PB83-140327

Behavioral Procedures for Reducing Worker Exposure to Carcinogens

FINAL REPORT

NIOSH Contract Number: 210-77-0040

Prepared by: The University of Kansas

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. 210-77-0040	2. NA	3. Recipient's Accession No. PB83 NA 140327
4. Title and Subtitle: Behavioral Procedures for Reducing Worker Exposures to Carcinogens			5. Report Date
			6. NA
7. Author(s): Anonymous			8. Performing Organization Rept. No. NA
9. Performing Organization Name and Address: The University of Kansas			10. Project/Task/Work Unit No. NA
			11. Contract(C) or Grant(G) No. (C) 210-77-0040 (G)
12. Sponsoring Organization Name and Address: NIOSH Cincinnati, Ohio			13. Type of Report & Period Covered: Contract
			14. NA

15. Supplementary Notes

NA

16. Abstract (Limit: 200 words)

The purpose for research into behavioral procedures for reducing worker exposure to carcinogens, the methods used, summary results, and analysis of results are discussed. Familiarization industrial facility visits, involving trips to manufacturers of products from fiberglass reinforced plastics, work procedures, and worker education, training, and motivation are considered. Major research results related to behavioral or work procedure data, data on housekeeping practices, data on air samples for styrene (100425), and data on urinary mandelic-acid concentrations are described. Among various conclusions, the authors note that work procedures and housekeeping practices, selected for their relevance to reducing exposures to workplace hazardous substances, can be readily and dramatically changed in prescribed directions.

17. Document Analysis a. Descriptors

Chemical-exposure, Occupational-medicine, Industrial-hygiene, Medical-research, Health-surveys, Behavior

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Available to Public	NA	36
	20. Security Class (This Page)	22. Price

ORGANIZATIONAL NOTE

This report is in three parts. The part titled "Behavioral Procedures for Reducing Worker Exposure to Carcinogens, Final Report" contains information on the rationale for the research, a description of the methods used, summary results, and a discussion of the results. A second part, "Behavioral Procedures for Reducing Worker Exposure to Carcinogens, Final Report: Detailed Data", includes graphic presentations of individual workers and plant areas, and data averaged over subjects and plant areas but not over work procedures and housekeeping practices. "Behavioral Procedures for Reducing Exposure to Carcinogens, Final Report: Appendices" contains a report of research that was conducted preliminary to the major research effort and material on procedural detail that might be of use to investigators who wished to replicate the research.

ACKNOWLEDGEMENTS

A research project as large and complex as this requires the efforts and cooperation of a great many people. Richard F. Dangel and H. Gordon Fitch were heavily involved in the conceptualization and design of the research methods. Bob Haynes, Randy Pine and Bob Spencer carried out the library research necessary to catalog the many work practices and procedures which were fundamental to the research effort. Albert Stewart's judgment and skill as an industrial hygienist were indispensible in setting up environmental sampling procedures, mapping the plants and identifying potentially useful work procedures and housekeeping practices.

Once data collection began many people, working as observers, were crucial to the effort. Outstanding work was done by Jan Kretsinger, Allen Twitchell, Elizabeth Holtzman and Suzette West. The work done by these people was tiring and exacting, and they carried it out very well.

Mr. James Snarr and the staff of the Utah Biomedical Test Laboratory provided the project reliable analyses of hundreds of charcoal tubes without an instance of lost shipments or delayed reports. Dr. Robert Sanders, with the assistance of Scott Parker, Sally Twente, and Joe Algaier, provided good analyses of what must have seemed like an endless collection of urine samples.

Field research of this magnitude encounters hundreds of unanticipated problems and obstacles that result from day-to-day vagaries of plant operations even when the research has been well conceptualized and designed. Our NIOSH project officers gave us a good set of workable questions and abundant advice and support in handling the practical difficulties.

Mr. Ken Hans was our teacher. He taught us about the production of fiberglass reinforced plastics and about the practicalities of work procedures and housekeeping practices. His experience in the industry and his good judgment saved us from making countless mistakes.

Jeffrey Sullivan, Lynn Hollenshead, William Van Lew, Randall Loebig, Jeanette Shaffer and Rodney Conard deserve all of the credit for the successful completion of the project.

Jeff, assisted by Mike Frost, Jim George, Bill DeArmond and Sandra Black, superbly managed, coordinated, analyzed and plotted in excess of ten million data facts. These were always available when needed and were done with almost perfect accuracy.

Bill, Lynn and Randy supervised the collection of those millions of data facts in the plants and carried out the worker training and motivation programs. This work often meant: showing up at plants at four in the morning; working until long after the subjects had gone home; many tiring cross- country drives; careful attention to innumerable details; and the constant maintenance of good relations with

the plant workers and managers who were our hosts. I have never seen a more difficult role in any research project than the one these people carried out cheerfully and reliably.

Our office manager, Jeanette Shaffer, made everything else possible. She kept us paid, informed, supplied with necessary forms and materials, mindful of our deadlines and obligations, and found ways to solve all problems created by bureaucratic rules and regulations. Her initiative, judgment and careful work left the rest of the staff free to concentrate on the research.

Rod Conard made everything happen. He developed the details of the research and ably hired, trained and supervised the field staff. He left me with a functioning project when he left for better employment. His interest and skill were essential to this research.

B. L. Hopkins
Project Director
Department of Human Development
University of Kansas
Lawrence, Kansas
August 10,1981

FORWARD

In August of 1977 the National Institute for Occupational Safety and Health issued a request for proposals titled "Behavioral Procedures for Reducing Worker Exposures to Carcinogens." This RFP called for prospective contractors to prepare technical and financial proposals to accomplish the following work:

1. To select a target carcinogen(s) and/or suspect carcinogen(s).

2. To become familiar with convenient industries which used that toxic substance.

3. To develop a comprehensive list of work procedures and select from that list test procedures which might be useful to reduce workers' exposures to the selected carcinogen(s) or suspect carcinogen(s).

4. To develop a training and motivation model which might be useful to help workers adopt the test work procedures.

5. To measure workers' uses of the selected work procedures and their exposures to the target carcinogen(s) or suspect carcinogen(s) in plants.

6. To introduce the training in plants in an experimental design that would allow for inferences about effects on work practices and any correlated changes in exposures.

A group at the University of Kansas submitted a response to the RFP and were awarded the contract. This group included B. L. Hopkins, Department of Human Development, (Principal Investigator); H. Gordon Fitch, School of Business, (Co-Principal Investigator); Rodney J. Conard, Human Development, (Research Assistant); and Robert Sanders, biochemistry, (Director of Biochemical Analyses).

The proposal had originally recommended work with both hexavalent chrome and styrene. During negotiations for the contract it was decided that styrene alone would be the target substance. The reasons for this decision were that:

1. Carcinogens were generally regulated to exposures at the lower end of the range in which they could be measured. Therefore, any changes in exposures to carcinogens might not be measurable.

2. Styrene was regulated only to a level which allowed a wide range of measurable exposures. Therefore, research would likely encounter exposures such that any systematic changes could be detected.

3. Styrene was known to be in use in manufacturing processes in many plants in the University of Kansas geographical area.

The remainder of this report details the research conducted under this contract and the results that were obtained.

TABLE OF CONTENTS

FAMILIARIZATION PLANT VISITS

Visits were made to fifteen different sites. Fourteen were involved in the manufacture of products or components of products from fiberglass reinforced plastics. The fifteenth site was at a Midwestern university which had an associate-level program to train people to work in the reinforced plastics industry. The following is a brief description of each of the sites:

Site 1- A plant which primarily made parts for a manufacturer of diesel truck tractors. The plant employed approximately 35 people on one shift and operated one gelcoat booth (a description of the processes which were carried out in the various locations in the plants will be given later), two chop booths and one layup booth. The booths were custom made and exhaust ventilation was operable in all of them. Two different visits were made to this plant.

Site 2- This was a manufacturer and distributor of laboratory equipment such as fume hoods and bacteriological glove boxes. The plant employed approximately 200 people, including office staff, and about 20 of these worked in the Reinforced Plastics Fabrication Department. This department operated one gelcoat booth and one chop booth. Both booths were constructed by a national manufacturer of ventilation equipment and both had operating exhaust ventilation.

Site 3- This plant was located in a limestone cave and manufactured small, reinforced plastic houses for radar installations and utility substations. Management of this plant declined to allow project staff to see their manufacturing facilities. This was the only site which declined the request for a familiarization visit.

Site 4- This plant manufactured plastic storage tanks using a relatively unique drum winding process. It employed only four people in manufacturing and the only styrene control procedure was passive dilution.

Site 5- Bathtubs, shower stalls and small fishing boats were manufactured at this plant which employed about 25 people. It had one gelcoat and one chop area and exhaust ventilation was operating.

Site 6- This plant also manufactured bathtubs and shower stalls. Secondary product lines included bubble skylights and cultured marble sinks. Fiberglass reinforced plastic work centered around one gelcoat booth and one chop booth both of which had operating ventilation.

Site 7- This was a small plant completely operated by the owner, his daughter and son-in-law and occasional part-time help. These people manufactured tops for horse trailers and burial vaults. There were no work stations in the production area and ventilation for the entire work area was provided by a single window exhaust fan.

Site 8- This plant employed about 60 people in the manufacture of pleasure motor boats. There was one gelcoat booth with operating

exhaust ventilation. Most chop spray and layup work was done in the open plant as the boat molds were moved from one location to another.

Site 9 - This plant employed about 35 people and also manufactured powered pleasure craft. Its production procedures were much like those at Site 8.

Site 10- This plant employed from 3 to 5 people in the manufacture of small sail boats. Spray and layup work were done in the open plant with window ventilation.

Site 11- This was the university-based training facility. It had ventilated spray booths. However, the training program was functioning at a low level when the site was visited and little could be discerned about processes and work procedures.

Site 12- This plant employed from 15 to 30 people to manufacture custom products for outside concerns. It had one functioning ventilated booth and several areas with grid floors and down-draft ventilation.

Site 13- This plant manufactured plastic vanes, outside shrouds and lattices for proprietary cooling towers. Unlike most of the sites which used movable molds, this plant had stationary molds in two long ventilation booths in which most of the spray and layup work was done. This plant was also experimenting with a resin inject process which is relatively novel in this industry. This plant employed about 65 people with 30 of them assigned to the initial fabrication of reinforced plastic parts.

Site 14- This plant manufactured fiberglass reinforced parts for pickup truck conversions and for farm implements. This particular industry was so depressed at the time the plant was visited that no production was taking place.

Site 15- This plant manufactured parts for diesel truck tractors, fiberglass reinforced plastic booms for cherry pickers and, later, a proprietary product, plastic hot tubs. Initially the plant employed 30 people with work centering around two operating ventilation booths, one used for gelcoating and one used for chop spraying. During later visits with this company, the manufacturing had been moved to a second plant with employment increased to 65 to 85 workers and production utilizing up to two gelcoat booths, one layup booth and two chop booths. All booths had been custom fabricated with operating exhaust ventilation.

Manufacturing Processes

Manufacturing of reinforced, laminated plastic products, such as those manufactured from styrene-containing resins, typically consists of a series of operations. A mold that has the converse shape of the desired product is cleaned and waxed and then moved to the gelcoat sprayer who sprays a mixture of pigmented polyester resin and styrene monomer onto the mold with the compressed air sprayer. The compressed air sprayer is similar to a paint sprayer and is constructed to mix a catalyst such as methyl ethyl ketone peroxide (MEK-p) with the resin-

styrene mixture as it leaves the gun.

When styrene is used as a diluent-reactant it polymerizes with the resin after application to the mold. During this curing process, the mold is set aside to allow the gelcoat layer to harden. After hardening, the cured gelcoat is given a reinforcing lamination of fibrous-glass. The lamination is applied with a second spray gun that shoots a mixture of chopped fibrous-glass, resin-styrene mixture and catalyst. The operator of this machine is called the chop sprayer.

Immediately after application of the reinforcing lamination, additional reinforcement may be built into the part by the integration of wooden or metal members or woven fibrous-glass mats soaked in a resin-styrene-catalyst mixture. The reinforcement is typically bonded to the part with a light spray of the chopped fibrous-glass mixture.

In the next operation, workers using rollers, much like those employed for painting, roll the newly applied lamination to remove gas bubbles from the mixture and to insure that the resin and fibrous-glass are thoroughly compressed and mixed. These workers are called rollout persons. The molds and parts are set aside to cure. After curing, the parts are removed from the mold, and the mold is inspected and repaired if necessary. The person who performs this latter operation is called the mold repair person.

Although other finishing operations may be performed, and plants differ with respect to floor plans, engineering controls, storage, and equipment, the above described steps are typical and characterize the industry.

The parts or products resulting from these processes have predictable appearance and structural characteristics. On one side there will be a hard, pigmented surface and on the other side there will be a reinforcing lamination of hardened plastic and fiberglass with occasional reinforcing members. For example, production of a sailboat hull would begin with a concave mold with a shape the converse of the shape the completed hull will have. Blue pigmented gelcoat resin would be sprayed onto this mold and allowed to cure or harden. Subsequently, resin and chopped fiberglass would be sprayed onto the surface of the gelcoat layer that is away from the mold. This laminating layer would be rolled out as described above. Resin-soaked mats of woven fiberglass would probably be layed onto the chop-spray layer at strategic points, perhaps be chop-sprayed again, and rolled out. Wooden pieces would be added for ribs, and perhaps metal pieces in the bow and keel. These pieces would be chop-sprayed at least where they must be fastened to the lamination and then these areas would be rolled out. The part and mold would be set aside so that the fresh resin could cure. Then the part would be pulled from the mold. The result would be a sailboat hull with a blue outer surface, attached ribs and other reinforcing members. This part would probably be trimmed, have other parts such as a deck and seats added, perhaps be drilled for mounting cleats, brackets and lights. Finally, the outside, blue surface would be buffed and polished for appearance. Simply by changing the shape of the mold and the color of the pigment, but otherwise using the same processes, the result could

be a red hot tub, a green top for the cab of a truck, a beige bathtub or a white liner for a fume hood.

Exceptions to these processes were seen in only two plants. The site which manufactured liquid storage tanks used a large rotating drum as a mold, did not apply an initial gelcoat layer (the appearance of the inner surface of a tank is not important), wound fiberglass filament onto the drum, used some automatic chop spraying equipment, and did relatively little rollout work. The resin inject process used for some of the production at the plant which made cooling towers involved pumping a pigmented resin-fiberglass mixture into a closed mold where it was allowed to remain until it had cured.

Plant Mapping

As the project staff were becoming familiar with the manufacturing processes, the project industrial hygienist took numerous grab tube samples with a Bendix, Model 400 Gastec pump and Fink styrene detector tubes to identify the processes, jobs and plant areas that involved relatively high exposures to styrene. Assuming that a plant had functioning exhaust ventilation, the following results were relatively general over plants.

High exposure areas, with momentary concentrations ranging from 110-280 ppm, were two kinds of spray booths in which the gelcoat mixture and the resin-chopped fiberglass mixture were sprayed onto the molds. These two processes apparently introduced a majority of the styrene into the plant because styrene was vaporized by the spraying process and came to evaporate at a high rate because of the fact that the surface area for evaporation became large and the addition of the catalyst to the mixture produced heat.

The rollout and curing areas of the plant also yielded relatively high momentary levels of styrene, ranging from 70-170 ppm, resulting from the action of the catalyst. The two spraying jobs and the job in which the resin-fiberglass mixture was rolled out involved not only the greatest momentary exposures for workers, but also the greatest total time of relatively high exposure.

Several jobs such as repairing molds and touching up blemishes in gelcoat surfaces, occasionally introduced relatively small quantities of styrene into the air. Many jobs, such as those involved in grinding flashings from parts, polishing parts and moving parts from one area to another, introduced no or negligible styrene into the plant. Workers in these jobs were exposed to styrene as a result of the ambient concentrations produced by the styrene-introducing processes described above. These momentary ambient concentrations typically ranged from 2-20 ppm.

SEARCHES FOR PROMISING WORK PROCEDURES

At the same time the plant familiarization visits were occurring, project staff were conducting a systematic search for work procedures

which might be useful to reduce workers' exposures to styrene. This search consisted of three kinds of activities:

Literature Reviews - MEDLARS and MEDLINE computer searches were conducted at the University of Kansas. The NIOSH project officers provided the staff a collection of NIOSH publications including criteria documents, copies of the NIOSH series with titles beginning "Health and Safety Guide for---" and "Good Work Practices for---" and several other NIOSH publications. Searches were conducted in several journals such as the Journal of Occupational Medicine, Archives of Environmental Health, Annals of Occupational Hygiene, and the American Industrial Hygiene Association Journal.

All relevant articles were read for suggested work practices, kinds of exposures for which they might be useful, conditions of use and the extent, if any, to which the work procedure had been evaluated and had been found useful to reduce exposures. These searches were not limited specifically to styrene but were broadened to include any substances which had physical properties like styrene or which workers might contact as they contact styrene.

Plant Surveys - During the familiarization visits in the plants, once high exposure jobs and processes had been identified, project staff observed how work was being done and speculated about ways in which job tasks could be accomplished so that workers would receive less exposure to styrene. At times workers were asked to briefly try out a work procedure suspected to be useful and provide the staff feedback on the ease with which the procedure could be used and whether or not any change in exposure could be subjectively noticed. At other times, grab tube samples would be collected to determine momentary styrene exposures as the workers carried out a procedure in their accustomed way and in the manner suspected to be more useful to reduce exposures.

Interviews with Workers and Management - During the plant familiarization visits, informal interviews were conducted with 38 workers and lead persons and with 14 members of management at the various plants. During these interviews project staff explained their interests and the reasons behind them and the plant employees were asked to make suggestions. These suggestions were sometimes tested for practicality and momentary exposure differences as described above for work procedure suggestions made by the project staff.

Results of Searches for Promising Work Procedures. Two hundred and fifty-four publications were read and indexed. There was great overlap in the work procedures and practices recommended. For example, most of the criteria documents recommend exactly the same work practices regardless of the chemical substance being reviewed or the kinds of manufacturing processes in which the substance is used.

In addition, almost no empirical base was found to exist for work practices recommended. Only eight publications mentioned any measurement of exposures to a substance as a recommended work practice was introduced. None of the publications attempted to measure use of recommended work practices to determine if they changed as prescribed.

Therefore, it appears that recommended work practices are based largely on common sense.

Information obtained as a result of project staff surveys and interviews with plant employees was somewhat more promising. For example, one obvious suggestion was that workers should always engage exhaust ventilation when carrying out the spraying or roll out jobs in a booth. Momentary grab tube samples indicated that this work practice could reduce exposures. Similarly, if workers were spraying or doing roll out work in a ventilated booth, momentary samples would differ considerably depending on whether the worker stood on the upwind or downwind side of the part being produced.

The above searches produced a compendium of possible work practices which is included as Appendix A.

WORKER EDUCATION, TRAINING AND MOTIVATION

Appendix B is a review of behavioral education, training and motivation technology and research. The following is a listing of major procedures for each of these methods:

Worker Education. This method typically includes: 1) use of short units of instruction; 2) use of study questions or guides; 3) use of frequent reviews and opportunities to demonstrate learning; 4) use of mastery criteria; and 5) use of self-pacing and minimum porgress contingencies.

Worker Training. Common components of worker training programs are: 1) empirical derivation of behavioral training objectives; 2) precise specification and definition of behavioral training objectives; 3) difficulty and prerequisite analyses for sequencing of training tasks; 4) breaking training objectives into short units; 5) establishing quantitative criteria for target behaviors; 6) use of cumulative lesson criteria; 7) use of modeling to communicate target behaviors; 8) opportunities to engage in target behaviors in work situations; 9) Provision of immediate, objective performance feedback; 10) recycling through training units until criteria are mastered.

Worker Motivation. Typical motivation methods include: 1) minimization of aversive methods; 2) use of performance feedback; 3) point and token consequences; 4) tangible consequences; 5) use of privileges as consequences; 6) use of social consequences.

A fundamental characteristic of the research project was the assumption that some collection of these procedures could be used to reliably change the work behaviors of the plant employees who dealt with styrene.

INITIAL RESEARCH

Several assumptions and questions resulted from the plant visits and literature search:

Assumptions:

1. Management of plants within the fiberglass reinforced plastics industry seemed to be sufficiently interested in the contract research that reasonable cooperation could be expected for the experimental work.

2. Styrene, as used in this industry, was a good choice of substance for the research because it was used in many open, worker-performed manufacturing processes and because it occurred in measurable quantities in predictable locations.

3. Knowledge about the usefulness of work procedures and practices to reduce exposures was quite limited. The literature would provide little help in selecting procedures and practices.

4. It was possible to hypothesize, on the basis of observations and changes in momentary exposures, that certain procedures and practices might be useful to reduce the exposures of some workers.

Questions:

1. Could a subsample of work practices and procedures be introduced to workers so that they would reliably change the ways in which they worked with and around styrene?

2. If the workers could be induced to behave differently, would the changes in work practices and procedures yield practically important and statistically significant changes in exposures as measured by air sampling methods and by urinary mandelic acid (a metabolic product of styrene) concentrations?

3. Would the work practices and procedures be useful for all workers or, perhaps, only for those workers who dealt directly with styrene and not those who were passively exposed to styrene?

Structuring of Initial Research - It was decided that a small-scale experiment would be useful to answer these questions and that the questions should be answered before a large-scale experiment was begun in several plants.

Permission to conduct research was refused at two plants, sites 1 and 13 described above. A third request, at site 2, was successful.

Four workers, three of whom dealt directly with styrene and one who would have only passive exposures during most of a work day, volunteered to serve as subjects. A subset of work procedures was selected for study. Observers were trained to collect reliable data on the use of the procedures. Sampling and analysis procedures were established for air samples and urine samples. Data were collected for a period of time and then two of the workers were trained to use the selected work procedures while the other two subjects served as controls. Later, the

second two subjects were also trained to engage in the work procedures.

Summary of Results of Initial Research - Details of the procedures and results of the initial research are presented in Appendix C. In addition, reports on this research have been presented at the Second NIOSH Scientific Symposium, 1979, at the annual meeting of the Society of Plastic Industries, 1980, and at the annual meeting of the Society of Manufacturing Chemists, 1981.

Briefly, the training was successful to cause all four workers to engage in most of the desired work procedures. Exceptions were those behaviors which were occurring within acceptable limits and the use of a respirator, under certain conditions, by one worker. Practically large and statistically reliable reductions in air sample measures of styrene exposures occurred for all three workers who worked directly with styrene but there was no reduction for the fourth worker whose exposure was primarily passive. There were large and statistically reliable reductions in mandelic acid concentrations for two of the three workers for whom reductions in air sample concentrations of styrene were obtained.

MAJOR RESEARCH PREPARATIONS

The results of the initial research suggested, at least on a limited scale, that the research called for by the contract was not only feasible but quite promising. Hypothetically useful work procedures could be identified and workers could be efficiently trained to employ these procedures in their daily work routines. Styrene exposures, as determined by individual air samples, occurred in measurable ranges and, for some workers, were reduced by large amounts as the workers reliably used the recommended procedures. Measures of urinary mandelic acid concentrations were more variable but also had some promise as an index of exposures.

It was clear that the research should be focused on a subset of the workers in a typical plant. These workers were those who worked directly with styrene and styrene-containing resins in processes in which styrene was vaporized or evaporated into the air or was available in resins which had not yet cured. These workers were the ones who carried out the gelcoat spray, chop-resin spray, layup, and rollout operations.

If work procedures could be useful to other workers, those who did not deal with curing resins, it would probably not be because they used the work procedures themselves but because the work procedures, as used by the key workers, reduced the overall concentrations of styrene in the plant.

There remained, then, the major portion of the contract work; selecting a large number of potentially useful work procedures, developing a formalized training program, developing a motivation system to accompany the training, using the training and motivation to introduce the work procedures to a number of workers in several plants, and monitoring styrene exposures to see if they changed as the workers came to behave differently.

Plant Selection- Five different plants were approached about cooperating with the research. The management of Site 13 again declined to participate in the research. Site 5 agreed to participate in the research and a number of visits were made to the plant in preparation of conducting a portion of the research there. However, none of the exhaust ventilation equipment in the plant was working properly and was not repaired despite repeated requests by project staff. It was decided that this plant would be dropped as a research site because several of the more promising work procedures consisted simply of workers taking advantage of commonly available engineering controls. For example, there is little point in training a worker to turn on the exhaust ventilation before doing certain kinds of work if that ventilation is not functioning.

Sites 15, 6 and 2 cooperated with the research. They constituted a fairly broad sample of the industry with no overlap in the kinds of products produced. The product mix at site 15 was heavily concentrated on custom fabricated objects for outside concerns, while sites 6 and 2

fabricated only proprietary products. Sites 6 and 2 had been in operation for many years with little change in manufacturing processes. Site 15 was a plant just recently acquired as part of a company expansion.

Site 6 was located in a small industrial park six miles outside a midwestern town that was supported by agriculture and light industry. Sites 15 and 2 were located in a large midwest metropolitan area. Sites 6 and 2 had very stable work forces while site 15 had just finished hiring many new workers as a result of their expansion.

The ages of the workers ranged from 19 years to 61 years and their experience in the industry ranged from 1 month to 14 years. The work forces at all three sites were racially mixed with blacks and whites employed at site 6, and blacks, whites and Chicanos at sites 15 and 2.

Workforce Orientation- As work was begun at a plant, the project staff held a meeting with the supervisor and all the workers in the plant (for sites 15 and 6) and with the department manager and all the workers in the reinforced plastics department at site 2. Several topics were always presented by the project staff at these meetings. These topics included:

1. The general purposes and nature of the research.

2. A description of styrene and how it could be identified by use of the unaided senses.

3. What was known about the harmful effects of styrene.

4. Why styrene exposures had been selected as a focus of the research.

5. The relationships that would exist among the workers, the supervisor or manager, and the project staff during the research.

6. The fact that not everyone would be asked to participate as subjects and how workers would be selected for participation.

7. The fact that participation would be strictly voluntary.

These meetings were kept very informal and the workers were invited to ask questions and were given other opportunities to talk. Workers' comments during these meetings were generally friendly and interested.

Selecting Work Practices- The list of selected practices was expanded beyond those employed in the initial research. Particularly, a number of housekeeping practices were added. Many of the housekeeping practices were not particularly promising as methods for reducing exposures to styrene. However, some of them probably made it easier for the workers to carry out the more promising procedures. For example, keeping chopped fiberglass from accumulating on spray booth lighting

fixtures probably would not directly produce practical reductions in styrene exposures. However, the improved lighting resulting from such a practice enabled rollout workers to see bubbles and imperfections in a part lamination from a greater distance and made it easier for them to keep their faces more than 18 inches from curing resin, a practice suspected to be very important. Moreover, the addition of the housekeeping practices allowed for the construction of a training program that relatively completely showed good practices for spray, layup and rollout work.

The Work Practices and Procedures- Eleven production work procedures and 20 housekeeping practices were selected for worker training. The production work procedures and the reasons they might be important were:

1. Exhaust ventilation should be turned on any time a worker is present in the work area. [Work areas were defined for each of the plants in relation to the ventilated booths in and near which nearly all spray, layup and rollout work was done. This practice provided for dilution of styrene concentrations, removal of evaporated and vaporized styrene from the work area, and reduction of styrene introduced into the ambient plant air.]

2. Workers should position themselves with respect to parts and materials so that their breathing zones remained 18 inches or more from sources of vaporizing or evaporating styrene. These sources particularly included the nozzles of spray guns, containers of raw styrene and parts on which there were curing resins. [Concentrations of airborn styrene generally decrease with distance from the source. Therefore, the greater the distance from the source to a worker's breathing zone the less styrene that person might inhale.]

3. Workers should not get styrene or styrene containing resins on any body surfaces. [Styrene is readily absorbed through the skin. Rollout and layup workers, particularly, often worked with styrene containing resins with their bare hands. Reducing skin contact might reduce the amount of styrene absorbed into the body and also reduce a close source of evaporating styrene which could then be inhaled.]

4. Workers should always work on the upwind side of any source of airborn styrene. [Presumably, airborn exposures would generally be less when workers kept their breathing zones in the relatively clean air being drawn through the work area by the exhaust ventilation rather than in the styrene- contaminated air that would exist in between the source of styrene and the ventilation exhaust.]

5. Spray, layup and rollout work should be done in the defined work area. [Predictable air flows and exhausting of airborn styrene existed only in these areas. Therefore, only that work done in these areas would allow some of the other work procedures to be effective and avoid contributing to styrene concentrations in the plant ambient air.]

6. Any worker who is not operating a spray gun should remain at least 6 feet from the nozzle of the gun and no worker should enter a cone-shaped area 45 degrees to any side of the direction in which a gun nozzle was pointing. [The spraying operations were assumed to be the greatest sources of airborn styrene and this procedure might help to reduce exposures of rollout and layup personnel by keeping them away from vaporized and evaporated styrene and, in combination with procedure #4 might reduce exposures of spray gun operators.]

7. A spray gun operator should not spray within six feet of another person and should not direct the spray within 45 degrees of another person. [The rationale for this procedure is the same as for #6.]

8. A spray gun operator should not direct the spray from the gun more than 90 degrees from the booth exhaust port. [This would also help to keep airborn styrene from being drawn into the gun operator's breathing zone and reduce the chances that the spray from the gun would reach another person working in the same booth.]

9. A spray gun operator should always position work and aim the gun so that at least 50 percent of the spray from the gun would fall on the mold or part on which work was being done. [There was a common, artistic but non-functional practice in the industry that consisted of directing a gun, when spraying the edge of a mold, so that the sweep of the spray completely passed the edge. This may have resulted in unnecessary styrene being introduced into the air. In addition, the practice contributed greatly to the amount of overspray that collected on walls, filters and floors, and this overspray might contribute to airborn styrene. Certainly accumulations of unnecessary overspray contributed to difficulties in mold and worker movement within the work areas.]

10. Work should be located in designated areas which were selected on the basis of their having predictable, maximal airflow to exhaust ports and minimizing the extent to which one worker would contribute to the exposure of another worker. [It was observed that a sprayer would frequently spray a mold which was located close to but outside a ventilated spray booth while the exhaust would be much stronger inside the booth and near to the exhaust ports. Spray, layup and rollout workers would also often position their work unnecessarily close to each other in a spray booth and probably, thereby, contribute to each others' exposures. The recommended practice was designed to correct these habits.]

11. Workers should wear clean, properly fitting respirators with functioning organic vapor cartridges when engaged in spraying, in layup, or rollout work in a concave shaped mold. [This practice was included to cover situations in which common engineering controls and the recommended work practices might not be adequate to reduce exposures to styrene. However, this

practice would be only weakly offered to workers in the training and motivation programs with the workers having a clear option to adopt or reject it as they saw fit.]

The 20 housekeeping practices and the rationales for including them were:

1. All booth filters should be in place. [If filters were omitted or improperly seated in their frames, the exhaust ventilation system could soon become sufficiently blocked by gelcoat, resin and chopped fiberglass that its efficiency would be reduced.]

2. Overspray on booth filters should be kept to depths of less than 1/2" in chop spray booths and 1/4" in gelcoat booths. [Excessive overspray buildup on the filters would reduce the efficiency of the exhaust ventilation system.]

3. Floors in work areas should be covered by a disposable material. [This practice provided for the frequent changing of the floor coverings thereby reducing overspray buildup as a source of evaporating styrene and making it easier to move parts to locations which provided good directional airflows to exhaust ports.]

4. Any torn or soaked through floor coverings in the work areas should be replaced. [Part of the rationale for this practice is the same as for #3. In addition, both tears in coverings and spills which remained on coverings long enough to soak through them constituted safety hazards, and spills which soaked through the coverings were likely to glue the coverings to the floor making them difficult to remove.

5. All resin saturated debris should be removed from work areas. [The rationales for this practice are the same as those for numbers 3 and 4].

6. Overspray buildup on spray booth floors should be kept to less than a 1-inch depth. [The rationale for this practice is the same as for number 3.]

7. Overspray buildup on rollout area floors should be kept to a depth of less than 1/2". [The rationale for this practice is the same as for number 3.]

8. Resin and gelcoat spills larger than 6" in diameter should be removed from work area floors and work table tops. [This practice might reduce the amount of styrene evaporating from spills and reduce safety hazards from slips.]

9. Overspray buildup on booth walls should be kept to a depth of less than 1/2". [This work practice might reduce the amount of styrene becoming airborn by evaporation.]

10. Spray booth lights should be operational and visible. [This practice might reduce exposures by decreasing the necessity for workers to get their breathing zones close to curing resins in order to see their work.]

11. Wastecans for disposal of excess resin, gelcoat and trim scraps and for catching spray gun tests should be available in spray booths and located within 6 feet of exhaust ventilation ports. [The presence of these wastecans might reduce the amount of scrap on the floor thus making it easier for workers to engage in the practices which involve their moving themselves or parts about the spray booths. Keeping the cans near to exhaust ports might reduce the styrene present in a work area of a booth by quickly exhausting styrene evaporated from scrap.]

12. Torn or soaked through work table coverings should be removed and replaced by new ones. [This practice might reduce styrene available for inhalation or skin absorption by reducing the amount of curing resin present on work table tops.]

13. Work areas should be free of empty chemical containers. [Sometimes empty containers were left open thus adding to air styrene content. The presence of the containers created trip hazards thus increasing the chances that a worker might fall onto styrene-containing, curing resin.]

14. Curing parts should be removed from work areas as soon as work on them is completed. [Curing resin and gelcoat evaporated considerable quantities of styrene. If this source of styrene were left close to where people worked, it might add to their breathing zone concentration.]

15. Wheels on mold carriages should turn freely whenever the carriage is moved. [This practice should facilitate turning molds to allow people to work on the upwind side of sources of resin and removing curing resin from work areas once work was completed.]

16. Resin and gelcoat containers should be kept covered. [This might reduce the amount of styrene evaporating from the surface of the gelcoat and escaping in the work area air.]

17. Spray equipment gauges should be visible. [This practice might allow spray personnel to more accurately control resin-gelcoat/catalyst mixtures and, thereby, reduce repeated work which introduced extra styrene into the work area air.]

18. Acetone containers should be closed when not in use. [Acetone is used as a solvent to clean resin and gelcoat from tools. The acetone typically quickly becomes contaminated with styrene containing resin and gelcoat thus constituting a possible source for the evaporation of styrene.]

19. Spray guns and hoses should be free of leaks. [Styrene-containing resin or gelcoat leaking from a fitting or hole in a hose might increase the evaporation of styrene in the working area and drops of resin or gelcoat might fall on workers, thus increasing skin absorption of styrene.]

20. Food and drink should be kept out of the work area. [Styrene or styrene containing resin might contaminate food or drink and be ingested.]

Videotapes - Nine black and white videotapes were made to serve as a basic component of a worker training program. Original footage for the videotapes was shot in one of the cooperating plants. Footage was edited and narration added to focus each tape on a few of the work procedures and housekeeping practices. The resulting tapes ranged in length from five to fifteen minutes. Topics for the nine tapes were:

1. Introduction to Styrene
2. Good Housekeeping Practices
3. Preventing Skin Contact
4. Ventilation and Airflow
5. Taking Advantage of Airflow
6. Spraying Procedures
7. Special Examples of Spraying Procedures
8. Respirator Use and Care
9. Personal Hygiene Practices

Copies of these video tapes are filed with the project officer, Dr. Michael Smith, Taft Laboratories, 4676 Columbia Parkway, Cincinnati, Ohio, 45226, and with the Project Director, Dr. Bill Hopkins, Department of Human Development, University of Kansas, Lawrence, Kansas, 66045.

Observational Definitions - The eleven work procedures and twenty housekeeping practices were converted into observational definitions and the definitions were revised until project staff could use them, while observing conditions and workers in a plant, and obtain a high degree of inter-observer agreement on the occurrence and non-occurrence of the specified events. The resulting definitions for work procedures are presented in Appendix D.

MAJOR RESEARCH METHODS

Subjects -Some data were collected on 41 subjects at Site 15 (Plant A), 9

subjects at Site 6 (Plant B), and 10 subjects at Site 2(Plant D). However, there was a very high rate of voluntary turnover and layoffs at Plant A and a layoff because of a downturn in housing construction at Plant B. Because of these uncontrollable events, both pre-training and post-training data were collected on only 9 experimental subjects at Plant A, 3 at Plant B and 7 at Plant D. One work crew of five people was originally assigned to the night shift at Plant A. Data were collected on these subjects with the intent that they would serve as untrained controls for the experimental, day shift workers. The control crew was reassigned to day shift work after only 2 weeks of data collection.

They were assigned to work in a part of the plant in which they had little contact with experimental subjects. However, turnover again reduced the number of usable subjects to only two for whom there were at least some pre and post-training data.

The workers ranged in age from 19 to 52 years and in duration of employment at a plant from one day to 15 years. All subjects participated voluntarily after being informed about the nature of the research and signing consent forms.

Data Collection Procedures

Behavioral Data - Paid observers were trained to use the observational definitions. This training consisted of familiarizing observers with the definitions and codes, using videotaped sequences of workers carrying out their jobs to familiarize them with the behaviors as they occurred in plants, practicing observers in the use of the definitions and an observational code, practicing them in collecting data from videotapes, and practicing on-the-job until all observers obtained 90 percent agreement (defined as total agreement on occurrences and non-occurrences of specific behaviors) with other observers and with project management staff.

During each day of data collection, all observers participated in qualifying practice observations at the beginning of the work shifts. These consisted of brief reviews of all of the observational definitions followed by five minutes of practice data collection. All observers' data records were then compared. If there were any instances of less than 90 percent agreement among the records of any observers, the definitions of the involved behaviors were reviewed and the observers practiced collecting data for another five minutes. This procedure was repeated until there was at least 90 percent agreement among all observers for all behaviors being recorded.

Throughout the data collection periods in each plant, reliability checks were conducted on a randomly selected 17 percent of all observations. During a reliability check, two observers simultaneously but independently collected behavioral data on the same worker. The two data records would be compared and percentages of agreement on occurrences, non-occurrences and total intervals would be calculated. Anytime the total agreement fell below 90 percent or occurrence and non-

occurrence agreements fell below what might be obtained by chance, the observational definitions were reviewed and observers would practice data collection until total percentage agreement with each other and with management staff was in excess of 90 percent.

During each day data were collected in a particular plant, all subjects present at the plant would be scheduled for four 15-minute observations. The times of day the observations were scheduled and assignment of observers to subjects, and the observations selected for reliability checks were randomly determined. Observations were made only when subjects were engaged in assigned work. If an observation was scheduled for a time when a subject was not engaged in assigned work, the time for that observation was randomly redetermined.

During an observation period, the assigned observer was stationed within 20 feet of the worker, in an out-of-way location such that the observer had an unobstructed view of the subject. The observer was equipped with stopwatch, clipboard, pencil, and data sheet. A specimen of the data sheets is presented as Appendix E. The observer recorded data for 60 successive 15 second-long intervals. During each interval, the first occurrence of each of the defined behaviors occurring at any time during the interval was indicated by a mark through the behavior code letter on the data sheet.

Housekeeping Data - Observers were trained and observational reliability determined exactly as described above for behavioral data collection.

Five times per day, at the beginning of a work shift, during the morning and afternoon coffee breaks, at the lunch break, and at the end of the shift, observers inspected all of the gelcoat and chop spray booths and all of the curing areas in a plant and recorded on a data sheet (see Appendix F) the presence or absence of each of the defined housekeeping conditions appropriate for that area.

Material Usage Data - To provide an index of production and exposure potential in each of the plants, the amount of gelcoat and resin used each day was measured. This was done by measuring with calibrated sticks, the gallons present in the fifty five-gallon gelcoat and resin containers before and after the shift. These figures were independently determined by two different observers and records were compared. If differences greater than one gallon existed, both observers again measured the liquid present in the given containers until the difference was rectified. These measurements were recorded on the data sheet presented in Appendix G.

Air Sample Data - Three different kinds of air sample data were obtained with Bendix BDX Super Sampler Pumps and activated charcoal collector tubes. The pumps were modified for low flow operation. Before a shift began, all pumps to be used during the day at a plant were calibrated with a stopwatch and 100 cubic centimeter burettes to a 50 cc. per minute flow rate. Flow rates were then verified by a second calibration. Battery voltages were checked daily for full charges. After each observation, a pump's strokes per minute were calculated from the impulse counter reading and the pump was replaced if the stroke rate

deviated by more than 5 percent from the rate produced when the pump was calibrated. Appendix H is a specimen of the data sheets on which daily pump calibrations information was recorded.

Temperature, humidity, and air pressure in the plant were recorded five times per day and the averages of the recordings calculated. This information and the sealed and coded charcoal tubes were air expressed once each week to the Utah Biomedical Test Laboratory where the contents of the tubes were analyzed using the NIOSH P & CAM method #127 with ethylbenzine as an internal standard and results adjusted for temperature, humidity and atmospheric pressure.

One unexposed charcoal tube was sent in the batch of exposed tubes each day and the laboratory always correctly identified this tube. In addition, duplicate samples were collected on 21 different occasions and the differences between two samples were always less than 10 percent.

Three different kinds of air samples were collected. Eight-hour area samples were collected in arbitrarily selected locations near the work areas. For these samples, the pumps were turned on at the beginning of a shift, off at the beginning of the lunch break, on at the end of the lunch break, and off at the end of the shift. Eight-hour personal breathing zone samples were collected by having each subject wear a pump from a webbed, waist belt and the collector tube affixed to clothing so that the tube was located below and to the side, five inches from a subject's mouth when the subject was standing. These pumps were turned on and off at the same times as the area pumps.

Intermittent samples were obtained by affixing pumps and collector tubes exactly as were those for eight-hour samples. However, pumps for intermittent samples were turned on at the beginning of each 15-minute-long behavior observation and off at the end of the observation.

Urine Sample Data - Urine samples were collected from each subject at the end of the work shifts. A worker was provided a sterile, capped container and would retreat to a bathroom to reappear after a short time with the requested sample. Containers were sealed, coded, and immediately refrigerated. They were transported in styrofoam cases with frozen cold packs to the biochemistry laboratory of Dr. Robert Sanders at the University of Kansas, Lawrence. There samples were refrigerated at 4 ^{o}C until processed.

Sulfuric acid (ACS) and pyridine (HPLC) were purchased from Mallinckrodt, Inc. Ethyl acetate (spectrograde) and sodium chloride (ACS) were purchased from Fisher Scientific Co. Mandelic acid (99% gold label) (alpha-hydroxyphenylacetic acid or alpha-hydroxybenzenacetic acid) and Hydrocinnamic acid (99%) (3-phenylpropionic acid, also termed PPA) were purchased from Aldrich Chemical Co., Inc. N,O-Bis-(trimethylsilyl) -acetamide (termed BSA or Tri-sil/BSA Formula P) was purchased form Pierce Chemical Co.

All gases were purchased from Burnidge Oxygen Distributing Co. They were nitrogen (99.995% or better purity), hydrogen (99.8±0.1% pure), compressed air (79% nitrogen 21% oxygen).

A Varian Aerograph Series 1400 was used for all gas chromatographic analyses. The specifications of this device were as follows: column- a glass column 6' x 1/4" x 2mm with 3% SE-30 on gas chrome O WHP 80-100 mesh; detector-hydrogen flame ionization detector; detectability- 2.7 x 10^{-2} g/sec; sensitivity- 0.01 coulomb/g (ionization and collection efficiency); linear range- $>10^{7}$; injector block temperature- 180°C; column temperature- 140°C; detector temperature- 300°C; carrier gas- N_2 at 30 ml/min; fuel gases- H_2 at 30 ml/min and compressed air at 300 ml/min: range-amps/1mv=10^{-11}; Recorder -Varian recorder model 9176 set at 1 cm/min; integrator CDS-111 with attenuator set at 128; Chromatograph attenuator- set at 1.0.

The extraction from urine samples was initiated, usually within 8 hours and completed within 12 hours of voiding the urine. A 2.0 ml aliquot of urine was pipeted into a 15 x 15 mm test tube, acidified with 0.05-0.1 ml of 10 M sulfuric acid, and mixed vigorously by vortexing. To this mixture, 1.2 g of sodium chloride and 2.0 ml of ethylacetate were added, and the tube was quickly covered with parafilm. This mixture was placed in the dark, shaken vigorously (ca 120 cycles/min) for 15 minutes, and cetrifuged at 2500xg for five minutes. The ethylacetate layer (top layer) was carefully removed with a Pasteur pipet, and 0.5ml of it was pipeted into a 12 x 75 mm test tube, after which 0.1 ml of 1.80 mg of PPA/ml was added. This mixture was evaporated to dryness in a water bath (90-95°C). The dried extract was covered with parafilm and stored at 4°C before forming a TMS derivative.

To the dried ethylacetate extract, 0.300 ml of Tri-Sil/BSA formula P (2.5 meq/ml) [1.0 ml of N,O-Bis (Timethylsilyl)- Acetamide (BSA) in 10 ml of pyridine] was added. Only three samples were prepared at any one time because of the instability of the derivative in moist air. This mixture was placed in the dark and shaken vigorously at 120 cycles/min for 15 minutes. The extract was now ready for gas chromatographic analysis. Using a Hamilton syringe, ca one µl of derivatized extract was injected into the Varian Aerograph. Appropriate urinary standards were analyzed at the same time under identical conditions.

Fresh urinary standards of mandelic acid were prepared biweekly by taking urine from individuals who were not exposed to styrene and by following the procedure described above. The standards contained 0.00, 100.00, 200.00, 400.00, 600.00, 1000.00 and 2000.00 µg of mandelic acid per ml of urine.

Chromatographic retention times were 1.5-2.0 minutes for PPA and 2.5-3.0 minutes for mandelic acid under standard laboratory conditions. Eluted peaks were recorded on a Varian model 9176 recorder, and areas under the peaks were determined using a Varian CDS-111 integrator. Data from the standards were subjected to linear regression analysis and the unknown mandelic acid concentrations were corrected for specific gravity and calculated from these data.

Linear regression analysis of the urinary mandelic acid standards: r= 0.9999, slope= 13676.5, and y intercept= b= -91108.9.

Initially, it was planned that the linear regression of urinary mandelic acid levels on 8-hour personal styrene samples would be determined and a mandelic acid datum rejected if it fell more than two standard deviations above or below the least squares line. This procedure was followed for 8 days on which urine samples were collected. However, the correlation between mandelic acid levels and personal styrene levels were much lower than expected. In addition, the day-to-day variabiliity in mandelic acid levels for single subjects were proportionately much greater than the variability of air sample styrene exposures. Therefore, the method for rejecting results of urinary mandelic acid concentrations were changed. On the ninth and all succeeding days on which urine samples were collected, the sample of each subject was divided into two equal parts and placed in two coded containers. The above analyses were subsequently conducted on both parts of the sample and the results compared. If the mandelic acid concentrations of the halves of a sample were found to be greater than 20 percent different from each other, the sample was rejected.

Data Collection Schedules - During most of the period data were collected in each plant, all forms of data were taken three days per week, on Tuesdays, Wednesdays, and Thursdays. During this time urine samples were collected only two days per week, on Wednesdays and Thursdays.

Several weeks after training was completed, the schedule of data collection was reduced to one day per week, on Wednesdays, in Plants B and D.

Training

Training consisted of; 1) short meetings during which the subjects viewed the videotapes in which the recommended work procedures and housekeeping practices were presented and in which brief discussions of the procedures and practices were held, 2) on-the-job rehearsal of the procedures and practices, 3) on-the-job behavioral tests of the extents to which the workers engaged in the recommended procedures and practices, 4) quantitative criteria for passing the tests, 5) immediate feedback on the results of the tests, 6) social approval and praise for good performances, and 7) opportunities to rehearse again and retake tests when a subject did not meet the criteria for passing.

Nine meetings for viewing tapes and discussing procedures and practices were scheduled at the convenience of the department manager and the workers in each of the plants. These meetings were usually held at the beginning of a shift or during coffee breaks. Meetings averaged about 20 minutes in length and the longest meeting required 30 minutes. All meetings were held in the lunch areas of the departments.

During a meeting,the trainer showed a videotape to the subjects, stopping the tape to answer any questions. At the conclusion of the tape, the trainer asked the subjects if they had any questions about the procedures and practices shown. Particularly, the trainer encouraged the workers to discuss ways in which the procedures and practices might cause them problems and ways in which they could share responsibilities

for housekeeping requirements. At the end of each session, the trainer gave the workers sheets of paper describing the criteria they would have to meet to pass the on-the-job tests. These criteria were to engage in the specified work procedures 100 percent of the time and to meet each of the specified housekeeping conditions at least 90 percent of the time. If a subject missed a training session because of an absence from work, a makeup meeting was held for this person during the next day of attendance at work.

The nine training sessions were spread over 4 weeks in Plant A, 4 weeks in Plant B, and 5 weeks in Plant D.

On-The-Job Practice - After seeing a videotape, workers were given a period of time to practice the work procedures or to prepare their work areas to meet the housekeeping criteria before being given the on-the-job tests. The length of these practice and preparation periods varied depending on the topic of the test. Workers were allowed a week to prepare their work areas before being given the test on housekeeping conditions. Workers watched the videotape, "Ventilation and Airflow", and then, within three days, saw the videotape, "Taking Advantage of Airflow", and then, within two days, took one test that covered all of the work procedures presented in both of these tapes. Each of the other on-the-job tests was given within two days after the workers saw the videotape introducing the work procedures covered by a test.

No specific methods were used to control the extent to which the workers rehearsed the procedures and practices. However, the trainer visited each worker on-the-job several times each day of practice to provide verbal feedback on the usage of the procedures and practices, and made approving comments whenever a worker was engaged in the recommended procedures or the work area met the criteria for housekeeping conditions specified in the tape.

On-The-Job-Tests - On-the-job tests were given both as the last steps of training, to insure that workers had learned what was intended by the videotapes, and as a maintenance procedure, to insure that they continued to use the procedures and practices once they had learned them.

After the workers watched a videotape and practiced the recommended work procedures or prepared their work area in accordance with the recommended housekeeping practices, the trainer administered the appropriate on-the-job test. The trainer took a stopwatch and behavioral observation sheet for a test over work procedures or a housekeeping checklist for a test over housekeeping practices and went to a subject's work area. The trainer would explain the purpose of the visit and answer any questions asked by workers. If the test were over work procedures, the trainer would ask the subject to return to work and would assume a position as for data collection and record the subject's behaviors for five minutes. If the test were over housekeeping practices, the trainer would ask the subject(s) assigned to a particular area to participate in an inspection of that area.

As soon as the observation or inspection was completed, the trainer calculated the percent of time the subject engaged in the spcified behavior or the percent of housekeeping requirements met. Quantitative feedback was given to the employee(s). Any instances of faulty procedures or unacceptable conditions were described or shown to the workers and the trainer answered any questions asked by the worker(s).

If the worker's performance or the condition of the area met the criteria, the trainer provided congratulations and told the worker(s) to keep up the good work. If performance or conditions failed to meet the criteria, the trainer carefully explained the reasons to the worker(s) and modeled the work procedures if the worker expressed uncertainty about them or helped the workers fix the conditions in the work area so that they would meet criteria. If a worker failed to pass a test, another test was given within a few hours and this procedure was repeated until all tests were passed.

As soon as a worker passed a test over one of the videotapes, maintenance tests began to be administered each day the project staff were in the plant for data collection. The maintenance tests over work procedures were given for five minutes each day for each worker. The maintenance tests for housekeeping practices were adminstered three times each day at the beginning of the work shift, at the beginning of the lunch break and at the beginning of the afternoon coffee break. The procedures involved in the administration of the maintenance tests were exactly like those used for the tests given at the end of training.

Social Approval and Correction

From the beginning of training until the termination of data collection in a plant, the trainer provided social approval whenever subjects were observed to be following the work procedures or work area conditions were observed to meet criteria for housekeeping practices. The trainer was instructed to make the approving comments informal and to use the vernacular of casual conversation in the plant. Examples of typical comments would be; "That's the way to stay upwind of your work!", "I see you have on your gloves. That'll help keep the resin off your hands!", and "You guys are doing a good job keeping the overspray off the walls. This place really looks neat!"

Whenever workers failed to engage in the recommended work procedures, the trainer corrected them. Corrective comments were again informal and not negative and they always included a statement of explanation. Typical comments would be; "George, move the mold over here and the exhaust will draw the fumes away from you better.", "You need to spray in this direction only so the fumes won't blow back up in your face.", and "The overspray is getting too deep on the floor. That will make it harder to turn the molds." The trainer was instructed to follow up on each corrective comment by visiting a worker again within a few minutes and provide approving comments if the suggested corrective action was being taken.

The trainer was instructed to adjust the frequency of approving and corrective interactions with workers throughout the course of post-

training data collection. The frequency should be low at the beginning of training because there was not a large number of procedures and practices for which the workers were responsible. The frequency should then gradually increase during training and remain high until the work procedures and housekeeping practices were occurring as desired. The frequency of approval and correction should then gradually decrease but should remain high enough to maintain acceptable use of the procedures and practices.

Incentives

Several monetary incentives were provided to each subject for cooperating with the research and for meeting certain criteria. These incentives were announced to the workers in advance and were paid to the workers as cash as soon as the specified event occurred. The events and incentives were:

Event	Incentive
Joining the subject pool	$10.00
Passing the initial housekeeping test	25.00
Passing the initial test over airflow videotapes	25.00
Passing the initial test over all other videotapes	5.00 each test
Passing all maintenance work procedures tests	5.00 per week
Passing all housekeeping practices tests	5.00 per week

Research Design

The research design employed was a multiple baseline design over plants with the introduction of training staggered over plants.

Data were collected in one or another of the plants for 71 weeks. Data collection began in Plants A and B on the first week and in Plant B on the 38th week. Initial data collection in each plant provided a baseline for work procedures, housekeeping practices and styrene exposure levels against which changes could be compared. Training began in Plant A in week 13, Plant B in week 23, and Plant D in week 37. This arrangement allowed for Plant B to serve as a control for Plant A during the time training had begun in A but not in B. Similarly, Plant D provided a control for Plant B during the period of time training was occurring in B but not yet in D.

MAJOR RESEARCH RESULTS

The results of the research are presented in two parts. This report contains only summary data and statistical analyses of these data. A companion report, "Behavior Procedures for Reducing Worker Exposure to Carcinogens, Final Report: Detailed Data", includes data for individual workers and plant areas and mean data averaged over subjects but not over behaviors or housekeeping practices.

The present report contains results of four major kinds of data, behavioral or work procedures data, data on housekeeping practices, data on air samples for styrene, and data on urinary mandelic acid levels.

Behavioral Data

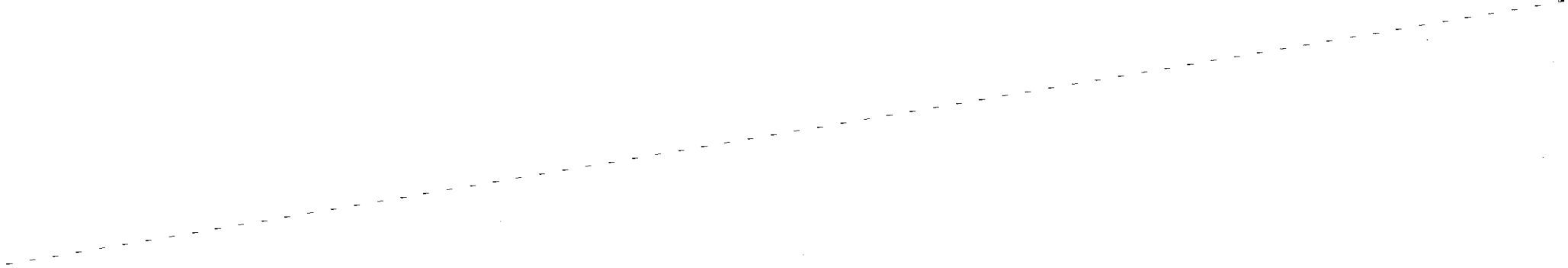
Figure 1 is a set of plots of the mean percent of intervals in which selected, recommended work procedures were observed to occur during each day of data collection in each of the three plants. These data are averaged over all workers in the indicated plants and over all work procedures except those that were already occurring at acceptable levels in a given plant. Specifically, the work procedures included in the averages were: workers having breathing zones close to styrene sources, body contact with styrene, working downwind of sources of airborn resin or gelcoat, and working on misplaced molds, in Plant A; not engaging exhaust ventilation, workers having their breathing zones close to styrene sources, body contact with styrene, working downwind of sources of airborn resin or gelcoat, working on misplaced molds, directing spray from guns against the airflow, spraying towards other workers and workers exposing themselves to spray, in plant B; and workers having their breathing zones close to styrene sources, body contact with styrene, working downwind of sources of airborn resin or gelcoat, working on misplaced molds, directing spray from guns against the airflow and spraying towards others, in Plant D.

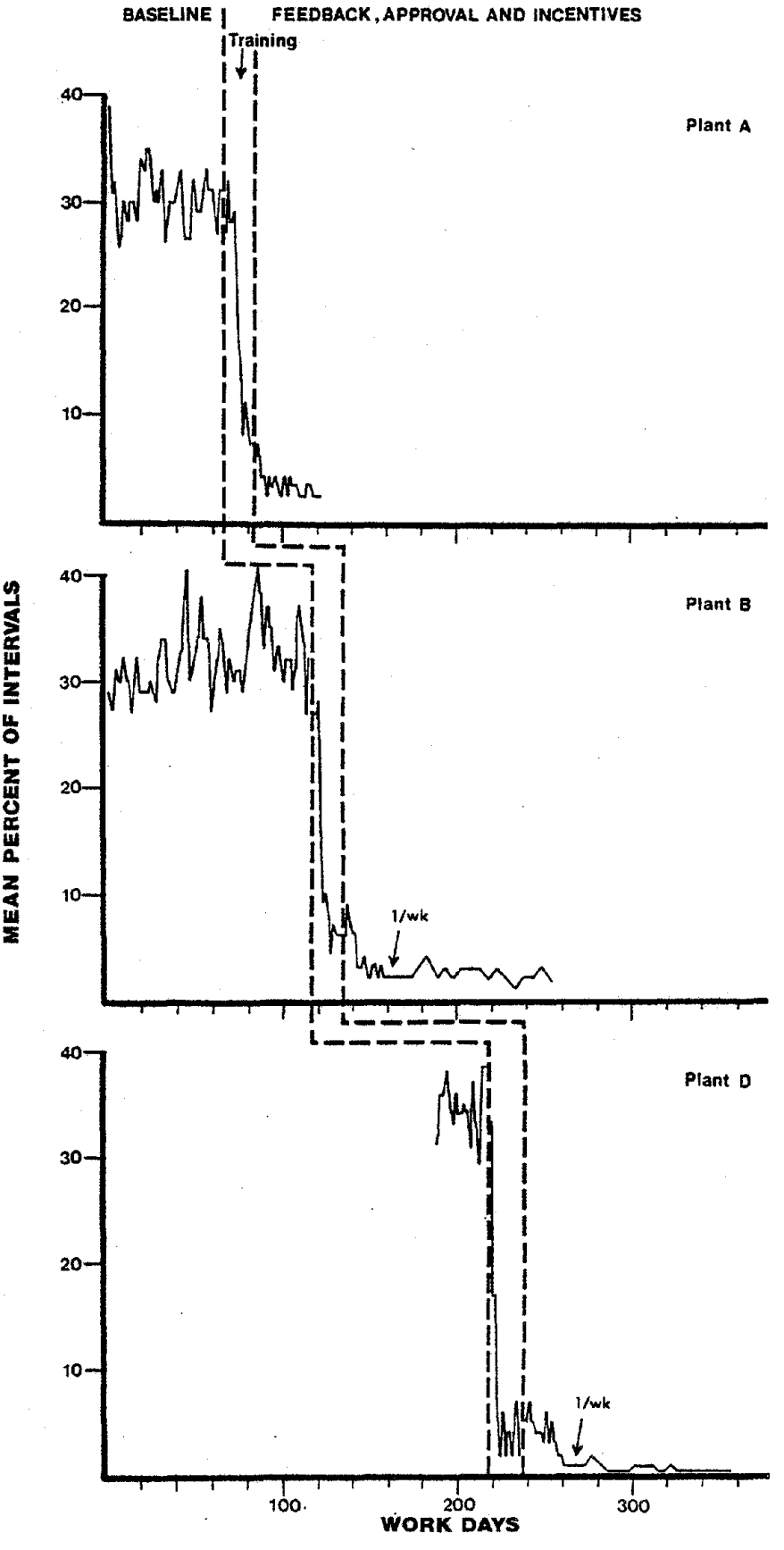
The mean percent of observation intervals in which the behaviors which could change occurred during baseline data collection was between 30 and 40 percent in all three plants. No appreciable improvements in these data were occurring during baseline in any of the plants; the baseline slopes were .0009 in Plant A, -.0003 in Plant B, and .0005 in Plant D. None of these slopes were significantly different than zero.

During training, the mean percent of intervals in which the behaviors occurred decreased rapidly to less than 8 percent in each of the three plants. The slopes during training were -.017 in Plant A, -.03 in Plant B, and -.024 in Plant D. The differences in the slopes between baseline and training periods were statistically reliable. In each of the plants these differences in slopes would have occurred less than 1 time in a thousand by chance.

The percent of intervals in which the behaviors occurred continued to decline after the completion of training. The slopes when feedback, approval and incentives continued to be provided following training were -.002 in Plant A, -.001 in Plant B, and -.001 in Plant D.

Figure 1. The mean percent of observation intervals in which the workers in each of the three plants failed to engage in the selected work procedures on each day data were collected in the plants. These data are averaged over all subjects present and over all work procedures which were not already occurring within acceptable limits during baseline data collection. The period during which training occurred in each plant is bounded by the dashed lines. The points at which once per week data collection began in Plants B and D are denoted by 1/wk.




BASELINE
FEEDBACK, APPROVAL AND INCENTIVES
Training
Plant A
Plant B
Plant D
1/wk
1/wk
MEAN PERCENT OF INTERVALS
40
30
20
10
100
200
300
WORK DAYS

25.a

These data approached asymptotes at less than 3 percent of intervals in Plants A and B and less than 1 percent in Plant D. The mean percent of intervals in which the behaviors occurred following training were statistically different than they had been during the baseline periods. These differences were highly reliable, with expectations of occurrence less than 1 time in a thousand, by chance, in each of the three plants.

The slope in Plant A during training was statistically, reliably different than the slope, during the same work days, in Plant B which was serving as a control during this time. This difference would have occurred less than one time in a hundred by chance. Similarly, the difference in the mean percent of intervals in which the behaviors occurred, in Plants A and B, in which the behaviors occurred during the time from the end of training in Plant A to the beginning of training in Plant B, was reliably different.

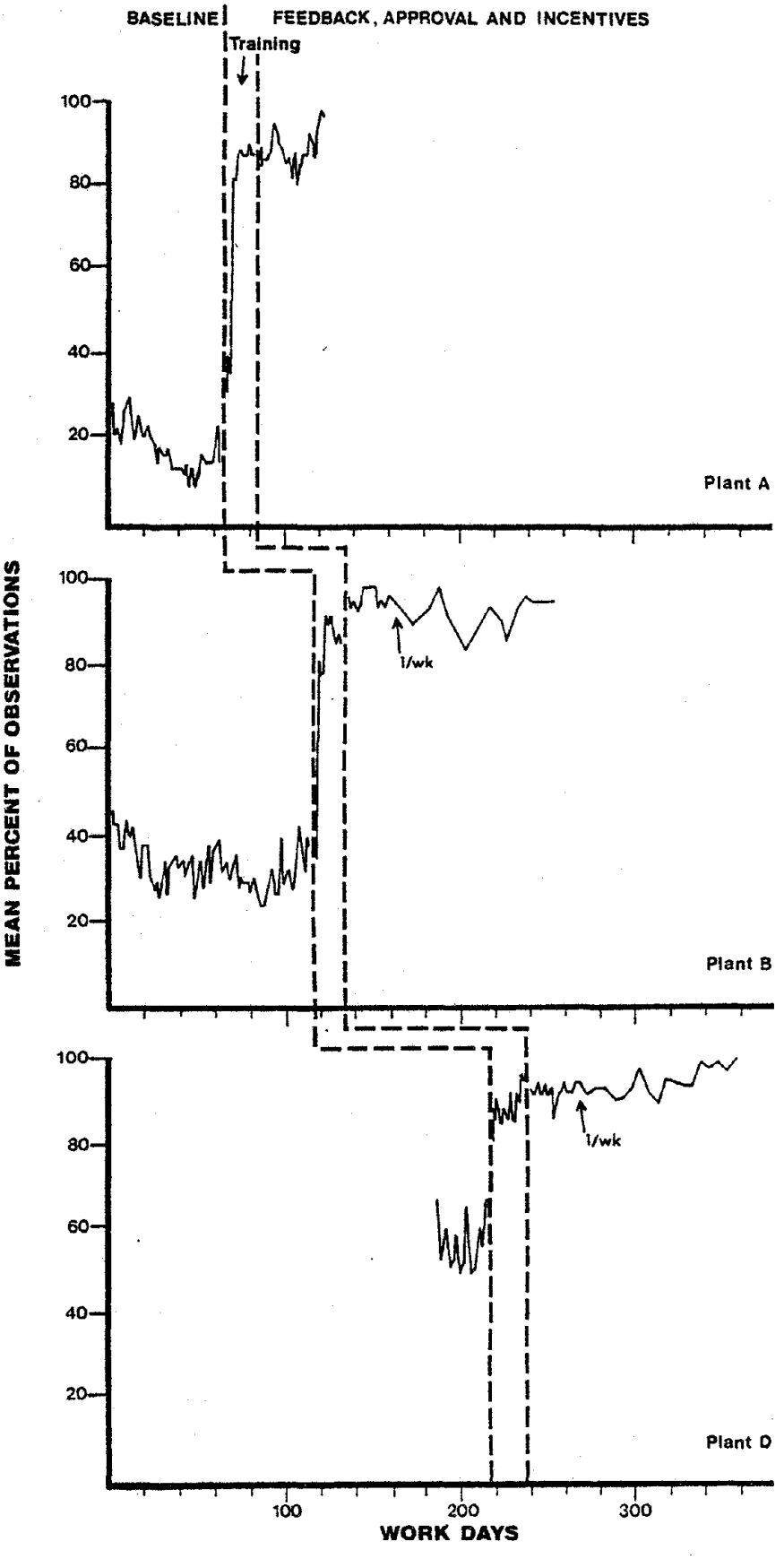
Housekeeping Data

Mean housekeeping data (Figure 2) were treated in much the same way as behavioral data. First, those housekeeping practices which were already occurring or trending to occur as desired were eliminated from consideration. Practices not considered were: the visibility and operability of spray booth lights, the removal of curing parts from the work area after work on them was completed, the extent to which wheels of mold carriages turned freely, the absence of leaks in hoses and guns, and the extent to which work areas were free of food and drink, in Plant A; having spray booth filters in place, the absence of overspray buildup from spray booth filters, the visibility and operability of spray booth lights, the absence of torn or soaked through places in table coverings, the removal of curing parts from the work areas after work on them was completed, the extent to which the wheels of mold carriages turned freely, and the absence of leaks in hoses and guns, in Plant B; and the visibility and operability of spray booth lights, the presence of resin waste cans within six feet of booth ventilation exhaust ports, the absence of torn or soaked through places in table coverings, the extent to which the wheels of mold carriages turned freely, and the absence of leaks in hoses and guns, in Plant D. Data on all remaining practices were averaged over all housekeeping conditions and all work areas inspected in each plant.

During baseline, housekeeping conditions were best in Plant D with conditions conforming to specifications with a mean of 55 percent of the observations, worst in Plant A with conditions as desired in only 17 percent of the observations, and intermediate in Plant B with conditions as desired in 33 percent of observations. No systematic improvements in housekeeping conditions were occurring in any of the plants during baseline; the baseline slope was -.004 in Plant A, -.0009 in Plant B and -.004 in Plant D. The slope in Plant A was reliably different than zero ($p<.01$), but the slopes in the other two plants were not statistically different than zero.

During training the mean percent of observations in which housekeeping conditions were as recommended increased sharply in all three plants. The slopes were .07 in Plant A, .03 in Plant B, and .01 in Plant D during train-

Figure 2. The mean percent of observations in which housekeeping conditions in each of the three plants met specified criteria on each day data were collected in the plants. These data are averaged over all observed work areas in each plant and over all housekeeping conditions that were not already occurring at criteria or trending to the criteria during baseline data collection. The period during which training occurred in each plant is bounded by the dashed lines. The points at which once per week data collection began in Plants B and D are denoted by 1/wk.


BASELINE
FEEDBACK, APPROVAL AND INCENTIVES
Training
100
80
60
40
20
Plant A
1/wk
Plant B
1/wk
Plant D
MEAN PERCENT OF OBSERVATIONS
100
200
300
WORK DAYS

21.a

ing. In all cases the training slopes were statistically reliably different than during baseline beyond the .01 confidence level.

After the completion of training, the mean percent of observations in which the conditions were as desired approached asymptotes in excess of 90 percent in Plants A and B, and in excess of 95 percent in Plant D. The post-training means differed significantly from the baseline means in each of the three plants with alpha-levels in excess of .001.

The slope in Plant A was significantly different ($p<.01$) than the slope in Plant B during the time Plant A workers were being trained but Plant B workers were still serving as controls. The mean level of use of the recommended housekeeping practices in Plant A, from the end of training in Plant A to the beginning of training in Plant B, was reliably greater ($p<.01$) than the mean levels during the same days in Plant B when Plant A data were adjusted for the initial differences in baseline levels.

Air Sample Data

Two kinds of personal air samples were collected for each of the subject-workers in each of the three plants. Intermittent, personal, breathing zone samples were collected with pumps that were operated only during those times that observations were made of the subjects' use of the work procedures. In addition, eight-hour, personal, breathing zone samples were collected with pumps that were operated during the entire work shifts.

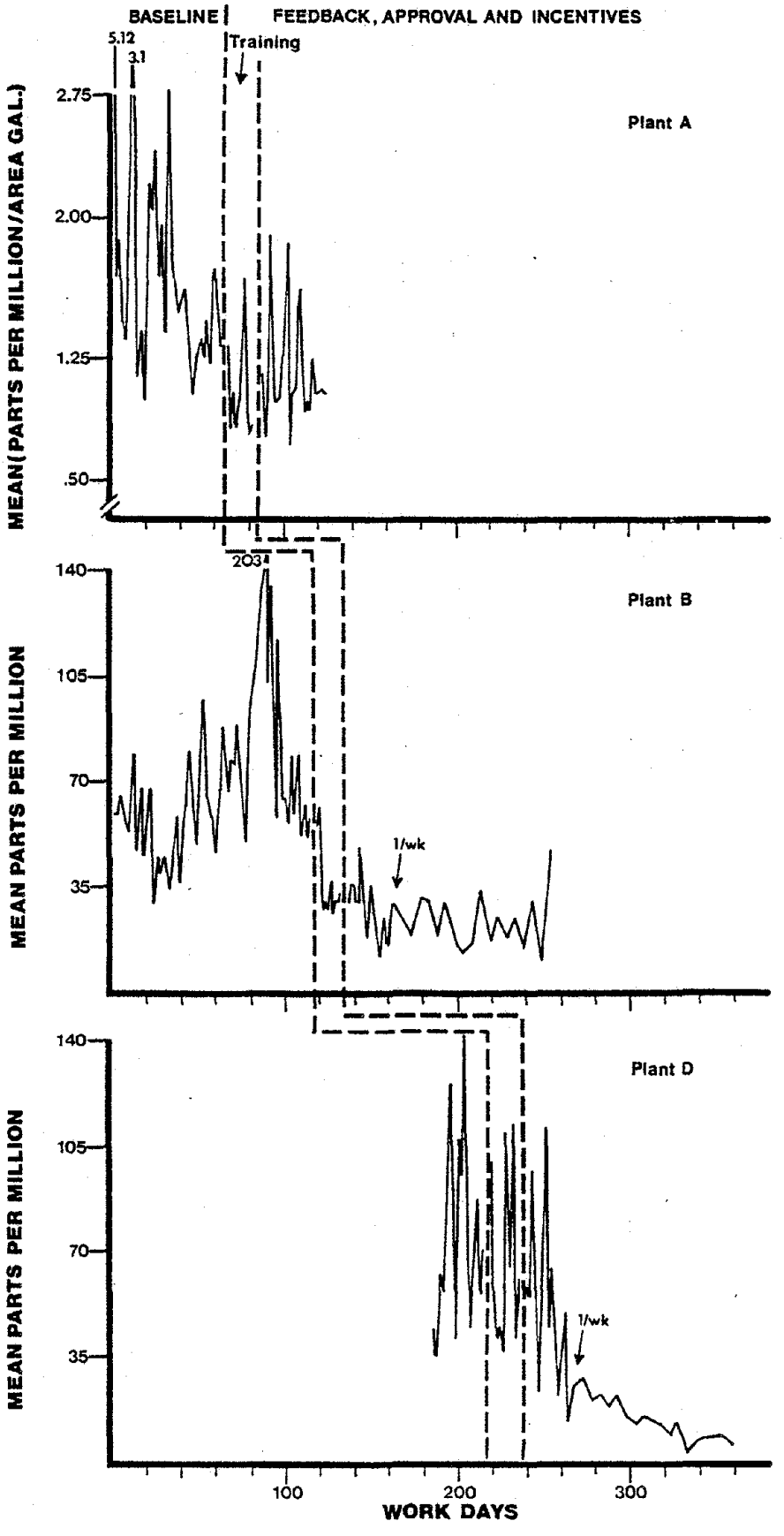
The data from the intermittent samples are displayed in Figure 3. Note that the data from Plant A are transformed by dividing the parts of styrene per million parts of air by the number of gallons of resin or gelcoat used in each subject's work area. This transformation was carried out to correct the exposure data for anticipated changes in the volume of production because Plant A had opened just before the beginning of data collection and production was regularly increasing and probably contributing increasing amounts of styrene to exposures.

There were changes in the mean data, averaged over subjects, for the intermittent air samples in Plants B and D, Figure 3, that paralleled the changes that occurred in the workers' use of the recommended work procedures and housekeeping practices. The baseline slopes were .02 in Plant A, .47 in Plant B, and .86 in Plant D. During training the slopes became -.0015, -2.66, and .54, respectively, in Plants A, B and D. These measures remained low or continued to decline, yielding slopes of .003 in Plant A, -.26 in Plant B, and -1.95 in Plant D on samples taken from the completion of training to the end of data collection.

Post-training asymptotes were at approximately 20 parts per million in Plant B and at less than 10 parts per million in Plant D. The reductions in mean intermittent exposures from baseline levels to post-training levels were approximately 33 percent in Plant A, 62 percent in Plant B, and 56 percent in Plant D. The post-training exposures were statistically different than the baseline exposures, $p<.01$ in Plant A and $p<.001$ in Plants B and D.

The Plant A data from the eight-hour, personal, breathing zone samples

Figure 3. The mean parts of styrene per million parts of air for personal breathing zone air samples collected intermittently during behavioral data collection in each of the three plants on each day data were collected in the plants. Each data point is averaged over all subjects present at the plant on the given day. The data for Plant A are transformed by dividing the parts of styrene per million parts of air for each subject by the number of gallons of styrene-containing resins used in the subject's work area on the given day. The period during which training occurred is bounded by the dashed lines. The points at which once per week data collection began in Plants A and D are denoted by 1/wk.


BASELINE
FEEDBACK, APPROVAL AND INCENTIVES
5.12
3.1
Training
2.75
2.00
1.25
.50
MEAN(PARTS PER MILLION/AREA GAL.)
Plant A
203
140
105
70
35
MEAN PARTS PER MILLION
Plant B
1/wk
140
105
70
35
MEAN PARTS PER MILLION
Plant D
1/wk
100
200
300
WORK DAYS

were transformed to adjust for increasing production in the same manner as were the data from the intermittent samples. The eight-hour air sample data are displayed in Figure 4.

The baseline for Plant A again had a negative slope, -.02. The baseline slopes in Plants B and D were .32 and .53, respectively. During training the slope for Plant A was -.02, -1.46 for Plant B and .14 for Plant D. Following training slopes became .004 in Plant A, -.33 in Plant B, and -.68 in Plant D. The slopes from the beginning of training to the end of data collection differed significantly from the baseline slopes, $p<.01$, in both Plants B and D.

The post training asymptotes were 36 percent less than the baseline mean in Plant A, 65 percent less in Plant B, and 80 percent less in Plant D. The probabilities that the differences between baseline and post-training means would have occurred by chance were $p<.05$ for Plant A data and $p<.01$ for Plants B and D.

Urinary Mandelic Acid Data

Figure 5 is plots of the mean urinary mandelic acid data, averaged over subjects, for the three plants. The data from Plant A were transformed, as described above, to adjust for increasing production.

The baseline slopes in all three plants were positive, .17 in Plant A, 12.47 in Plant B, and 15.56 in Plant D, and progressively lower mean mandelic acid levels developed in all three plants so that mean levels following training were 26 percent, 55 percent, and 31 percent, respectively, lower than they were during baseline. These differences were statistically reliable ($p<.05$, in Plant A; $p<.01$, in Plant B, and $p<.05$ in Plant D).

Figure 4. The mean parts of styrene per million parts of air for personal, breathing zone air samples collected continuously during eight-hour shifts in each of the three plants on each day data were collected in the plants. Each data point is averaged over all subjects present at the plant on the given day. The data for Plant A are transformed by dividing the parts of styrene per million parts of air for each subject by the number of gallons of styrene-containing resin used in the subject's work area on the given day. The period during which training occurred is bounded by the dashed lines. The points at which once per week data collection began in Plants B and D are denoted by 1/wk.

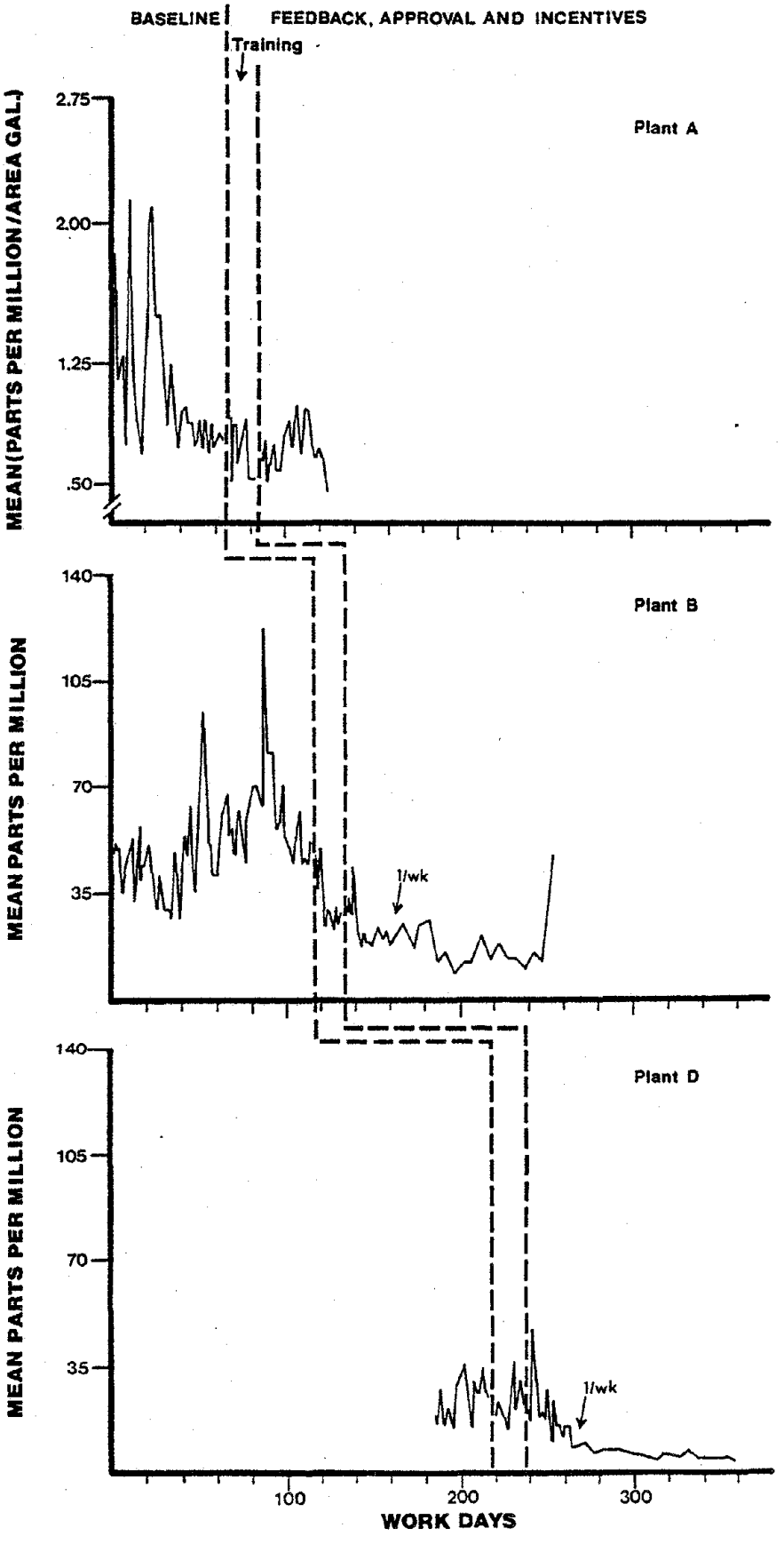
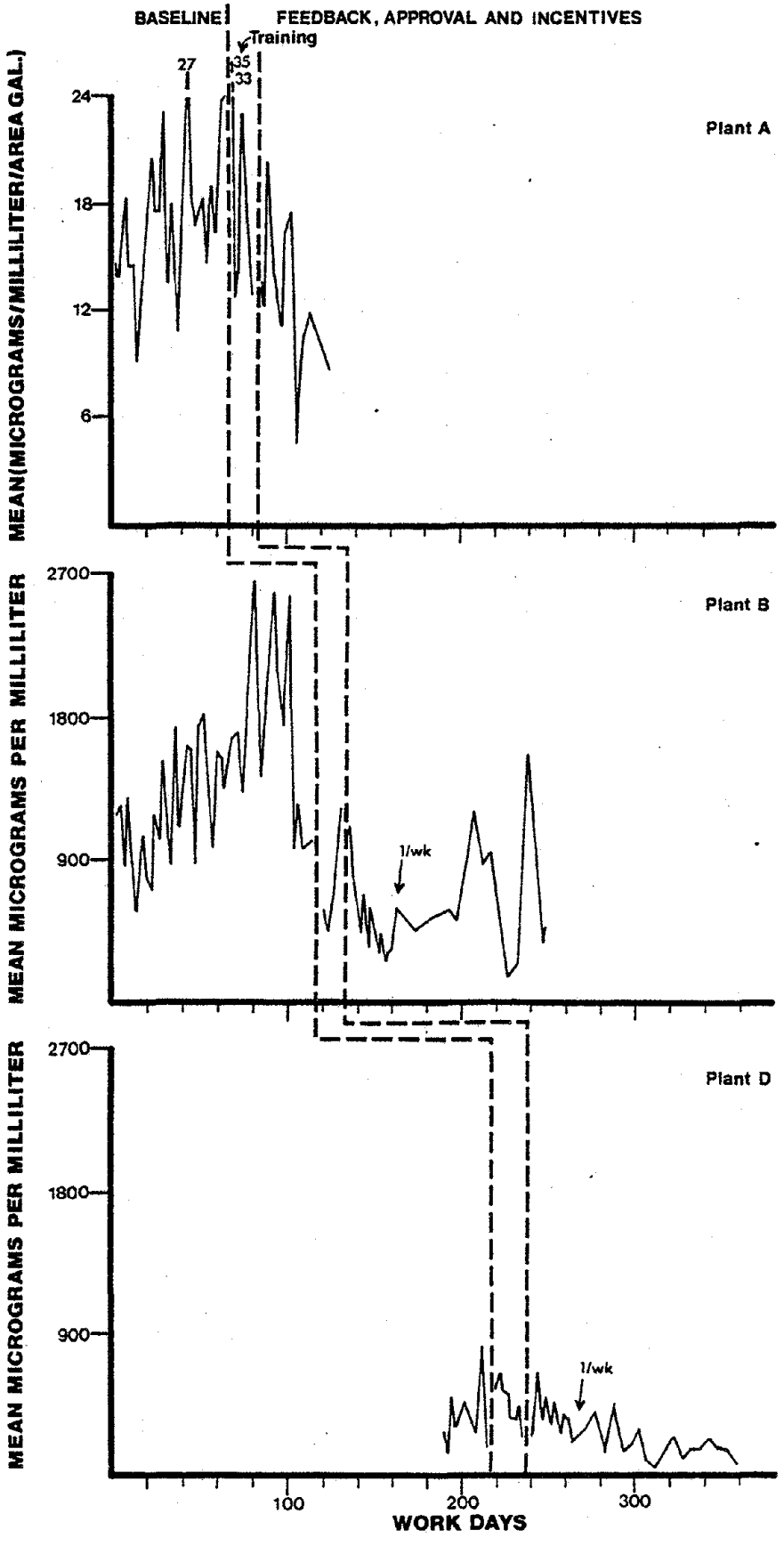

BASELINE
FEEDBACK, APPROVAL AND INCENTIVES
Training
MEAN(PARTS PER MILLION/AREA GAL)
2.75
2.00
1.25
.50
Plant A
MEAN PARTS PER MILLION
140
105
70
35
Plant B
1/wk
MEAN PARTS PER MILLION
140
105
70
35
Plant D
1/wk
100
200
300
WORK DAYS

Figure 5. The mean micrograms of mandelic acid per milliliter of urine for samples collected at the end of work shifts in each of the three plants on each day data were collected in the plants. Each data point is averaged over all subjects present at the plant on the given day. The data for Plant A are transformed by dividing the micrograms of mandelic acid per milliliter of urine for each subject by the number of gallons of styrene-containing resin used in the subject's work area on the given day. The period during which training occurred is bounded by the dashed lines. The points at which once per week data collection began in Plants B and D are denoted by 1/wk.


BASELINE
FEEDBACK, APPROVAL AND INCENTIVES
Training
27
35
33
MEAN(MICROGRAMS/MILLILITER/AREA GAL.)
24
18
12
6
Plant A
MEAN MICROGRAMS PER MILLILITER
2700
1800
900
1/wk
Plant B
MEAN MICROGRAMS PER MILLILITER
2700
1800
900
1/wk
Plant D
100
200
300
WORK DAYS

32.a

DISCUSSION

The training and motivation programs were clearly and strongly effective to change the subjects' work procedures and housekeeping conditions in all three plants. This conclusion holds, not only for the mean data, averaged over subjects, work procedures, plant areas, and housekeeping practices, but for all of the individual workers and plant areas and for all of the recommended practices and procedures (see "Behavioral Procedures for Reducing Worker Exposure to Carcinogens, Final Report: Detailed Data"). Thus it is quite safe to assume that the major objective of the research was met in every respect. Work procedures and housekeeping practices, selected for their relevance to reducing exposures to workplace hazardous substances can be readily and dramatically changed in prescribed directions.

The changes in work procedures and housekeeping practices, when produced by the selected methods, are clearly not transient. They were maintained in both Plant B and Plant D for over 120 work days with no systematic tendencies to revert to baseline levels. Although the research was not intended to address the question of necessary and sufficient causes for the long-term maintenance of changed worker behavior, it is likely that some of the relatively unique motivation methods were resonsible for these prolonged effects. Instead of treating needed changes in behavior as a problem for one-shot training or education, the approach to control provided training but also included on-going feedback, social approval and motivation. This approach is similar to many engineering approaches which do not install intended controls and forget them but build them and adjust and maintain them as necessary to produce the desired result. In this context, it is interesting that improvements in the use of the recommended work procedures and housekeeping practices continued to occur in all three plants long after training had been completed.

It is perhaps also significant that the approach to behavior control did not simply consist of the presentation of information about the suspect carcinogen and about general forms of work procedures and housekeeping practices. Rather, the objectives of the training and motivation methods were specific behaviors and conditions. Much of the training was carried out on the job. Many of the workers and their supervisors had been involved in the development of the recommendations and the workers were involved in developing the practical details of how they would carry out the recommendations. The recommendations were not selected by management and imposed on the workers or vice versa. Rather, they were developed jointly by the workers, management, and the research staff.

It is important that this approach to controlling exposures be viewed as a supplement to other control methods. Specifically, the research staff speculate that the procedures and practices that were particularly useful to reduce exposures were those that consisted of taking advantage of existing engineering controls. It is speculated that engaging exhaust ventilation, placing work to take advantage of exhaust airflow, and posi-

tioning oneself to take advantage of airflow and dilution were particularly important behaviors. All of these are supplemental to the engineering controls typically provided in this industry. However, it should also be noted that, if these behaviors are important as hypothesized, the engineering controls would be relatively less effective unless the proper behaviors also occurred.

Research into the mechanisms of worker behavior to control exposures to hazardous substances is not yet sufficiently advanced to allow for many generalities about which procedures and practices are necessary co-controls for engineering practices. It is perhaps axiomatic that the usefulness and importance of particular behaviors will vary with the physical properties of hazardous substances and their routes of possible entry into the body. It is also likely that behaviors having to do with use and maintenance of engineering controls and proper responses to emergencies and/or equipment failures will be relatively more important in those industries which have more complete engineering controls while behaviors that are directly involved in production and handling of substances will be more important in industries in which engineering controls still allow frequent, direct contact with hazardous substances.

Methods for selecting those human behaviors that must be controlled to achieve good exposure control should still be viewed as tentative. The present research methods, the identification of the areas of a plant and the processes which generated exposures, observations of ways in which people behave with respect to styrene, the hypothesizing of alternate behaviors which might reduce exposures, and the partial use of momentary samples to estimate the value of the alternate behaviors to reduce exposures, seem rational but can probably be improved.

The value of the recommended work procedures and housekeeping practices to reduce exposures was quite good in Plant B and D, and difficult to interpret in Plant A. The reductions in exposures from baseline levels to asymptotic post-training levels, as estimated by air samples, ranged from 56 to 80 percent in Plants B and D. All of these changes occurred following no systematic trends to improvement during the baseline period and the differences between baseline and post-training levels were highly statistically significant. Similarly, there were statistically significant decreases in urinary mandelic acid levels in Plants B and D following training. Again, these improvements occurred when there had been no systematic decreases in these estimates of exposures during baseline periods. The baseline to post-training, asymptotic levels represented a 55 percent improvement in Plant B and a 31 percent improvement in Plant D.

Even though there were reliable differences between the baseline and asymptotic means of air sample estimates of exposures in Plant A, these changes occurred following improving trends during the baseline period. Therefore, it is not safe to assume that the changes in work procedures and housekeeping practices produced these improvements. In contrast, the 26 percent reduction from baseline to post-training mandelic acid levels represents a reversal of an increasing baseline trend.

The potential worker behavior has for reducing exposures will, of course, vary with substances, industries, plants and, even, individual workers. In the present case, the reduction in estimates of exposures were also quite consistent across individual workers in Plants B and D (see "Final Report: Detailed Data").

The apparent lack of effect of the work procedures and housekeeping practices to reduce the air samples of styrene in Plant A could be explained in a number of ways. It is, of course, possible that the recommended procedures and practices were simply not effective to reduce individual exposures in Plant A. However, in light of the systematic changes that occurred in Plants B and D and the fact that production procedures and engineering controls were similar in all three plants, different interpretations are plausible. Because the plant had opened just prior to the beginning of data collection, systematic changes were occurring in the rates of production, the amount of styrene and styrene-containing resins used each day, and, probably, the amount of styrene introduced into the work areas. A change in production-induced exposures was anticipated and it was determined before-the-fact that all Plant A measures of exposures would be transformed by multiplication by the reciprocal of the quantity of styrene-containing resin used each day. This may not have been an effective transformation and could have disguised possible effects. In addition, many uncontrollable changes were occurring in Plant A. There was a very high turnover among the workers so that only seldom did the same trained subjects work together as a crew, say a chop sprayer and two or three rollout persons, for more than a few days at a time. Therefore, untrained workers may have consistently contributed to the exposures of those who were behaving as recommended.

It was determined that urinary mandelic acid concentrations, as well as personal air samples, would be used as indices of exposures because there is a literature suggesting that this may be a useful practice (Bardodej and Bardodejova, 1966; Harkonen, Kalliokoski, Hietala, and Hernberg, 1974). For example, mandelic acid concentrations might reflect the ingestion and skin absorption of styrene as well as styrene which could be inhaled. In addition, the collection of urine samples is a relatively simple procedure. A comparison of these two procedures is beyond the scope of this report. However, it should be noted that there was never a difference in the laboratory determinations of parts of styrene per million parts of air as collected by duplicate pumps and charcoal tubes greater than 10 percent. The use of a statistical rule of discarding data whenever laboratory results of split urine samples yielded differences greater than 20 percent resulted in a rejection of 24 percent of the mandelic acid data. In contrast, if a similar discard rule were applied to the behavioral data only a fraction of one percent of the data would have been rejected because of differences in data obtained by two observers.

The use of both eight-hour personal air samples and intermittent samples collected during observations of behaviors provides a partial answer to one important question. Would workers, perhaps, engage in the recommended work procedures only when they knew they were being observed? In fact the data from the two kinds of samples correlated highly ($r = .87$), and the reductions in exposures, following training, were actually somewhat greater, as estimated by the eight-hour samples, than they were for the

the samples taken during the observations.

It can be argued that the training and motivation methods used in the present research were so elaborate, time consuming and expensive that they would have a low probability of being voluntarily adopted by industry. This argument or counter arguments are not relevant at this time. It is relevant that an effective behavior control technology exists as a complement to engineering control technology. Future research can address issues of practicality.

There has been skepticism that worker behavior can be reliably changed so that people can usefully participate in their protection from exposures to harmful workplace conditions. For example, Dr. Anita Bahn (1976) has stated:

> "... in general, modification of individual behavior so as to reduce personal hazards is the principal impediment ...(in the industrial setting)...today."

The present research should stand as an example that worker behavior can be changed greatly and with good endurance, and that those changes can lead to important reductions in exposures.