IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR FIBER REINFORCED PLASTICS INDUSTRY

AT

PHILIPS INDUSTRIES INCORPORATED,LASCO DIVISION
ELIZABETHTOWN, PENNSYLVANIA

REPORT WRITTEN BY:

WILLIAM F. TODD

December 7, 1983

REPORT NO. 107-17b

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: Philips Industries, LASCO Division, Conewago Industrial Park,
40 Industrial Road, Elizabethtown, Pennsylvania

SIC CODE: 3079 Miscellaneous Plastics Products

SURVEY DATE: June 15, 1983

SURVEY CONDUCTED BY: William F. Todd, Dennis M. O'Brien, Charleston K. Wang, and, John Frede, NIOSH, DPSE, ECTB

EMPLOYER REPRESENTATIVES CONTACTED: Mr. Don Frank, Plant Superintendant and Mr. Dave Baker, Plant Manager

TABLE OF CONTENTS

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 conmpleted 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: This plant employs 54 full-time workers, 29 of whom work in the lamination operation. Of those 29, 16 work directly with the lamination operation. The product of this plant is FRP bathtubs and shower stalls produced for the private residence or hotel market. The plant uses about 130,000 #/month of styrene resin. This plant currently operates two shifts, the first from 6:00 am to 2:30 pm; the second shift runs from 3:00 pm to 11:30pm.

Process Description: A continuous process is used for producing the bathtubs and shower stalls. The molds are suspended from an overhead track as shown in Figure 1. The entire lamination process takes place while the mold makes one lap of the oval conveyor track. As soon as the finished product is removed from the mold, the mold is cleaned, polished, wiped with release oil and pushed on to the gel coat station shown in Figure 2. The gel coat is applied by one of two spray gun operators in a booth-like enclosure. The operators rotate spraying assignments with mold wiping/polishing. The color of the gel coat is determined by the gel coat line to which the spray gun is attached. Changing the gel coat color involves purging the spray gun with acetone to eliminate traces of the previous color. The mold moves through an unventilated tunnel to the next station where a barrier coat is applied by spray gun. The barrier coat is an additional layer of neutral colored resin applied heavier than the gel coating that helps to mask the markings of the chopped glass strands applied at the next step. This is shown in Figure 3. The barrier coat is applied in an enclosure similar to that used for the gel coat. The mold moves through a cure area, a short, heated enclosure to the first lamination area shown in Figure 4 where chopped-glass strand is added along with wood and cardboard stiffeners. In lamination area 2 shown in Figure 5, additional resin bonded glass strand is built to a thickness of about 1/4 inch. The two operators alternate spraying with roll out in each of the two lamination booths. Carbon black is added to the resin to reduce light penetration, an aesthetic feature which increases the opacity of the resin. Additional workers assist in roll out of the resin, add cardboard reinforcing panels, and attach a wood base. After lamination, the tub or shower stall travels through a second curing area, then is pulled from the mold and the mold is again readied for lamination. The pulled unit is carted to a downdraft grinding booth shown in Figure 6 where mold flashing is removed with a disc grinder.

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 and acetone. 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 areas located along the mold conveyor line. Exposure to acetone can occur during the purging of the spray nozzles or when transferring acetone from drums. The exposure to MEKP occur to those persons mixing resins and to those exposed to the spray mist in lamination. A summary of the legal and recommended levels for the previously mentioned substances and their health effects appear in Table 1.

Solids are blended into the resin as fillers and fire retardants. Aluminum hydrate is used as a fire retardant and calcium carbonate as a filler. These materials are stored in the mixing room in large cloth bags called Super Bags™ which hold several hundred pounds of solids each. These bags are emptied with a forklift into a ventilated hopper. Some solid fines escape the hopper vent system, but these materials are of low toxicity.

Table 1. Summary of Hazards Associated with the production of small parts in the FRP industry

Materials or Agents	PEL[1] (ppm)	TLV[2] (ppm)	NIOSH[4] Recommended level (ppm)	Major[5] 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
o-chlorotoluene		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] Styrene Criteria Document, NIOSH, October, 1983

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

[5] Sax, Toxicology 1968, Page 1013

III. METHODOLOGY

List of Equipment

The equipment used in the study is listed in Table 2.

Table 2. Equipment items used in the study

Item	Model	Use
Sampling pumps	MDA Accuhaler	Styrene vapor
" "	DuPont P2500	Fiber glass dust
Hot-wire anemometer	Kurz model 440	Air velocity
" "	TSI model 1650	Air velocity
Pitot-tube	Dwyer	Air velocity

Measurement of Control Parameters

The survey team was provided with detailed air flow measurements made by the company. Therefore, air flow measurements were limited to the determination of total volumetric air flow supplied to and exhausted from each of the lamination booths and the gel and barrier coating areas. 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 each spray gun operator and selected other lamination workers. 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.

IV. CONTROL TECHNOLOGY

Introduction - 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 subject plant is discussed below.

Engineering Controls: This plant uses ventilation and styrene suppressed resins as styrene control methods. The principal control is the ventilation system. The design of the ventilation is a cross-flow, push-pull type. The lamination area is designed like a tunnel so that air blown across the spray-on area goes directly into the exhaust air vents. The movement of the resin spray, in the lamination areas indicated that the velocity there was adequate to collect the styrene vapor. Since the preliminary survey in February 1983, the plant has installed a vapor incinerator shown in Figure 7 to reduce the styrene level on the exhaust stack, a change necessary to meet the State Department of Air Resources limit of 100 tons of volatile organic compounds per year. To build up the styrene concentration in the incinerator chamber, the ventilation in the gel coating and barrier coating areas was reduced 75% to 5000 CFM. It was apparent, from the odor of styrene and the eye irritation, that the present air flow rates in the gel coating and barrier coating areas do not provide sufficient velocity to prevent backspray from contacting the spray gun operator. The intent was to rely on respirators for worker protection since the styrene concentration was certain to rise in these areas. The exhaust air vents are covered with glass fiber filter media which is changed twice each day. The inlet (push) fans are located on the ground level while the exhaust (pull) fans are located on the roof. The roof ventilaton ductwork is shown in Figure 8. The flow rates in the roof ductwork and in the air supply ducts were obtained by velocity traverses with the Kurz hot wire anemometer. Data for the velocity traverses is shown in Appendix A. There are three large exhaust fans for the lamination areas that vent to the roof ductwork; one exhaust fan for the gel and barrier coat areas that vent to the vapor incinerator shown in Figure 9; and one smaller exhaust fan for the grinding booth that vents through a 20" diameter duct to a separate stack on the roof. The outlet ducts for all exhaust fans join just before entering the exhaust stack. Two additional large fans supply outside air to the exhaust stack to increase the effective stack height and to further dilute the styrene vapors. The total exhaust air flow was stated to be, in February 1983, 69,300 CFM compared to a design goal of 86,500 CFM.

This plant has been using a styrene suppressed resin manufactured by Pittsburg Plate Glass Chemical Company (PPGC). PPGC has however discontinued production of polyester resins, so comparable resins made by the Glidden Company of Cleveland, Ohio and others will be substituted when current stocks are exhausted.

The grinding booth is a source of resin dust generated when the mold flash is trimmed from the finished part. Resin dust is considered a nuisance dust. There was no plant exposure data available for this operation. A sample pump with a filter cartridge was placed on the grinder operator during each of the three days. The sample periods were generally about 71 minutes but varied from 53 minutes to 88 minutes with one sample period of 209 minutes on the first day. The average of the total dust exposure for the three days is 24 mg/m^3 which is above the 15 mg/m^3 PEL for nuisance dust established by OSHA. The make-up air (supplied from the room air) was also checked for dust. This was found to be about 7.0 mg/m^3 which is about 50% of the PEL. The filter media in this system was fiberglass battens such as used in home heating systems. This type of filter is inefficient for use in controlling the resin dust.

Work Practices: The plant floor is kept clean, filter media is changed frequently, work practice training is provided to new employees, and periodic sampling for styrene is performed by the company. The floor is covered with clean kraft paper each day and the waste paper is thrown into the dumpster outside the building. The exhaust filters are changed two times each day to maintain the efficiency of the ventilation system. Each new employee, upon hiring, is given a training course in work practices.

Monitoring: Results from an industrial hygiene survey performed by a company chemist on February 17, 1983 indicate that the average TWA exposure for 9 employees in the lamination area was 22.7 ppm styrene. The range of employee exposure was 8 ppm for the parts repairman to 34 ppm for the barrier coat operator. This monitoring test was performed prior to the installation of the vapor incinerator which required altering the air flow to the gel coat, barrier coat, parts cooling and part pulling work areas. For the subject survey, the 9 employees who worked on the lamination line were sampled for two periods during the work day. Each sample time was approximately 3 1/2 hours (210 min) but ranged from 185 to 210 minutes. Sampling began about 8:30 am and ended about 2:00 pm. This allowed us to sample the most active portion of the first shift. A total of 54 personal samples were taken for styrene Thirteen personal samples for resin dust exposure in the grinding booth were taken using DuPont P2500 pumps and 5 micron PVC membrane filters. The sampling period for these varied from 53 minutes to 209 minutes, but most were about 80 minutes. Since this was a recirculating air system it was decided to sample the return air. Two particulate samples were obtained for the return air.

Area samples for styrene vapor were obtained in the gel coat and barrier coat areas because the styrene concentration appeared very high at times as indicated by odor, eye irritation or direct reading instruments

Personal Protection: Workers in the lamination area wear coveralls and were observed wearing 3M standard particulate disposable respirators. This type of respirator seems to be adequate for the conditions observed. Workers in the gel coat and barrier coat areas wear MSA # OV 464031 quarter face mask type respirators.

V. RESULTS OF SAMPLING

A total of 54 personal samples for styrene were obtained. Twelve area samples for styrene were obtained and 13 personal samples for grinder dust were obtained. The personal samples for styrene are shown in the following table. The workers are coded A to I. The mean styrene concentration is a 3 day TWA.

Table 3. Styrene concentration, personal samples

Worker	Job Title	Styrene Concentration, ppm 3-Day TWA +/- 1 SD
A	Gel Coater	87 +/- 18
B	Gel Coater	79 +/- 13
C	Barrier Coater	170 +/- 20
D	Chopper Gun Lam #1	38 +/- 11
E	Roll Out Lam #1	60 +/- 16
F	Chopper Gun Lam #2	58 +/- 10
G	Chopper Gun Lam #2	50 +/- 6
H	Roll Out Lam #2	49 +/- 10
I	Chopper Gun Lam #1	52 +/- 7

The styrene concentrations, based upon previous information and impressions obtained in the preliminary survey in February 1983, are higher than anticipated for the gel coaters and barrier coaters. The company obtained personal sample data in their own survey in February, 1983. These data, 8-hour TWA are shown in Table 4.

Table 4. Company personal sampling data, February, 1983

Job	Styrene concentration 8-hour TWA, ppm
Gel Coater	21
Barrier Coater	34
Lam #1 Chopper Gun Operator	32
Lam #1 Roll Out	26
Trimmer	19
Lam #2 Chopper Gun Operator	21
Lam #2 Roll Out	28
Parts Puller	15
Parts Repair	8

The great differences in the exposure of the gel coaters and barrier coaters reflects the change in the ventilation system when the vapor incinerator was installed. It should also be noted that our data indicates an average exposure about double that of the company data. This may result in part from different plant operating conditions and different operators.

The area samples obtained in the gelcoat and barrier coat areas indicate a high level of styrene. These data are shown in Table 5. It should be noted that the personal samples for the gel coating operators is higher than the area sample. In the case of the barrier coat operator, the area and personal samples are approximately the same. Detailed sampling results are listed in Appendix B.

Table 5. Styrene concentration in gel coat and barrier coat area samples*

DAY	Gel Coating ppm Styrene	Barrier Coating ppm Styrene
1	49	123
	62	80
2	66	192
	64	249
3	61	167
	58	218
Average	60 ± 6	171 ± 62

*Average sample time was 200 minutes

VI. CONCLUSIONS AND RECOMMENDATIONS:

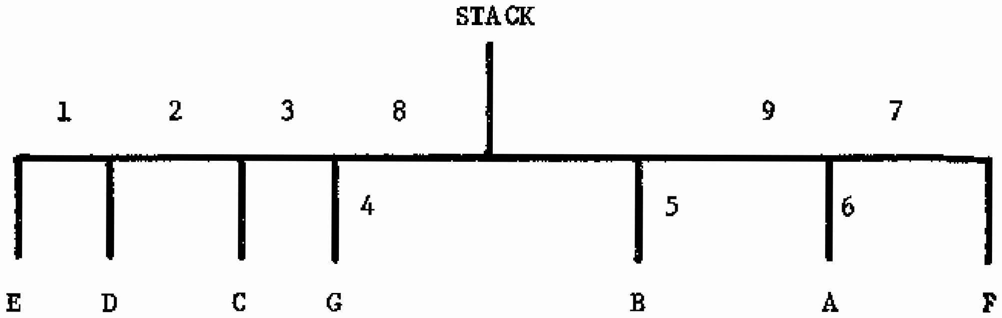
This plant was well designed to control styrene vapor for the original production schedule of one shift operation. This was apparent in the preliminary survey in March 1983 and is supported by personal sampling data obtained by the company in February 1983. The redesign of the ventilation system for the barrier and gel coating areas was brought about by the scheduling of a second production shift. The most important result of this survey was the realization that the installation of the styrene vapor incinerator changed the styrene exposure level drastically in the gel and barrier coating areas and to a lesser extent in the laminating areas. This has changed what appeared to be an ideal cross flow ventilation system into one which marginally meets the PEL of 100 ppm styrene in the gel and barrier coating areas and substantially raises the exposure of the lamination workers. In the case of the lamination workers, it is not clear why the exposure has almost doubled since the ventilation flow rates in the lamination areas did not change significantly due to the installation of the styrene vapor incinerator. It is concluded that because of the increase of styrene exposure in the barrier and gel coating areas, the reduced ventilation in those areas is an unsatisfactory approach to meeting air pollution emission standards. It is acknowledged that 20,000 CFM is a large volume of air to treat by incineration, adsorption or absorption but other approaches to removing styrene from the exhaust air should be examined. An interim approach would be to provide the worker with a supplied air respirator which would prevent the eye irritation experienced in the gel coat and barrier coat areas. It should be noted that this type of respirator can cause problems such as dry eyes due to the air flow and that visibility is reduced when resin deposits on the plastic facepiece. It is also recommended that this problem be discussed with the State Department of Air Resources and the State or Federal occupational health authorities.

The barrier coat operator has the highest exposure of all the workers and experienced a five fold increase in styrene exposure due to the modification in the ventilation system. This high exposure is also a result of the barrier coater working continuously in the spray area whereas the gel coaters alternate between spray and mold preparation. This reduces their average exposure to about one-half that of the barrier coater.

VII. APPENDIXES

Appendix A. Detailed Ventilation Data

1. Flow data for roof ducting system by NIOSH survey team



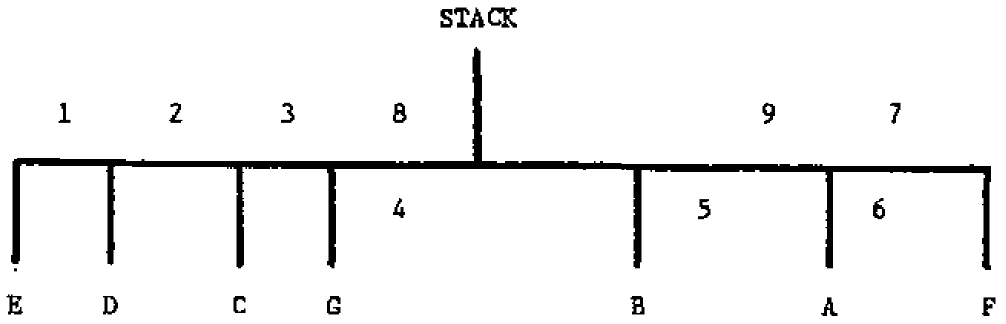
Blowers indicated by A to G

Data obtained from velocity traverse

DATA POINT	DUCT SIZE in.	DUCT AREA ft^2	AVERAGE VELOCITY FPM	FLOW RATE CFM	COMMENTS
1	31 x 18	3.875		11,500	By ratio of flows D & E (contractor's data)
2	48 x 31	10.33	2400	24,800	
3	48 x 52	17.33		39,900	Same as point #8, #4 is 0
4	12 x 10	0.835	0	0	Duct plugged with debris
5	48 x 16	5.33	2033	10,800	
6	40 x 24	6.67		16,810	By difference, #9 - #7
7	20 x 8	1.11		1,390	Contractor's data
8	52 x 48	17.33	2303	39,900	
9	48 x 24	8.00	2272	18,200	

The stack flow is 68,900 CFM, the sum of #5, #8 and #9

2. Flow data for roof ducting system by contractor



Blowers indicated by A to G

Data was marked on roof ductwork

DATA POINT	DUCT SIZE in.	DUCT AREA ft^2	AVERAGE VELOCITY FPM	FLOW RATE CFM	COMMENTS
1	31 x 18	3.875	3613	14,000	
2	48 x 31	10.33	3194	33,000	
3	48 x 52	17.33	3001	52,000	
4	12 x 10	0.835	1800	1500	
5	48 x 16	5.33	2064	11,000	now pulls ambient air
6	40 x 24	6.67	3120	18,000	now pulls ambient air
7	20 x 8	1.11	1250	1,390	
8	52 x 48	17.33			no data on ductwork
9	48 x 24	8.00	2750	22,000	

The stack flow is 86,500 CFM, the sum of #3, #4, #5 and #9

3. Company exhaust flow data for Gel Coating and barrier Coating areas

3a. Gel coat 17" exhaust duct data. Area = 1.6 ft^2

DATA point	HORIZ FPM	VERT-TOP FPM	VERT- BTM FPM	HORIZ-RT FPM	HORIZ-TOP FPM	VERT-BTM FPM
1/2"	1850	2100	1950	1850	2150	2150
1 3/8"	1950	2300	2100	2300	2250	2200
2 1/2"	2150	2350	2250	2300	2400	2300
3 7/8"	2200	2500	2350	2600	2600	2250
5 3/4"	2200	2500	2400	2600	2650	2450
11 1/4"	2250	2550	2500	2600	2550	2750
Summation	12,600	14,300	11,600	14,250	14,600	14,100
Average FPM	2100	2380	1930	2380	2430	2350
Overall average		2140 FPM			2390 FPM	
Flow		3420 CFM			3820 CFM	

3b. Company flow data for barrier coat area

Exhaust duct is 13" diameter, 0.9127 ft^2

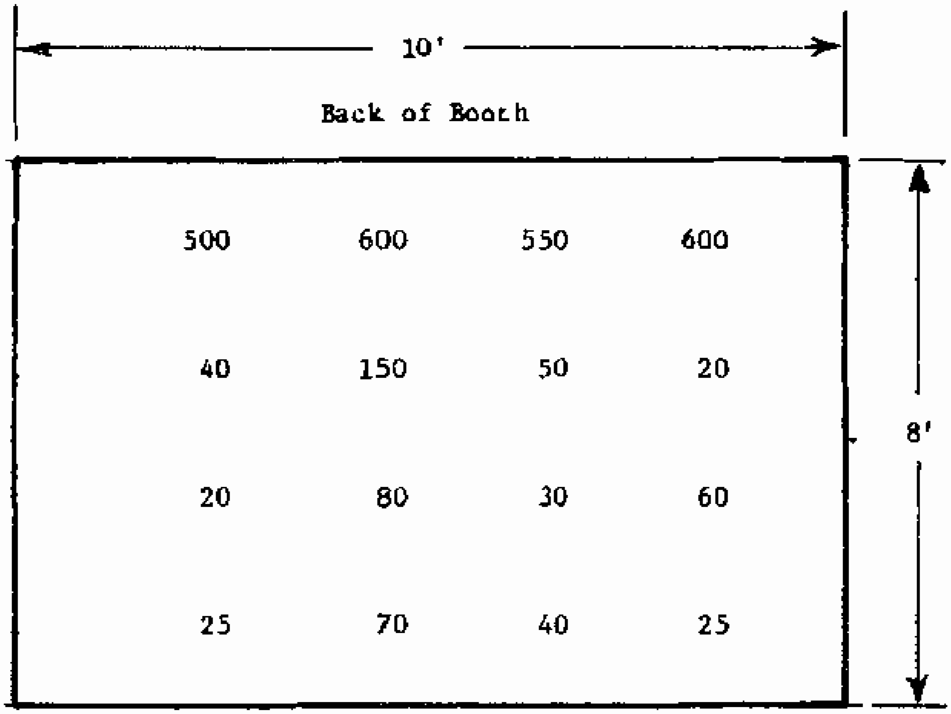
	Data set I		Data set II	
Data Point	Horizontal FPM	Vertical FPM	Horizontal FPM	Vertical FPM
3/8"	1900	1800	1900	1750
1"	2100	2350	2100	2050
1 7/8"	2250	2100	2200	2100
2 7/8"	2300	2200	2300	2300
4 1/2"	2300	2300	2250	2250
8 1/2"	2230	2300	2200	2300
10 1/8"	2300	2300	2250	2250
11 1/8"	2300	2150	2250	2200
12 "	2310	2100	2200	2100
12 5/8"	2350	2050	2300	2100
Summation	22,340	21,650	21,950	21,400
Average FPM	2230	2170	2200	2140
Flow CFM	2040	1980	2000	1950
Average CFM	2010		1980	

4. Company flow data for make-up air to gel and barrier coat areas
Data supplied by company.

Make-up air duct is 20" diameter, area = 2.182 ft^2

	DATA SET I			DATA SET II		
Data Point	Horiz. FPM	Horiz. FPM	Vert. FPM	Horiz. FPM	Horiz. FPM	Vert. FPM
5/8"	2200	2600	2600	2250	2500	2100
1 3/4"	2250	2600	2850	2350	2550	2400
3 1/4	2800	2500	2850	2700	2700	2400
5"	2600	2600	2850	2600	2750	2300
7 1/4"	2700	2600	2650	2800	2850	2100
12"	2700	2550	2600	2850	-	2100
Summation	15,250	15,500	16,400	15,550	13,350	13,400
Average	2540	2580	2730	2590	2670	2230
Velocity	2620 FPM				2460 FPM	
Flow	5720 CFM				5450 CFM	

5. Grinder booth air flow, 6-9-83



500	600	550	600
40	150	50	20
20	80	30	60
25	70	40	25

Front of booth

Open area of floor grid is 63%. This was based on a 16 1/2" by 5 1/2" area having 16 openings 3 1/2" by 1' in size.

The average velocity in the floor grid of the booth was 180 FPM in a total open area of 50 ft^2 ($80ft^2$ x .63).

The total flow is then 9000 CFM.

6. Traverse of supply air duct to Lamination #1 area, 6-9-83
24 point traverse, duct size is 48" x 40"

48"

Top of duct

1750	1650	1725	1700	1700	1400	1450	1400
1800	1700	1600	1675	1650	1550	1650	1500
1600	1550	1600	1625	1500	1500	1550	1450

40"

Average velocity is 1600 FPM
Total flow to Lamination #1 area is 21,200 CFM

7. Lamination #2 air supply duct, 6-9-83
Twenty seven point traverse, duct is 56" x 34" (13.2 ft^2)

56"

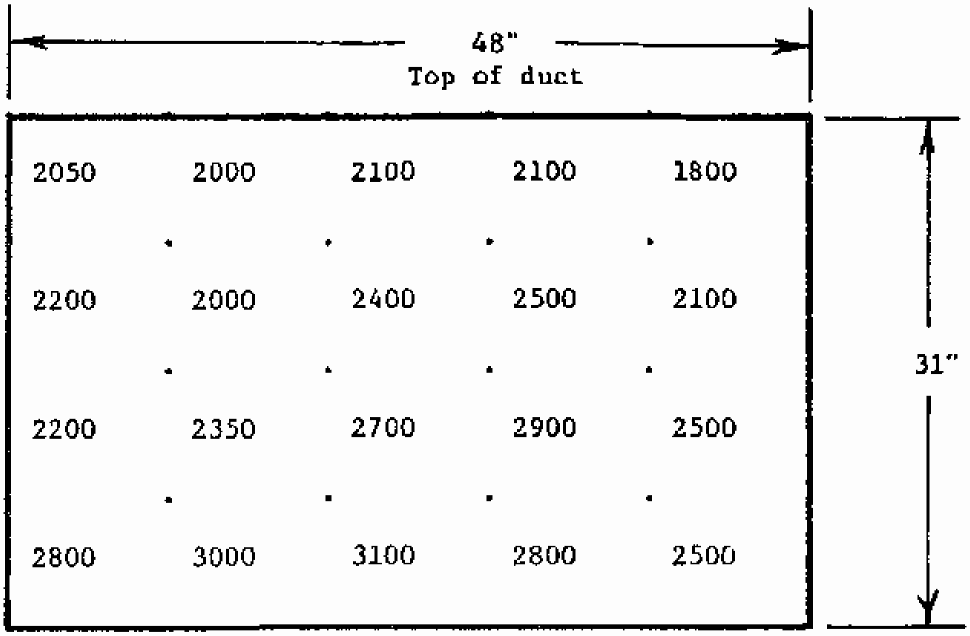
Top of duct

900	1050	1100	1150	1200	1150	1250	1250	1150
900	1050	1100	1100	1200	1150	1250	1250	1200
850	1000	950	1100	1150	975	1150	1200	1100

34"

Average velocity is 1100 FPM
The total flow to Lamination #2 area is 14,600 CFM

8. Roof ductwork, Traverse point 2, 6-9-83
20 Point traverse, duct size is 48" x 31" (10.33 ft^2)



2050	2000	2100	2100	1800
2200	2000	2400	2500	2100
2200	2350	2700	2900	2500
2800	3000	3100	2800	2500

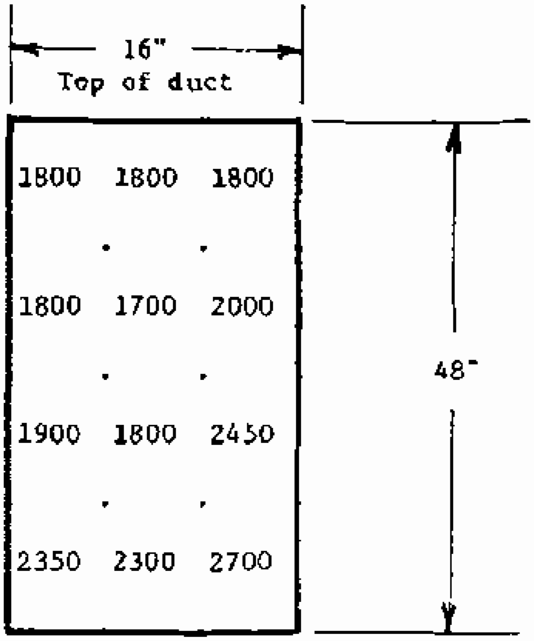
Average velocity in duct is 2400 FPM

Total flow in duct is 24,900 CFM

9. Roof ducting, Traverse point #4, 6-9-83
Duct size is 12" x 10"

No flow was observed in this duct. It was found to be clogged with debris.

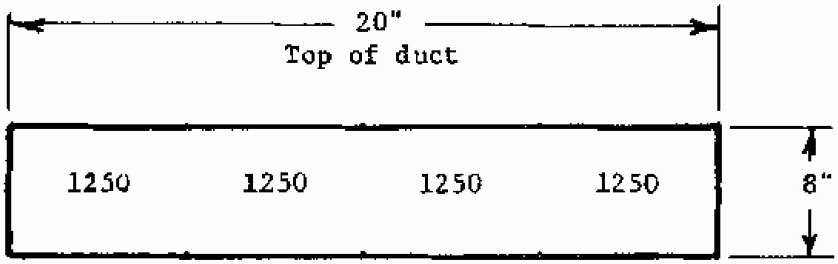
10. Roof ducting - Traverse point #5, 6-9-83
12 point traverse, duct size is 48" x 16" (5.333 ft^2)



1800	1800	1800
1800	1700	2000
1900	1800	2450
2350	2300	2700

Average velocity in duct is 2030 FPM
Total flow in duct is 10,800 CFM

11. Traverse point #7, 6-9-83
Velocity traverse is duct 20" x 8" (1.11 ft^2)

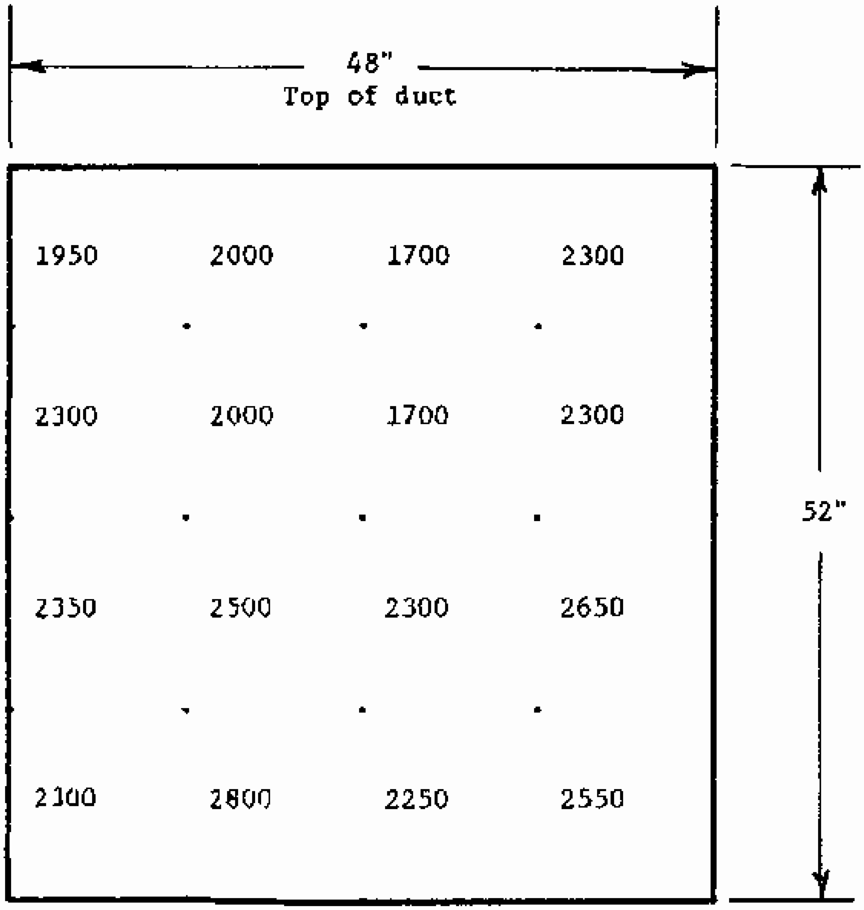


1250	1250	1250	1250

Average velocity is 1250 FPM
Total flow is 3330 CFM

Note: we did not measure this flow in the duct, we used the data written on the duct work by the ventilation contractor.

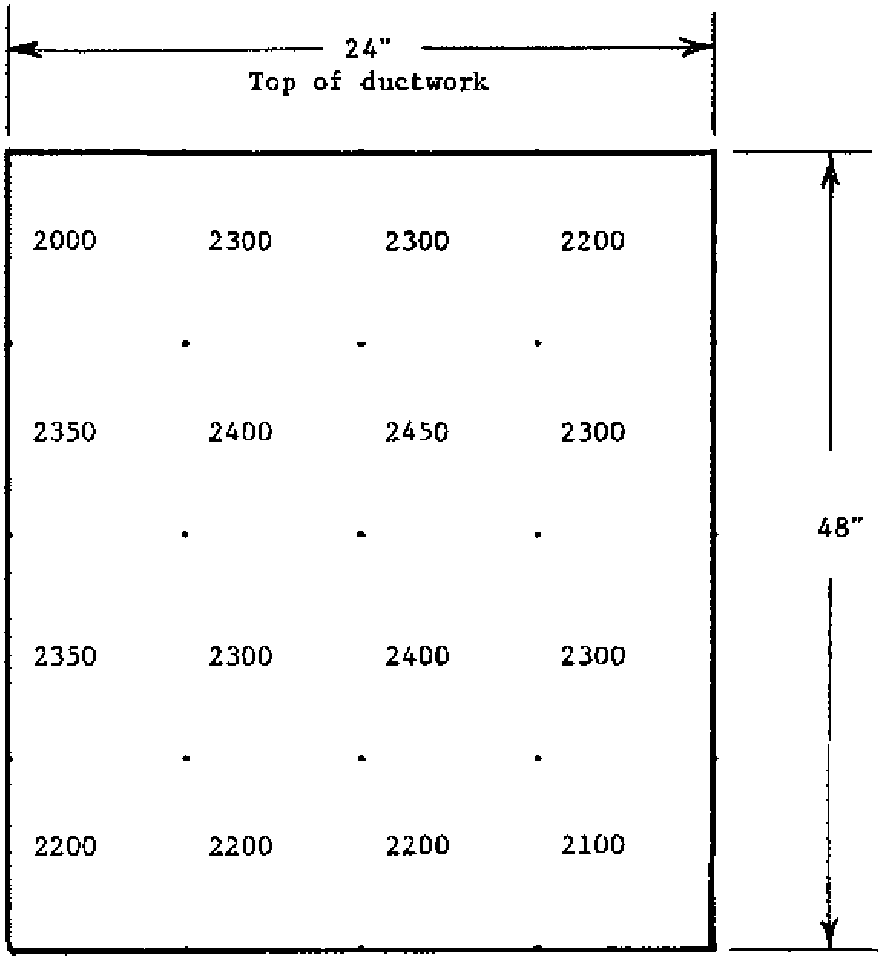
12. Roof ducting - Traverse point #8
16 point traverse, duct size is 48" x 52" (17.333 ft^{23})



1950	2000	1700	2300
2300	2000	1700	2300
2350	2500	2300	2650
2100	2800	2250	2550

Average velocity in duct is 2300 FPM
Total flow in duct is 39,900 CFM

13. Roof ducting - Traverse point #9, 6-9-83
16 point traverse, duct size is 24" x 48" (8 ft^2)



2000	2300	2300	2200
2350	2400	2450	2300
2350	2300	2400	2300
2200	2200	2200	2100

Average velocity is 2270 FPM
Total flow ios 18,200 CFM

14. Velocity traverse of 13" diameter duct (0.9128 ft^2), 6-8-83
10 point traverse (20 loci) of barrier coat exhaust duct

Data Point	Vertical FPM	Horizontal FPM
3/8"	1700	1850
1"	1550	1725
1 7/8"	1800	1850
2 7/8"	1875	1950
4 1/2"	1975	1950
8 1/2"	2025	1925
10 1/2"	2050	1950
11 1/8"	2050	1975
12"	2050	2025
12 5/8"	2050	1950
Sum	19,125	19,150
Average	1910	1920
	1915 FPM	

Total flow is 1750 CFM

Velocity traverse of 17" diameter duct (1.576 ft^2) 6-8-83
10 point traverse (20 loci) of Gel coat exhaust duct with TSI Velometer

Data Point	Vertical FPM	Horizontal FPM
1/2"	1000	1950
1 3/8"	1650	1975
2 1/2"	2125	2200
3 7/8"	2250	2300
5 3/4"	2400	2300
11 1/4"	2350	2275
13 1/8"	2350	2275
14 1/2"	2200	2275
15 7/8	2300	2300
16 1/2"	1975	2100
Sum	20,600	21,975
Average	2060	2200
	2130 FPM	

Total flow is 3360 CFM

Appendix B. DETAILED SAMPLE DATA

1a. Personal sampling data, lamination, gel coat and barrier coat workers[a].

EMPLOYEE	DAY	SAMPLE TIME Minutes	SAMPLE VOLUME Liters	STYRENE ppm
A	1	93	0.99	59
A	1	181	1.09	106
B	1	93	0.99	57
B	1	181	1.90	181
C	1	87	1.40	149
C	1	182	3.40	154
D	1	80	0.77	37
D	1	185	1.74	38
E	1	78	0.64	33
E	1	185	1.47	62
F	1	73	0.74	70
F	1	185	1.86	56
G	1	71	0.80	59
G	1	185	1.98	47
H	1	69	0.82	57
H	1	186	2.13	63
I	1	82	0.82	52
I	1	185	1.92	49
A	2	215	2.21	78
A	2	184	1.90	106
B	2	215	2.20	84
B	2	184	1.89	86
C	2	217	3.47	169
C	2	183	2.89	203
D	2	222	2.15	32
D	2	195	1.85	56
E	2	221	1.82	58
E	2	193	1.45	73
F	2	225	2.25	70
F	2	190	1.95	47
G	2	223	2.44	45
G	2	190	2.10	51
H	2	224	2.63	51
H	2	190	2.23	34
I	2	223	2.29	41
I	2	185	1.96	53

Appendix B. 1a. Personal sampling data (continued).

EMPLOYEE	DAY	SAMPLE TIME Minutes	SAMPLE VOLUME Liters	STYRENE ppm
A	3	223	2.26	89
A	3	187	1.91	84
B	3	224	2.33	76
B	3	187	1.95	78
C	3	225	3.50	161
C	3	185	2.83	83
D	3	222	2.14	29
D	3	184	1.81	b
E	3	223	1.86	LT 1.25[c]
E	3	191	1.41	72
F	3	228	2.23	49
F	3	194	1.93	54
G	3	224	2.41	44
G	3	194	2.04	54
H	3	224	2.58	43
H	3	194	2.19	45
I	3	224	2.43	60
I	3	191	2.08	58

a. Data was obtained with MDA Accuhaler pumps and charcoal sampling tubes.
b. Sample lost in analysis
c. Result considered as outlier; no reason for low value

1b. Personel sampling data, grinder booth worker.

EMPLOYEE	DAY	SAMPLE TIME MINUTES	SAMPLE VOLUME LITERS	DUST mg/m^3
J	1	79	119	12
J	1	209	314	46
K	2	82	117	6.5
K	2	73	110	7.5
K	2	59	89	4.6
K	2	74	111	11.7
K	2	55	83	11.3
K	2	60	90	5.4
K	3	86	129	3.41
K	3	53	80	4.38
K	3	65	98	5.5
K	3	88	132	10.83
K	3	77	116	5.86

Data was obtained with DuPont P2500 pumps and 5 micron PVC membrane filters.

Appendix B 2. Area sampling data.

2.a Area sampling data, grinder booth make-up air dust concentration.[a]

DAY	SAMPLE TIME MINUTES	SAMPLE VOLUME LITERS	DUST mg/m^3
3	239	359	4.3
3	186	279	10.2

a. Data obtained with DuPont P2500 pumps and PVC 5 micron filters.

2.b. Area sampling data, gelcoat and barrier coat areas.[a]

DAY	LOCATION	SAMPLE TIME Minutes	SAMPLE VOLUME Liters	STYRENE ppm
1	Gel coat area	77	3.81	49
1	"	220	10.9	62
1	Barrier coat area	73	3.64	123
1	"	218	10.9	80
2	Gel coat area	231	11.4	66
2	"	223	11.0	64
2	Barrier coat area	231	11.5	192
2	"	226	11.3	249
3	Gel coat area	250	12.4	61
3	"	206	10.2	58
3	Barrier coat area	256	9.1	167
3	"	202	9.4	218

a. Data obtained with MDA Accuhaler pumps and charcoal sampling tubes.

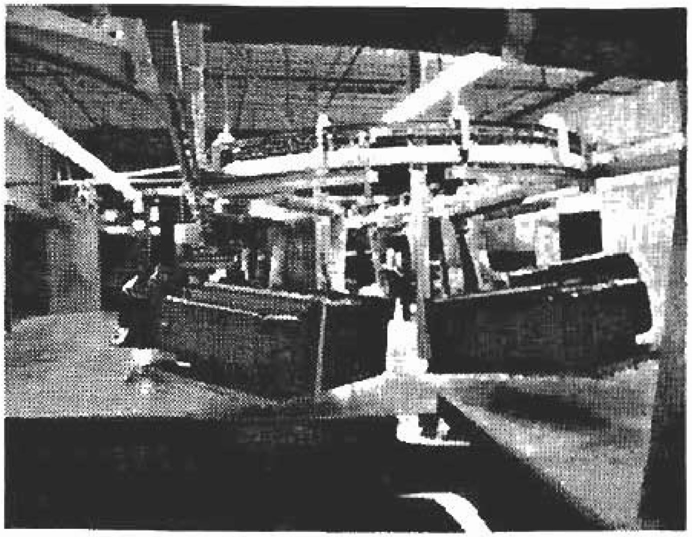


Figure 1. Mold suspension-overhead track

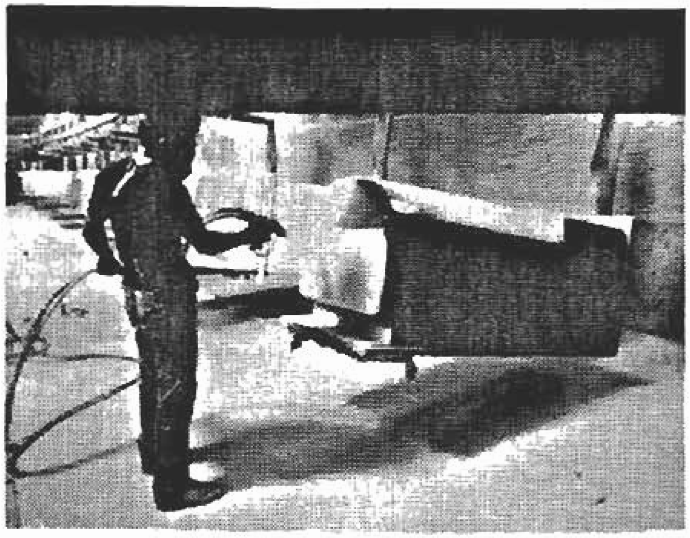


Figure 2. Gel coat area

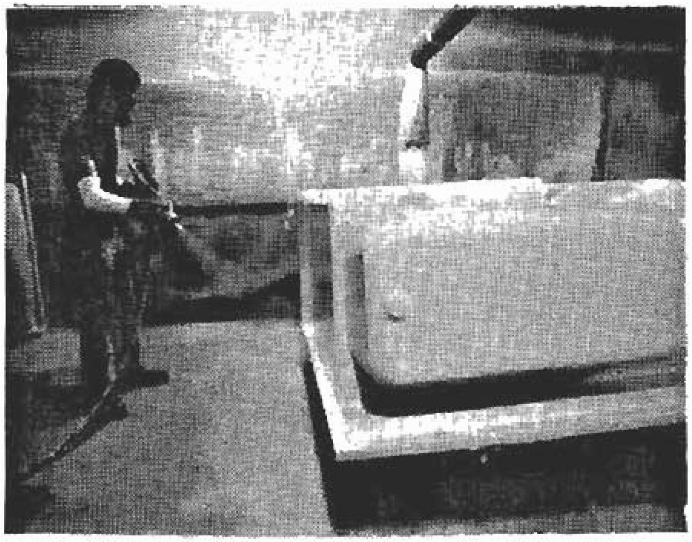


Figure 3. Barrier coat area

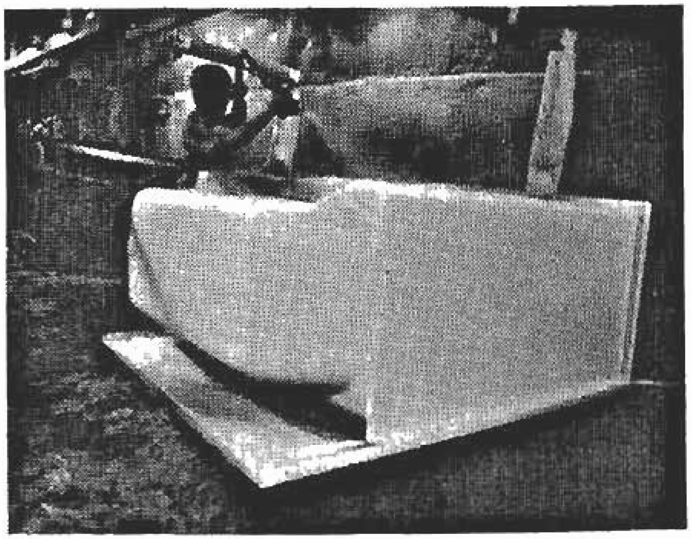


Figure 4. Lamination area #1

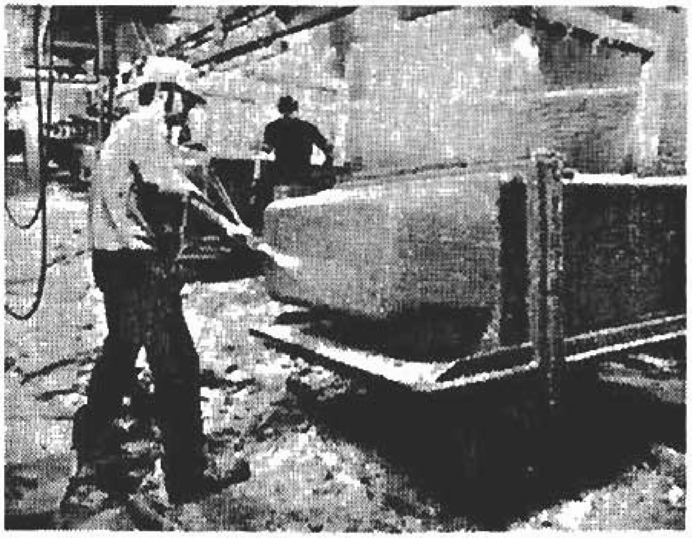


Figure 5. Lamination area #2

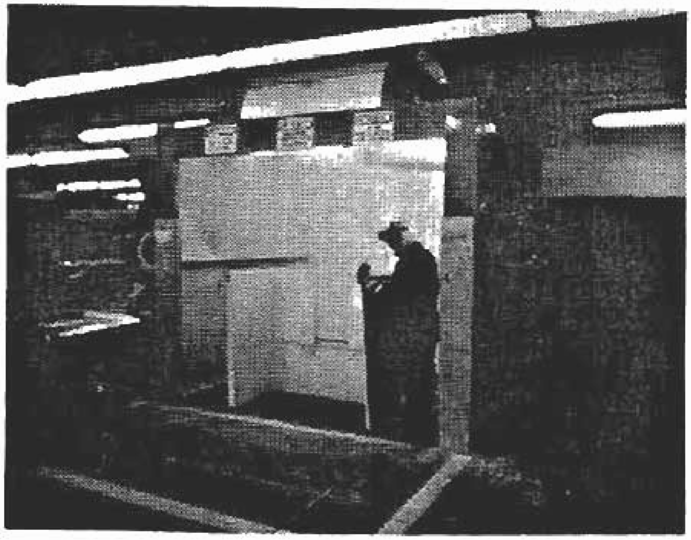


Figure 6. Downdraft grinding booth

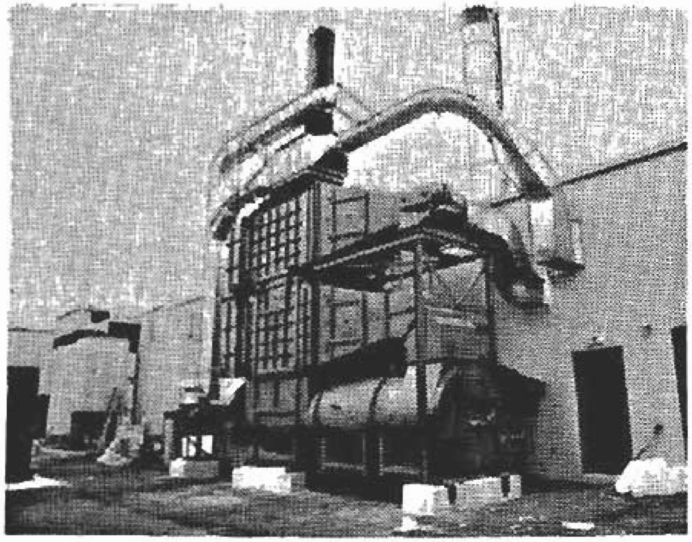


Figure 7. Styrene vapor incinerator

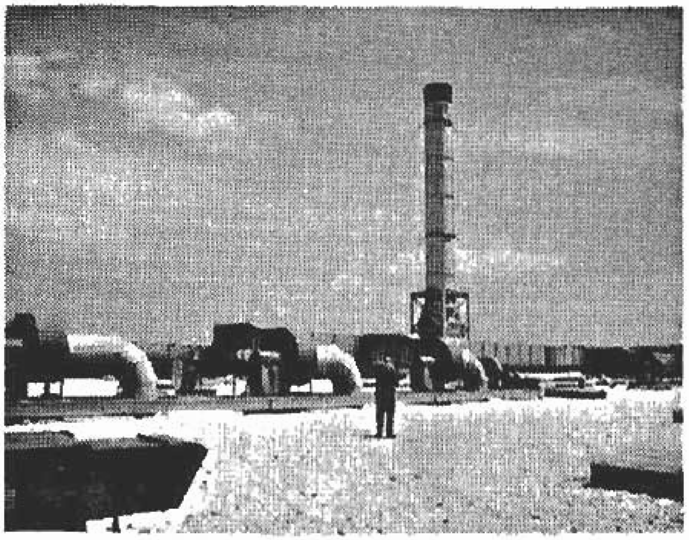
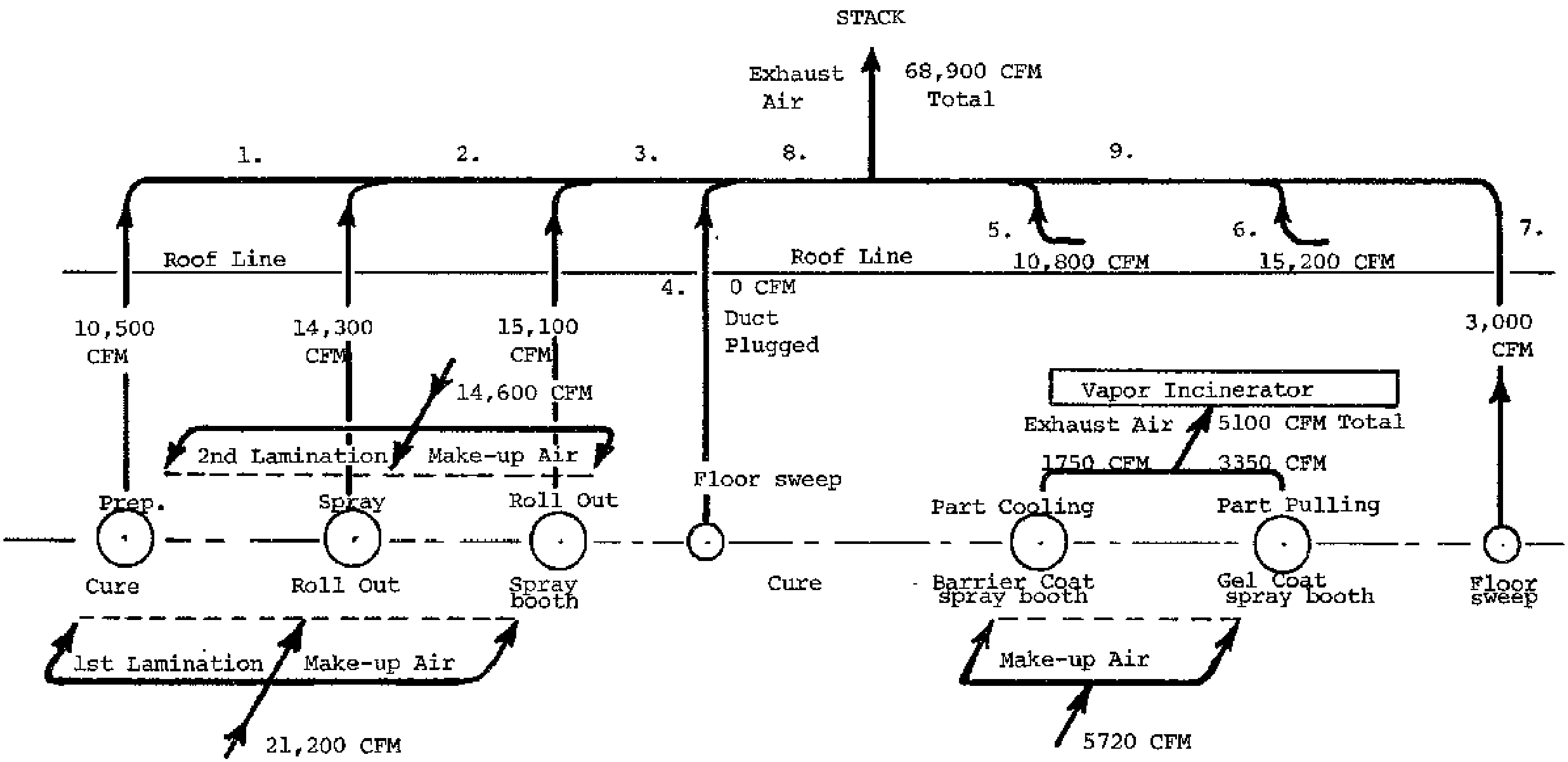


Figure 8. Roof ventilation ductwork



Numbers 1-9 are velocity traverse points

Figure 9. Exhaust air and make-up air flow rates in lamination area of plant