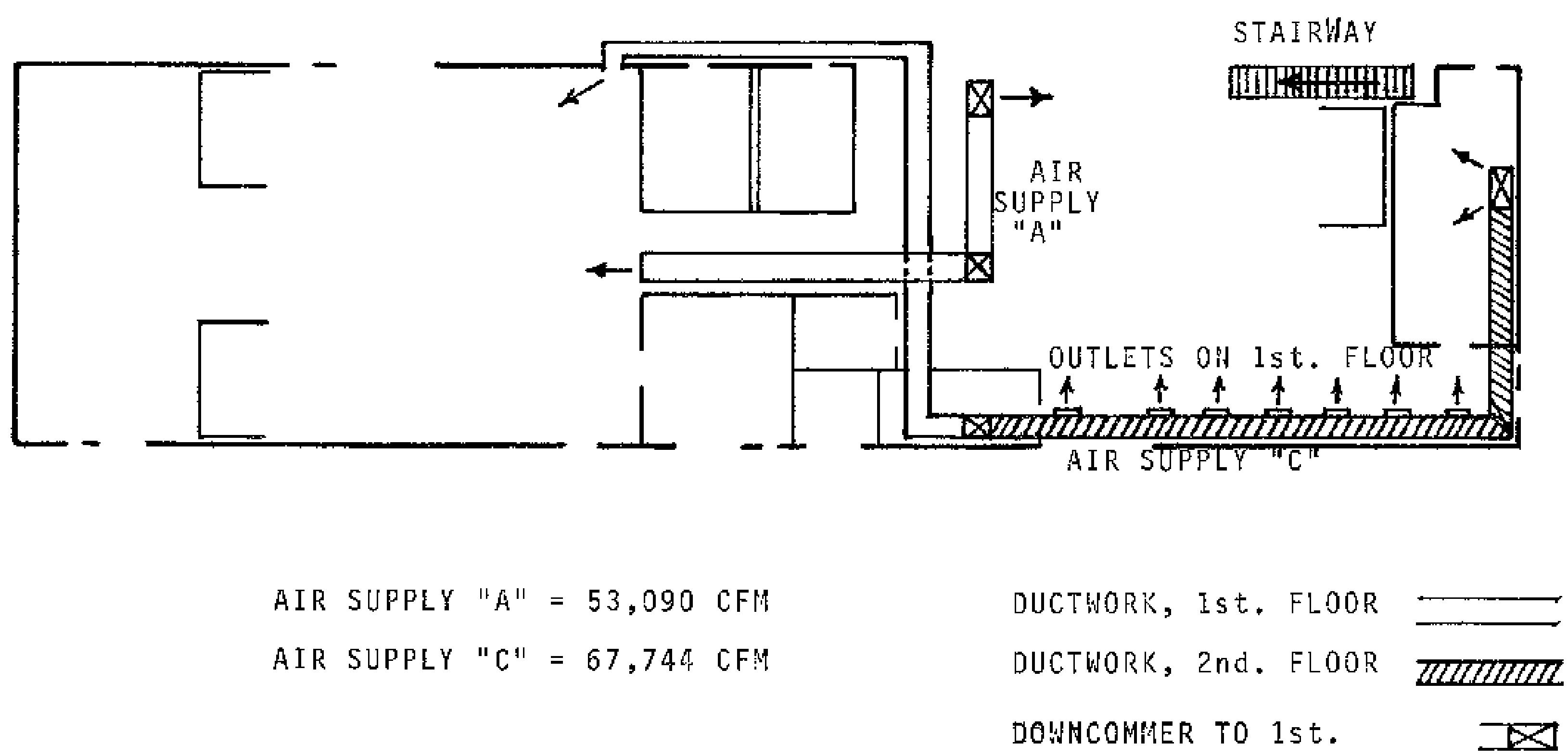


Figure 6. Location of small parts production area

Figure 7. Supply air ductwork to small parts work area



APPENDIX A. PERSONAL AND AREA SAMPLING DATA

Personal Sample Data - Hatteras Yachts, New Bern, North Carolina
Worker A, Group Leader, Small Parts

DATE	SAMPLE NUMBER	TIME Min.	VOLUME Liters	STYRENE mg	mg/m³	ppm
9/13	073	234	6.8	0.24	35.29	8
9/13	083	316	9.2	0.26	28.26	7
9/15	159	204	4.5	0.30	66.67	16
9/15	151	251	5.3	0.24	45.28	11
9/14	095	34	3.5	0.34	97.14	23
"	096	24	2.7	0.19	70.37	17
"	112	31	3.0	0.81	270.00	63
"	113	32	3.5	0.43	122.86	29
"	084	32	3.0	0.23	76.67	18
"	074	27	2.9	0.46	158.62	37
"	110	29	2.8	0.40	142.86	34
"	107	32	3.5	0.12	34.29	8
"	103	28	3.1	0.07	22.58	5
"	127	31	3.4	0.05	14.71	3
"	122	32	2.7	0.02	7.41	2
"	125	32	3.3	0.05	15.15	4
"	135	30	3.3	0.08	24.24	6
"	134	30	3.4	0.05	14.71	3
"	137	32	3.6	0.47	130.56	31
"	145	25	2.5	0.13	52.00	12
Sum of 9/14 data		481	50.2	3.90	77.69	18

APPENDIX A. (cont.)

Personal Samples - Hatteras Yachts, New Bern, North Carolina
Worker B, Small Parts Laminator

DATE	SAMPLE NUMBER	TIME Min.	VOLUME Liters	STYRENE mg	STYRENE mg/m^3	STYRENE ppm
9/13	087	314	6.3	0.83	131.75	31
9/13	075	234	4.9	0.86	175.51	41
9/15	157	209	0.8	0.22	275.00	65
9/15	160	251	1.3	0.33	253.85	60
9/14	094	27	2.5	0.06	24.00	06
"	100	31	2.6	1.50	576.92	136
"	119	29	2.2	0.61	277.27	65
"	114	31	2.5	0.37	148.00	35
"	086	30	1.6	0.13	81.25	19
"	082	27	2.4	0.19	79.17	19
"	104	25	2.0	0.90	450.00	106
"	105	25	2.2	0.95	431.82	102
"	115	28	0.1	0.01	100.00	24
"	109	16	1.7	0.01	5.88	1
"	131	29	2.8	0.74	264.29	62
"	129	31	3.2	0.42	131.25	31
"	141	31	3.0	0.21	70.00	16
"	138	33	3.2	0.07	21.88	5
"	140	30	2.4	0.23	95.83	23
"	142	28	2.7	0.16	59.26	14
Sum of 9/14 data		451	37.1	6.56	176.82	42

Personal Samples - Hatteras Yachts, New Bern, North Carolina
Worker C, Small Parts Laminator

DATE	SAMPLE NUMBER	TIME Min.	VOLUME Liters	STYRENE mg	STYRENE mg/m^3	STYRENE ppm
9/13	079	235	4.9	0.28	57.14	13
9/15	153	250	5.1	0.75	147.00	35
9/14	093	29	2.8	0.19	67.86	16
"	092	28	2.9	0.56	193.10	45
"	121	28	2.7	0.25	92.59	22
"	120	30	3.0	0.37	123.33	30
"	081	28	3.1	0.56	180.65	42
"	116	30	2.6	0.15	57.69	14
"	106	27	2.6	0.46	176.92	42
"	102	30	3.1	0.62	200.00	47
"	108	28	2.7	0.16	59.26	14
"	123	29	2.9	0.03	10.34	2
"	128	31	3.0	0.11	36.67	9
"	139	32	3.4	0.12	35.29	8
"	133	30	3.0	0.04	13.33	3
"	136	31	3.1	0.03	9.68	2
"	111	27	2.6	0.32	123.08	29
"	150	28	2.8	0.38	135.71	32
Sum of 9/14 data		466	46.3	4.35	93.95	22

APPENDIX A. (cont.)

Personal Samples - Hatteras Yachts, New Bern, North Carolina
Worker D, Tank Laminator

DATE	SAMPLE NUMBER	TIME Min.	VOLUME Liters	STYRENE mg	STYRENE mg/m^3	STYRENE ppm
9/13	072	234	5.1	0.26	50.94	12
9/14	099	217	4.6	0.26	56.52	13
9/14	124	254	5.3	0.33	62.26	15
9/15	155	207	4.3	0.33	76.74	18
9/15	161	252	5.5	0.36	65.45	15

Personal Sample Data - Hatteras Yachts, New Bern, North Carolina
Worker E, Gel Coater, Small Parts*

DATE	SAMPLE NUMBER	TIME Min.	VOLUME Liters	STYRENE mg	STYRENE mg/m^3	STYRENE ppm
9/13	080	26	2.8	0.89	312.86	74
9/14	097	27	2.7	0.72	266.67	63

* The Gel Coater was observed wearing a respirator while spraying gel coat.

APPENDIX A. (cont.)

Area Samples - Hatteras Yachts, New Bern, North Carolina

DATE	SAMPLE NUMBER	LOCATION	TIME Min.	VOLUME Liters	STYRENE mg	mg/m³	ppm
9/13	078	Betw'n small prts. & hull lay-up[1]	252	2.8	0.24	85.71	20
9/13	088	"	351	2.5	0.12	48.00	11
9/13	076	On column in small	244	6.8	0.29	42.65	10
9/13	085	parts room[2]	354	9.2	0.20	21.74	5
9/14	098	See foot note 1.	252	5.0	0.03	6.00	1
9/14	126	"	335	6.4	0.02	3.13	1
9/14	101	See footnote 2.	256	6.9	0.22	31.88	7
9/14	130	"	332	9.0	0.10	11.11	3
9/15	156	See footnote 1.	215	4.3	0.05	11.63	3
9/15	152	"	330	6.6	0.27	40.91	10
9/15	158	See footnote 2.	214	5.8	0.17	29.31	7
9/15	144	"	331	8.9	0.22	24.72	6

1. Sample site located in doorway by booth #2 between small parts area and the hull lamination area. See Figure 1. for location.
2. Sample site is located in small parts area on column between booths #1 and #2. See Figure 1. for location.

APPENDIX B. VELOCITY DATA

Hatteras Yachts, Small Parts Department - New Bern, North Carolina
Exhaust Duct Velocities and Flows for Lamination Booths
All velocities were obtained with TSI Velometer, Model 1650
Velocities expressed in feet per minute (FPM)

Booth #1, Duct size 42" x 20" (area = 5.833 ft^2)

WIDTH, 42 inches

DEPTH						
	20 inches	3500	3300	3000	1500	2600
		3800	3500	3200	2500	2800
		3500	3600	3100	2800	3100
		900	2200	3200	3100	2000

Average velocity = 2860 FPM, Flow = 16,680 CFM

Booth #2, Duct size 50" x 18" (area = 6.25 ft^2)

WIDTH, 50 inches

DEPTH						
	18 inches	2500	2500	2500	2800	3200
		2800	2900	2600	2400	3100
		3000	2900	2700	2600	2900

Average velocity = 2760 FPM, Flow = 17,250 CFM

Booth #3, Duct size 62" x 20" (area = 6.243 ft^2)

WIDTH, 62 inches

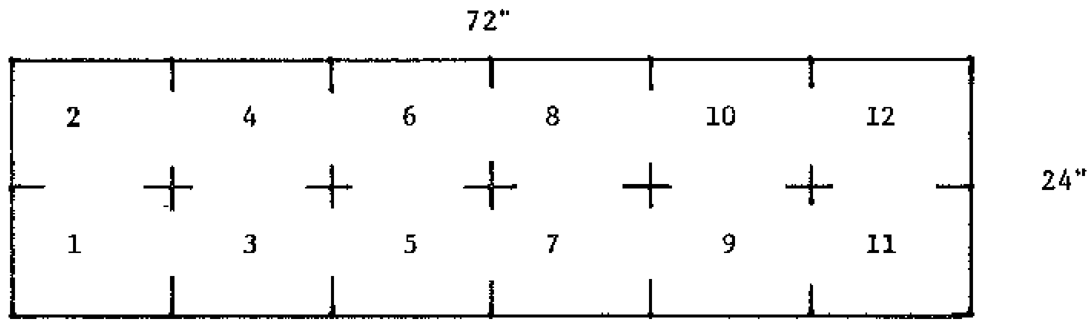
DEPTH						
	20 inches	2800	2700	2900	2700	2400
		2800	2700	2800	2600	2500
		2900	2700	2500	2500	2500

Average velocity = 2667 FPM, Flow = 16.650 CFM

Total flow for booths #1. #2, and #3 = 50,580 CFM

AIR SUPPLY TO SMALL PARTS ROOM TOWARD BOOTHS #1 AND #2

Velocity traverse by pitot tube and TSI hot wire velometer Model 1600



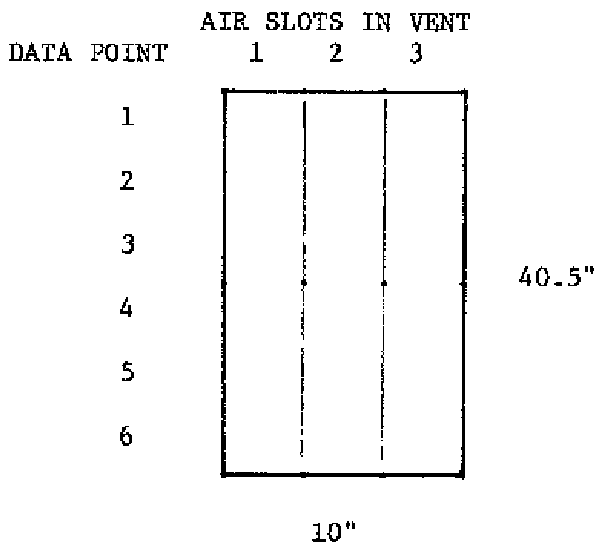
	PITOT TUBE			TSI
DATA POINT	VP in. H_2O	VELOCITY FPM		VELOCITY FPM
1	0.30	2,195		2,500
2	0.36	2,405		2,550
3	0.37	2,435		2,650
4	0.39	2,500		2,550
5	0.35	2,370		2,450
6	0.29	2,160		2,400
7	0.31	2,230		2,400
8	0.34	2,335		2,450
9	0.30	2,195		2,300
10	0.36	2,405		2,500
11	0.24	1,960		2,100
12	0.33	2,300		2,500
Total velocity, FPM		27,490		29,350
Average velocity, FPM		2,290		2,445
Flow, CFM		27,480		29,340

(Duct area = 12 ft^2)

Average flow, CFM = 28,410

HATTERAS YACHTS, NEW BERN, NORTH CAROLINA
AIR SUPPLY TO SMALL PARTS AREA
WALL VENT NEAR REST ROOM AREA

This duct passes through the wall then turns right and exits immediately through louvered outlet.



Note: The width of the vertical air slots varies from 3.25" to 4" and results in different data point areas.

DATA POINT	VELOCITY IN SLOT, FPM 1	2	3	AVG. VEL.	AREA ft^2	FLOW CFM
1	700	1750	500	983	0.474	466
2	950	600	1150	1417	0.542	768
3	1950	2100	2000	2017	0.440	887
4	1000	1300	1000	1100	0.510	561
5	400	360	1400	720	0.583	420
6	340	700	1650	897	0.474	425
						Total CFM = 3,527

APPENDIX C.

Comparison of Means for Day 2 Data, Man Cooling Fan On and Off

APPENDIX C. COMPARISON OF MEANS FOR DAY 2 DATA
MAN-COOLING FAN ON AND MAN-COOLING FAN OFF

FAN OFF

X	lnX
23	3.135
16	2.773
63	4.143
29	3.367
18	2.890
37	3.611
34	3.526
8	2.079
5	1.609
4	1.386
2	0.693
6	1.792
136	4.913
65	4.174
35	3.555
19	2.944
19	2.944
106	4.663
102	4.625
24	3.178
1	0.000
62	4.127
16	2.773
45	3.807
22	3.091
29	3.367
43	3.761
14	2.639
42	3.738
47	3.850
14	2.639
2	0.693
9	2.197

$\overline{X}_1 = 2.990$
GSD = 1.177
VARIANCE = 1.343
n = 33

$\overline{X}$ = 37 ppm

FAN ON

X	lnX
4	1.386
6	1.792
4	1.386
31	3.434
12	2.485
31	3.434
16	2.773
5	1.609
23	3.135
14	2.639
8	2.079
3	1.099
2	0.693
29	3.367
32	3.466

$\overline{X}_1 = 2.318$
GSD = 0.949
VARIANCE = 0.841
n = 15

$\overline{X}$ = 15 ppm

COMPARISON OF MEANS

Normal Distribution Test, Where $n \geqslant 30$

The criteria for this test is whether a value μ calculated from the sample means and the sample standard deviations producés a sufficiently low value of probability that the two means are of the same population that it can be concluded that the difference in the means is real or vice versa that they are of the same sample population.

The equations for this test are as follows:

$$\mu = \frac{(\bar{X}_1 - \bar{X}_2)}{\sigma_d}$$

$$\sigma_d^2 = \frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}$$

The value of μ calculated from these equations is 2.15.

The interpretation of this value from Table A-4 of the reference text* is that there is only 1.6% chance of obtaining a chance value of μ of this magnitude. The conclusion is that the difference in the means is real.

* Reference: Basic Statisticl Methods for Engineers and Scientist, Neville and Kennedy, International Textbook Company, 1964.

COMPARISON OF MEANS

The Student's t-Test

The Student's t-Test is applied to the null hypothesis that the two means being tested are from the same population.

The test calculated a value of "t" which is compared to a table which yields the probabilities for the compared means being of the same population, and which makes allowance for the sample sizes being tested.

The equations used are:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_d}$$

Degrees of Freedom, = 33 + 15 - 2 = 46

$$S_d = \sqrt{\frac{S_c^2}{n_1} + \frac{S_c^2}{n_2}}$$

The value of "t" calculated for the two means for the two means being tested is 2.731.

Reference to Table A-8 in the text*, gives the following values.

α = 0.1 $\quad\quad$ t = 1.684

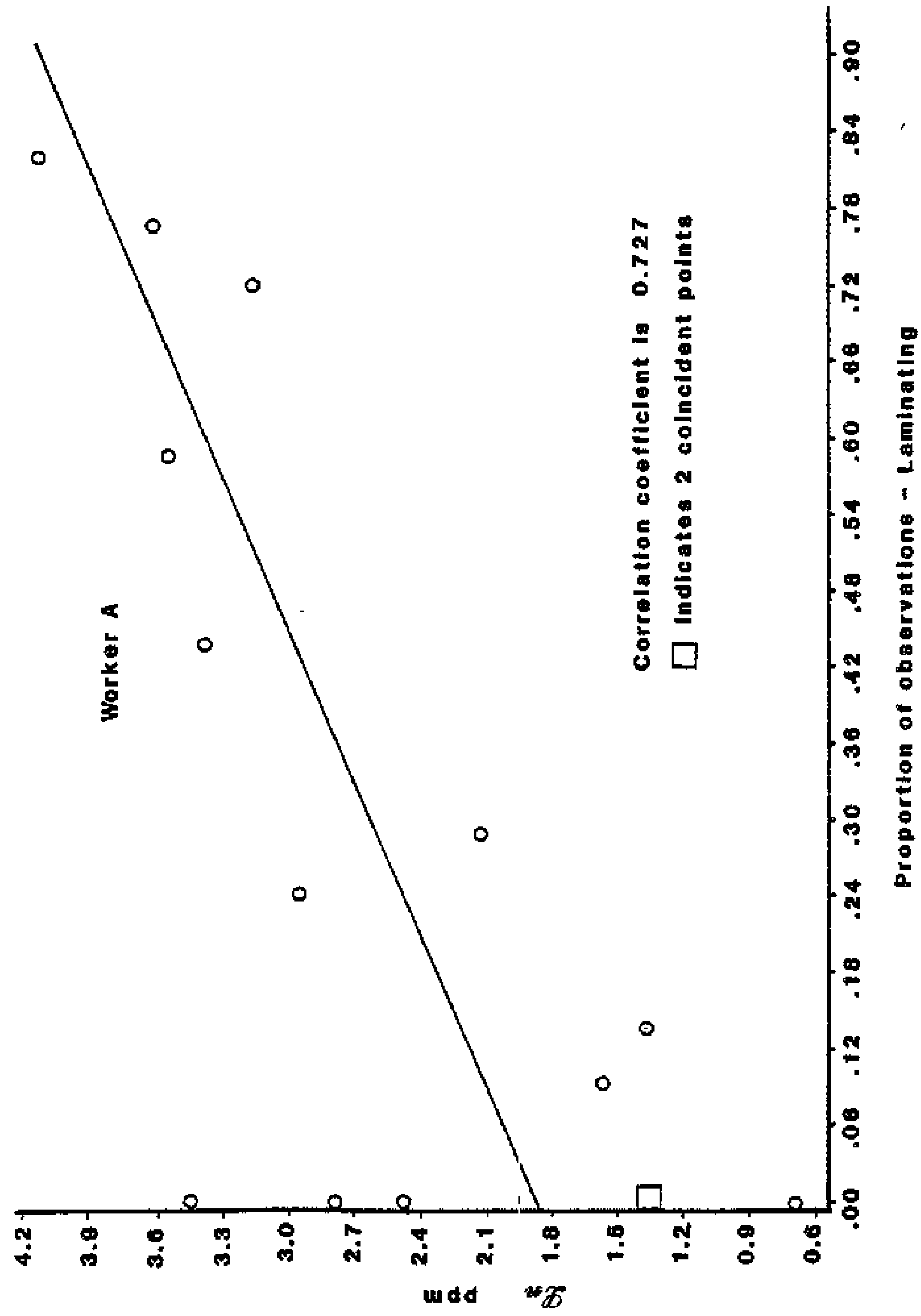
Where alpha = 0.1 represents the 10% confidence level that the means are of the same population.

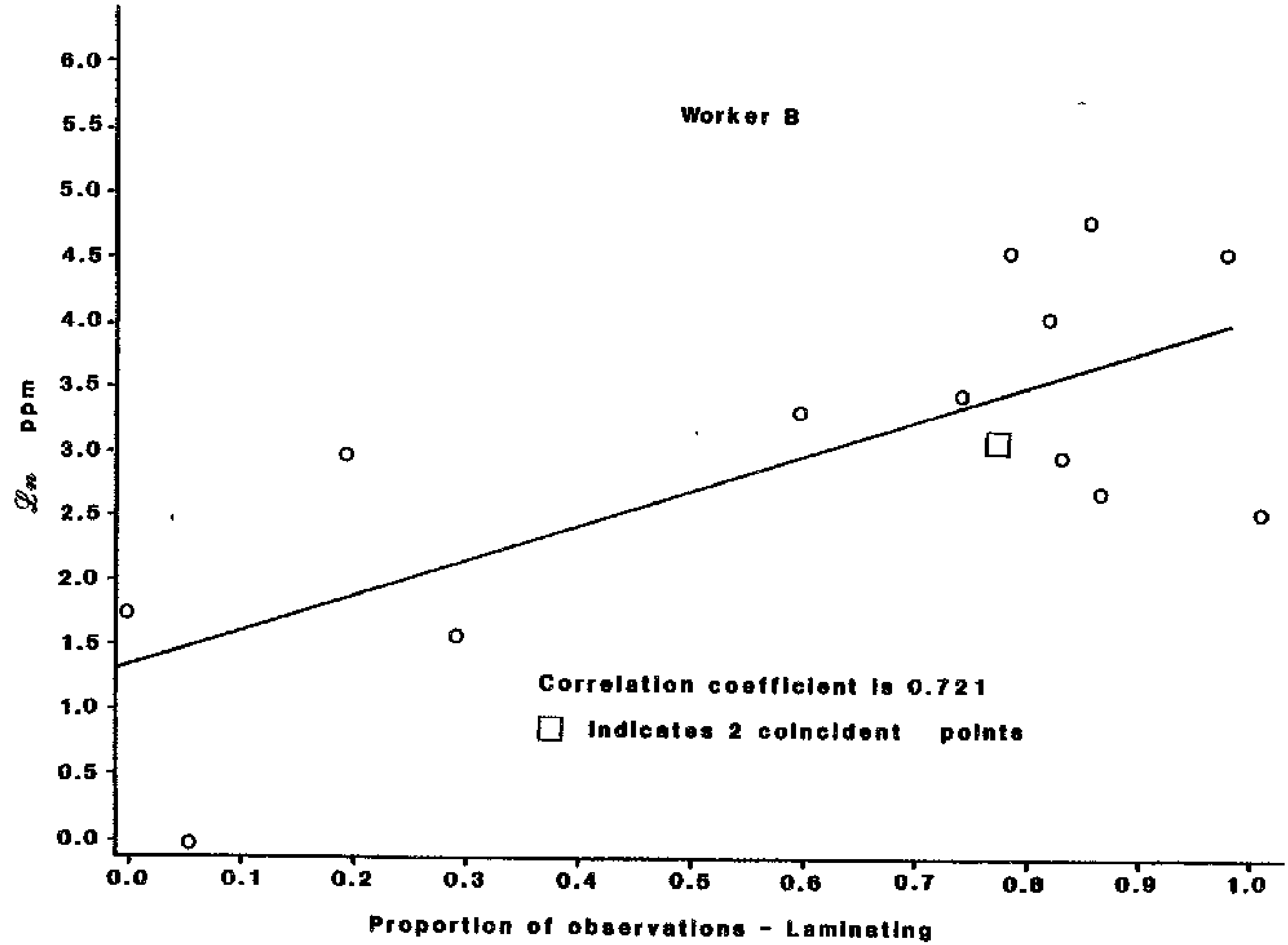
Since the tabular value of "t" is less that the calculated value of "t", it is concluded that the means are not of the same population and are therefore different.

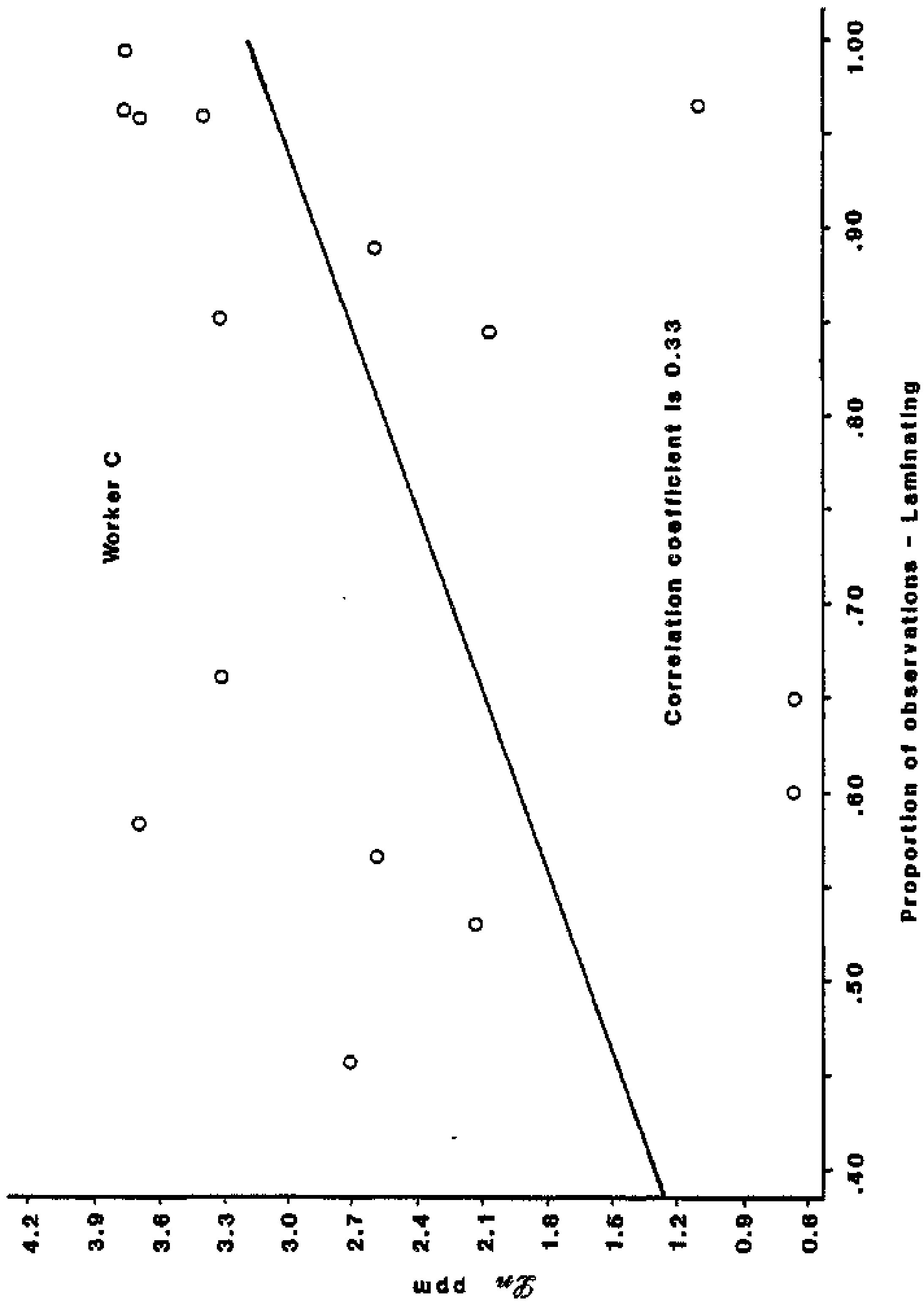
* Reference: Basic Statistical Methods for Engineers and Scientists, Neville and Kennedy, International Textbook Company. 1964.

APPENDIX D.

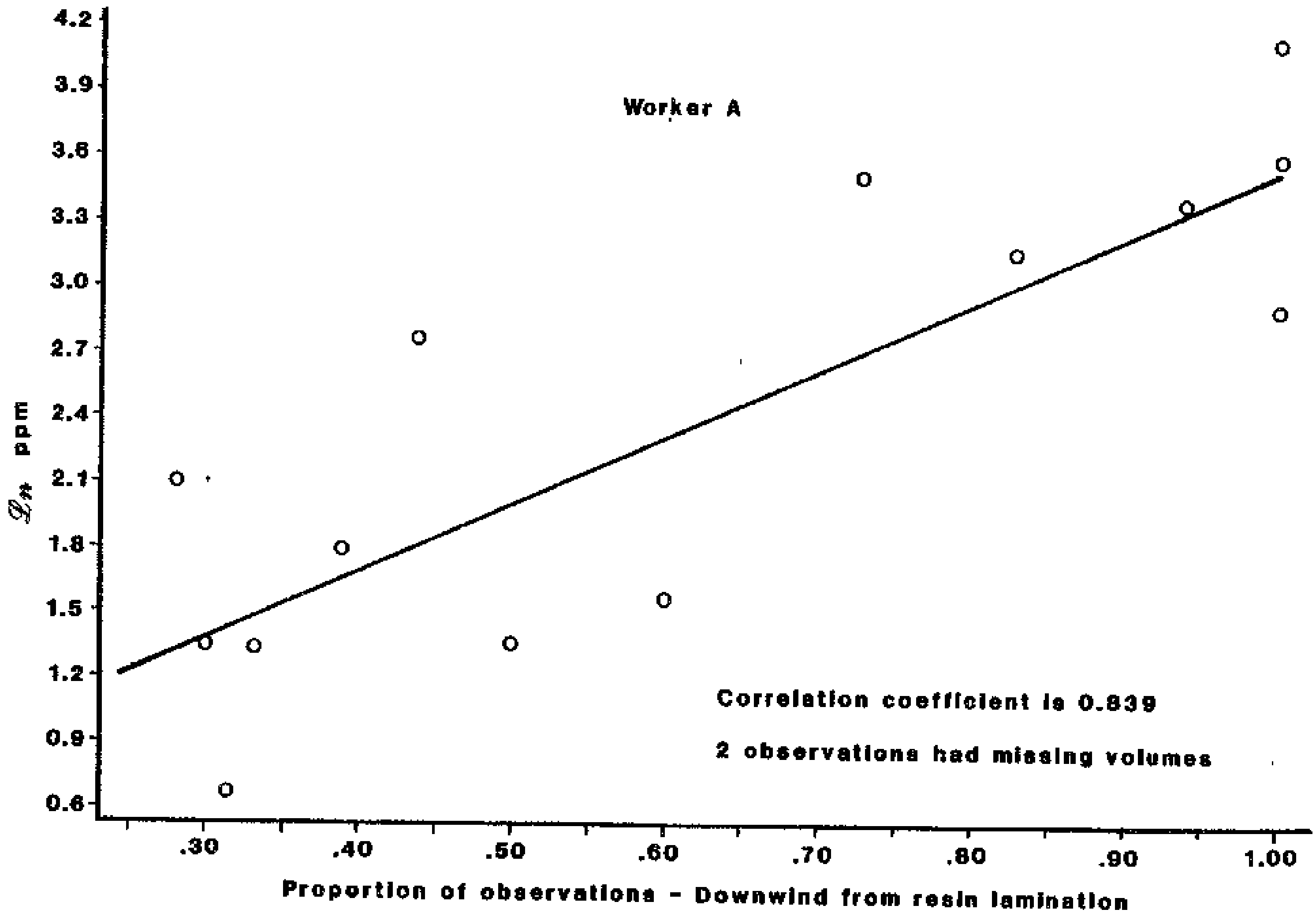
LINEAR REGRESSION GRAPHS OF WORK PRACTICES DATA, 9-14-83


Worker A
Correlation coefficient is 0.727
Indicates 2 coincident points
ppm
Proportion of observations - Laminating
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
.00
.06
.12
.18
.24
.30
.36
.42
.48
.54
.60
.66
.72
.78
.84
.90

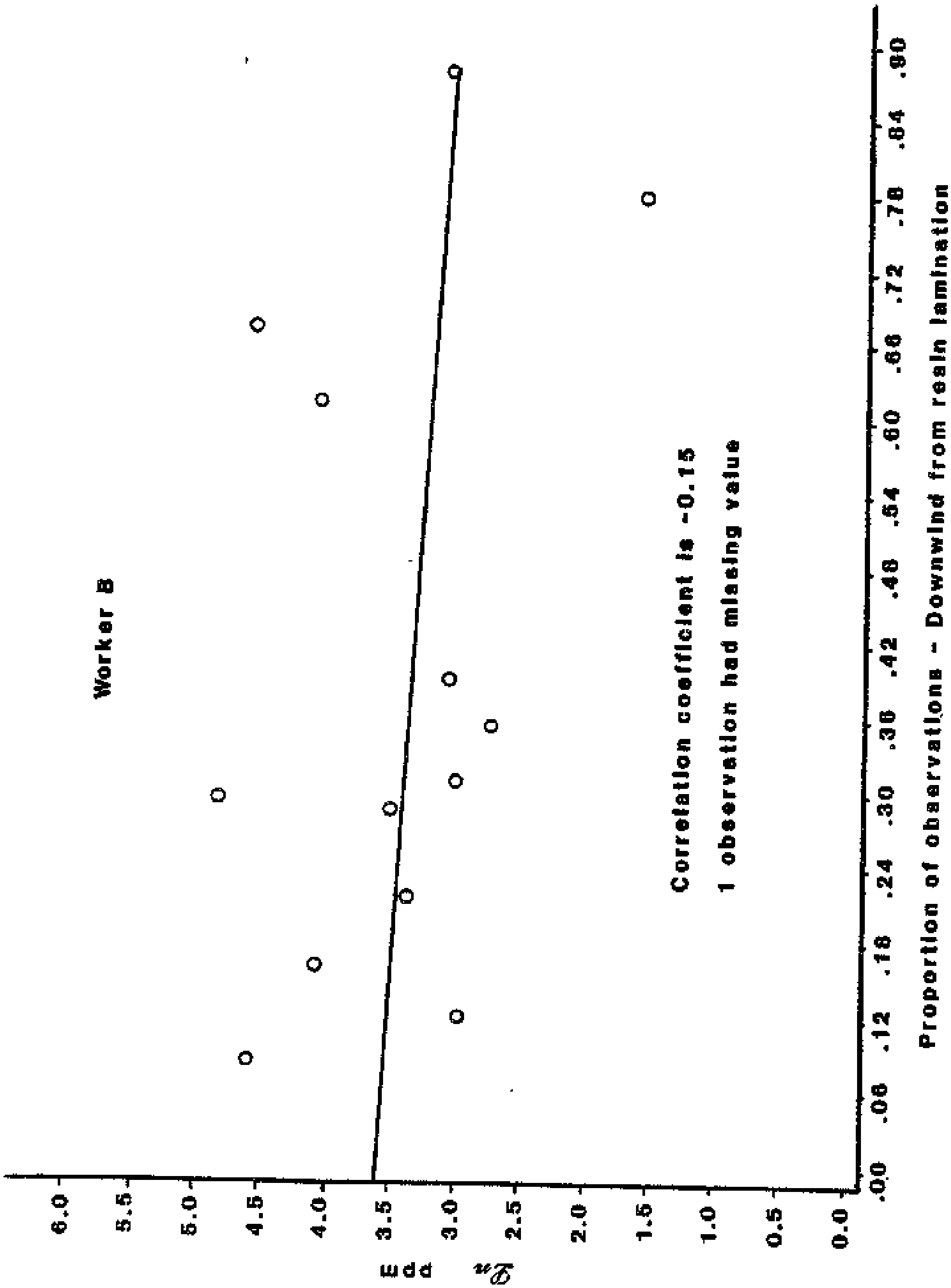

Worker B
Correlation coefficient is 0.721
indicates 2 coincident points
ppm
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Proportion of observations - Laminating



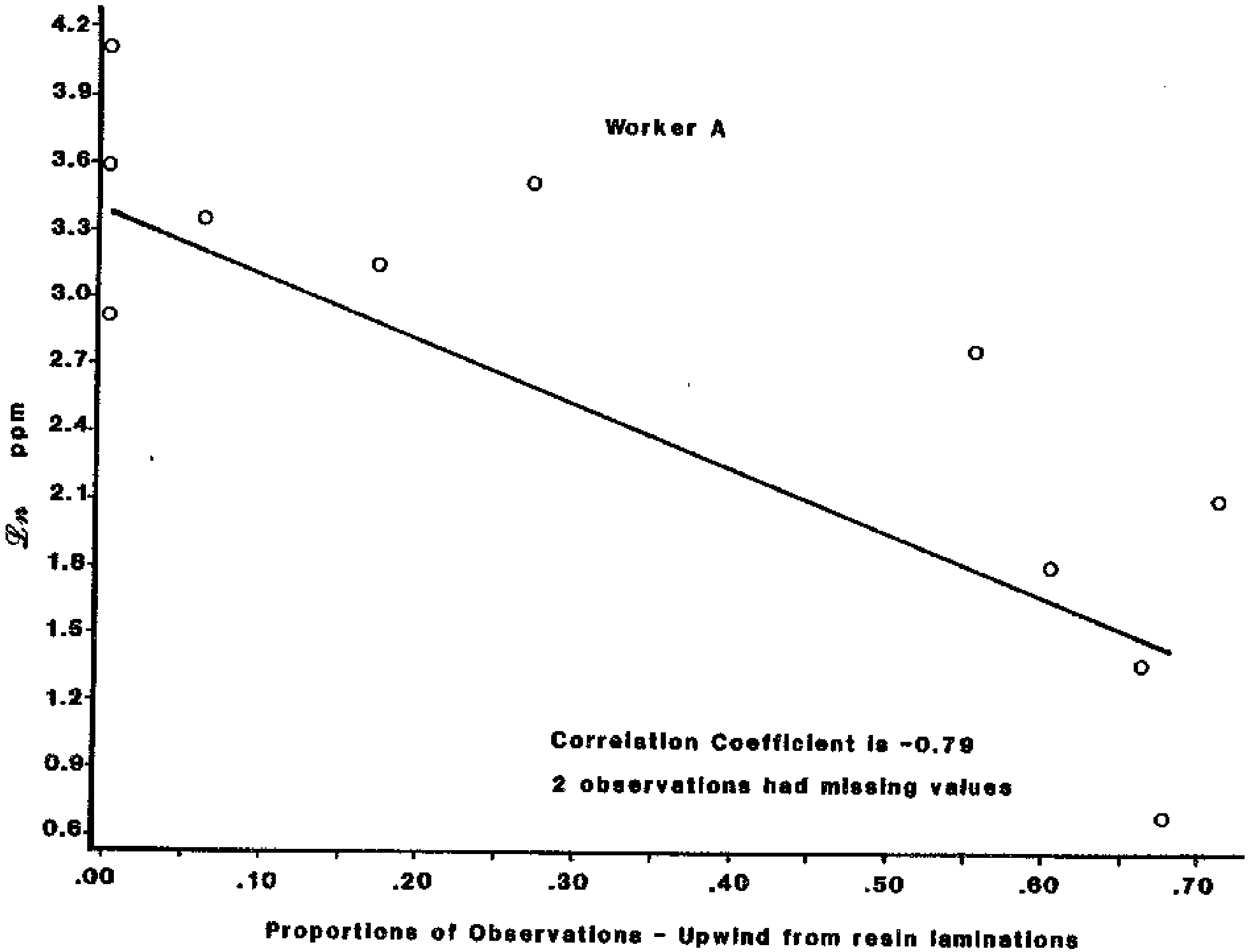
Worker C
Correlation coefficient is 0.33
Proportion of observations - Laminating
ppm
.40
.50
.60
.70
.80
.90
1.00
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
3.3
3.6
3.9
4.2

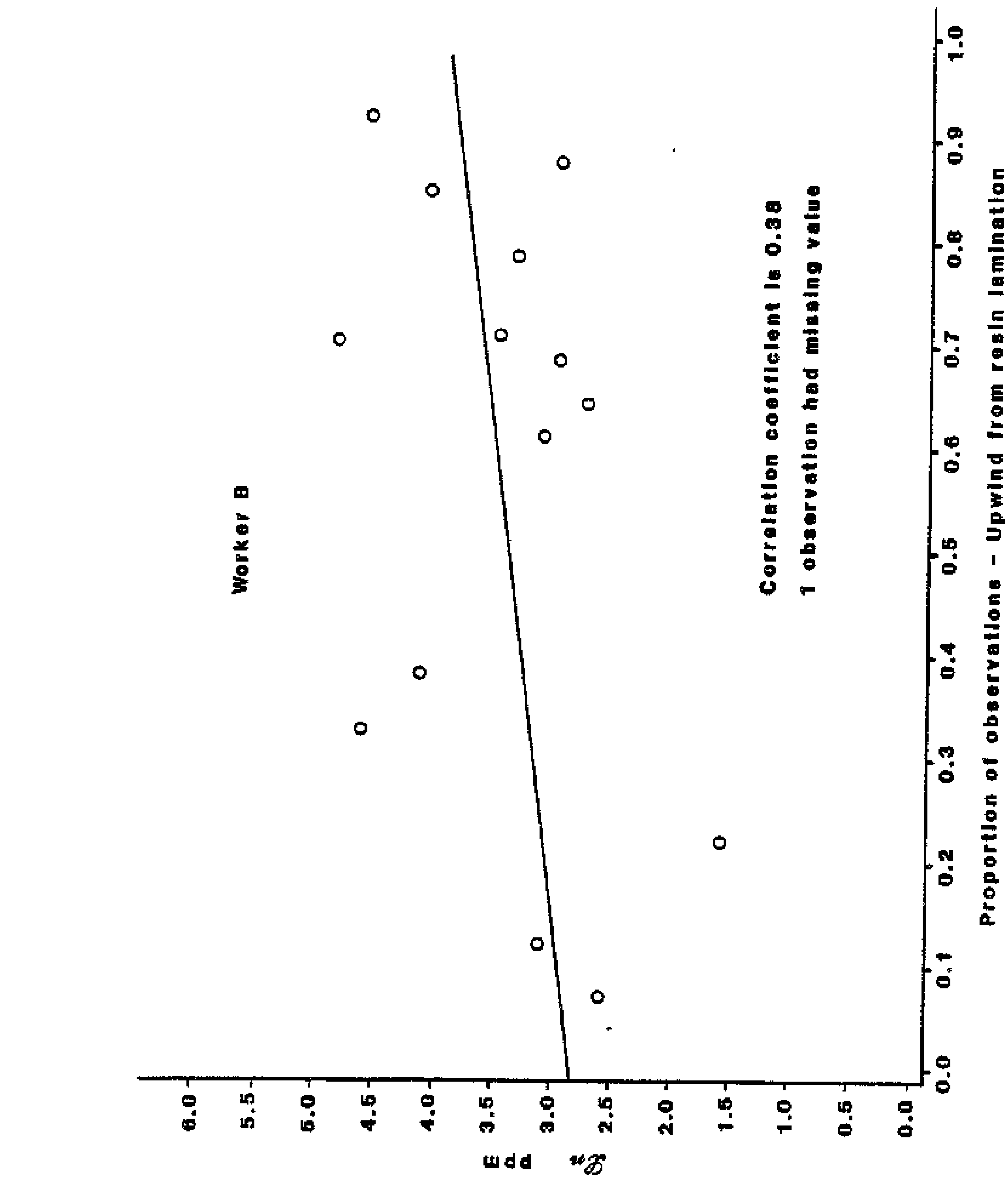


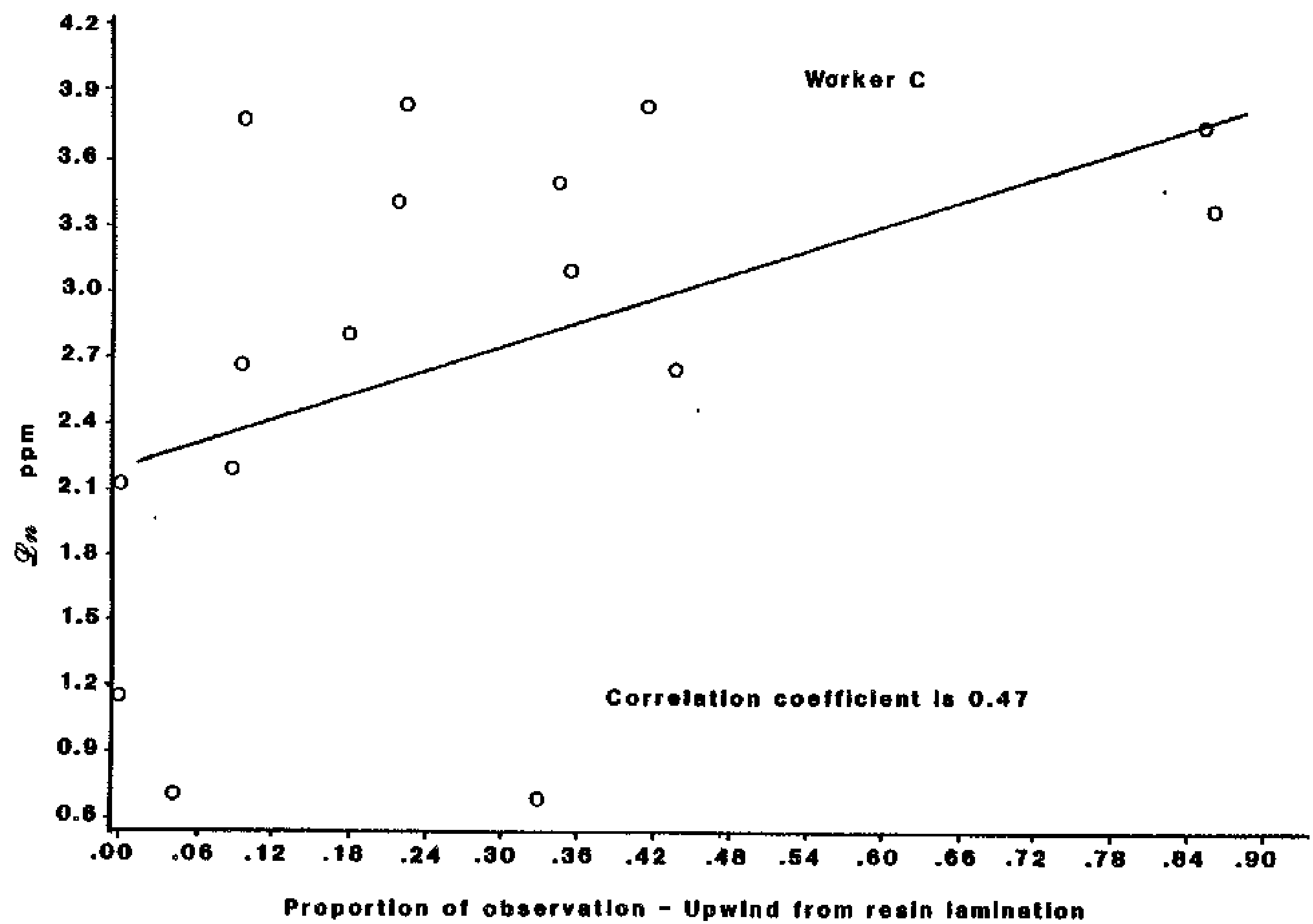
Worker A
ppm
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
.30
.40
.50
.60
.70
.80
.90
1.00
Correlation coefficient is 0.839
2 observations had missing volumes
Proportion of observations - Downwind from resin lamination


Worker B
Correlation coefficient is -0.15
1 observation had missing value
Proportion of observations - Downwind from resin lamination
.00 .06 .12 .18 .24 .30 .36 .42 .48 .54 .60 .66 .72 .78 .84 .90
ppm
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0


Worker C
Correlation coeffient is -0.462
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
Ln ppm


Worker A
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
Ln ppm
.00
.10
.20
.30
.40
.50
.60
.70
Correlation Coefficient is -0.79
2 observations had missing values
Proportions of Observations - Upwind from resin laminations


Worker B
Correlation coefficient is 0.38
1 observation had missing value
ppm
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Proportion of observations - Upwind from resin lamination


Worker C
Correlation coefficient is 0.47
ppm
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
.00
.06
.12
.18
.24
.30
.36
.42
.48
.54
.60
.66
.72
.78
.84
.90
Proportion of observation - Upwind from resin lamination