IMPACT OF STYRENE PEL REDUCTION ON COMPOSITES MANUFACTURERS IN CALIFORNIA

For

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Executive Summary

Cal-OSHA is considering a reduction of the permissible exposure limit (PEL) for styrene from 50 ppm to 20 ppm or lower. In California, the businesses most severely affected by this issue are manufacturers of reinforced composite plastics (RCP) products that are open-molded, such as shower stalls, recreational vehicle parts, and boats.

On behalf of this industry, the American Composites Manufacturers Association (ACMA) and the National Marine Manufacturers Association (NMMA) retained Environmental Compliance & Risk Management Inc. (ECRM) to evaluate the potential impact of a more stringent styrene PEL on companies complying with the current standard. This study involved surveying a number of typical composites manufacturing operations to collect data on exposures, exposure reduction methods, and other relevant factors. The results of this study are contained in this report, and a summary of our findings follows.

1. Worker exposure data collected during this study suggest that many composites manufacturers have barely met the current 50-ppm PEL for worker styrene exposure by modifying processes, improving ventilation and/or implementing administrative controls. At such plants resulting 8-hr exposures range from 40-50 ppm. However, these techniques are insufficient to meet the current standard for manufacturers of large parts and in certain highly automated small-part production scenarios, where respiratory protection is required for workers applying gelcoat and applying or rolling out reinforced resin.

2. Reduction of the 8-hr PEL below 50 ppm will mandate increased reliance on respiratory protection, and at 20 ppm all affected workers would require it. Even after modifying processes and resin formulations to reduce styrene emissions, ventilation improvements needed to comply much below 50 ppm will be either technically infeasible or prohibitively expensive. Reduction of the PEL to 20 ppm would force an estimated 5,000 California workers into respiratory protection.

3. Respiratory protection via a mix of supplied air and air purifying equipment would cost businesses $1300 to $3100 per employee, and subject these employees to risk of potential injury and cardiopulmonary distress associated with respirator use. Further, plants requiring use of respirators might find it more difficult to hire and retain operators.

4. Based on an evaluation of current studies by SIRC, the health benefit of PEL reduction from 50 ppm to 20 ppm might be the avoidance of mild and possibly reversible effects on color discrimination, hearing, and behavior, though evidence is inconclusive. Given our current state of knowledge, this benefit would appear to be uncertain at best.

5. Since benefits are uncertain, it would be imprudent to lower the PEL at this time. The cost to comply with a reduced PEL would needlessly place California plants at an economic disadvantage relative to their counterparts in states that enforce the 50 ppm Federal PEL.

6. If additional health effects studies determine that the PEL should be lowered, Cal-OSHA should exempt all composite plants from the requirement to determine the feasibility of engineering controls. The data presented in this report prove conclusively that to limit composite worker exposures much below 50 ppm, only respiratory protection is feasible.

1. Introduction

In April 2003, the California Department of Industrial Relations, Division of Occupational Safety and Health (Cal-OSHA) began a review to determine if the state's permissible exposure limit (PEL) of 50 ppm for styrene should be reduced to 20 ppm or lower. In doing so, Cal-OSHA must consider not only health benefits but also technical feasibility and adverse economic impacts. In California, the businesses most severely affected by this issue are manufacturers of reinforced composite plastics (RCP) products that are open-molded, such as shower stalls, recreational vehicle parts, and boats. There are nearly 300 RCP manufacturers in the state, producing over $1.25 billion worth of goods, and directly employing almost 10,000 workers. Overall, this industry contributes 17,000 jobs and $2.63 billion annually to the economy of California. ACMA estimates that at least 85% of RCP companies are small businesses as defined by the Small Business Administration.

On behalf of this industry, the American Composites Manufacturers Association (ACMA) and the National Marine Manufacturers Association (NMMA) retained Environmental Compliance & Risk Management Inc. (ECRM) to evaluate the potential impact of a more stringent styrene PEL on companies complying with the current standard.

ECRM investigated the impact of the proposed PEL reduction on a typical composite manufacturer (as profiled in Section 2 of this report), considering both the company's business and the health of its affected workers. The methodology we used was consistent with Cal-OSHA requirements specifying a hierarchy of controls to reduce inhalation exposures risks (Section 3), and included the following tasks.

- Surveys of worker exposures were conducted at six plants representing a cross-section of the open-molding composites manufacturers that would be affected by the lowered PEL (Section 4). The purpose of these surveys was (a) to determine whether typical exposures meet the current PEL and if so (b) whether there might be an exposure level below the current PEL that could be adopted without adverse impact because it is already being met.

- The feasibility of exposure reduction through resin reformulation and modification of material application techniques controls was assessed (Section 5).

- An engineering analysis of the feasibility and cost of ventilation improvements to further reduce exposures was completed (Section 5).

- Where ventilation controls were infeasible, the required increased reliance on respiratory protection to meet a 20-ppm standard was estimated, and the adverse impacts of respirator use were reviewed and summarized (Section 6).

In drawing our conclusions (Section 7), we considered the potential health benefits of PEL reduction from 50 to 20 ppm, based upon information submitted to the Cal-OSHA Airborne Contaminants Advisory Committee (ACAC) under separate cover by the Styrene Information and Research Center (SIRC) in November 2003. SIRC presented three reviews by independent scientists of various studies purported to show adverse effects of styrene exposure on color discrimination, hearing and behavior (reaction time, memory, dexterity, and balance). Based on these reviews, SIRC concluded there is some evidence of "extremely slight" effects on color discrimination, "no good evidence" of hearing loss, and inconclusive evidence of behavioral effects at or below 50 ppm. SIRC proposed studies to define exposure levels of concern, clinical significance, and reversibility of these effects, but concluded that " the current literature does not provide an adequate regulatory basis" for lowering the styrene PEL.

The members of the study team were David Lipiro of ECRM (project manager), Dr. Robert Haberlein of Engineering Environmental Consulting Services, Dr. Joseph Jurinski of NuChemCo Inc., and Stuart Sessions of Environomics Inc. All team members have extensive experience in the composites industry.

2. Styrene in Composites Manufacturing

Styrene is a colorless, oily, moderately volatile liquid with a sweet aromatic odor at low concentrations and a sharp disagreeable odor at higher ones. It may occur naturally in cranberries, currants, grapes, vinegar, dairy products, whiskey, tea, coffee, and roasted peanuts. Besides composites production, major industrial users of styrene in California are organic chemical and polystyrene production plants. However, worker exposures to styrene are low at such plants because polymerization takes place in closed chemical reactors.

In this report, what we refer to as composites are technically *reinforced thermoset plastic composites.* These materials consist of a *laminate* (layered mixture) of fibrous reinforcement that provides strength and plastic matrix that binds and protects the reinforcement. Fiberglass is by far the dominant material used as reinforcement, and may be incorporated within products in three forms: as randomly oriented chopped fibers, woven cloth, or fiber bundles (roving). Plastic matrix is formed from the *curing* (chemical reaction) of liquid resin mixture, which contain a blend of *resins* (unconnected plastic subunits), *monomers* (connecting links between subunits), and various agents that promote curing at room temperature and affect the properties of the resin mix. During the curing process, the resins *polymerize* (connect through monomer crosslinks) to form a tough solid plastic.

Many composite parts, especially consumer items such as shower stalls, require a durable gloss surface. To provide this, a separate layer of non-reinforced *gelcoat* (surface plastic) resin is either applied to part molds before laminate is formed or applied over laminate parts. During curing the gelcoat layer binds to the laminate surface.

Typical polyester resin blends contains from 30 to 50% by weight of styrene, the principal monomer used by the industry. Most of the styrene is either polymerized or evaporates during the curing process; the small fraction of the styrene that remains is trapped within the composite laminate. Liquid resin blends also contain other organic compounds, none of which is emitted in significant amount.

The composites industry employs a wide variety of molding processes to produce finished goods ranging in size from small handheld parts to room-sized structures. Of concern here are processes involving formation of composite parts on open molds, during which curing laminate is exposed to room air. The four main open molding processes that expose workers to styrene vapor are described below.

Hand lay-up is a simple manual lamination technique. Dry glass fiber reinforcement (chopped, cloth, or roving) is first cut and then fitted into or onto the open mold surface. A small precise quantity of catalyst (which promotes curing) is added to cups or small buckets full of resin, and the catalyzed resin is then quickly poured onto the dry glass reinforcement. Squeegees, special roller tools or brushes are used to spread the resin, smooth down the reinforcement and remove trapped air bubbles from the wet glass. This sequence of dry reinforcement application and resin wetting may be repeated several times to build up the desired part thickness.

Spray lay-up is a high-volume lamination technique that uses a special spray application device called a "chopper gun" to produce fiberglass parts in open molds. A chopper gun applies the glass reinforcement and resin simultaneously, without the manual steps required for hand lay-up. A small rotating knife on the top of the gun chops a continuous feed of roving into small pieces that are thrown out onto the mold surface. At the same time, two streams of both resin and catalyst are mixed together in an external spray. This catalyzed resin spray coats the chopped glass fibers and mold surface. Once the proper thickness of wet glass fibers has been deposited, a rolling process identical to the hand lay-up rolling is used to compact and smooth the laminate.

Gelcoat spraying is an additional step in the production of a part that requires a gelcoat surface. Gelcoat is sprayed onto the bare waxed mold surface, forming the outer finished surface of the part. Sometimes gelcoat may be applied externally to the outside of finished part or tool. Gelcoat is usually applied with special air-powered or airless spray guns.

Filament winding is a technique used to produce tubular products such as tanks and pipe. Continuous reinforcement fibers are pulled through a resin bath and then wound on a *mandrel* (revolving mold) that is in the shape of the final product.

At composites facilities, styrene is emitted primarily from aerosols and wetted surfaces produced during spray application, from wetted surfaces during rollout, and from parts as they cure. Spray application often is confined to open-ended enclosures (booths), but typically rollout and curing occur out in open areas of the shop floor. Emitted vapor is collected by forced air ventilation and exhausted outside.

Recently, production techniques have been developed that greatly lower styrene emissions and resulting worker exposures, by reducing or eliminating *atomization,* the formation of fine mists, during resin application. Further, modified resins have been developed with lower styrene content or with vapor suppressants, both of which also reduce styrene emissions. These *pollution prevention* techniques typically increase production costs; non-atomized application requires more time and labor than atomized spray techniques, and modified resins are more expensive than traditional resins. Nevertheless, pollution prevention is expanding in California as most composite manufacturers adopt it to meet new Federal and state emission standards.

3. Exposure Control and Impact Assessment Methodology

Cal-OSHA currently regulates work exposures to styrene through a Permissible Exposure Limit (PEL) of 50 ppm Time Weighted Average (TWA) over eight hours and a Short Term Exposure Limit (STEL) of 100 ppm over 15 minutes. The STEL is not an independent exposure limit; rather it supplements the TWA limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. Exposures above the TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There must also be 60 minutes between successive STEL exposures in this range.

Central to this study is the *hierarchy of controls* employed by industrial hygienists to reduce workplace exposures below the PEL and STEL. This risk reduction strategy ranks exposure controls based on effectiveness and lack of offsetting health risk, and requires that controls be implemented to the extent feasible in order of preference until the desired exposure reduction is attained. As this concept is applied to the inhalation exposure risks of composite manufacturing workers, the order of preference is:

1. Reduction of ambient styrene levels at the source of emission through modification of raw materials or their methods of application. For composites, this might be accomplished by reducing styrene content in resins, employing vapor suppressants, or reducing atomization (fine droplet formation) during application of gelcoat and resin.

2. Engineering controls such as production line reconfiguration and ventilation improvements to reduce styrene concentrations in the breathing zone of workers. For composites, this might involve modification of work enclosures (booths or rooms), repositioning of work or operators within enclosures, redirection of supply and exhaust flow, and increasing ventilation airflows.

3. Education or administrative controls such as worker rotation.

4. Use of supplied air or air purifying respirators to reduce inhalation exposures.

The State of California has accepted and codified this hierarchy of controls. State regulations require that engineering controls be used to limit hazards whenever feasible. In the absence of effective engineering controls, administrative controls are to be used. The routine use of respiratory protection to control exposures is only permitted when engineering controls and ventilation controls cannot achieve full compliance with a permissible exposure limit. (CCR 8, Section 5141). This control approach has been further codified by the State of California in a Division of Occupational Safety and Health Guidance on Feasibility of Engineering Controls for the Reinforced Plastics Industry (P&P C 38, Issued 1/15/91, Revised 8/1/94; http://www.dir.ca.gov/doshpol/p%26pc%2D39.htm, hyperlink date 6/14/03).

ECRM evaluated the adverse impact of the proposed PEL reduction on a typical composite manufacturer, considering both the company's business and the health of its affected workers. Adverse business impacts include costs to implement the control hierarchy, and potential worker recruitment and retention problems due to any required respiratory protection programs. The recognized adverse health impacts of respirator use would be imposed on any worker previously protected by source reduction or engineering control at the current PEL who would be required to wear a respirator under the lowered PEL.

4. Industrial Hygiene Surveys

To assess the impact of lowering the PEL from 50 ppm to 20 ppm or lower on the composites industry in California, we must first determine the levels of exposure typical under the current PEL. After all, if exposures at composite plants subject to the current PEL do not exceed 20 ppm, lowering the PEL to that level would have no impact on this industry.

This section presents data from two industrial hygiene surveys conducted by study team members to characterize baseline exposures. Survey 1 was actually part of a prior evaluation conducted in February and March of 2001 on three open molding plants in the Midwest, here redesignated as Plants 1-3. [See Jurinski et al, Relationships between Capture of Vapor Emissions and Occupational Exposures for Open Molding of Reinforced Plastic Composites, August 2001.] Survey 2 was conducted as part of the current study in July of 2003 on three open molding plants in California, here designated Plants 3-6. [A fourth plant was evaluated during the first survey, but will not being considered here. Exposures noted at this plant were low, but capacity utilization was too low (10-25%) to allow meaningful extrapolation to normal production levels.]

We believe the six plants evaluated typify the range of open molding processes and associated operator exposures in California. Products range in size and complexity from small tub enclosure pans to boat hulls exceeding 20 feet in length. Two plants operate at relative high production levels using automated conveyorized lines, while other plants operate at lower levels using non-automated processes.

All surveys were conducted in accordance with standard industrial hygiene sampling procedures set forth in the OSHA Technical Manual, Section II, Chapter 1 (see OSHA website at http://www.osha-slc.gov). Samples were taken over an eight-hour work shift to determine exposures for comparison to the PEL. For Survey 2, 15-minute samples were taken for comparison to the STEL. Upper and lower confidence limits (UCLs and LCLs respectively) were calculated based on a sampling and analytical error (SAE) of 0.11. Per OSHA interpretive guidance, sampled concentrations yielding both a UCL and an LCL above one were deemed *violations*, while those yielding only a UCL above one were deemed *possible overexposures*. Colorimetric detector tubes were used to take one-minute spot samples of ambient styrene concentrations.

Plant 1

Plant 1 produces a variety of recreational vehicle (RV) and heavy truck parts. Parts produced during the survey ranged in size from 10-365 square feet. All lamination takes place in two lines (Bake and Non-Bake) in the east end of the single plant building in an area measuring 205 feet long by 150 feet wide by 25 feet high. Within this area are three gelcoat booths, two lamination booths, a common gelcoat cure area, and a common laminate cure area. Parts are moved on wheeled carts. Production was estimated to be 80% of capacity at the time of survey.

Table 1 below summarizes the configuration and ventilation of all process enclosures.

Enclosure	**Size LxWxH ft**	**Ventilation System**	**Airflow cfm**
Gelcoat Booths (2)	45 x 20 x 16	Downdraft supply air, floor-level sidewall exhausts, flexible end curtains.	19200 each
Laminate Booths (3)	75 x 20 x 16	Downdraft supply air, floor-level sidewall exhausts, air curtains at ends	Bake: 54100 Nonbake: 36700
Gelcoat Curing	60 x 40 x 25	General area ventilation	Dilution
Laminate Curing	75 x 24 x 25	General area ventilation	Dilution

There were no detector tube readings taken in the gelcoat booths, Detector tube readings in the lamination booths ranged from 5-50 ppm Non-Bake and 5-60 ppm Bake. Results of exposure sampling are summarized in Table 2 below. Each result is the average of two replicate samples.

Plant: 1			50 ppm TWA			20 ppm TWA		
Sample	ppm	Operator	UCL	LCL	Violation?	UCL	LCL	Violation?
1A-5	49.5	Bake roll 1	1.10	0.88	Overexposure?	2.59	2.37	Yes
1A-6	45.7	Bake Roll 2	1.02	0.80	Overexposure?	2.40	2.18	Yes
1A-9	44.8	Bake line gel	1.01	0.79	Overexposure?	2.35	2.13	Yes
1A-10	41.0	Nonbake line gel	0.93	0.71	No	2.16	1.94	Yes
1A-1	28.6	Bake line chop	0.68	0.46	No	1.54	1.32	Yes
1A-2	27.0	Nonbake roll-1	0.65	0.43	No	1.46	1.24	Yes
1A-3	18.3	Nonbake roll-2	0.48	0.26	No	1.02	0.80	Overexposure?
1A-4	11.8	Nonbake chop	0.35	0.13	No	0.70	0.48	No

None of these results indicate a violation of the current 50 ppm Cal-OSHA PEL, although samples collected from the Bake Line rollers and gelcoater indicate a "possible overexposure" (UCL >1) to styrene. These possible overexposures appeared related to the time the employees spent bent over the edges of the large molds to roll out the fresh surface. Clearly though, the margin of compliance at 50 ppm is slight. However, six of eight operators would have been overexposed and one other possibly overexposed if the PEL had been 20 ppm.

Plant 2

Plant 2 produces RV parts ranging in size from 40 to 250 square feet. All lamination takes place in the east end of the single plant building in an area measuring 205 feet long by 90 feet wide by 22 feet high. Within this area is a single production line including one gelcoat booth, one lamination booth, and a separate room enclosure for each curing operation. Parts are moved on wheeled carts. Production was estimated to be 50% of capacity at the time of survey.

Table 3 below summarizes the configuration and ventilation of all process enclosures.

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booth	40 x 16 x 12	Open-ended booth with push-pull crossflow, overhead supply duct on one side, low-level exhaust pickups on other.	38,200
Laminate Booth	48 x 36 x 12	Open-ended booth with push-pull crossflow, central overhead supply duct, low-level exhaust pickups at sides	45550
Gelcoat Curing	40 x 16 x 22	Two small floor-level corner exhausts	<3400 cfm
Laminate Curing	40 x 36 x 22	Two small floor-level corner exhausts	<3400 cfm

Detector tube readings ranged from 10-110 ppm in the gelcoat booth, and 10-100 ppm in the lamination room. Results of exposure sampling are summarized in Table 4 below. Each result is the average of two replicate samples.

Plant: 2			50 ppm TWA			20 ppm TWA		
Sample	ppm	Operator	UCL	LCL	Violation?	UCL	LCL	Violation?
1B-5	23.5	Roll 2	0.58	0.36	No	1.29	1.07	Yes
1B-4	23.2	Roll 1	0.57	0.35	No	1.27	1.05	Yes
1B-3	22.8	Chop	0.57	0.35	No	1.25	1.03	Yes
1B-2	21.7	Gel	0.54	0.32	No	1.20	0.98	Overexposure?
1B-6	20.1	Roll 3	0.51	0.29	No	1.12	0.90	Overexposure?

All five samples were well below the current 50-ppm PEL. However, recorded exposures would certainly increase if production were higher than the 50% level observed during survey. The compliance margin at the current PEL under those conditions would be slight at best. If the PEL were 20 ppm, all operators would experience overexposures at full production capacity.

Plant 3

Plant 3 produces bathware such as residential tub-shower enclosures, separate shower pans and tub enclosures, and small whirlpool spas. Parts produced during the survey ranged in size from 40 to 120 square feet. Lamination takes place in a 200-foot long by 150-foot wide room on the northwest side of the single plant building. Within this room are two identical production lines, in total consisting of four gelcoat booths two lamination rooms, two gelcoat curing areas, and two laminate curing areas. Parts are moved via conveyor systems. This plant is unique in that ventilation exhausts from booths and curing areas are tied to a large thermal oxidizer system installed to abate styrene odor offsite. Production was estimated to be 90% of capacity at the time of survey.

Table 5 below summarizes the configuration and ventilation of all process enclosures.

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booths (4)	20 x 15 x 10	Push-pull crossflow, sidewall supply duct on one side, low-level exhaust pickups on other, air curtains across booth open ends	8300 ea
Laminate Booths (2)	115 x 35 x 10, 130 ft conveyor within	Push-pull crossflow, overhead supply duct at back end, low-level exhaust pickups at sides	56900 ea
Gelcoat Curing (2)	90 x 50 x 22, 250 ft conveyor within	None – diffusion dilution in space	NA
Laminate Curing (2)	220 ft conveyor in 4200 sq ft room	None – diffusion dilution in space	NA

Detector tube readings ranged from 10-190 ppm in one of the gelcoat booths, and 10-180 ppm in one of the lamination booths. Results of exposure sampling are summarized in Table 6 below. Each result is the average of two replicate samples.

Plant: 3			50 ppm TWA			20 ppm TWA		
Sample	ppm	Operator	UCL	LCL	Violation?	UCL	LCL	Violation?
1D-9	52.7	Chop 4	1.16	0.94	Overexposure?	2.75	2.53	Yes
1D-8	50.7	Roll 4	1.12	0.90	Overexposure?	2.65	2.43	Yes
1D-1	46.4	Gel 1	1.04	0.82	Overexposure?	2.43	2.21	Yes
1D-3	39.6	Chop 1	0.90	0.68	No	2.09	1.87	Yes
1D-2	39.5	Gel 2	0.90	0.68	No	2.09	1.87	Yes
1D-5	29.9	Roll 1	0.71	0.49	No	1.61	1.39	Yes
1D-7	27.9	Roll 3	0.67	0.45	No	1.51	1.29	Yes
1D-6	25.4	Chop 3	0.62	0.40	No	1.38	1.16	Yes
1D-10	23.6	Roll 2	0.58	0.36	No	1.29	1.07	Yes
1D-4	20.0	Chop 2	0.51	0.29	No	1.11	0.89	Overexposure?

Three samples recorded exposures just above 50 ppm, indicating possible overexposures at the current PEL. Five of 10 samples recorded exposures above 39.5 ppm. If the PEL had been 20 ppm, nine of 10 samples would have recorded violations, and the remaining would have recorded a possible overexposure.

Plant 4

Plant 4 manufactures boats (boat hulls and matching decks) ranging in length from 16 to 25 feet. Lamination activities are confined to two rooms each 100 ft long by 84 feet wide by 25 feet high at one end of the single plant building. Within one room were two 60-foot gelcoat booths and a gelcoat curing area; the other was a common room housing all lamination and associated curing areas. Parts are moved on large wheeled carts. During the survey five boats were built, equivalent to just over 70% of capacity.

This plant is typical of facilities producing large parts of complex geometry in three dimensions. Rollout of each part involves a team of operators, who must reach across wetted surfaces far into the part at times. As many as four operators were observed rolling out laminate on one boat hull at this plant. When rolling out the base of the hull, these operators were hanging well into the hull interior.

Table 7 below summarizes the configuration and ventilation of all process enclosures.

Enclosure	**Size LxWxH ft**	**Ventilation System**	**Airflow cfm**
Gelcoat Booths (2)	60 x 10 x 10 auto paint booths	Pull system, supply duct at one end, hinged doors at ends	18,000 each 36,000 total
Laminate Room	Work area: 84 x 30 x 25 (~half of open room)	Push-pull crossflow, overhead supply duct across long end of work area, two 14 x 7 exhaust pickups on opposite side, one pickup on opposite wall	12,000 ea 36,000 total
Gelcoat Curing	40 x 16 x 22	In Gelcoat Room	Dilution
Laminate Curing	40 x 36 x 22	In Lamination Room	Dilution

No detector tube readings were taken in the gelcoat booths. Detector tube readings in the lamination room were 20-40 ppm in background areas, and 40-120 ppm in the work area. Results of exposure sampling (including short-term samples) are summarized in Table 8 below.

Plant: 4			50 ppm TWA/100 ppm STEL			20 ppm TWA/40 ppm STEL		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation?**	**UCL**	**LCL**	**Violation?**
2A-4	88	Lamination, Polycure	1.88	1.66	Yes	4.53	4.31	Yes
2A-7	62	Roller #3	1.34	1.12	Yes	3.19	2.97	Yes
2A-15	63	Lamination Chopper #2	1.36	1.14	Yes	3.24	3.02	Yes
2A-6	62	Roller #2	1.35	1.13	Yes	3.22	3.00	Yes
2A-2	61	Gel Coat Sprayer #2	1.33	1.11	Yes	3.16	2.94	Yes
2A-8	61	Roller #4	1.32	1.10	Yes	3.14	2.92	Yes
2A-12	60	Roller #7	1.31	1.09	Yes	3.12	2.90	Yes
2A-11	57	Roller #6	1.24	1.02	Yes	2.94	2.72	Yes
2A-9	55	Roller #5	1.22	1.00	Overexposure?	2.88	2.66	Yes
2A-10	49	Lamination Chopper #1	1.10	0.88	Overexposure?	2.58	2.36	Yes
2A-13	45	Roller #8	1.01	0.79	Overexposure?	2.36	2.14	Yes
2A-1	44	Gel Coat Sprayer #1	0.99	0.77	No	2.30	2.08	Yes
2A-14	44	Roller #9	0.98	0.76	No	2.30	2.08	Yes
2A-5	36	Roller #1	0.83	0.61	No	1.92	1.70	Yes
2A-3	19	Gel Coat Helper	0.49	0.27	No	1.06	0.84	Overexposure?
2A-20 (STEL)	135	Roller #5	1.46	1.24	Yes	3.49	3.27	Yes
2A-16 (STEL)	103	Gel Coat Sprayer #1	1.14	0.92	Overexposure?	2.69	2.47	Yes
2A-18 (STEL)	101	Gel Coat Sprayer #1	1.12	0.90	Overexposure?	2.65	2.43	Yes
2A-17 (STEL)	100	Roller #3	1.11	0.89	Overexposure?	2.62	2.40	Yes
2A-19 (STEL)	62	Roller #6	0.73	0.51	No	1.66	1.44	Yes

Eight of 15 samples recorded violations of the 50-ppm PEL, and another three recorded possible overexposures. There was only one of five short-term samples violating the 100-ppm STEL, but three others recorded possible overexposures. If the 20-ppm PEL and 40 ppm STEL were in place, all samples except the gelcoat helper's would have recorded violations. Note that at this plant gelcoat operators were required to wear air-purifying respirators (half-face) with charcoal canisters, and other operators voluntarily wore carbon-impregnated dust masks for nuisance odor abatement.

Plant 5

Plant 5 manufactures a wide variety of moderate-size parts (40-140 square feet), including RV end caps, truck fenders and front caps, and storage tank stands. Lamination activities are confined to a single building with a floor area 275 feet long by 250 feet wide by 28-35 feet high. Within this building are two gelcoat booths, three laminate booths, and a common open-air curing area for gelcoat and laminate. Parts are moved on wheeled carts. Production was estimated to be 50% of capacity during the time of survey.

Table 9 below summarizes the configuration and ventilation of all process enclosures.

Enclosure	**Size LxWxH ft**	**Ventilation System**	**Airflow cfm**
Gelcoat Booths (2)	30 x 16 x 16 30 x 16 x 10	Push- pull systems, supply duct at one end, outlets flush with door top, wall exhaust on one side [recirculation zone noted on opposite side]	10,000 each 20,000 total
Lamination Booths (3)	30 x 16 x 16 30 x 16 x 10 (2)	Push- pull systems, supply duct at one end, outlets flush with door top, wall exhaust on one side [recirculation zone noted on opposite side]	10,000 each 30,000 total
Rollout/Curing	60 x 60 x 40	'Dilution" ventilation + oscillating fans	Dilution

Detector tube readings taken behind the booths indicated a background styrene concentration of 5 ppm. The maximum reading in a booth was 220 ppm. Readings were 20-30 ppm in the doorway of that booth facing the rollout area, and 80-200 ppm in the rollout area itself. Results of exposure sampling (including short-term samples) are summarized in Table 10 below.

Plant: 5			50 ppm TWA/100 ppm STEL			20 ppm TWA/40 ppm STEL		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation?**	**UCL**	**LCL**	**Violation?**
2B-4	83	Temp. Roller #2	1.78	1.56	Yes	4.28	4.06	Yes
2B-8	52	Roller #5	1.15	0.93	Overexposure?	2.70	2.48	Yes
2B-9	50	Roller #6	1.11	0.89	Overexposure?	2.62	2.40	Yes
2B-7	45	Chopper, Roller #4	1.01	0.79	Overexposure?	2.36	2.14	Yes
2B-1	39	Roller #1	0.88	0.66	No	2.04	1.82	Yes
2B-5	35	Chopper, Roller #3	0.81	0.59	No	1.85	1.63	Yes
2B-3	24	Utility #1	0.58	0.36	No	1.29	1.07	Yes
2B-6	17	Gel Coater #1	0.45	0.23	No	0.95	0.73	No
2B-2	4	Helper #1	0.19	-0.03	No	0.30	0.08	No
2B-25 (STEL)	82	Chopper, Roller #3	0.93	0.71	No	2.16	1.94	Yes
2B-22 (STEL)	73	Chopper, Roller #3	0.84	0.62	No	1.95	1.73	Yes
2B-24 (STEL)	43	Gel Coater #1	0.54	0.32	No	1.18	0.96	Overexposure?
2B-23 (STEL)	35	Chopper, Roller #4	0.46	0.24	No	0.97	0.75	No
2B-21 (STEL)	25	Gel Coater #1	0.36	0.14	No	0.72	0.50	No

One out of nine samples violated the current 50-ppm PEL, and three other samples recorded possible overexposures. If the PEL had been 20 ppm, seven of nine samples would have recorded violations. None of the five short-term samples violated the current 100-ppm STEL. If the STEL had been 40 ppm, two of five samples would have recorded violations and another sample would have recorded a possible overexposure. Note that all operators except the helper wore half-face negative pressure air purifying respirators.

Given the current booth configuration and ventilation at this site, it is likely that additional exposures exceeding the current PEL would be recorded if production were to increase much above the 50% level observed during the survey.

Plant 6

Plant 6, located in a large industrial park in the Los Angeles metro area, manufactures residential tub and shower enclosures about 40 square feet in size. All lamination activities take place on an automated line. Parts are moved along this line by a continuous overhead conveyor through successive 18-foot wide by 10-foot high tunnel sections (analogous to booths) for application of gelcoat and barrier coat (an inner gelcoat layer), application and rollout of laminate, with curing areas between tunnel sections. The line was running at full capacity at the time of survey, producing a unit every two minutes. Table 11 below summarizes the configuration and ventilation of tunnel sections.

Enclosure	**Size LxWxH ft**	**Ventilation System**	**Airflow cfm**
Gelcoat booth + tunnel	70 x 18 x 10	Push-pull crossflow, 2 x 5 supply registers mid-high on one side, exhaust pickup mid-low opposite - operators move alongside moving parts into flow	75000 design, register airflow not balanced, higher in rollout
Barrier Coat booth + tunnel	72 x 18 x 10		
Lamination 1 booth + tunnel	70 x 18 x 10		
Lamination 2 booth + tunnel	70 x 18 x 10		

Detector tube readings taken in the wood shop indicated a background styrene concentration of 20 ppm. Readings in lamination spray areas ranged from 40-150 ppm, and from 90-200 ppm in rollout areas. Results of exposure sampling (including short-term samples) are summarized in Table 12 below.

Plant: 6			50 ppm TWA/100 ppm STEL			20 ppm TWA/40 ppm STEL		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation?**	**UCL**	**LCL**	**Violation?**
2C-9	122	Lam #2, Roller #2	2.54	2.32	Yes	6.19	5.97	Yes
2C-11	82	Lam #2, Gun	1.74	1.52	Yes	4.19	3.97	Yes
2C-1	74	Lam #3 Gun	1.59	1.37	Yes	3.81	3.59	Yes
2C-5	70	Lam #1, Roller #3	1.50	1.28	Yes	3.59	3.37	Yes
2C-15	65	Lam #1 Gun	1.41	1.19	Yes	3.36	3.14	Yes
2C-3	59	Lam #2, Roller #1	1.29	1.07	Yes	3.07	2.85	Yes
2C-10	53	Gel Coat	1.16	0.94	Overexposure?	2.74	2.52	Yes
2C-14	52	Barrier Coat	1.14	0.92	Overexposure?	2.70	2.48	Yes
2C-12	49	Trimmer	1.09	0.87	Overexposure?	2.57	2.35	Yes
2C-7	39	Gel Coat	0.89	0.67	No	2.07	1.85	Yes
2C-4	34	Lam #1, Roller #2	0.79	0.57	No	1.81	1.59	Yes
2C-8	33	Trimmer	0.77	0.55	No	1.76	1.54	Yes
2C-6	31	Lam #1 Gun	0.73	0.51	No	1.65	1.43	Yes
2C-2	25	Lam #1 Roller #1	0.60	0.38	No	1.34	1.12	Yes
2C-13	20	Lam #1, Roller#4	0.51	0.29	No	1.11	0.89	Overexposure?
2C-21 (STEL)	90	Gel Coat	1.01	0.79	Overexposure?	2.37	2.15	Yes
2C-23 (STEL)	49	Lam # 1 Gun	0.60	0.38	No	1.32	1.10	Yes
2C-22 (STEL)	44	Barrier Coat	0.55	0.33	No	1.20	0.98	Overexposure?
2C-24 (STEL)	30	Lam #1, Roller #2	0.41	0.19	No	0.87	0.65	No
2C-25 (STEL)	14	Lam #2, Gun	0.25	0.03	No	0.46	0.24	No

Six of 15 samples recorded violations of the 50-ppm PEL, and another three recorded possible overexposures. There was only a single possible overexposure of the 100-ppm STEL recorded out of five samples. If the PEL had been 20 ppm, 14 of 15 samples would have recorded violations, and the remaining a possible overexposure. If the STEL had been 40 ppm, two of five samples would have recorded violations and one a potential overexposure. Note that at this plant all operators wore half-face negative pressure air purifying respirators.

Evaluation of Survey Results

None of the six plants surveyed could comply with a proposed 20-ppm PEL (and associated STEL) as currently configured and operated. Unprotected operators at three (Plants 4, 5 and 6) would be exposed to styrene in excess of the 50-ppm PEL However, these plants currently require some (Plant 4) or all of these potentially overexposed operators to wear respirators.

5. Exposure Reduction Alternatives

Source Reduction

Source reduction measures decrease worker exposures by lowering the amount of styrene emitted per unit of production. If lamination emissions are reduced 20%, it is reasonable to assume that lamination worker exposures would decrease roughly 20%. Emissions may be reduced at the source by modifying material properties and/or material application techniques.

The composite products and composite boatbuilding industries are each subject to National Emission Standards for Hazardous Air Pollutants that require the implementation of Maximum Achievable Control Technology (MACT) for styrene. Both MACT standards require the most stringent source reduction measures deemed feasible by USEPA. For this reason, the potential for source reduction at the plants studied is best evaluated by comparing current material properties and application techniques to those required under these national standards. Note that averaging provisions, which allow use of resins above MACT limits under certain circumstances, are not considered here.

Table 13 below summarizes materials used and application techniques employed during the exposure survey. Entries in bold text indicate conditions that do not comply with the associated MACT requirement listed.

PRODUCTION DATA DURING STYRENE EXPOSURE SAMPLING

Plant	Gelcoat Type	Application Method	Lb Applied	Styrene Content	MACT Limit % Styrene	Lb Styrene Used	Lamination Resin Type	Application Method	Lb Applied	Styrene Content	MACT Limit % Styrene	Lb Styrene Used
1	Polar	Atomized spray	538	**31.0%**	30.0%	166.8	GP Bake	Nonatomized	1320	30.0%	38.4%	396.0
	Arctic	Atomized spray	158	**31.0%**	30.0%	49.0	GP	Nonatomized	2200	30.0%	38.4%	660.0
	Platinum	Atomized spray	41	32.0%	37.0%	13.1	Ashland	Nonatomized	1505	34.0%	38.4%	511.7
	Gray NB	Atomized spray	73	36.0%	37.0%	26.3						
	Gray	Atomized spray	1125	36.0%	37.0%	405.0						
	Tan	Atomized spray	22	31.0%	37.0%	6.8						
	Adobe	Atomized spray	27	33.0%	37.0%	8.9						
		TOTAL GC	1984	34.1%		675.9		TOTAL LR	5025	31.2%		1567.7
2	GP	Atomized spray	399	32.0%	37.0%	127.7	GP	Nonatomized	2093	33.0%	38.4%	690.7
3	WH	Nonatomized	1444	24.5%	30.0%	353.7	GP	Nonatomized	7597	34.0%	38.4%	2583.0
	DT	Nonatomized	18	24.5%	37.0%	4.4						
	Bone	Nonatomized	334	24.4%	37.0%	81.4						
	BT	Nonatomized	77	24.4%	37.0%	18.8						
		TOTAL GC	1872	24.5%		458.3		TOTAL LR	7597	34.0%		2583.0
4	White	Atomized spray	460	**34.0%**	33.0%	156.4	DCPD	Nonatomized	2850	32.8%	35.0%	934.8
	Barrier	Atomized spray	230	31.8%	33.0%	73.1						
	Ceramic	Atomized spray	28.5	**34.0%**	33.0%	9.7						
		TOTAL	718.5			239.2		TOTAL	2850	32.8%		934.8
5	White 1	Nonatomized	225	24.0%	30.0%	54.0						
	White 2	Nonatomized	127	15.0%	30.0%	19.1	DCPD	Nonatomized	1550	34.1%	38.4%	528.6
	Gray 1	Nonatomized	22	33.9%	37.0%	7.5	EVE	Nonatomized	600	**45.9%**	38.4%	275.4
	Gray 2	Nonatomized	26	25.4%	37.0%	6.6						
	Dark Gray	Nonatomized	54	35.5%	37.0%	19.2						
	Black	Nonatomized	26	35.0%	37.0%	9.1						
		TOTAL GC	480	24.0%		115.4		TOTAL LR	2150	37.4%		804.0
6	White	Nonatomized	1982	29.7%	30.0%	588.7	Lam Resin	Nonatomized	7509	**43.0%**	38.4%	3228.9
	Barrier	Nonatomized	873	32.0%	37.0%	279.4						
		TOTAL GC	2855	30.4%		868.0		TOTAL LR	7509	43.0%		3228.9

The impact of source reduction on worker exposures at each plant is discussed below.

Plant 1 - The 31% styrene content of two white gelcoats would have exceeded the 30% MACT limit. Reformulation to this limit would reduce the styrene exposure of gelcoat workers by about one percent. All lamination resins would have met MACT styrene content limits.

Plants 2 and 3 – All gelcoats and lamination resins would have met MACT styrene content limits.

Plant 4 – The 34% styrene content of white and ceramic gelcoats would have exceeded the 33% MACT limit. Reformulation to this limit would reduce the styrene exposure of gelcoat workers by about one percent. All lamination resins would have met MACT styrene content limits.

Plant 5 – All gelcoats would have met MACT styrene content limits. The 45.9% styrene content of heavily filled EVE lamination resin would have exceeded the 38.4% MACT limit. Reformulation to this limit would reduce the styrene exposure of lamination workers by about six percent.

Plant 6 - All gelcoats would have met MACT styrene content limits. The 43% styrene content of lamination resin would have exceeded the 38.4% MACT limit. Reformulation to this limit would reduce the styrene exposure of lamination workers by about five percent.

In summary, feasible source reduction measures would have little or no impact on employee exposures at these six plants.

Ventilation Improvement

An engineering evaluation of ventilation improvements at the study plants is included in Exhibit A. Table 14 below summarizes information presented in Exhibit A on the feasibility and cost of ventilation upgrades needed to achieve the proposed 20-ppm PEL at current and proposed levels.

Feasibility and Cost of Ventilation Improvements to Meet 20-ppm PEL	
Plant	**Improvements Required**
1	New fans to increase airflow 276,000 cfm to 406,000 cfm through existing booths – $230,000 capital + installation $27,300 annual electricity $164,700 annual fuel gas
2	Infeasible – a new building would be required to house required booths.
3	Infeasible – would require complete rebuild of lamination room and replacement of current emission control system
4	Infeasible at either PEL – would require complete rebuild of entire production area
5	Replace existing booths with larger side-downdraft booths and increase airflow 450,000 cfm to 500,000 cfm – $525,000 installed cost of booths $45,400 annual electricity $89,500 annual fuel gas
6	Infeasible – would require complete rebuild of production area

For Plants 1 and 5, the only facilities where ventilation improvements were deemed feasible, we have evaluated the degree to which these costs would be affordable against several measures of the facility economic strength. We adopted an approach developed previously by the reinforced plastics composites industry for the U.S. Environmental Protection Agency to evaluate the affordability of proposed Federal air pollution control requirements. The full analysis is presented in Exhibit B. Feasibility, cost and affordability data from Exhibits A and B are discussed below for each plant.

Plant 1 would require only fans to reduce styrene exposures below the proposed PEL. Costs encompass purchase of fans and accessories, and operating expenses associated with a tripling of ventilation airflow: $230,700 capital + installation, $27,300 annual electricity, and $164,700 annual fuel gas. Affordability analysis (Appendix B) indicates that if required to bear these costs, this plant might be forced to close, or at best might continue to operate in a substantially weakened financial condition.

Plant 2 and Plant 3 would require extensive ventilation improvements to meet the proposed 20-ppm PEL, necessitating changes that are clearly infeasible given the layout and floor space at both these facilities. A new building would be required at Plant 2 to house the new booths required. At Plant 3, the large lamination room would have to be entirely rebuilt, and the existing emission control system replaced with a far larger unit to handle increased ventilation airflow.

Plant 4 cannot improve ventilation enough to meet even the 50-ppm PEL, much less the 20-ppm PEL. The entire production area would have to be completely rebuilt and expanded; and even then, it would be very difficult to avoid above-PEL exposures to rollout operators reaching deep inside boat hulls.

Plant 5 would certainly be unable to meet the 20-ppm PEL under full-capacity production without major ventilation improvements. Existing booths would have to be replaced with larger side-downdraft booths, and new fans would be needed to provide a tenfold increase in airflow. Capital costs would exceed $500,000 and annual operating costs would total nearly $135,000. Affordability analysis (Exhibit B) indicates that this facility would probably be forced to close if required to incur these costs.

Plant 6 is considering a ventilation system redesign sufficient to meet the current 50-ppm PEL. The performance and final cost of this innovative system are uncertain. Moreover, there are concerns that overspray, which is now high enough to require exhaust filter changeout after each shift, would increase to unacceptable levels with increased airflows. This would waste resin and could force slowdown of the line to ensure full part coverage. Hence, meeting the current PEL through ventilation improvement will be a severe challenge at best. It is inconceivable that ventilation of the current line could be improved even further to meet the 20-ppm PEL. The entire production area and line would have to be redesigned and expanded first, and even then the outcome would be uncertain.

Summarizing, ventilation improvements to comply with the proposed 20-ppm PEL would be either infeasible or unaffordable at every plant studied. Moreover, at two of the six plants studied, ventilation improvement could not even meet the current PEL.

Note that California stringently regulates air emissions at state and district levels, and already imposes heavy emission fees that are expected to rise. Hence a California composite plant might be required to at least partially control emissions, or might desire to do so to gain production flexibility. But ventilation improvement sufficient to meet the 20-ppm PEL at such a plant would always require a substantial increase in the exhaust airflow at the inlet of the control device. Such increases might make even partial control systems infeasible or unaffordable.

Administrative Controls

There are relatively few practical administrative measures that can significantly reduce styrene exposures in composites manufacturing. Workers can be trained to recognize and minimize unnecessary time spent in areas or activities that involve potentially high exposures. For instance, workers might be trained in specific practices designed to minimize exposures when reaching into large part concavities that tend to trap styrene vapor. Further, training workers in the proper application methods may avoid over-application of gel coat or resin and serve to limit vapor generation in the work place. It is possible to rotate workers from high concentration tasks to work in low concentration areas, but this is inefficient from a production standpoint. Also, work task rotation is not a generally accepted exposure control option and is not favored relative to implementation of other forms of exposure control.

Summary of Exposure Reduction Evaluation

Neither source reduction of styrene emissions, feasible ventilation improvements, nor administrative controls would enable composite manufacturers to meet a 20-ppm PEL. In fact, the data gathered during this study indicate that the current 50-ppm PEL is a severe challenge that a significant portion of this industry cannot meet – at least some workers at many plants are properly required to wear respirators. Under the proposed PEL, respiratory protection of all gelcoat and lamination workers would be required.

6. Adverse Impact of Respiratory Protection

There are two broad classifications of respirators - supplied air and air purifying. Each class of respirators has advantages and disadvantages in use, as discussed below. Note that description of health and safety issues is based on a review of relevant studies given in Exhibit C.

Supplied Air Respirators

Supplied air respirators provide clean breathing air to the worker, typically through a hose. There are requirements that the supply air system deliver Compressed Gas Association Grade D or better breathing air. Protection factors for supplied air systems are typically much higher than for air purifying respirators. This is because the supply air respirators are positively pressurized relative to the surrounding environment and air moves from the face piece into the work environment.

Applicability at Composites Plants - At all plants surveyed, gelcoat and resin are supplied to applicator guns via suspended overhead lines. The same suspension system could also carry air supply lines. However, lamination workers whose jobs are restricted to rollout will not be able to use such hoods because air supply lines overly restrict mobility hoses – the lines would quickly become hopelessly entangled as operators constantly shift position and move from part to part. Further, use of supplied air systems is problematic in automated process areas (such as at Plants 3 and 6) where the supply hose may become entangled in the automated conveyer equipment.

Health and Safety Concerns - Use of supplied air respirators imposes certain health and safety risks. The primary concern is that operator air supply hoses might become entangled with each other or within moving equipment, imposing a possible slip, trip and fall hazard. Supplied air respirators can also interfere with speech recognition, an effect noted in several studies. Finally, supplied air respirators may impair vision due to clouded facepieces.

Costs - Annual costs for equipment, operation and maintenance of a supplied air system were reported by one California plant to be approximately $1,300 per employee.

Air Purifying Respirators

Air-purifying respirators for styrene would typically employ half-face masks fitted with an organic vapor cartridge, through which air is drawn by the wearer's lungpower. Since they are under negative pressure and rely on the action of an absorbent, they are assigned a lower protection factor than are supplied air respirators. However, they do not impede operator movement, and are much less likely to become entangled than are supplied air respirators. Air purifying respirators may also be powered by a small fan connected to a portable battery pack.

Applicability at Composite Plants - Negative pressure, half-face respirators are feasible for use at all composite plants. Powered units might prove inconvenient or unworkable for rollout operators, because the bulk and weight of the battery pack could restrict mobility (though less than an air supply line would).

Health and Safety Concerns - The primary vision impairment associated with half-mask respirators is a blocking of the line of site imposed by the location of the face piece and the protrusion of the filter cartridges. Speech recognition impacts are similar to those described for supplied air respirators.

Physiological effects from air-purifying respirator wear are varied, and impact a worker's pulmonary and cardiovascular systems. Use of negative pressure respirators increases the physiological load on the wearer through increasing resistance to inspiratory breathing, increasing the dead space volume and in limiting the ability to dissipate body heat. The use of coated chemical protective clothing employed at all plants surveyed can also have significant adverse effects on cardiovascular performance, which would be compounded by respirator use.

Costs - The following costs provided by a composites manufacturer are believed to be typical for the use of negative pressure half-face respirators. On this basis total annual cost would be $3100 per employee.

Program elements
Program Administrator
Written respiratory program
Medical evaluation
Fit testing
maintenance and care of respirators
Record keeping
Program Evaluation

First time set up cost per employee	Number of units / hrs	unit price	total cost
Face piece	1 ea	$20.00	$20.00
Inhalation connector	2 ea	$3.97	$7.94
Inhalation valve	2 ea	$0.69	$1.38
Exhalation valve seat	1 ea	$3.97	$3.97
Exhalation valve	1 ea	$1.40	$1.40
Exhalation valve guard	1 ea	$2.64	$2.64
Cradle suspension system	1 ea	$10.79	$10.79
Prefilter retainer	2 ea	$1.40	$2.80
Paint prefilter	2 ea	$0.67	$1.34
Ov cartridge	2 ea	$5.95	$11.90
Fit test	.5 hr	$40.00	$20.00
Medical Evaluation	.75 hr	$40.00	$30.00
Cleaning / storage kit	1 ea	$5.00	$5.00
Administration / Record keeping	2 hrs	$40.00	$80.00
Medical Evaluation review by Examiner	1 ea	$35.00	$35.00
Total set up cost per Employee			$234.16

Monthly cost per employee on program	Number of units / hrs	unit price	total cost
Cleaning & maintenance	3.25 hrs	$40.00	$130.00
Ov cartridge change out	10 ea	$5.95	$59.50
Paint prefilter change out	40 ea	$0.67	$26.80
maintenance inspection	.25 hr	$40.00	$10.00
Administration / Record keeping	.5 hr	$40.00	$20.00
Annual PPE training	.25 hr	$40.00	$10.00
Total monthly cost per Employee			$256.30

Summary of Impacts on Composite Manufacturers

Respiratory protection via a mix of supplied air and air purifying equipment would cost businesses $1300 to $3100 per employee, and subject these employees to risk of potential injury and cardiopulmonary distress. Further, plants requiring use of respirators might find it more difficult to hire and retain operators.

7. Findings and Conclusions

- Worker exposure data collected during this study suggest that many composites manufacturers have barely met the current 50-ppm PEL for worker styrene exposure by modifying processes, improving ventilation and/or implementing administrative controls. At such plants resulting 8-hr exposures range from 40-50 ppm. However, these techniques are insufficient to meet the current standard for manufacturers of large parts and in certain highly automated small-part production scenarios, where respiratory protection is required for workers applying gelcoat and applying or rolling out reinforced resin.

- Reduction of the 8-hr PEL below 50 ppm will mandate increased reliance on respiratory protection, and at 20 ppm all affected workers would require it. Even after modifying processes and resin formulations to reduce styrene emissions, ventilation improvements needed to comply much below 50 ppm will be either technically infeasible or prohibitively expensive. Reduction of the PEL to 50 ppm would force an estimated 5,000 California workers into respiratory protection.

- Respiratory protection via a mix of supplied air and air purifying equipment would cost businesses $1300 to $3100 per employee, and subject these employees to risk of potential injury and cardiopulmonary distress associated with respirator use. Further, plants requiring use of respirators might find it more difficult to hire and retain operators.

- Based on an evaluation of current studies by SIRC, the health benefit of PEL reduction from 50 ppm to 20 ppm might be the avoidance of mild and possibly reversible effects on color discrimination, hearing, and behavior, though evidence is inconclusive. Given our current state of knowledge, this benefit would appear to be uncertain at best.

- Since benefits are uncertain, it would be imprudent to lower the PEL at this time. The cost to comply with a reduced PEL would needlessly place California plants at an economic disadvantage relative to their counterparts in states that enforce the 50 ppm Federal PEL.

- If additional health effects studies determine that the PEL should be lowered, Cal-OSHA should exempt all composite plants from the requirement to determine the feasibility of engineering controls. The data presented in this report prove conclusively that to limit composite worker exposures much below 50 ppm, only respiratory protection is feasible.

Exhibit A– Feasibility and Cost of Ventilation Controls to Achieve Current and Proposed California PEL at Six Open Molding Composite Plants

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Ventilation Techniques in the Composites Industry

Dilution Ventilation – This technique is widely used at many composite facilities to reduce the concentration of styrene in the workplace and thereby limit the worker exposure. As the name suggests, this form of ventilation simply dilutes the styrene vapor emitted during the lamination processes by introducing a large volume of fresh air into the lamination areas. This supply of fresh air is usually added to the areas through several supply air outlets distributed throughout the area, and the contaminated air is removed from the areas through several exhaust inlets. The styrene mixes into this large airflow, and is removed before it can build up to a hazardous concentration. OSHA regards dilution ventilation as the best exposure control options to prevent worker overexposure to styrene. However, dilution ventilation usually results in very large exhaust flow rates, which makes ventilation controls prohibitively expensive in most cases.

Area Ventilation – According to Frees, the leading designer and manufacturer of horizontal push-pull area ventilation systems at composite facilities, the design of a push-pull area ventilation system is affected by four important variables: part size, part shape, push-to-pull capture distance, and ceiling height

Once the necessary flow pattern through the work area is determined to properly sweep across the part, the system flow rate needed to create this flow pattern is fairly easy to determine. The cost of the push-pull capture system is a function of the ventilated area, so when the system flow rate has been determined the system cost can be readily estimated. The "push" air leaving the supply registers usually entrains a significant amount of the nearby ambient building air as it travels across the work zone. Due to this entrainment, the flow of air moving across the work zone towards the exhaust side is greater than the flow from the supply registers. In many installations, a significant portion of this moving air can spill past the exhaust inlets and recirculate back towards the supply registers. Most of this recirculating air is then re-entrained into the supply air flowing across the work zone, but a portion may escape into the general building space and add to the background exposure. The only way to contain the contaminated air would be to place the entire push-pull system inside an enclosure. Push-pull systems that are not fully enclosed are particularly vulnerable to cross drafts and wind flowing through the building.

Ventilation Enclosures – The use of ventilation enclosures is a common design approach to capture contaminants at many composite facilities. These enclosures include spray booths, tunnels, and spray rooms. Note that hoods and shrouds, which are also enclosures, are typically classified as local ventilation devices, and are discussed in the next section.

In *side draft (cross flow)* booths the airflow inside moves horizontally, either from the entrance to the rear of the booth or from side to side. Occasionally, a directed area cross flow system is installed inside large booths or rooms.

In *updraft* booths the airflow inside moves vertically upward, either from floor registers or side outlets along the base of the walls to ceiling registers. This configuration is not effective for composite operations because the contaminated air is usually generated below the workers chest level.

In *downdraft* booths the airflow inside moves vertically downward, from ceiling registers to floor registers. This configuration is very effective for composite operations because the contaminated air is usually generated below the workers chest level.

In *side downdraft* booths the airflow inside moves vertically downward, from ceiling registers to side outlets along the base of the walls. This configuration is very effective for composite operations because the contaminated air is usually generated below the workers chest level.

In *semi-downdraft* booths the airflow inside moves vertically downward and horizontally to the rear of the booth, from ceiling registers to floor level outlets at the back of the booth. This configuration is not as effective as downdraft or side downdraft booths.

Local Ventilation – A local exhaust ventilation system captures the pollutants very close to the contaminant source, so a small volume of concentrated exhaust air is immediately collected before mixing with the surrounding air. Specialized capture devices, such as hoods, shrouds, and flexible exhaust pickups, are used to capture the contaminants at the source, which enables a relatively small exhaust flow to then control the associated exposure. In this situation, the concentration in the exhaust can be quite high, but worker overexposure is not a problem, because the workers are isolated from the contaminants by the local ventilation system.

Local ventilation is not a practical option for the composite operations in general. Hoods, shrouds, and suction hoses could not be installed, because these devices would unduly interfere with the existing gelcoating and laminating processes.

Specialized Ventilation Techniques – recirculation, split-flow, and displacement ventilation are three specialized ventilation techniques that have been proposed and investigated by government researchers, as possible methods for reducing the ventilation flow rate from open molding processes at typical composites facilities.

Recirculation has been tried in the spray paint finishing industry. This technique creates a zone of recirculating air inside a spray booth that traps the contaminants generated during spraying. Just enough ventilation air is added to the booth and then removed from the recirculation zone to prevent the buildup of an explosive concentration. The operator either stands outside the highly concentrated recirculation zone or a fresh supply of air is directed around the operator's breathing zone.

Recirculation appears most suitable for smaller parts that can be enclosed by fixed partitions and carefully designed airflows. Employee overexposure to hazardous vapors is not an issue under those conditions, because the employee breathing zone is isolated from the recirculation zone. However, this technique is unsuitable for any process that requires the employee to spend substantial time in the recirculation zone.

Recirculation is not a practical technique for ventilating the composite operations at typical plants for the following reasons:

- This is an experimental technique - there is no known application of a successful recirculation system at a composites facility.
- The workers would normally be in the recirculation zone during the gelcoating, lamination, and rollout process steps. This would result in serious employee overexposure to styrene.
- Any conceivable recirculating booth design could probably only handle a very narrow range of mold sizes, and would be infeasible for the wide range of parts produced at most plants.

Split-Flow Booths use a specialized push-pull design that splits the airflow inside the booth into two parts. One part of the airflow is directed across the bottom of the booth where the concentration of spraying emissions is believed to be higher. This part is then captured at the floor. The other part of the airflow, which is assumed to have a lower concentration, is either mixed with fresh supply air and recirculated through the booth, or is simply exhausted to the atmosphere.

A serious concern with the split-flow concept is the apparent lack of production flexibility or robustness. Most composite lamination activities require a great deal of dexterity for high productivity. Many parts could simply not be fabricated if the workers were forced to stand in one place. Furthermore, many composites parts are large in size and have unusual shapes. It is hard to imagine a split-flow system that would be equally effective across even a narrow range of part sizes and shapes. Like the recirculation approach, the split-flow booth concept is not a practical technique for ventilation control of composite operations at the most plants.

Displacement Ventilation is a novel approach developed in Sweden that employs ceiling-mounted low-impulse air delivery systems to produce a steady, slow, downward flow of cool fresh supply air across the breathing zones of the workers. This cool fresh air is gently introduced to the building and does not mix with the surrounding contaminated plant air. The contaminant sources in the work area are heated and are carefully positioned to be somewhat isolated from the workers. An upward air movement from each contaminant source is caused by the difference in density between the cool fresh air and hot buoyant contaminated air. The thermal buoyancy force lifts the contaminated air to the ceiling, where the contaminants are exhausted from the workplace.

Displacement ventilation is not a feasible or suitable technique for the capture of contaminants from composite operations, because the contaminant sources at most plants are at the same approximate temperature as the ambient supply air, hence there are no buoyant forces to carry the contaminants away. Moreover, this is an experimental technique - there is no known application of successful displacement ventilation at a composites facility anywhere and the required equipment is not commercially available. Expensive third-party engineering R&D and testing expertise would be needed to design and test such sophisticated equipment

Impact of Production Capacity on Ventilation Design

Care must be taken when evaluating design ventilation airflows derived from comparison of worker exposure data (TWAs) to target criteria such as PELs. The ventilation system should be designed to reduce exposures below the PEL at <u>full</u> production capacity, whereas the exposure data may have been collected during a period of lower production. Unless this factor is taken into account, design airflows will inevitably be underestimated.

Worker styrene exposure is a direct function of styrene emissions from the processes in the workplace. For each process, there is a characteristic emission rate per unit of production, a function of styrene content of materials used and application techniques. Therefore, as production levels per unit of time increase, styrene emissions increase, driving up workplace concentrations and subsequent worker exposures. This suggests that exposures Ec (ppm TWA) at full production capacity C may be estimated from sampled exposures Es at sample-period production level S as follows:

$$Ec = k*Es, \text{ where } k = \text{constant scaling factor} = P/S$$

For this assessment, the above equation was applied to roughly predict the likely exposures at maximum production based on exposure data collected at the six plants studied. On that basis, evaluations of ventilation improvements necessary at each plant to meet the proposed 20-ppm PEL are presented in the sections of this appendix that follow.

Plant 1

Plant 1 produces a variety of recreational vehicle (RV) and heavy truck parts. Parts produced during the survey ranged in size from 10 to 365 square feet. All lamination takes place in two lines (Bake and Non-Bake) in the east end of the single plant building in an area measuring 205 feet long by 150 feet wide by 25 feet high. Within this area are three gelcoat booths, two lamination booths, a common gelcoat cure area, and a common laminate cure area. Parts are moved on wheeled carts. Ventilation systems are summarized below.

Table 1 – Summary of Plant 1 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booths (2)	45 x 20 x 16	Downdraft supply air, floor-level sidewall exhausts, flexible end curtains.	19,200 each 38,400 total
Laminate Booths (3)	75 x 20 x 16	Downdraft supply air, floor-level sidewall exhausts, air curtains at ends	Bake: 54,100 Nonbake: 36,700
Gelcoat Curing	60 x 40 x 25	General area ventilation	Dilution
Laminate Curing	75 x 24 x 25	General area ventilation	Dilution

Total exhaust (and supply) airflow is 38,400 + 54,100 + 36,700 = ~130,000 cfm
Average downdraft velocity = 130,000 / (2x45x20 + 3x75x20) = 20 fpm

The production level during the exposure sampling period was estimated to be about 80% of maximum production capacity, at which time the following data were recorded.

Table 2 – Summary of Plant 1 TWA Styrene Exposure

Plant 1 Sample	ppm	Operator	50 ppm			20 ppm		
			UCL	LCL	Violation?	UCL	LCL	Violation?
1A-5	49.5	Bake roll	1.10	0.88	Overexposure	2.59	2.37	Yes
1A-6	45.7	Bake Roll	1.02	0.80	Overexposure	2.40	2.18	Yes
1A-9	44.8	Bake line	1.01	0.79	Overexposure	2.35	2.13	Yes
1A-	41.0	Nonbake line	0.93	0.71	No	2.16	1.94	Yes
1A-1	28.6	Bake line	0.68	0.46	No	1.54	1.32	Yes
1A-2	27.0	Nonbake	0.65	0.43	No	1.46	1.24	Yes
1A-3	18.3	Nonbake	0.48	0.26	No	1.02	0.80	Overexposure
1A-4	11.8	Nonbake	0.35	0.13	No	0.70	0.48	No

As demonstrated by the exposure sampling listed above, the existing ventilation system can just meet the 50-ppm PEL and the 100-ppm STEL by a slight margin. However, this sampling was performed while the plant was operating at about 80% of maximum capacity. If the emission rates and exposures were increased by a factor of 1.2 to account for full production, then four of the worker would not meet the 50 ppm PEL, but by slight margins.

As also demonstrated by the exposure sampling, the existing ventilation system cannot meet the proposed 20-ppm PEL or 50-ppm STEL by very large margins. If the emission rates and exposures were increased by a factor of 1.2 to account for full production, then this margin would be even greater.

Potential Ventilation Improvements

The only recommended modification to the ventilation system is an increase in the existing airflow rate through the current booths. The proposed capture velocity will be increased from 20 to 62.5 fpm, which increases the total exhaust (and supply) airflow rate to 406,000 cfm. This is a 276,000 cfm increase.

Capital Cost – the only capital cost is the installation of new larger fans & fan motors and new larger makeup heaters:

Five new fans plus installation:	$10,000 x 5 =	$ 50,000
Two new makeup air heaters plus installation:	$115,000 x 2 =	$230,000
Total:		$280,000

Operating Cost (not including the amortized capital cost) – the annual operating costs include three main components:

- Electricity cost to operate the fan motors - listed in **Table 3**.
- Natural gas fuel cost to heat the supply air - listed in **Table 4**.
- Replacement costs for filters, motor bearings, control parts, etc.

The annual operating cost analyses assume that the lamination area will be operated at full capacity during two 8-hour work shifts per day for 250 days per year. This is a total of 4,000 hours per year of operation.

The electricity cost is estimated with the fan power equation:

$$E = \frac{0.000117 \times Q \times dP_{FAN} \times hr/yr \times \$/kWh}{Efficiency_{FAN}}$$

where:		
	Q	exhaust flow rate (scfm)
	dP_{FAN}	total pressure drop across the fan (in w.g.)
	hr/yr	hours of equipment operation
	$/kWh	cost of electricity including the demand charge
	$Efficiency_{FAN}$	overall energy efficiency of motor, drive, fan (%) - assume 65%

Assuming an electricity rate of 7.0 cents per kilowatt-hour including demand charges, a maximum 2.0 in wg pressure drop across the supply fan and the exhaust fans, the corresponding annual electricity cost is ~$28,000 per year as computed below.

Table 3 – Annual Electricity Cost for Plant 1 Ventilation Modifications

Airflow	(scfm)	276,000
Total Pressure Drop	(in.wg)	2
Hours of Operation	(hr/yr)	4,000
Electricity Cost	($/kwh)	0.07
Fan %	(%)	0.65
Electricity Cost	**E ($/yr)**	**$27,820.80**

This worst-case analysis assumes that the annual heating season will last 1,500 hours and will have a worst-case average air temperature of 30°F during this entire period. The supply air temperature is assumed to be 80°F, so the worst-case average temperature rise during the heating season is assumed to be about 50°F. The natural gas utility rate for the plant is assumed to $0.007 per cubic foot ($0.7 per therm or $0.7 per CCF). Based on these assumptions the worst-case heating cost is ~$165,000 per year.

Table 4 – Annual Make-up Air Heating Cost for Plant 1 Ventilation Modifications

Airflow	(scfm)	276,000
Temperature Rise	(F)	50
Hours in Season	(hr/yr)	1,500
Natural Gas Cost	($/ft3)	0.007
Thermal %	(%)	0.95
Heat Value	(Btu/ft3)	1,000
Fuel Cost	**F ($/yr)**	**$164,728.42**

Plant 2

Plant 2 produces RV parts ranging in size from 40 to 250 square feet. All lamination takes place in the east end of the single plant building in an area measuring 205 feet long by 90 feet wide by 22 feet high. Within this area is a single production line including one gelcoat booth, one lamination booth, and a separate room enclosure for each curing operation. Parts are moved on wheeled carts. Ventilation systems are described below.

Table 5 – Summary of Plant 2 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booth	40 x 16 x 12	Open-ended booth with push-pull crossflow, overhead supply duct on one side, low-level exhaust pickups on other.	38,200
Laminate Booth	48 x 36 x 12	Open-ended booth with push-pull crossflow, central overhead supply duct, low-level exhaust pickups at sides	45,550
Gelcoat Curing	40 x 16 x 22	Two small floor-level corner exhausts	<3,400 cfm
Laminate Curing	40 x 36 x 22	Two small floor-level corner exhausts	<3,400 cfm

The production level during exposure sampling was estimated to be about 50% of maximum production capacity, at which time the following data were recorded.

Table 6 – Summary of Plant 2 TWA Styrene Exposure

Plant: 2			50 ppm TWA			20 ppm TWA		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation?**	**UCL**	**LCL**	**Violation?**
1B-5	23.5	Roll 2	0.58	0.36	No	1.29	1.07	Yes
1B-4	23.2	Roll 1	0.57	0.35	No	1.27	1.05	Yes
1B-3	22.8	Chop	0.57	0.35	No	1.25	1.03	Yes
1B-2	21.7	Gel	0.54	0.32	No	1.20	0.98	Overexposure?
1B-6	20.1	Roll 3	0.51	0.29	No	1.12	0.90	Overexposure?

Based upon the exposure sampling data, the existing ventilation system at the plant is in compliance with the 50 ppm PEL by a significant margin, and would still be in compliance even if the plant were operating at full capacity. The existing ventilation system at the plant cannot meet the proposed 20-ppm PEL at 50% production, yet alone at full production.

Potential Ventilation Improvements

This plant already employs a downdraft booth for the gelcoating operation. This booth can just barely comply with the proposed 20 ppm PEL at a 50% production rate, but obviously could not comply at a higher production rate. Further, the lamination area completely occupies the existing building space. There is no room to install new downdraft spray booths for the lamination operation and still maintain the existing production capacity. For this reason, modifications to the lamination are cost-prohibitive, because a new building would be required.

Plant 3

Plant 3 produces standard bathware parts through the mechanical application of sanitary gelcoats and heavily filled polyester resins. The bathware parts include residential tub-shower enclosures, separate shower pans and tub enclosures, and small whirlpool spas. These parts vary in size from 40 to 120 square feet in area, although the typical part size is usually about 80 square feet. The plant produced an average of about 730 units per day, during three shifts per day. About 800 units per day can be produced at peak production. The plant operates three shifts per day, 5 days per week, 50 weeks per year, which is equivalent to 6,000 hours of operation per year.

Parts produced during the survey ranged in size from 40 to 120 square feet. Lamination takes place in a 200-foot long by 150-foot wide room on the northwest side of the single plant building. Within this room are two identical production lines, in total consisting of four gelcoat booths, two lamination rooms, two gelcoat curing areas, and two laminate curing areas. Parts are moved via conveyor systems. This plant is unique in that ventilation exhausts from booths and curing areas are tied to a large thermal oxidizer system installed to abate styrene odor offsite. Production was estimated to be 90% of capacity at the time of survey.

Each of the two production lines has two gelcoat booths, which contain the gelcoat spraying operation, and a lamination room, which contains the spray lay-up and rollout operations. The two lines share common open curing areas for the freshly gelcoated and laminated parts. Some of the curing emissions from the freshly gelcoated and laminated parts are released outside the booth and lamination rooms in these curing areas and diffuse through the open room.

Each gelcoat booth incorporates a push-pull area ventilation system made by Frees Inc. These systems are called the Directed Flow® system. The gelcoat booths are really small rooms with open doors at each end. Most of the gelcoat spray emissions are captured in these small rooms, but a significant portion of the contaminants probably escapes to the building space.

The lamination activities, including both spray and rollout, are contained in large closed rooms that also incorporate Frees Directed Flow® systems. These lamination rooms appear to have much greater capture efficiency due to the relative size and locations of the doors. Practically all of the lamination spray phase emissions are probably captured in these rooms, and very little fugitive emissions seem to escape to the building space.

The plant ventilation system is described in the table on the following page.

Table 7 – Summary of Plant 3 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booths (4)	20 x 15 x 10	Push-pull crossflow, sidewall supply duct on one side, low-level exhaust pickups on other, air curtains across booth open ends	8,300 ea
Laminate Booths (2)	115 x 35 x 10 130 ft conveyor within	Push-pull crossflow, overhead supply duct at back end, low-level exhaust pickups at sides	56,900 ea
Gelcoat Curing (2)	90 x 50 x 22 250 ft conveyor within	None – diffusion dilution in space	NA
Laminate Curing (2)	220 ft conveyor in 4200 sq ft room	None – diffusion dilution in space	NA

The production level during exposure sampling was estimated to be about 90% of maximum production capacity. However, this level of production is probably the greatest rate that can be achieved in practice and represents the actual maximum production level for the plant. Under these conditions, the following exposure data were recorded.

Table 8 – Summary of Plant 3 TWA Styrene Exposure

Plant: 3			50 ppm TWA			20 ppm TWA		
Sample	ppm	Operator	UCL	LCL	Violation?	UCL	LCL	Violation?
1D-9	52.7	Chop 4	1.16	0.94	Overexposure?	2.75	2.53	Yes
1D-8	50.7	Roll 4	1.12	0.90	Overexposure?	2.65	2.43	Yes
1D-1	46.4	Gel 1	1.04	0.82	Overexposure?	2.43	2.21	Yes
1D-3	39.6	Chop 1	0.90	0.68	No	2.09	1.87	Yes
1D-2	39.5	Gel 2	0.90	0.68	No	2.09	1.87	Yes
1D-5	29.9	Roll 1	0.71	0.49	No	1.61	1.39	Yes
1D-7	27.9	Roll 3	0.67	0.45	No	1.51	1.29	Yes
1D-6	25.4	Chop 3	0.62	0.40	No	1.38	1.16	Yes
1D-10	23.6	Roll 2	0.58	0.36	No	1.29	1.07	Yes
1D-4	20.0	Chop 2	0.51	0.29	No	1.11	0.89	Overexposure?

The existing ventilation system at the plant is just barely in compliance with the 50-ppm PEL, and clearly cannot meet the proposed 20-ppm PEL

Potential Ventilation Modifications to Reduce Styrene Exposure

Ventilation modification to meet the proposed 20-ppm PEL is not feasible at this plant for three main reasons:

- Worker practices – the workers do not have fixed work locations and move through the lamination room area.
- Cross flow configuration – this ventilation configuration inside the lamination rooms causes the workers to frequently work downstream from active emissions sources

- Air pollution controls – treating additional exhaust airflow with new air pollution control equipment would incur enormous costs.

On the latter point, note that a state-required plantwide control system must reduce styrene emissions roughly 90% to mitigate local styrene nuisance odors. This system employs an activated carbon preconcentrator tied to with an exhaust capacity of 180,000 cfm, tied to a thermal oxidizer. This exhaust capacity is fully utilized at present, so no additional exhaust airflow could be controlled by this system. Hence, any modifications to the ventilation system must either:

- Reallocate the existing 180,000 cfm exhaust flow, by removing ventilation from another area in the plant – not feasible.
- Reduce the styrene emission rate – not feasible, since all available source reduction options have already been implemented, this would require a reduction in plant production capacity.
- Install new air pollution controls with increased exhaust capacity, a multimillion-dollar project.

Plant 4

Plant 4 manufactures boats (hulls and matching decks) ranging in length from 16 to 25 feet. Lamination activities are confined to two rooms each 100 ft long by 84 feet wide by 25 feet high at one end of the single plant building. Within one room were two 60-foot gelcoat booths and a gelcoat curing area; the other was a common room housing all lamination and associated curing areas. Parts are moved on large wheeled carts.

This plant is typical of facilities producing large parts of complex geometry in three dimensions. Rollout of each part involves a team of operators, who must reach across wetted surfaces far into the part at times. As many as four operators were observed rolling out laminate on one boat hull at this plant. When rolling out the base of the hull, these operators were hanging well into the hull interior. Ventilation systems are described below.

Table 9 – Summary of Plant 4 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booths (2)	60 x 10 x 10 auto paint booths	Pull system, supply duct at one end, hinged doors at ends	18,000 each nominal 36,000 total
Laminate Room	Work area: 84 x 30 x 25 (~half of open room)	Push-pull crossflow, overhead supply duct across long end of work area, two 14 x 7 exhaust pickups on opposite side, one pickup on opposite wall	12,000 each nominal 36,000 total
Gelcoat Curing	40 x 16 x 22	In Gelcoat Room	Dilution
Laminate Curing	40 x 36 x 22	In Lamination Room	Dilution

The plant produced five boat units per shift during the exposure sampling. The typical maximum production rate is seven units per shift, so the production rate during the sampling was 5/7 or about 70% of the maximum rate. Under these conditions the exposure data on the following page were recorded.

Table 10 – Summary of Plant 4 TWA Styrene

Plant: 4			50 ppm TWA/100 ppm STEL			20 ppm TWA/40 ppm STEL		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation?**	**UCL**	**LCL**	**Violation?**
2A-4	88	Lamination, Polycure	1.88	1.66	Yes	4.53	4.31	Yes
2A-7	62	Roller #3	1.34	1.12	Yes	3.19	2.97	Yes
2A-15	63	Lamination Chopper #2	1.36	1.14	Yes	3.24	3.02	Yes
2A-6	62	Roller #2	1.35	1.13	Yes	3.22	3.00	Yes
2A-2	61	Gel Coat Sprayer #2	1.33	1.11	Yes	3.16	2.94	Yes
2A-8	61	Roller #4	1.32	1.10	Yes	3.14	2.92	Yes
2A-12	60	Roller #7	1.31	1.09	Yes	3.12	2.90	Yes
2A-11	57	Roller #6	1.24	1.02	Yes	2.94	2.72	Yes
2A-9	55	Roller #5	1.22	1.00	Overexposure?	2.88	2.66	Yes
2A-10	49	Lamination Chopper #1	1.10	0.88	Overexposure?	2.58	2.36	Yes
2A-13	45	Roller #8	1.01	0.79	Overexposure?	2.36	2.14	Yes
2A-1	44	Gel Coat Sprayer #1	0.99	0.77	No	2.30	2.08	Yes
2A-14	44	Roller #9	0.98	0.76	No	2.30	2.08	Yes
2A-5	36	Roller #1	0.83	0.61	No	1.92	1.70	Yes
2A-3	19	Gel Coat Helper	0.49	0.27	No	1.06	0.84	Overexposure?
2A-20 (STEL)	135	Roller #5	1.46	1.24	Yes	3.49	3.27	Yes
2A-16 (STEL)	103	Gel Coat Sprayer #1	1.14	0.92	Overexposure?	2.69	2.47	Yes
2A-18 (STEL)	101	Gel Coat Sprayer #1	1.12	0.90	Overexposure?	2.65	2.43	Yes
2A-17 (STEL)	100	Roller #3	1.11	0.89	Overexposure?	2.62	2.40	Yes
2A-19 (STEL)	62	Roller #6	0.73	0.51	No	1.66	1.44	Yes

Exposure sampling data indicate that the existing ventilation system cannot meet the 50-ppm PEL by significant margins for some workers. However, this sampling was performed while the plant was operating at about 70% of maximum capacity. If the emission rates and exposures were increased by a factor of 1.4 to account for full production, then most of the worker would not meet the 50-ppm PEL by even greater margins.

The push-pull cross flow area ventilation cannot reliably limit TWA exposures much below 50 ppm for the following reasons:

- The lamination process generates areas of locally high-styrene concentration such as downstream from active resin spraying, laminate rollout, and wet curing surfaces). These areas cannot be isolated and are not always obvious to the workers.
- As a practical necessity, the production workers must routinely enter and remain in these areas in order produce parts.
- Modifications to the current work practice might reduce the time that workers spend in these areas, but these modifications would be difficult to identify and enforce, and might be only partially effective.

The cross flow gelcoat booths are effective for one worker but ineffective for another worker. If the emission rates and exposures were increased by a factor of 1.4 to account for full production, then both gelcoat workers would not meet the 50-ppm PEL.

The proposed 20-ppm PEL appears to be technically infeasible with ventilation controls alone, unless the plant is completed redesigned and rebuilt. Under these circumstances, the only feasible method to protect the workers at 20 ppm would be respirator use.

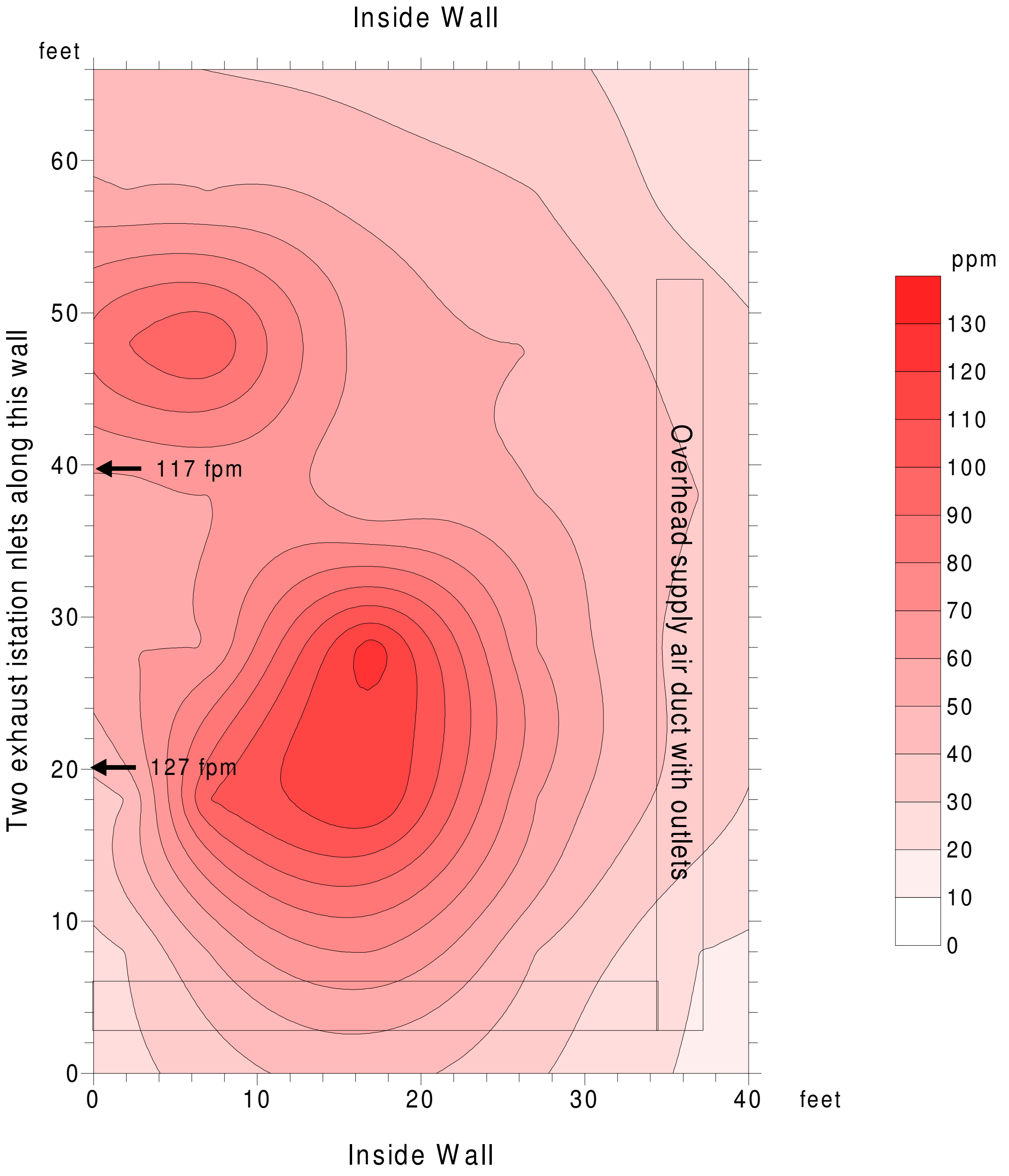
Potential Ventilation Modifications

Part sizes and working capture distances at this plant are too great to enable effective local ventilation. Resulting capture efficiencies would be too low at feasible capture velocities and airflows.

Due to the relatively large size of the parts produced, the existing layout of the lamination areas, the large volume of the Production Building, and the spatial distribution of current workplace concentrations (see Figure 1 for static detector tube results), neither dilution nor area ventilation are practical for Plant 4.

A downdraft spray booth design is the only possible ventilation option that might achieve the proposed 20-ppm PEL, but its application would be purely experimental given the size and concave shape of the hulls and decks produced. Moreover, the downdraft booth design cannot fit into the available plant building floor space and still maintain the same maximum production rate as the current crossflow ventilation system. The cost to demolish and rebuild an entirely new plant building to house new downdraft booths of experimental design would clearly be prohibitive and unwarranted.

Figure 1 – Isopleth Map of Styrene Concentrations in the Lam Area at Plant 4



Plant 5

Plant 5 produces a variety of heavy truck and recreational vehicle (RV) parts, specialized body parts for transit systems, and small de-ionized water storage tanks. The plant currently has the capability of producing practically any custom fiberglass part up to a maximum size limit of about 9 feet wide ×10 long × 6 feet high.

All composite production activities are contained within one large building at the plant site, which is called the “Production Building.” This building has a steel frame, an insulated metal panel roof, and insulated metal panel walls with concrete block walls in some places. The building floor area measures about 275 feet × 250 feet. The building has a gently sloping peaked roof, with a ridge height of about 35 feet at the center and a wall height of about 28 feet.

The existing ventilation system in the Production Building consists of five primary spray booths. Two of these booths are used for gelcoat application and are called gelcoat booths and three booths are used for resin application and are called lamination booths. The booths are very similar in size and shape. Each booth floor area measures 16 feet by 30 feet. Each booth door way opening is 10 feet wide and 7 feet high. One of the lamination booths and one of the gelcoat booths has a higher ceiling that can accept taller molds.

Table 11 – Summary of Plant 5 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat Booths (2)	30 x 16 x 16 30 x 16 x 10	Push- pull systems, supply duct at one end, outlets flush with door top, wall exhaust on one side [recirculation zone noted on opposite side]	10,000 each 20,000 total
Lamination Booths (3)	30 x 16 x 16 30 x 16 x 10 (2)	Push- pull systems, supply duct at one end, outlets flush with door top, wall exhaust on one side [recirculation zone noted on opposite side]	10,000 each 30,000 total?
Rollout/Curing	60 x 60 x 40	Dilution + oscillating fans	Dilution

The production level during exposure sampling is estimated to be about 50% of maximum production capacity, during which time the following exposure data were recorded.

Table 12 – Summary of Plant 5 TWA Styrene Exposure

Plant: 5			50 ppm TWA/100 ppm STEL			20 ppm TWA/40 ppm STEL		
Sample	ppm	Operator	UCL	LCL	Violation?	UCL	LCL	Violation?
2B-4	83	Temp. Roller #2	1.78	1.56	Yes	4.28	4.06	Yes
2B-8	52	Roller #5	1.15	0.93	Overexposure?	2.70	2.48	Yes
2B-9	50	Roller #6	1.11	0.89	Overexposure?	2.62	2.40	Yes
2B-7	45	Chopper, Roller #4	1.01	0.79	Overexposure?	2.36	2.14	Yes
2B-1	39	Roller #1	0.88	0.66	No	2.04	1.82	Yes
2B-5	35	Chopper, Roller #3	0.81	0.59	No	1.85	1.63	Yes
2B-3	24	Utility #1	0.58	0.36	No	1.29	1.07	Yes
2B-6	17	Gel Coater #1	0.45	0.23	No	0.95	0.73	No
2B-2	4	Helper #1	0.19	-0.03	No	0.30	0.08	No
2B-25 (STEL)	82	Chopper, Roller #3	0.93	0.71	No	2.16	1.94	Yes
2B-22 (STEL)	73	Chopper, Roller #3	0.84	0.62	No	1.95	1.73	Yes
2B-24 (STEL)	43	Gel Coater #1	0.54	0.32	No	1.18	0.96	Overexposure?
2B-23 (STEL)	35	Chopper, Roller #4	0.46	0.24	No	0.97	0.75	No
2B-21 (STEL)	25	Gel Coater #1	0.36	0.14	No	0.72	0.50	No

As demonstrated by these data, the existing ventilation system can just meet the 50-ppm PEL and the 100-ppm STEL by a slight margin with one exception (Temp Roller #2). This temporary worker might not be as well trained in proper work practices as others sampled, a possible explanation for the exposure exceedance. However, this sampling was performed while the plant was operating at about 50% of maximum capacity. If the emission rates and exposures were increased by a factor of two to account for full production, then most of the worker would not meet the 50-ppm PEL, by significant margins.

Results also indicate that the existing ventilation system cannot, by a very large margin, meet the proposed 20-ppm PEL or 50-ppm STEL. If the emission rates and exposures were increased by a factor of two to account for full production, then this margin of exceedance would be even greater.

Potential Ventilation Improvements

Neither dilution nor local area ventilation are feasible, because the building and work area volumes are too large. Part size, shape, and production access issues render close-capture ventilation unworkable as well. Enclosures are required to provide effective ventilation.

Static detector tube readings taken during exposure sampling (see Figure 5) revealed that ‘hot-spots” of high styrene concentrations in existing booths These booths could be modified to create a true down draft configuration, which is the most effective flow configuration to minimize worker exposures. However, the cost of modifying the existing equipment is believed to be greater than the cost for new booths. For this reason, the following cost analysis will be based on booth replacement rather than modification.

Improvements would involve replacement of the five existing booths with larger side-downdraft booths. The design downdraft velocity should be 125 fpm, which would require a 450,000 cfm increase in the total plant exhaust and supply airflow (from 50,000 to 500,000 cfm).

Installed Equipment Cost includes
- Site Preparation – demolition, remodeling, and renovation
- Equipment Cost
- Freight, Insurance, and Sale Tax
- Direct Installation Costs – labor, overhead, profit and contingency
- Indirect Installation Costs – permits, fees, licenses, insurances

The budgetary installed equipment costs (circa August 2003) for a large turnkey system of several large downdraft spray booths is listed below [source - verbal quote from AEI Spray Booths Steve Moessing]:

18 booths each 16’W × 50’L × 20’H	$1.9 million =	$105,000 per booth
15 booths each 20’W × 50’L × 20’H	$1.6 million =	$107,000 per booth
4 booths each 8’W × 12’L × 10’H	$125,000 =	$31,000 per booth

The installed cost for the recommended new booths at Plant 5 is estimated as follows:

Two new downdraft gelcoat booths 16’W × 50’L × 20’H	$105,000 each
Three new downdraft gelcoat booths at 16’W × 50’L × 20’H	$105,000 each
Total installed cost – five booths at $105,000	$525,000

For 20 ppm PEL assume 125 fpm average downdraft velocity
Required airflow = 5*16*50*125 = 500,000 cfm

Lost Production Time – extensive modifications to the existing ventilation system would require a prolonged shutdown of the production area. The cost of this shutdown would depend on the length of shutdown, the cost to idle plant, and company's financial status. This confidential financial data was not provided as part of this study, so specific cost estimates cannot be made. However, this cost could be prohibitive if production were lost for an extended time period.

Operating Costs – the annual operating costs include three main components:

- Electricity cost to operate the fan motors - computed in **Table 13**.
- Natural gas fuel cost to heat the supply air - computed in **Table 14**.
- Replacement costs for filters, motor bearings, control parts, etc.

The annual operating cost analysis assumes that the plant will be operated at full capacity during two 8-hour work shifts per day for 250 days per year. This is a total of 4,000 hours per year of operation.

The electricity cost is estimated with the fan power equation:

$$E = \frac{0.000117 \times Q \times dP_{FAN} \times hr/yr \times \$/kWh}{Efficiency_{FAN}}$$

where:

Q	exhaust flow rate (scfm)
dP_{FAN}	total pressure drop across the fan (in w.g.)
hr/yr	hours of equipment operation
\$/kWh	cost of electricity including the demand charge
$Efficiency_{FAN}$	overall energy efficiency of motor, drive, fan (%) - assume 65%

Assuming an electricity rate of 7 cents per kilowatt-hour including demand charges, a maximum 2 in.w.g. pressure drop across the supply fan and the exhaust fans, the corresponding annual electricity cost is ~$45,000 per year as calculated below.

Table 13 – Annual Electricity Cost for Plant 5 Ventilation Modifications

Airflow	(scfm)	450,000
Total Pressure Drop	(in.wg)	2
Hours of Operation	(hr/yr)	4,000
Electricity Cost	($/kwh)	0.07
Fan %	(%)	0.65
Electricity Cost	**E ($/yr)**	**$45,360.00**

The heating cost is more difficult to estimate, because the cost to heat the supply air is directly proportional to the outside air temperature during the heating season, which is can be quite variable. However, the worst-case heating cost is estimated with a simple energy balance equation:

$$F(\$/yr) = \frac{1.08 \times Q \times dT_{AIR} \times hr/yr \times \$_{GAS}}{Efficiency_{HEAT} \times H_{GAS}}$$

where:

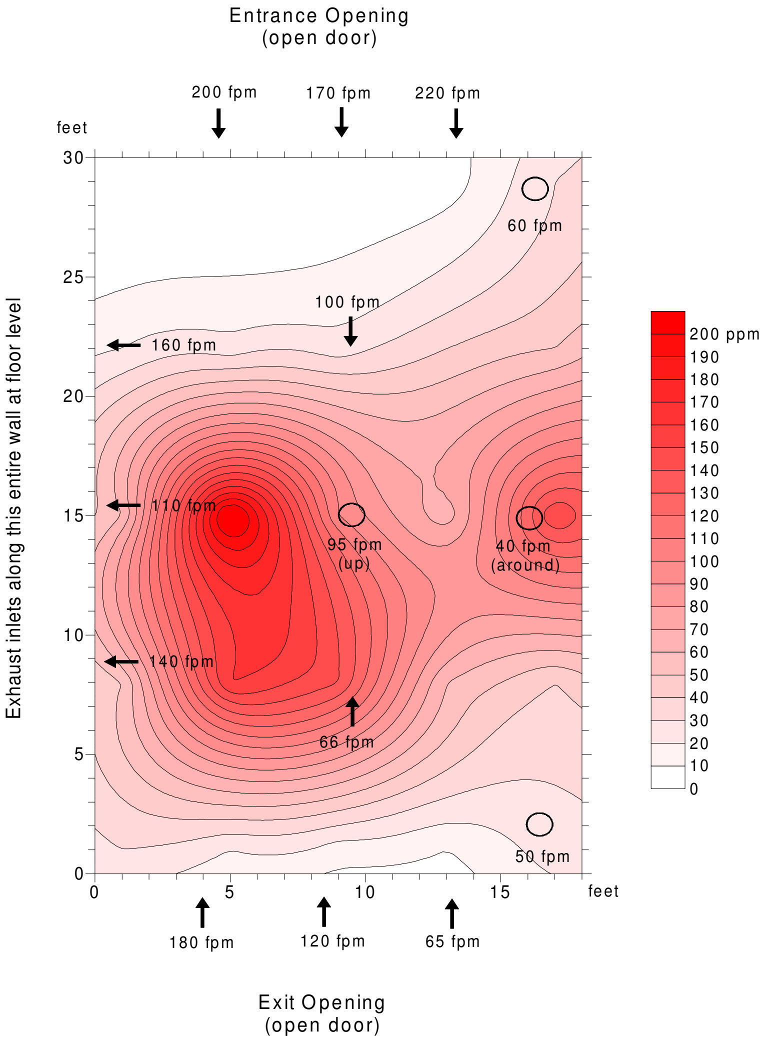
Q	exhaust flow rate (scfm)
dT_{AIR}	average temperature rise during heating season (°F)
hr/yr	hours in heating season
$\$_{GAS}$	cost of natural gas fuel ($\$/ft^3$)
H_{GAS}	heat value of fuel (Btu/ft^3) - assume 1,000 Btu/ft^3
$Efficiency_{HEAT}$	overall thermal efficiency of heater unit (%) – assume 95%

This worst-case analysis assumes that the annual heating season will last 500 hours and will have a worst-case average air temperature of 40°F during this entire period. The supply air temperature is assumed to be 90°F, so the worst-case average temperature rise during the heating season is assumed to be about 50°F. The natural gas utility rate for the plant is assumed to $0.007 per cubic foot ($0.7 per therm or $0.7 per CCF). Based on these assumptions the worst-case heating cost is ~$90,000 per year as computed below.

Table 14 – Annual Make-up Air Heating Cost for Plant 5 Ventilation Modifications

Airflow	(scfm)	450,000
Temperature Rise	(F)	50
Hours in Season	(hr/yr)	500
Natural Gas Cost	($/ft3)	0.007
Thermal %	(%)	0.95
Heat Value	(Btu/ft3)	1,000
Fuel Cost	**F ($/yr)**	**$89,526.32**

Figure 2 – Isopleth Map of Styrene Concentrations inside the Booth at Plant 5



Plant 6

Plant C produces commercial bathware parts on a highly automated oval production line that moves the production molds through the line on a mechanized, overhead chain-belt conveyor system. The production line is operated nearly continuously for three shifts per day and 300 days per year. The production operation is completely enclosed with booths and tunnels within the plant building. The work areas around the production line and ventilation systems are described below.

Gelcoat spray booth - one spray gun operators in a personal respirator
Gelcoat curing tunnel - no employees
Barrier coat booth - one spray gun operator in a personal respirator
Barrier coat curing tunnel - no employees
Lam 1 spray booth - one spray gun operator in a personal respirator
Lam 1 rollout tunnel - rollout workers in personal respirators
Lam 1 curing tunnel - no employees
Lam 2/3 spray booth - two spray gun operators in personal respirators
Lam 2/3 rollout tunnel - rollout workers in personal respirators
Lam 2/3 curing tunnel - no employees

Table 15 – Summary of Plant 6 Ventilation Equipment

Enclosure	Size LxWxH ft	Ventilation System	Airflow cfm
Gelcoat – booth & tunnel	70 x 18 x 10	Push-pull crossflow, 2 x 5 supply registers mid-high on one side, exhaust pickup mid-low opposite - operators move alongside moving parts into flow	Nominal 75,000 design, register airflow not balanced, higher in rollout
Barrier Coat – booth & tunnel	72 x 18 x 10		
Lam 1 – booth & tunnel	70 x 18 x 10		
Lam 2/3 – booth & tunnel	70 x 18 x 10		

The automated production line operates at one speed, so the production level during sampling was 100%. Under those conditions the following exposure data were recorded.

Table 16 – Summary of Plant 6 TWA Styrene Exposure

Plant: 6			50 ppm TWA/100 ppm			20 ppm TWA/40 ppm		
Sample	**ppm**	**Operator**	**UCL**	**LCL**	**Violation**	**UCL**	**LCL**	**Violation**
2C-9	122	Lam #2, Roller	2.54	2.32	Yes	6.19	5.97	Yes
2C-11	82	Lam #2,	1.74	1.52	Yes	4.19	3.97	Yes
2C-1	74	Lam #3	1.59	1.37	Yes	3.81	3.59	Yes
2C-5	70	Lam #1, Roller	1.50	1.28	Yes	3.59	3.37	Yes
2C-15	65	Lam #1	1.41	1.19	Yes	3.36	3.14	Yes
2C-3	59	Lam #2, Roller	1.29	1.07	Yes	3.07	2.85	Yes
2C-10	53	Gel Coat	1.16	0.94	Overexposure	2.74	2.52	Yes
2C-14	52	Barrier	1.14	0.92	Overexposure	2.70	2.48	Yes
2C-12	49	Trimmer	1.09	0.87	Overexposure	2.57	2.35	Yes
2C-7	39	Gel Coat	0.89	0.67	No	2.07	1.85	Yes
2C-4	34	Lam #1, Roller	0.79	0.57	No	1.81	1.59	Yes
2C-8	33	Trimmer	0.77	0.55	No	1.76	1.54	Yes
2C-6	31	Lam #1	0.73	0.51	No	1.65	1.43	Yes
2C-2	25	Lam #1 Roller	0.60	0.38	No	1.34	1.12	Yes
2C-13	20	Lam #1,	0.51	0.29	No	1.11	0.89	Overexposure
2C-21	90	Gel Coat	1.01	0.79	Overexposure	2.37	2.15	Yes
2C-23	49	Lam # 1	0.60	0.38	No	1.32	1.10	Yes
2C-22	44	Barrier	0.55	0.33	No	1.20	0.98	Overexposure
2C-24	30	Lam #1, Roller	0.41	0.19	No	0.87	0.65	No
2C-25	14	Lam #2,	0.25	0.03	No	0.46	0.24	No

As demonstrated by these data, the existing ventilation system cannot meet the 50-ppm PEL or the 100-ppm STEL by significant margins for three reasons:

1. High production levels – the production rate inside the enclosures is high due to conveyor automation and the tight production line layout. The applicator guns operate nearly continuously and the wet molds move continuously through the work areas.
2. Worker practices – the rollout workers and gun operators must stand between molds to access the mold surfaces. The rollout workers are often next to gun operators while resin is applied. The workers spend a large fraction of their work time downstream from the wet resin plumes and surfaces.
3. Booth geometry and airflow pattern – the booth enclosures have small supply inlets and small exhaust outlets. Large recirculation zones exist above, below, and to the side of the supply inlets due to the entrainment of booth air into the supply air jets. Some of the supply inlets near the gun stations have low supply airflows. The molds and gun plumes are very close to the exhaust inlets, which cause the exhaust filters to quickly plug with material overspray.

The existing ventilation system cannot meet the proposed 20-ppm PEL by a very large margin.

Potential Ventilation Improvements

This plant has retained Frees, the largest U.S. manufacturer of ventilation systems, to explore upgrades to plant ventilation. After review of the available exposure data, line configuration, and possible design scenarios, Frees would not guarantee that the any modification to the plant ventilation could meet the proposed 20-ppm PEL. On this basis we conclude that such ventilation improvements are infeasible.

Exhibit B - Evaluation of the Affordability of Ventilation Improvements

This analysis follows procedures developed by the Composites Fabricators Association (the predecessor to the current American Composites Manufacturing Association) for analysis of the affordability of the air pollution capture and control requirements proposed by the U.S. Environmental Protection Agency.[1]

In this analysis, we judge whether each plant could afford ventilation improvements designed to ensure compliance with a proposed lowered PEL of 20 ppm. We compare the projected cost of improvements against two measures of the plant's economic strength. The higher the projected compliance cost relative to the plant's financial capability, the more likely it is that the plant will be economically unable to comply and will have to close. The two measures we use to judge affordability are described below.

- Total Annual Cost (TAC) as a Percentage of Revenues provides for each plant an indication of:
    - Ability to pass the cost on to its customers.
    - Competitive position relative to other facilities that won't incur the cost.
    - Potential impact on profitability.

- Total Annual Cost (TAC) as a Percentage of Profits provides an indication of the ability of the facility to absorb the cost and still earn a return sufficient to justify continuing operation of the facility over the long term.

Computed using facility-specific cost estimates and actual facility financial performance, these two indicators provide a means for judging for each facility whether the costs for ventilation improvement are likely to be affordable. We interpret the values that these indicators might take on as follows.

Total Annual Cost as a Percentage of Revenues:

< 1%	Clearly affordable	When a facility's annualized cost to meet a requirement amounts to less than 1% of the facility's annual revenues, the requirement is clearly affordable. Regulatory costs at this level can likely be absorbed by a facility without significant harm to the facility's economic viability.
1% to 3%	Likely affordable but potentially problematic	Costs exceeding 1% of revenues is suggested in EPA's *Revised Interim Guidance for EPA Rulewriters; Regulatory Flexibility Act* (March, 1999) as a lower threshold for potentially significant impacts to small businesses. Regulatory costs at 1% of revenues or slightly more could pose a threat to long-term viability of lower-profitability firms in a relatively low profitability industry.
3% to 5%	Significant doubt about affordability	Costs exceeding 3% of revenues are regarded by EPA as a higher threshold beyond which facility closures become likely. 3 - 5% is often the range at which EPA's Economic Analyses begin to show significant concern and burden. Further, as shown later in this appendix, historical profitability for the composites industry as a whole

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[1] See: Environomics, Inc. *Affordability of Capture and Control: An Evaluation for the Existing Facilities Subject to EPA's Proposed Requirement*, October, 2001. Also: Environomics, Inc. *Affordability of Capture and Control of Hazardous Air Pollutant Emissions from the Open Molding of Reinforced Plastic Composites*, April, 2000.

		falls within the range of 3 - 5% of revenues, so that regulatory costs at this level may equal or exceed profits for many of the facilities in the industry.
> 5%	Likely not affordable	Costs exceeding 5% of revenues will exceed profits for most facilities in the industry. In surveys of more than 20 composites industry facilities conducted by consultants to the industry trade association, more than half of the facilities reported a rate of pretax profits less than this range. This means that potential regulatory costs at this level would be greater than or roughly equivalent to profits and would not be affordable unless most of these costs can be passed on to customers without penalty. However, as discussed in previous industry analyses, the composites industry is highly competitive, characterized by low returns, low barriers to entry, fierce competition from substitute materials (e.g., wood, sheet metal, vitreous china, molded plastics, etc.), and minimal pricing power.[2] Surveyed composites production facilities generally reported that an attempt to increase their prices by even 5% would cause detrimental losses of business to either other thermoset fabricators, thermoplastic fabricators, or fabricators using other materials.

Total Annual Cost as a Percentage of Profits:

< 25%	Clearly affordable	Costs amounting to up to about one-quarter of a facility's profits would be unlikely to cause closure of any facility that is otherwise expected to be viable in the long run.
25% to 50%	Likely affordable but potentially problematic	Regulatory costs of up to about half of a facility's profits might be problematic for already low-profitability facilities, but most average profitability facilities ought to be able to continue operating even if costs of this magnitude must be absorbed and profits decline commensurately.
50% to 80%	Significant doubt about affordability	Regulatory costs at this level, unless passed through to customers as price increases, will consume the bulk of profits for most firms in the industry. Pass through of costs is unlikely in this industry. Costs at this level might thus be affordable for facilities that enjoy healthy profits in the pre-regulatory baseline, but are unlikely to be affordable for facilities that earn less than average profits in the baseline.
> 80%	Likely not affordable	Costs exceeding 80% of profits clearly represent impacts that are very unlikely to be affordable for most facilities, even in the unlikely event that some costs can be passed through to customers.

Estimating Total Annualized Compliance Costs for the Two Plants

Note that these two indicators address the affordability of a continuing (unending) stream of annual costs for complying with the tighter PEL. The engineering analysis described in the body of the report has estimated the additional capital and annual O&M costs of the booth and ventilation improvements needed to meet the tighter PEL at each plant. We have annualized these costs, converting the one-time capital costs into an equivalent series of continuing annual costs representing, in effect, the charges that would need to be paid annually to finance the required capital investment. We did this assuming a useful life of

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[2] Environomics, Inc. (2000), op. cit.

10 years for the new capital equipment and a real discount rate of 7% per year. These useful life/discount rate assumptions yield a capital recovery factor (CRF) of 0.1424, and the annualized equivalent amounts for each of the plant's projected capital costs of meeting the tighter PEL are:

- Plant 1, capital cost of $230,000 x CRF of 0.1424 = $32,752 annualized cost equivalent;

- Plant 5, capital cost of $525,000 x CRF of 0.1424 = $74,760 annualized cost equivalent.

Adding these annualized capital costs to the incremental annual O&M costs for meeting the tighter PEL ($192,000/year for Plant 1 and $134,900/year for Plant 5) gives the following estimated total annual cost (TAC) for each facility:

- TAC for Plant 1 = $204,752/year

- TAC for Plant 5 = $209,660/year.

In judging the affordability of meeting the tighter PEL, these annual cost figures are compared against the two measures of financial performance.

Estimated Financial Performance of the Two Plants

Very limited economic data is available regarding the two plants. We make several assumptions in projecting economic variables for each facility. Plant 1 is estimated to have produced 4.65 million pounds of laminate in 2001, the most recent year for which production data can be estimated. Plant 5 is estimated to have produced about 2.78 million pounds of laminate in that year. At an average market price of $1.96 per pound of laminate in 2001,[3] the two plants are estimated to have earned the following revenues:
Revenues:

- Plant 1: $9.105 million/year;
- Plant 5: $5.442 million/year.

No information is available on the profitability of each these plants specifically. Long-term pre-tax industry profitability is estimated at 4.3% of sales, using data for NAICS subsector 326 (miscellaneous plastics and rubber products).[4] We assume these two plants earn profits at this long-term industry average rate of 4.3% of revenues. Profits for the two plants are thus estimated at:

Profits:

- Plant 1: $391,515/year (.043 x $9.105 million/year in revenues)
- Plant 5: $234,006/year (.043 x $5.442 million/year in revenues).

Affordability Analysis Results

For each plant, the projected Total Annual Cost of ventilation improvements to meet the tighter PEL is compared with the two measures of the plant's financial capability to bear these costs.

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[3] Environomics. Inc. *A Review of EPA's Economic Impact Analysis With Respect to the Affordability of the Proposed Capture and Control Requirements*. Prepared for the Composites Fabricators Association, October, 2001.

The results are shown below.

Affordability Assessment

	Plant 1	**Plant 5**
TAC to meet tighter PEL	$204,752/yr	$209,660/yr
Estimated revenues	$9.105 million/yr	$5.442 million/yr
TAC/revenues	2.2%	3.9%
Affordability per revenue measure	**Likely affordable, but potentially problematic**	**Significant doubt about affordability**
Estimated profits	$391,515/yr	$234,006
TAC/profits	52.3%	89.6%
Affordability per profits measure	**Significant doubt about affordability**	**Likely not affordable**

Combining the information from the two measures, we judge the costs of ventilation improvements to pose some risk of closure to Plant 1. It is uncertain whether this plant could afford this cost. The plant might be forced to close, or might be able to continue to operate in a substantially weakened financial condition.

The conclusion is much clearer for Plant 5. This plant would probably be unable to afford the cost of ventilation improvements. If required to install them, this plant would likely have to close.

Exhibit C – Adverse Health and Safety Impacts of Respiratory Protection

There are two broad classifications of respirators - supplied air and air purifying respirators (APRs). Each class of respirators has advantages and disadvantages in use.

Supplied Air Respirators

Supplied air respirators provide clean breathing air to the worker, typically through a hose. There are requirements that the supply air system deliver Compressed Gas Association Grade D or better breathing air. Protection factors associated with supplied air system are typically much higher than APRs. This is because the supply air respirators are positively pressurized relative to the surrounding environment and air moves from the face piece into the work environment.

Use of supplied air respirators imposes certain health and safety risks. The primary concern is that operator air supply hoses might become entangled with each other or within moving equipment, imposing a possible slip, trip and fall hazard. This hazard is amplified in automated process areas (such as at Plants 3 and 6) where the hose may get caught in the automated conveyer equipment.

Supplied air respirators can also interfere with speech recognition, an effect noted in several studies. A study of 13 paired speaker/listeners with normal hearing and speech was evaluated to study the effects of wearing face pieces on communication. It was found that at a distance of 12.2 m, sentence comprehension was 70%. Single word comprehension was zero at distances over 9.1 m. Respirator masks interfered with communication by attenuation sound and hiding visual clues associated with facial expressions (Coyne et al., 1998). The Coyne et al. (1998) study was performed with the speaker in a combined speech and background noise environment maintained at 70 dB(C). Plant conditions may be significantly louder and further inhibit effective communication. Communications involving telephone use while wearing respirators have shown that accuracy suffers by about 10% when respirators are worn and that word identification speed was about one-third to one-half when compared to similar communication without respirators or hoods (Johnson et al., 2000b). This study was conducted with eleven speaker-listener pairs of subjects.

Finally, vision may be impaired by supplied air respirators, where clouded lenses can adversely impact vision. A study was conducted of ten subjects engaged in treadmill exercise. The subjects wore the same type of respirator mask, but with different sets of clouded lenses. The full face-piece masks were found to adversely impact visual acuity under the test conditions by about three-fourths of a Snelling line (Johnson et al., 1997).

Air-Purifying Respirators

Air-purifying respirators for styrene would typically employ half-face masks fitted with an organic vapor cartridge, through which air is drawn by the wearer’s lungpower. Since they are under negative pressure and rely on the action of an absorbent, they are assigned a lower protection factor than are supplied air respirators. However, they do not impede operator movement, and are much less likely to become entangled than are supplied air respirators.

The primary vision impairment associated with half-mask respirators is a blocking of the line of site imposed by the location of the face piece and the protrusion of the filter cartridges. Speech recognition impacts are similar to those described for supplied air respirators.

Physiological effects from air-purifying respirator wear are varied, and impact a worker's pulmonary and cardiovascular systems. Use of negative pressure respirators increases the physiological load on the wearer through increasing resistance to inspiratory breathing, increasing the dead space volume and in limiting the ability to dissipate body heat (Harber et al., 1984). Taken to the extreme, the physiological burden imposed by respirators may lead to death. In a survey of workplace fatalities during the period of 1984-1995, it was found that there were 41 incidents with 45 fatalities associated with respirator use. Most of the fatalities involved procedural problems with the use of respirators. However, there was a fatality from cardiac arrest that occurred when a worker wearing a cartridge respirator was engaged in pesticide application. (Suruda et al., 2003).

Cardiovascular Effects: In a study of ten 25-35 year old healthy men, a significant increase in heart rate and respiratory rate was observed with disposable respirator use at heavy workloads and during rest when compared with similar activity without respirator use. Increases in both systolic and diastolic pressure were observed at heavy workloads (Jones, 1991). Hodous et al., (1989) presented a study of 20 men that evaluated cardiopulmonary effects of respirator use under workplace conditions. Respiratory inductive plethysmography (RIP) was employed to evaluate respiratory frequency, tidal volume, minute ventilation and heart rate. Cardiopulmonary parameters were noted to increase during respirator wear. Increases were attributed to increased exercise and the weight and heat stress associated with the respirator and protective clothing ensemble. A study of five unacclimatized workers was conducted that exposed the subjects to heat during 1 hour treadmill exercise while wearing half-face and full face cartridge respirators and also without respirators. The study was performed at 25 °C and 43 °C. Increased in physiological strain indicated by heart rate, minute ventilation, oxygen consumption, energy expenditure and oral temperature were noted. There was no detectable effect on sweat rate. (Dukes-Dobos and Smith, 1984).

The use of coated chemical protective clothing employed at all plants surveyed can also have significant adverse effects on cardiovascular performance (Hodous, 1986), which would be compounded by respirator use.

Pulmonary Effects: Respirators provide a physiological load to the body by increasing the resistance to inspiratory breathing, increasing the dead space volume, and decreasing the body's ability to dissipate heat (Szeinuk et al., 2000; Harber et al., 1984). The increase in resistance to inspiratory breathing is most prevalent with negative pressure respirators and is imposed by the resistance to airflow imparted by the filter cartridges. A linear relationship between dead space volume and a decrease in subject performance times at high workloads has been demonstrated (Johnson et al., 2000). The adverse effects of increasing the dead space volume arise from the accumulation of carbon dioxide in the respirator dead volume and its re-inhalation into the respiratory system with subsequent breaths. In the Duke-Dobos and Smith (1984) study, the oral temperature of the five unacclimatized workers rose an average of 0.6 °F. The increase in oral temperature was more pronounced for full-face respirator use.

In some cases, psychological effects have been described associated with respirator use. Morgan and Raven (1985) were able to employ Spielberger's trait anxiety scale to predict respiratory distress in a group of 45 male volunteers using a self-contained breathing apparatus (SCBA). The authors concluded that objective measures of trait anxiety could be used to identify individuals likely to experience respiratory distress while wearing a respirator and performing heavy work. In a separate study of 20 individuals, trait anxiety levels were evaluated and the subjects exercised at 80-85% of their maximum heart rate on a treadmill to a voluntary endpoint. It was found that performance times with respirator use averaged less than one half of the time without a mask. It was concluded that anxiety level could be a determinant of performance when using respirators (Johnson et al., 1995).

Exhibit C References:

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