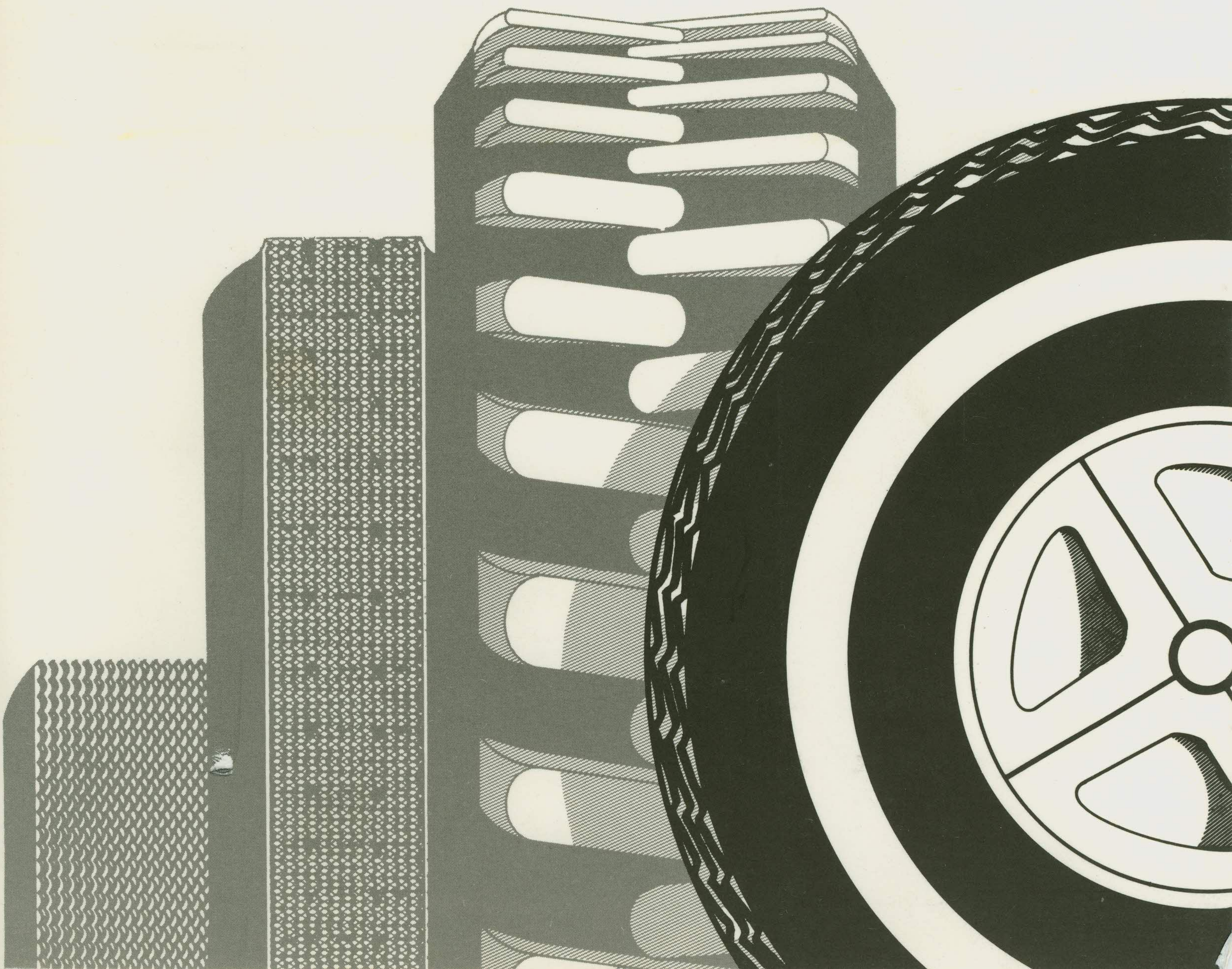
NIOSH

RESEARCH REPORT

Control of Air Contaminants in Tire Manufacturing

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



CONTROL OF AIR CONTAMINANTS IN TIRE MANUFACTURING

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PREFACE

Based upon a series of seven field studies and the associated in-depth plant reports, this report recommends approaches for the control of air contaminants in tire manufacturing plants. Because manufacturing operations vary, the application of these recommendations requires sound professional judgement. The control of air contaminants in industry is an interdisciplinary task which requires expertise in a number of different professions. Sections II, III, and IV stress this point.

This report is organized into four sections and five appendices. Sections II and III are the heart of the report. Section II concerns observed engineering conrols and observed effectiveness of those controls. Section III discusses specific work practices. Sections I and IV present an introduction and specific research recommendations based on field studies, respectively.

In the course of this study, controls were discussed and then selected for study on the basis of good design. A more detailed study of these controls showed that work practices and maintenance significantly affect a control's performance. The information gained during this study confirms there is more to the control of air contaminants than just "good engineering."

Appendices I and II present information that is not available in the plant reports. Appendix I summarizes the results of preliminary surveys. Appendix II discusses air sampling considerations from the detailed evaluation of controls.

Appendices III and IV summarize the various processes associated with the tire industry and the occupational health literature for this industry. The reader may wish to consult the references in these appendices to develop a more detailed understanding of the tire industry.

Appendix V summarizes hood efficiency studies accomplished during several of the detailed studies using tracer gas techniques.

ABSTRACT

An assessment of control technology for the control of air contaminants in the tire manufacturing industry was made through a program that included literature review, consultation with members of industry, labor, academia, and surveys of approximately 20 plants. In-depth survey reports were prepared on seven plants, and those reports contain detailed descriptions of the engineering controls present at the time of the survey. These reports should be useful to those interested in adopting effective control technology.

This report presents conclusions based upon these studies. The effect of work practices, ventilation, and process configuration upon worker exposure to air contaminants is discussed. Process configuration and work practices were found to have a significant effect upon worker exposure in the processing area of tire plants. Ventilation can be used to reduce worker exposure to air contaminants.

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ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation of the management and workers at the plants participating in all of the field studies. Their willingness to contribute their experience, their time, and their endurance for the benefit of others made this study possible.

We especially thank Mr. Frank Ryan and the members of the Occupational Health Committee of the Rubber Manufacturers Association for their assistance in this study. We appreciate the support of both Mr. Peter Bommarito, past President, and Mr. Milan Stone, President, of the United Rubber, Cork, Linoleum and Plastic Workers of America, AFL-CIO, CLC International Union. We deeply appreciate the help and encouragement of Mr. Louis Beliczky of the United Rubber Workers. Mr. Beliczky provided constructive reviews of the study protocol, the final report, and many other facets of this research.

We wish to acknowledge Mr. Matthew Klein's contribution to the field surveys and the in-depth plant reports which were the basis for the engineering portions of this report. We also wish to acknowledge Dr. Vladimir Hampl for his tracer gas research, abstracted in Appendix I.

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SECTION I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is charged with the responsibility of conducting research for dealing with occupational safety and health problems.[1] To expand the knowledge of available options for the solution of occupational health problems and the constraints that influence the selection of these options, NIOSH has sponsored a series of industrywide control technology evaluations or assessments. The goals of these evaluations are to stimulate private industry to prevent hazardous exposures of workers, and to establish a catalog of solutions by documenting successful application of control measures. These studies seek to identify exemplary control techniques practiced by different companies, encourage the dissemination of this knowledge across industries, and outline control technology research needs. The purpose for this effort is to provide information which will aid employers in fulfilling their responsibility to provide a safe and healthy work environment.

In 1978, NIOSH initiated the Control Technology Assessment of the Tire Manufacturing Industry. During the planning phase of the study, it became apparent that it would be impossible, using the resources available, to study every aspect of the tire manufacturing industry. Therefore, the investigation was restricted to methods for controlling worker exposure to air contaminants.

Information developed during this assessment, and summarized in Appendix III, suggests that there may be a need to define and control the worker's exposure to air contaminants generated in the manufacturing process to a greater extent than specified by existing standards.

This study concentrated on the following tire manufacturing operations:

- Hopper/bin filling
- Manual weigh-out and batching
- Cementing
- Curing
- Final finishing
- Milling
- Mixing

OBJECTIVE

The study objective was to assess control methods which are being used to effectively control worker exposure to air contaminants. These control methods include ventilation, substitution, work practices, and process configuration.

CONDUCT OF STUDY

The study objective was met by evaluating and documenting the controls for reducing worker exposure to air contaminants in the tire manufacturing industry. Preliminary surveys were conducted to identify these better controls. Thirteen plants were visited between March and August of 1979. During these visits, preliminary air sampling was conducted. The results of that sampling are discussed in Appendix I.

Based upon the results of preliminary studies, a number of controls were selected for further study. These controls involved the following operations: hopper/bin filling, weighing and batching (compounding), mixing, milling, calendering, under and end tread cementing, cement house, curing, and tire repair. Since individual operations and approaches to air contaminant control varied greatly from plant to plant, controls at seven select plants were judged to be worthy of detailed study. The field evaluation of these controls involved industrial hygiene air sampling, ventilation system measurements, and process and workplace observations. These evaluations were conducted between November 1979 and May 1980. The research involved approximately 45 person-weeks of field work.

After conducting the detailed studies, the data were analyzed to determine the effectiveness of each control. Then plant reports were prepared which presented the data and the results of the evaluation. These plant reports serve as the basis for the control methods found in this report.

The individual plant reports[2,3,4,5,6,7,8] contain a detailed presentation of air sampling data, observations concerning work practices and emission sources, and ventilation system measurements for the operations listed in Table 1. These data are evaluated to judge the control system's effectiveness.

Table 1. Operations covered in plant survey reports.

	Operation							
Plant Report Number	Hopper/Bin Filling	Manual Weigh-out and Batching	Mixing	Milling	Cementing	Curing	Final Finish	Cement House
CT 118-11a		X			X	X		
CT 118-12a	X	X	X	X	X	X	X	X
CT 118-15a	X	X	X				X	
CT 118-16a		X	X	X		X		X
CT 118-19a	X	X	X		X	X		X
CT 118-20a	X	X	X	X	X	X	X	X
CT 118-21a	X		X			X	X	

The plant survey reports are available from the National Technical Information Service (NTIS). They may be purchased from NTIS by calling (703) 487-4650 or writing NTIS, U.S. Department of Commerce, Springfield, Virginia 22161.[9]

APPLICATION OF RESULTS

This report is intended to assist engineers, industrial hygienists, and safety managers at the plant and corporate level. Designs for general dilution and local exhaust ventilation systems should be of interest to those who are responsible for the design and installation of such controls. Work practices should be of interest to those who manage production operations and those who are responsible for preventing needless exposure to air contaminants. The configuration of processing equipment can affect air contaminant concentrations. Knowledge of effective hazard control options will allow those who are designing new plants or major plant renovations to eliminate or minimize sources of work exposure.

OVERVIEW OF OCCUPATIONAL EXPOSURES FROM TIRE MANUFACTURING OPERATIONS

Technology transfer of successful techniques used in one industry to solve problems in a different industry is a major objective of this study. In order to provide a frame of reference for the readers who may be unfamiliar with rubber and tire manufacturing operations, a brief description of these operations has been included in Appendix IV.

Tire manufacturing involves a series of operations which have the potential for creating worker exposures to a variety of air contaminants. The process is summarized in Figure 1. The occupational title groups developed by Williams[10] provide a standard description of tire manufacturing operations. These are listed in Table 2.

Hopper/bin filling and weighing and batching are areas which present potential exposures to dust from the various chemical compounds used in tire manufacturing. In the mixing areas of the tire plant, rubber, carbon black, process oils, and chemicals are mixed in energy intensive mixers, such as Banbury mixers, and milled to produce rubber stocks. These operations produce air contaminants referred to as "compounding dusts" and "rubber fumes." In addition, anti-tack agents used to keep the rubber from sticking together after milling often causes additional dust in the mixing area.

Rubber stocks are either calendered or extruded to produce various parts of the tire tread stock and ply stock by applying a shear-stress to the rubber. This results in friction heat and the generation of a fume.

Rubber, dissolved in a petroleum distillate, is called "cement" and is applied to the tread ends and the bottom of the tread. The workers near this operation and the workers in the cement house where the cement is made are exposed to petroleum distillate. This petroleum distillate is essentially naphtha with potential benzene contamination.

After the individual tire parts are constructed, the tire is assembled on a drum. While assembling tires, workers sometimes use petroleum distillate to tackify the rubber parts.

After assembly, the tires are sprayed inside and out with a release agent (which may be water or solvent-based) and then sent to the curing room where they are loaded into the curing presses. When a tire is released from the curing press, it has its familiar shape. Freshly cured tires release a fume commonly called "curing fume."

After curing, the tires are sent to a final finish department for inspection and repair, and then to the warehouse.

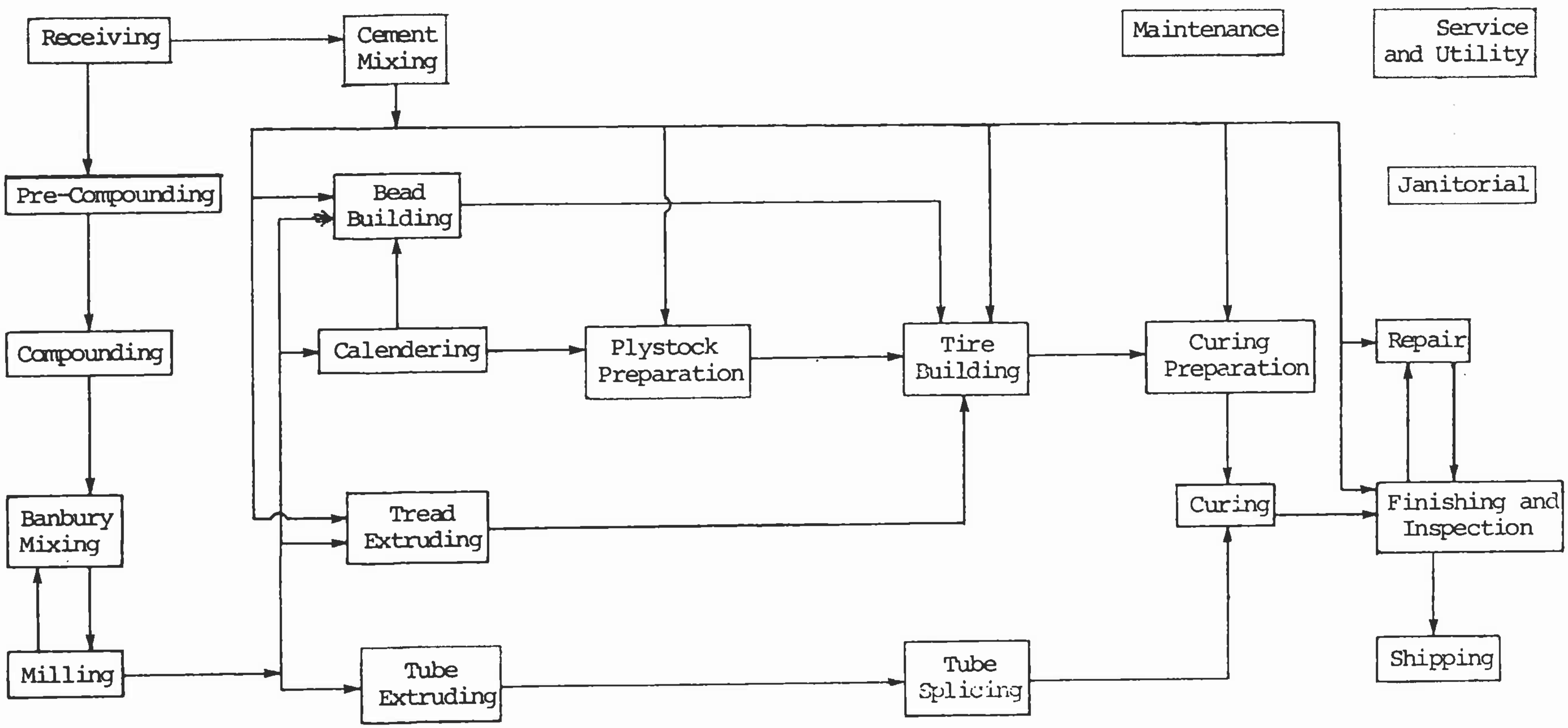

Figure 1. Production Stages in the Manufacture of Tires and Tubes.

Table 2. Description of occupational title groups in tire and tube manufacturing

Occupational Title Group	Description of Process
Compounding	Batch lots of rubber stock ingredients are weighed and prepared for subsequent mixing in Banburys; solvents and cements are prepared for process use.
Banbury Mixing	Raw ingredients (rubber, filler, extender oils, accelerators, antioxidants) are mixed together in a Banbury mixer. This internal mixer breaks down rubber for thorough and uniform dispersion of the other ingredients.
Milling	The batches from the Banbury are further mixed on a mill, cooled, and the sheets or slabs coated with talc so they are not tacky. The stock may return to the Banbury for additional ingredients, or go on to breakdown or feed mills prior to extrusion or calendering.
Extrusion	The softened rubber is forced through a die forming a long, continuous strip in the shape of tread or tube stock. This strip is cut in appropriate lengths, and the cut ends are cemented so as to be tacky.
Calendering	The softened rubber from the feed mill is applied to fabric forming continuous sheets of plystock by the calender (a mill with three or more vertical rolls and much greater accuracy and control of thickness).
Plystock Preparation	The plystock from the calender is cut and applied to the correct size for tire building, and so the strands in the fabric have the proper orientation.
Bead Building	Parallel steel wire is insulated with rubber vulcanizable into a semi-hard condition and covered with a special rubberized fabric. The beads maintain the shape of the tire and hold it on the sheel rim in use.
Tire Building	The tire is built from several sheets of calendered plystock, treads, and beads.
Curing Preparation	The assembled green or uncured tire is inspected, repaired, and coated with agents to keep it from sticking to the mold in vulcanization.
Tube Splicing	Assembly of tube stock; i.e., tube building.
Curing	The green tire or tube is placed in a mold and vulcanized under heat and pressure.
Final Inspection and Repair	The cured tire is trimmed, inspected, and labeled; repairable tires or tubes which do not pass initial inspection are repaired.

REFERENCES - SECTION I

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9. NIOSH Publications Catalog - 5th Ed. October 1981. DHHS (NIOSH) Publication No. 82-116.

10. Williams, Harris, Arp, Symons, and Van Ert. 1980. Worker Exposure to Chemical Agents in the Manufacture of Rubber Tires and Tubes. Am. Ind. Hygiene Assoc. J. 41:204-211.

SECTION II. ENGINEERING CONTROL STRATEGY

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

The control of air contaminants is an interdisciplinary task which requires the efforts and cooperation of industrial hygienists, engineers, safety managers, production supervisors, managers, and workers to develop and execute a workable system of control measures. With the efforts of all these groups, the control of air contaminants will be successful.

In general, a system of control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure, and/or maintenance. Process and workplace monitoring systems, personal exposure monitoring, monitoring and surveillance of controls to ensure proper use and operating condition, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete and effective control system.

In response to a recent OSHA advanced notice of proposed rulemaking (ANPR) on the issue of engineering control versus respirators, industry, labor, academia, government, and the AIHA unanimously agreed on the desirability of control by engineering measures as a first line of defense, with personal protection used as a backup measure. The AIHA has asserted its position on the control of workplace health hazards as follows: "The AIHA would like to go on record as stating that the elimination of workplace hazards is superior to the use of engineering controls, personal protective equipment, and other control strategies. Where elimination is not feasible, engineering and other control strategies should be the primary methods for reducing or eliminating exposures in the workplace."[1]

Material Substitution or Modification

Substitution of less hazardous materials can be an effective control option. This can be done in a number of ways:

- Use of materials which are inherently less toxic than alternate materials;

- Use of materials which do not contain unwanted toxic contaminants such as benzene;

- Use of chemicals and/or processing conditions which avoid unwanted side reactions such as nitrosamine formation;

- Use of formulations which are inherently less dusty;

- Use of water-based formulations in place of solvent-based formulations.

One particularly important type of material modification is the use of "dustless" compounds. In many cases, it has been found that the "dustless" compounds not only reduce dusting but improve material flow. The Rubber and Plastics Research Association[2] lists the following "dustless" forms:

- Oil-treated powder;
- Granules;
- Compacted or oil bound pellets;
- Polymer bound pellets;
- Polymer bound slabs;
- Flakes;
- Microgranules.

Hammond[3] proposes the following as criteria for evaluating powdered compound properties:

- Active content;
- Convenience of handling;
- Freedom from dust;
- General cleanliness and safety;
- Suitability for automatic weighing;
- Wastage;
- Ease of container disposal;
- Identification;
- Mill mixing behavior;
- Internal mixing behavior;
- Dispersion in rubber.

Hammond also reported the use of two dust assessing devices used by Vulnax Inc. and the Monsanto Company. The Vulnax device was developed by Hill and Robinson.[4] Monsanto's unit is similar to the Hill and Robinson device, but uses a photocell. Presently, there are no standards or criteria for using these devices. Should such standards be developed, one effective option would be to specify "dustiness level" as one aspect of required quality control in the purchase of raw materials.

Automation and Isolation

These techniques were not observed to be in wide use in tire manufacturing plants. Increased use of automated materials handling, measuring, and bag opening equipment should substantially reduce air contaminant exposures in tire plants. Receipt of premeasured quantities of materials in process compatible packaging could also help, as could the use of remote or centralized control stations supplied with clean, conditioned air. These techniques are used much more commonly in the other parts of the chemical processing industry than in tire manufacturing.

Local Exhaust Ventilation

Local Exhaust Ventilation (LEV) is the most widely used engineering control technique in tire plants. It is usually less desirable as a principle control strategy than the controls discussed above. It is more prone to misapplication and it can be more easily defeated by a lack of maintenance or by work practices or procedures such as the use of man-cooler fans.

There are a number of key considerations for the proper use of LEV:[5]

- Minimize capture distance while providing sufficient exhaust air volume.
- Provide the maximum amount of enclosure feasible (least amount of open face) over the area which is ventilated (clear plastic strips may be used at some locations).
- Maintain adequate conveying velocities and provide cleanouts for duct maintenance.
- Use natural gravity forces to work with the LEV (downdraft or side draft for bag dumping; canopy for hot plumes).
- Minimize pressure drops in entries and in ductwork.
- Design hoods and enclosures for uniform airflow distribution.
- Locate the prime air movers so the ventilation system operates under "negative" pressure to avoid forcing dust or fume (from leaks in the ducts) into the plant.
- Hood performance should be monitored initially and on a regular basis.
- LEV should be a part of a work station design which provides for good ergonomics and which makes it difficult for the worker's breathing zone to impinge on contaminated areas.

Other Considerations

Good work practices are needed to prevent the generation of air contaminants. It is possible for work practices to either reduce or enhance the effectiveness of engineering controls. Section III describes in detail how work practices associated with the handling of rubber chemicals can directly affect worker exposure. As long as workers must fill bins with dusty materials, manually weigh chemicals into batches, handle carbon black totes, and charge dusty material into mixers, they will need to use good work practices which minimize air contaminant generation.

A good housekeeping program is needed to minimize the resuspension of settled dust from spilled materials. Maintenance programs are needed to prevent equipment leaks or failures and to ensure the effective operation of engineering controls already in place. Once designed, the operation of engineering and work practice controls must be monitored to ensure these controls operate as designed.

During detailed surveys, controls were studied because their design was conceptually good. However, the maintenance of process equipment and ventilation systems proved to be as important as the original design. At one undertread cementer, ventilation rates were less than 50 percent of the design values.[6] This led to area air concentrations of petroleum distillate of almost 1,000 mg/m^3. Comparable values near other, better ventilated, undertread cementers were less than 300 mg/m^3. Inadequate maintenance of process equipment can cause needless air contaminant generation and the spillage of rubber chemicals. Such spillage can be resuspended in the air as dust, as well as becoming a housekeeping problem. Inadequately maintained materials handling equipment, combined with inadequate housekeeping, appeared to contribute to the total particulate concentrations in some plants.

Educational programs for both employer and employee are also necessary to ensure an awareness of potential health hazards in the tire manufacturing industry.

The remainder of this section presents and discusses some of the more effective engineering controls that were observed during the study for the following operations:

- Hopper/bin filling
- Manual weigh-out and transferring
- Mixing
- Milling
- Curing

These and other controls are discussed in more detail in the in-depth plant survey reports which form the data base for this document. Table 1, p. 2, shows the operations covered by each of these reports.

HOPPER/BIN FILLING

Workers frequently empty 50-pound bags of rubber chemicals into hoppers/bins. Control of air contaminants from these operations depends both on engineering measures such as work station design and on work practices. Engineering measures are discussed in the present section, and the work practices are discussed in Section III.

Observed Engineering Control Techniques

The engineering controls for hopper/bins fall in several areas: layout of the area, work tool design, material modification, and ventilation.

Layout

The layout of the hopper/bin filling area is an important factor in dust control. Both the plan and the elevation design are important, if dust generation is to be minimized. Two elements crucial to the design are: minimal compound transport distances and elimination of obstructions to material flow.

Attention to the relationship of bins/hoppers or totes to the worker is also essential. The following items should be considered when designing these areas:

- The material should flow into the bin by itself or with the help of a flow aid, but should not require the worker to use a hoe or shovel to move materials.
- The depth of the material in the bin should be such that a minimum of scooping is necessary.
- The face area of the bin or hopper should be large enough to assure free passage of the scoop.
- The depth of the bin or hopper should be such that the worker need only place, at most, his arm in the bin and not his head and body.
- A convenient place for storing scoops should be provided.
- The bin or hopper should be adequately ventilated.
- The height of the bin should be convenient to the worker (i.e., it is unnecessary to stoop to scoop).
- The bins should be tightly sealed or have sealable lids (especially important for transportable bins).
- The area should be designed so each bin fits into its specific place (especially true for portable bins).
- Bins that are two or more floors should have airtight, latchable doors and/or bin level indicators to signal when filling is required.

Ventilation

Local exhaust ventilation can control most of the dust generated from pouring the material into a hopper/bin; however, it must be used in conjunction with good work practices and work station design. Dust generated from handling empty bags should be controlled by a combination of LEV and good work practices. Many plants used LEV to control the dust generated from opening bags of powdered material and emptying them into bins but control of dust from handling the empty bags was often overlooked.

In general, the design of hoods for hopper/bin filling should provide adequate capture of dust without excessive product loss; it should allow for capture of dust over the expected range of bag and breathing zone locations; and it should be designed in conjunction with good work practices, both from the viewpoint of respiratory protection and ergonomics.[7]

Of the three bin filling hoods studied, the operation of those described in Figures 2 and IV-1, pp. 16 and 102, appeared to provide good design for control of dust during bag opening, emptying, and disposal.[8] This bin/hopper design followed the conceptual design presented in plate VS304 of the ACGIH Ventilation Manual[9] shown in Figure 3, p. 17, which recommends a face velocity of 150 fpm. Although no hoods with 150 fpm face velocity were studied, 200 fpm was found to be effective.[8,10,11]

Another attractive and potentially more effective control approach is automation of the bin/hopper filling areas. There are also automatic bag dumping and disposal devices available; however, none of these units were observed or evaluated during this study.

Material flow and construction of material dispensing areas are two important factors in bin and hopper design. Many devices have been used by the various companies to solve the material flow problem: vibrators, bridge breakers, and dry compressed air injection. The workers have also used manual hammering and "punching" of bins and hoppers. Colijn[12,13,14] has suggested solutions to many of these problems which must be instituted during the bin or hopper design based on the shear strength of the bulk solid fines, consolidation pressure, stress in material arch, etc.

Specific ventilation design parameters for bin/hopper hoods based on NIOSH studies, our observations, and our best engineering judgement are described in Table 3 and Figure 2, pp. 14 and 16.

Table 3. Ventilation design parameters for bin/hopper filling.

Parameter	Design	Notes
Type of hood	Side draft, enclosure	Observed to be best hood for meeting parameters.
Face velocity	150 fpm minimum	ACGIH[9] recommended hood design (Figure 3, p. 17). From NIOSH study, 200 fpm was found to be effective. However, no hood with exactly 150 fpm was encountered.
Duct transport velocity	3,500 fpm, minimum	ACGIH[9] recommended.
Duct entrance or slot placement and design	1. Located so bulk material is not pulled into it during bag emptying	For hood shown in Figure 2, face velocity varied ±30 percent from 200 fpm.
	2. Located so material from an overfilled bin does not block or spill into it.	
	3. Located so bag does not block it during emptying.	
	4. Located above dust source.	
	5. Located so dust is moved away from the worker.	
	6. Should be almost as wide as the enclosure.	
	7. Located for uniform flow.	
Bag disposal	Should be included in ventilated enclosure.	Tube bag on side of hood may be successful.[15]
Ergonomic considerations	Work surface should be 15-40cm below elbow, when worker is standing with hands at side.[7]	

(continued)

Table 3. (continued)

Parameter	Design	Notes
Structural	1. Sufficient face area to perform operations.	
	2. Face area adaptable to bags and drums.	
	3. Bag rest area on bin inside the hood capture zone.	
	4. Grating over bin.	Optional for manual compounding system, but needed for automatic systems to break compound clumps.
	5. Screening over duct entrance or slots.	
	6. Hood fabricated to withstand impacts of bags and other equipment.	
	7. Provision of adequate lighting in hood.	
	8. Appropriate consideration of material flow and explosive properties.[16,17,18]	Chute under hood should be designed for easy material flow.
	9. Minimize dust generation by designing for mass flow.[16]	

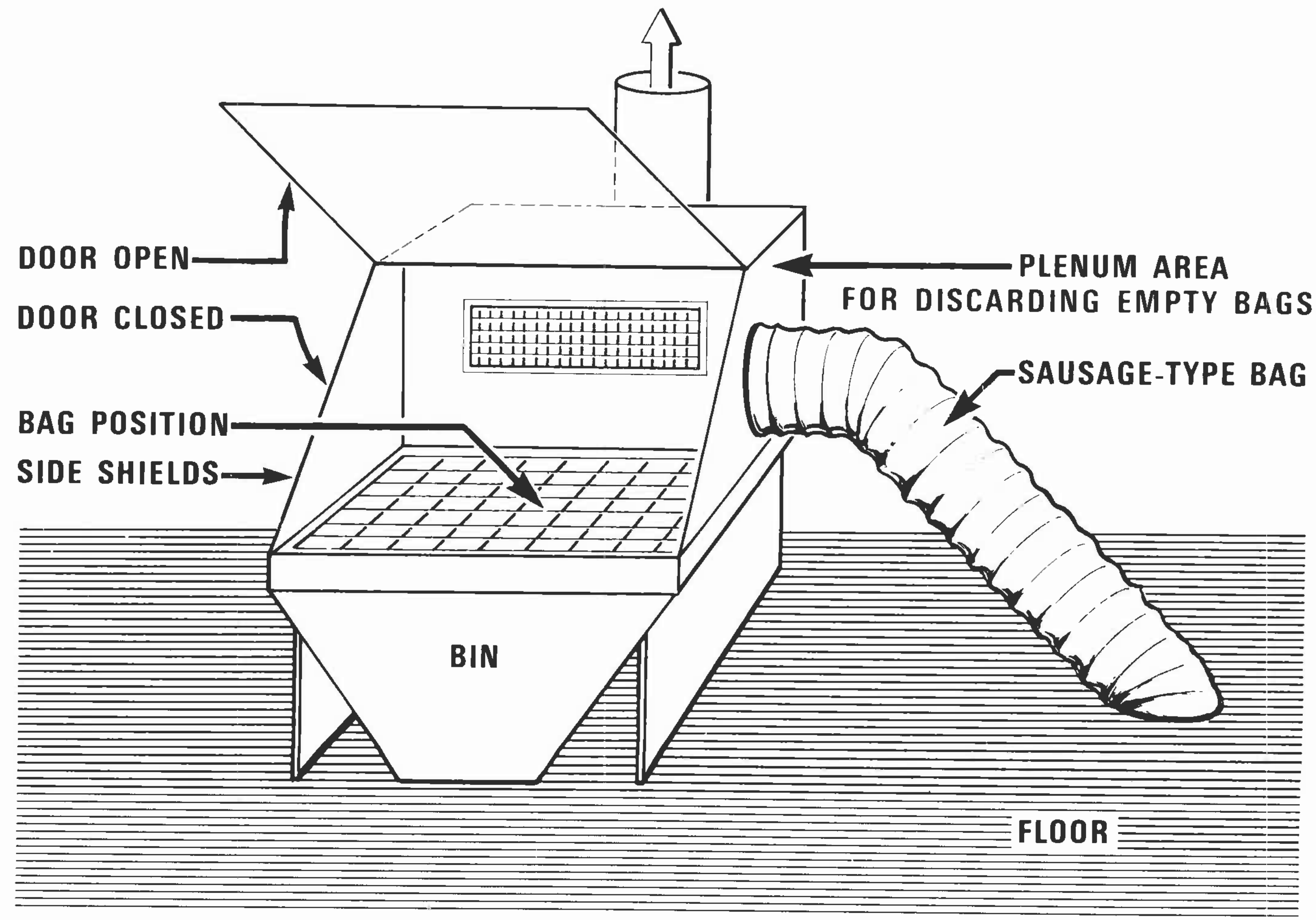


Figure 2. Bag dump hood mounted on bin.

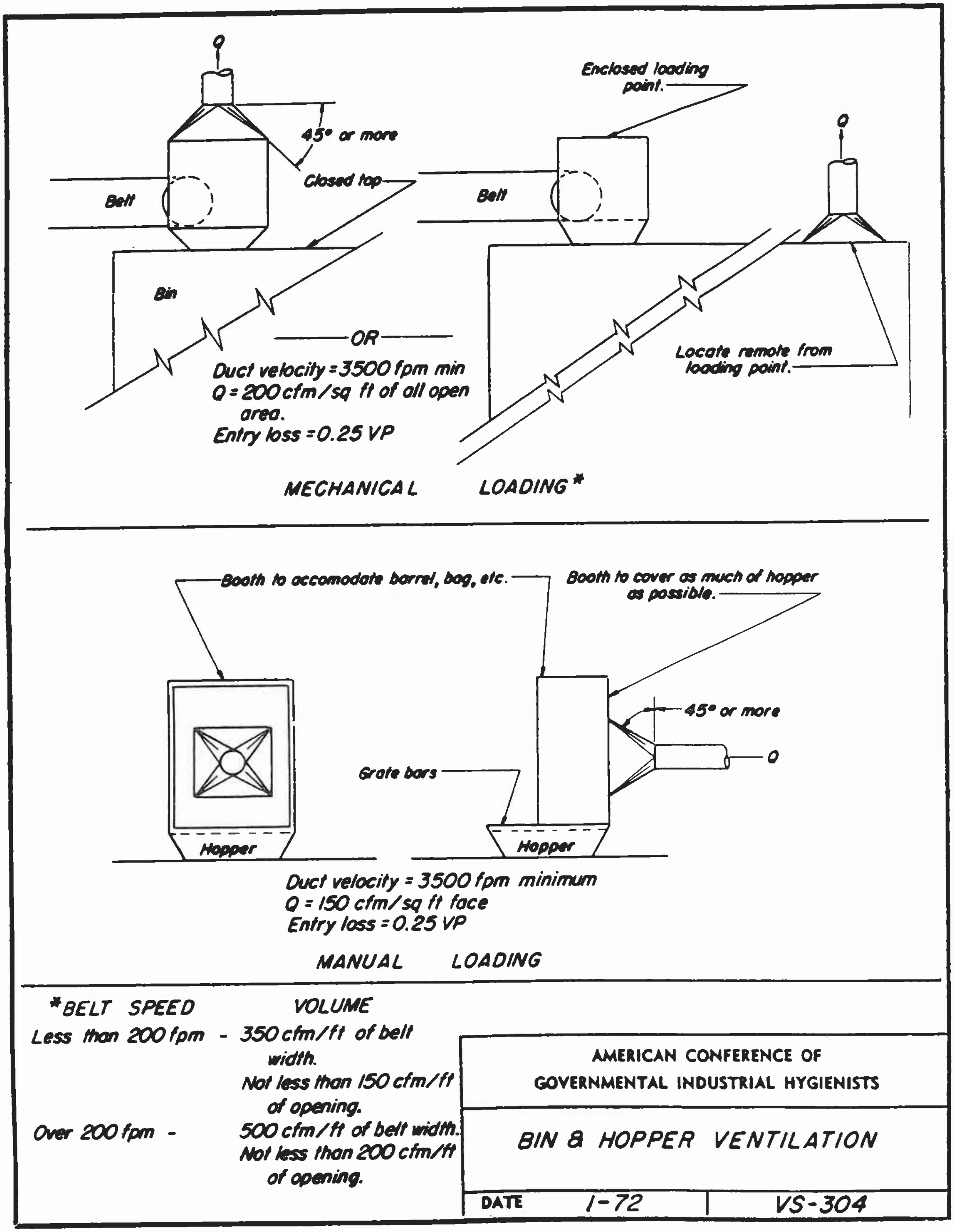


Figure 3. ACGIH design specifications for bin and hopper ventilation.

Courtesy of: Committee on Industrial Ventilation, Post Office Box 16153, Lansing, Michigan 48901.

Observed Control Effectiveness

Personal sampling results for bin filling operations taken from three separate plants[8,10,11] are summarized in Table 4.

Table 4. Summary of personal sampling results for bin filling.

Total Particulate GM*	N**	Respirable Particulate GM	N	Comments
0.60	1	0.09	1	Emptying bags of chemicals into a bin. Automated bag disposal system [8] (partial shift, 2-hour sample).
0.70	8	0.17	8	Emptying bags of chemicals into a bin[11] using good work practices (full shift).
4.30	8	0.40	8	Emptying bags of chemicals into a bin using poor work practices[10] (partial shift sample).

* - Geometric mean concentrations for all plants studied (mg/m^3).
** - Number of samples.

The data in Table 4 were not analyzed to determine whether the geometric means differed significantly from one another, since full-shift samples were taken at one plant and partial shift samples were taken at another.

At one plant,[11] personal and area samples were taken for eight full shifts. The workers' total particulate exposure was, at the 95 percent level of confidence, greater than the background total particulate exposure. This suggests that bin filling contributed significantly to the worker's dust exposure at this plant. A review of the ventilation data showed that hoods for opening and emptying the bags were, at best, partially effective at controlling the dust. Generally, there was no control provided for the dust generated by disposing of the empty bags.

WEIGHING AND BATCHING

There are three ways that weighing and batching are performed:

- o Manually - worker performs all material handling;
- o Semi-automatic - worker is aided by machine in material handling;
- o Automatic - machine is aided by worker in material handling.

Observed Engineering Control Techniques

All of the manual and semi-automatic weighing and batching operations that were observed caused some dust generation and the LEV, as applied, did not completely control the workers dust exposure. This conclusion is based on the observation that personal exposures were always higher than background concentration. However, LEV can (but often is not) be applied at specific material transfer points such as pouring, scooping, and conveying to control dusts. In areas away from these material transfer points, work practices are the principal dust control measure.

In order to minimize dust generation away from the weighing and batching stations, batches of chemicals should be assembled in plastic bags which can be charged unopened into the mixer. Sometimes, the additives can be purchased in this fashion from suppliers. This technique eliminates dust generated from emptying the contents of bags or rigid containers into the mixer and from disposing of the empty container. Rigid containers which have been emptied into a mixer inevitably contain pockets of highly contaminated air which may spill directly into the worker's breathing zone. This was observed during all the detailed studies.

The hood pictured in Figures 4 and 5 provided almost complete dust control at the point where material is poured into the bag. Table 5 provides the ventilation design parameters for this work station. As shown in Figure 4, the powdered material does not fall far, which minimizes dust dispersion. The face velocity around the perimeter of the ring, detailed in Figure 4, was 150 fpm and was generated using a 500 CFM volumetric flow rate. Based upon tracer gas measurements and observations, the hood captured all of the dust generated from pouring material into the bag, however, the zone of capture was at the worker's waist.[19,20] In the worker's breathing zone, tracer gas measurements showed there was only 50 percent capture efficiency.

Table 5. Ventilation design parameters for a manual weighing work station shown in Figures 4 and 5, pp. 21 and 22

Parameter	Design	Notes
Type of hood	Side draft, capture or enclosure (do not use capture for widths over 2').	Best design to meet other specifications.
Duct entrance	Locate so operation, material or equipment does not block vent. Locate as close to the source as possible without bulk material being pulled into the system. Locate high enough so capture velocity is maintained despite height of material in the bin. Should be the same length as the source area. Try to make the area self-cleaning. Make flanges as wide as duct entrance or 6" maximum. Slot width should not exceed 20 percent of its length.	ACGIH[9] recommendation.
Capture velocity	100-200 fpm, 150 fpm optional. at outer source perimeter; do not exceed 500 fpm across materials in the bin.	ACGIH[9] recommends 100-200 fpm for emissions released at low velocity into moderately still air.

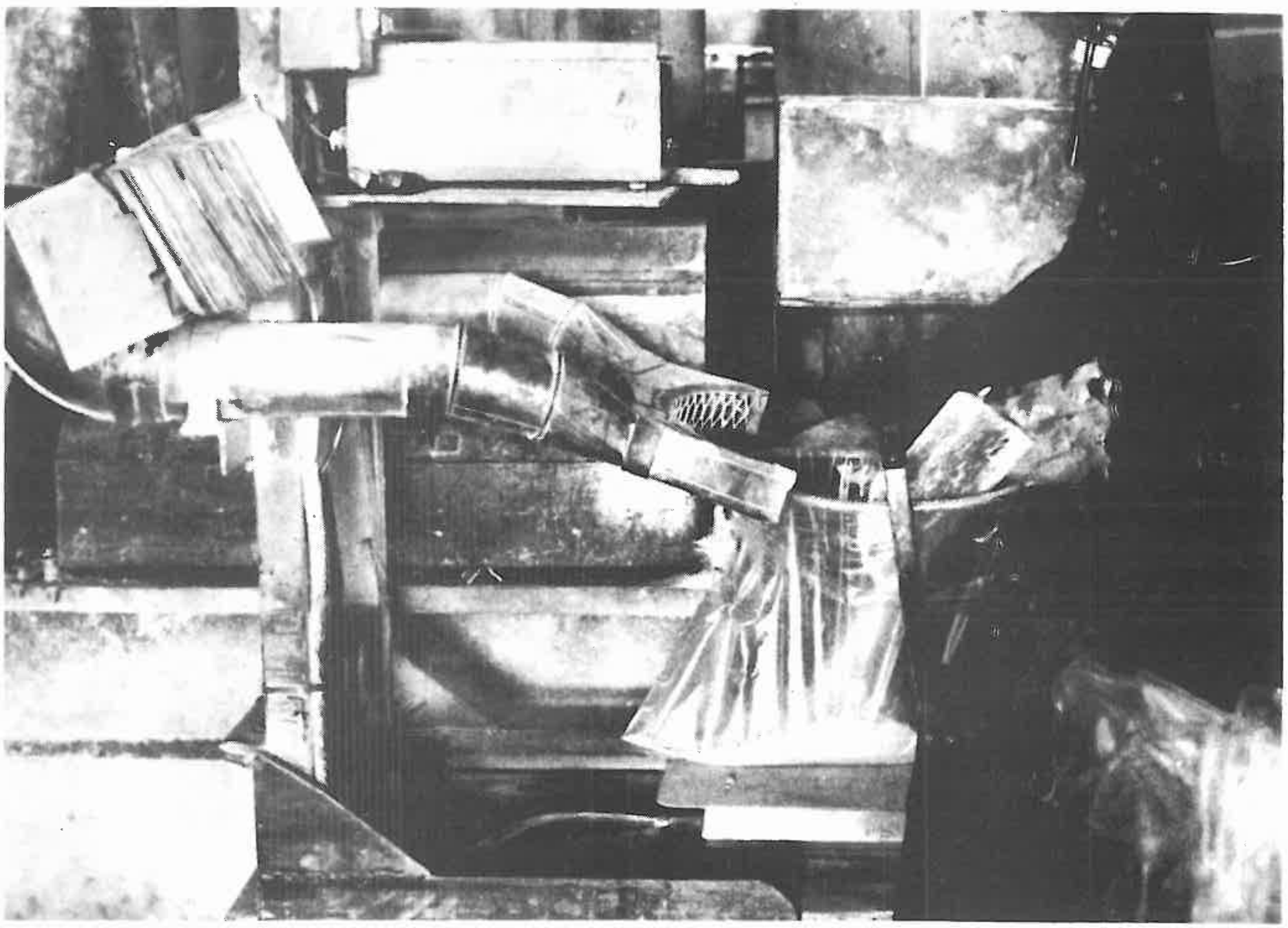


Figure 4. Trolley scale system for manual weighing and batching.

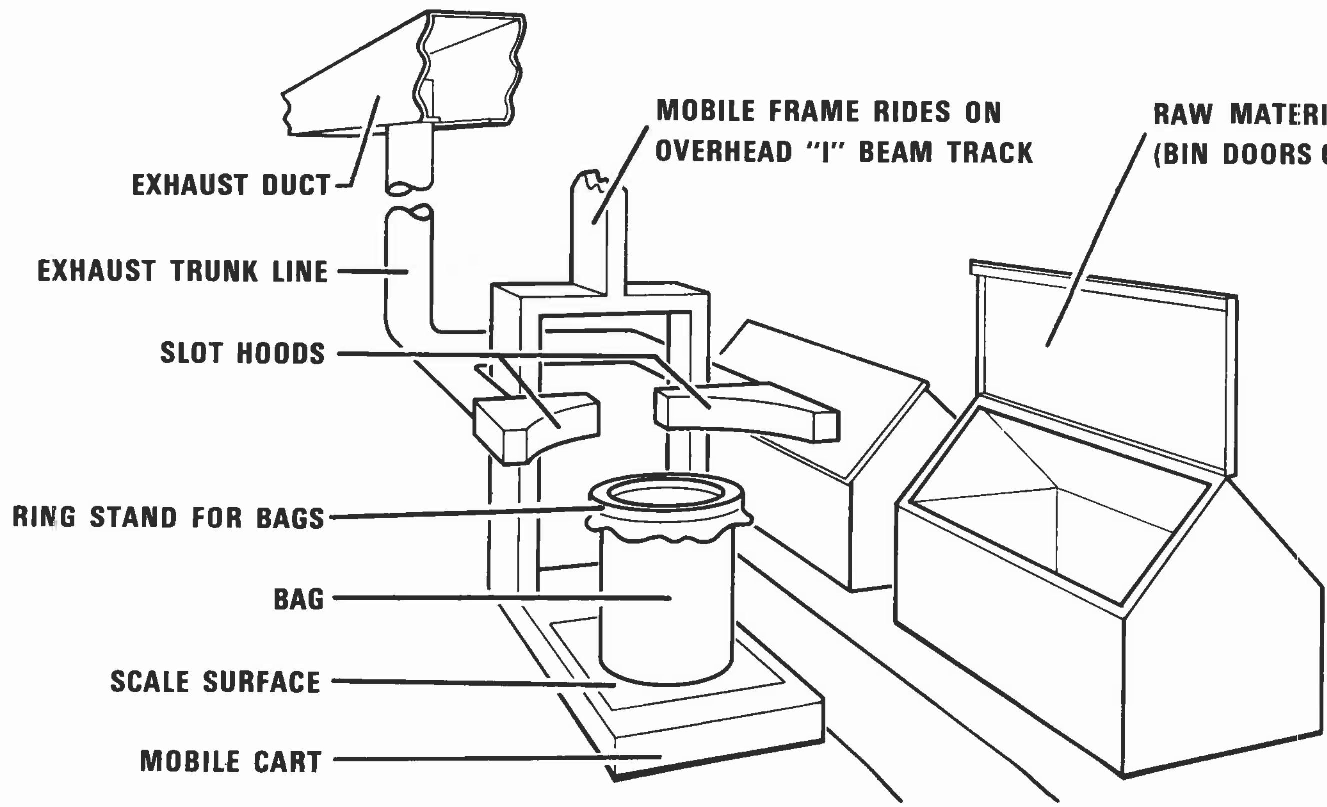


Figure 5. Schematic of hood shown in Figure 4, p 21.

At one plant, a semi-automatic weigh-out system was observed, Figures 6 and 7, pp. 24 and 25.[21] To use the device, the worker placed the plastic bag into the holder and then turned on the conveyor. To adjust the final weight, material was added or deleted using a scoop. This system did appear to minimize manual material handling. A sample collected near this device showed relatively low total particulate concentrations of 0.2 mg/m^3. However, the worker's exposure to total particulate was 2.0 mg/m^3. This is attributed to the worker's manual weighing and batching activities.

A hood was placed over the outlet of the screw conveyor which feeds material into the bag. This hood, however, did not completely control the dust generated by material hitting the bottom of the bag. An exhaust flow of 330 CFM produced a hood face velocity of 420 fpm and produced capture velocities of 20-120 fpm around the bag holder. Tracer gas capture efficiencies[19] for locations numbered in Figure 7 are listed in Table 6. The type of local exhaust hood described by Table 5 and Figures 4 and 5 probably would have provided better control of the dust generated at this location.

Table 6. Tracer gas capture efficiency for numbered locations in Figure 7.

Location	Efficiency	Velocity (fpm)
1	0.95	50
2	0.98	30
3	1.05	50
4	0.88	120
5	0.68	-
6	0.21	-

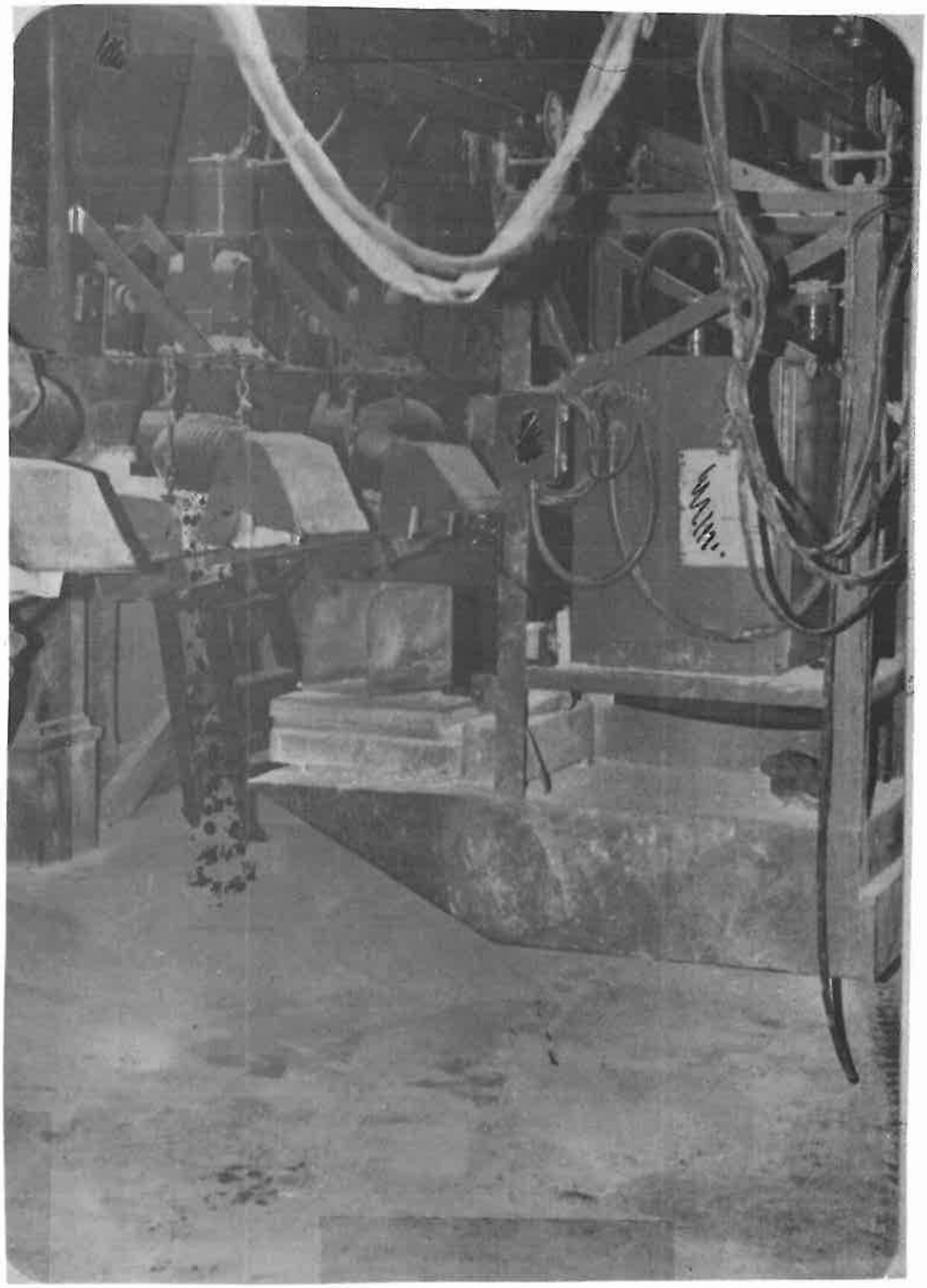


Figure 6. Semi-automatic weigh-out system showing conveyor, hood, and trolley scale.

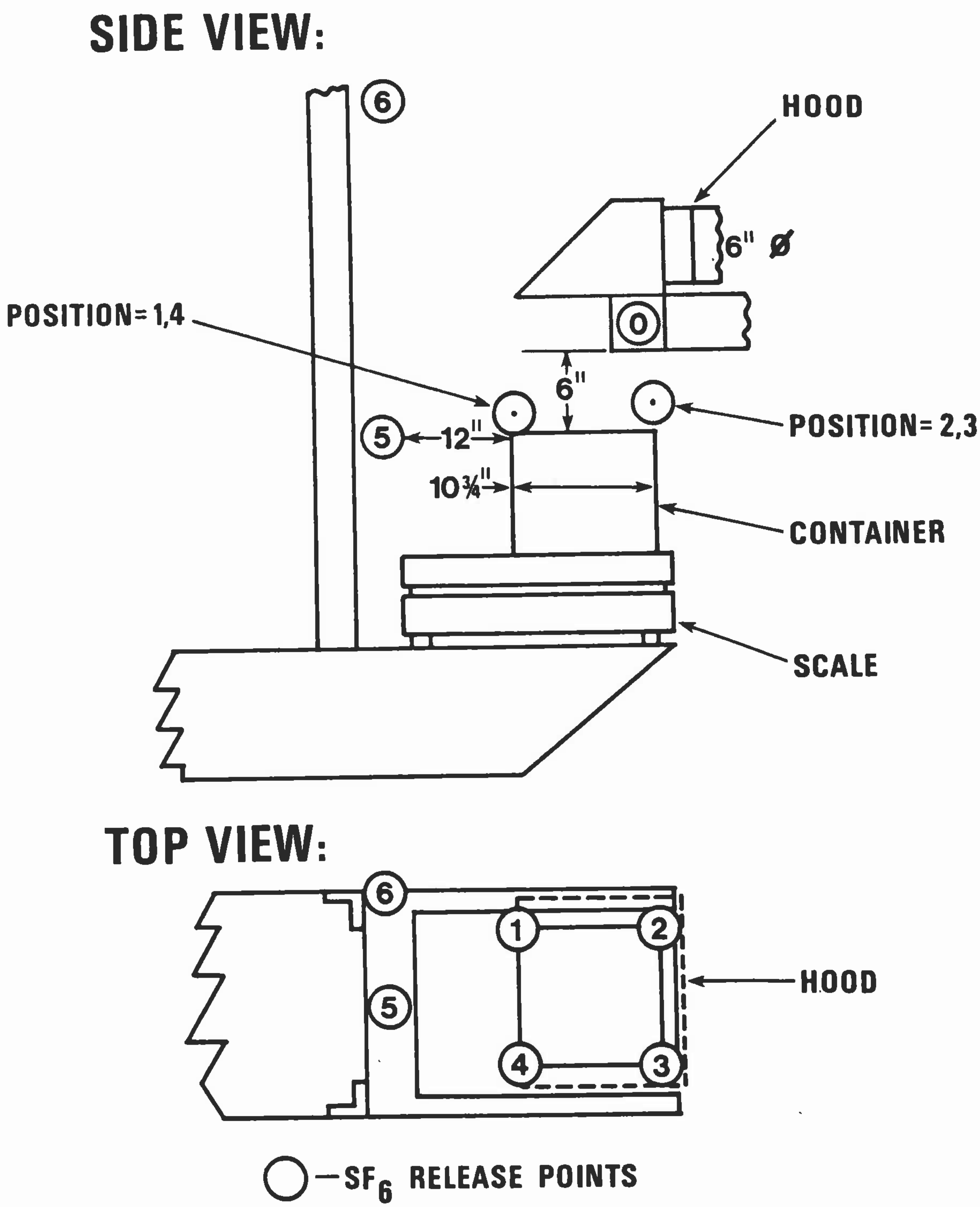


Figure 7. Schematic of Figure 6 showing location of SF_6 release points.

Observed Control Effectiveness

The data presented in Table 7 summarize personal sampling conducted at a number of different manual weighing and batching operations. Analysis of variance (ANOVA) showed the concentration differences are not significant (probability of a larger F = 0.44). Since some plants used local exhaust ventilation, this suggests that there is no benefit in providing LEV at manual weighing and batching stations, as it is applied by these plants. This result suggests that remote, automated weighing and batching operations, reduced dusting formulations, etc., should be investigated as a necessary improvement to current manual weighing and batching practice. Other data, available in plant reports,[20,21] show that LEV can be used to control dust generated by pouring powdered materials onto a weighing scale. Although this particular source of airborne dust is controlled, it is only one of several sources of airborne dust at manual weighing and batching operations. Here again, it appears that automation may be the most satisfactory way to eliminate these dust exposures.

Table 7. Summary of personal sampling results in weighing and batching areas.

Total Particulate GM*	N**	Respirable Particulate GM	N	Comment
2.2	8	0.27	8	Semiautomatic weighing and batching with LEV[21] (trolley system).
2.0	10	0.64	10	Manual weighing and batching using LEV[20] (at the weighing scale).
1.5	7	0.24	8	Manual weighing and batching in booth using LEV.[22]
2.1	8	0.46	8	Manual weighing and batching without LEV.[23]
2.5	8	0.42	8	Manual weighing and batching without LEV.[23]

* - Geometric mean concentrations for all plants studied (mg/m^3).
** - Number of samples.

A ventilated trolley was used at one plant to perform manual weighing and batching. As pictured in Figure 4, p. 21, the worker scoops powdered material out of a bin and pours it into a bag mounted on a scale. Based upon tracer gas measurements and observations, the local exhaust ventilation supplied at the scale controlled the dust generated from pouring material into a bag on the scale.[19] However, the dust generated from scooping the material out of a bin, carrying it to the bag, and placing excess materials back into the bin probably explains why the workers' exposure was greater than background at the 95 percent level of confidence.

In another plant,[21] a semi-automatic weighing and batching or weigh-out system was used. This system used a vibrating flow aid to transport material from a bin to a bag mounted on a scale. The total particulate concentration measured on the scale (a GM of 0.3 mg/m^3) was significantly lower (99.5 percent level of confidence) than the total particulate concentrations measured on the worker (a GM of 2.2 mg/m^3). The workers' increased exposure was attributed to manual weighing and batching activities conducted at a nearby work station.

At other plants,[22,23] work practices seemed to affect the workers' dust exposure. For workers doing the same job on different shifts, there were significant differences (95 percent level of confidence) in the workers' total particulate exposure. Based upon observation, these differences appeared to be caused by differences in work practices. As discussed in Section III, work practices are important to the control of dust when manually handling powdered materials.

MIXING

Mixing involves the charging and operation of high shear mixers. Unless otherwise noted in this document, "mixer" means a Banbury(R)-type mixer. A number of engineering and work practice controls are necessary to control the exposures from this operation.

Observed Engineering Control Techniques

In the tire manufacturing plants studied, mixer ventilation was somewhat similar to the ACGIH ventilation recommendations[9] shown in Figure 8. LEV was also used at a number of additional points. These points, and the observed ventilation rates, are listed in Table 8. Properly implemented, LEV at the charge door, drop door, and internal mixer exhaust vents can contain the emissions generated by charging rubber chemicals and carbon black into the mixer, mixing the rubber, and discharging the rubber from the mixer. If manual compounding is not done at the mixer, the operator's particulate exposure should be the result of overall conditions at the plant.

The charge door hood required the majority of the mixer ventilation airflow. Regardless of the hood's airflow and face velocity, all of the charging hoods studied controlled the dusts generated. These hoods contained the dusts forced past the charge door by the movement of the mixer's internal parts. The charge door's range of movement was completely inside the hood.

At drop gates or slide gates, LEV was used to capture fumes emitted from the hot rubber stock. Such ventilation was frequently part of the overall mixer/drop mill ventilation system. These hoods were generally observed to capture the fumes. For drop gates, the hood was typically formed by placing an exhaust take-off between two of the mixer legs. The rest of the area between the legs of the mixer and the mill hopper was enclosed. Usually, there is a small opening in the enclosure to allow air to enter. In-depth studies did not include slide gate ventilation.

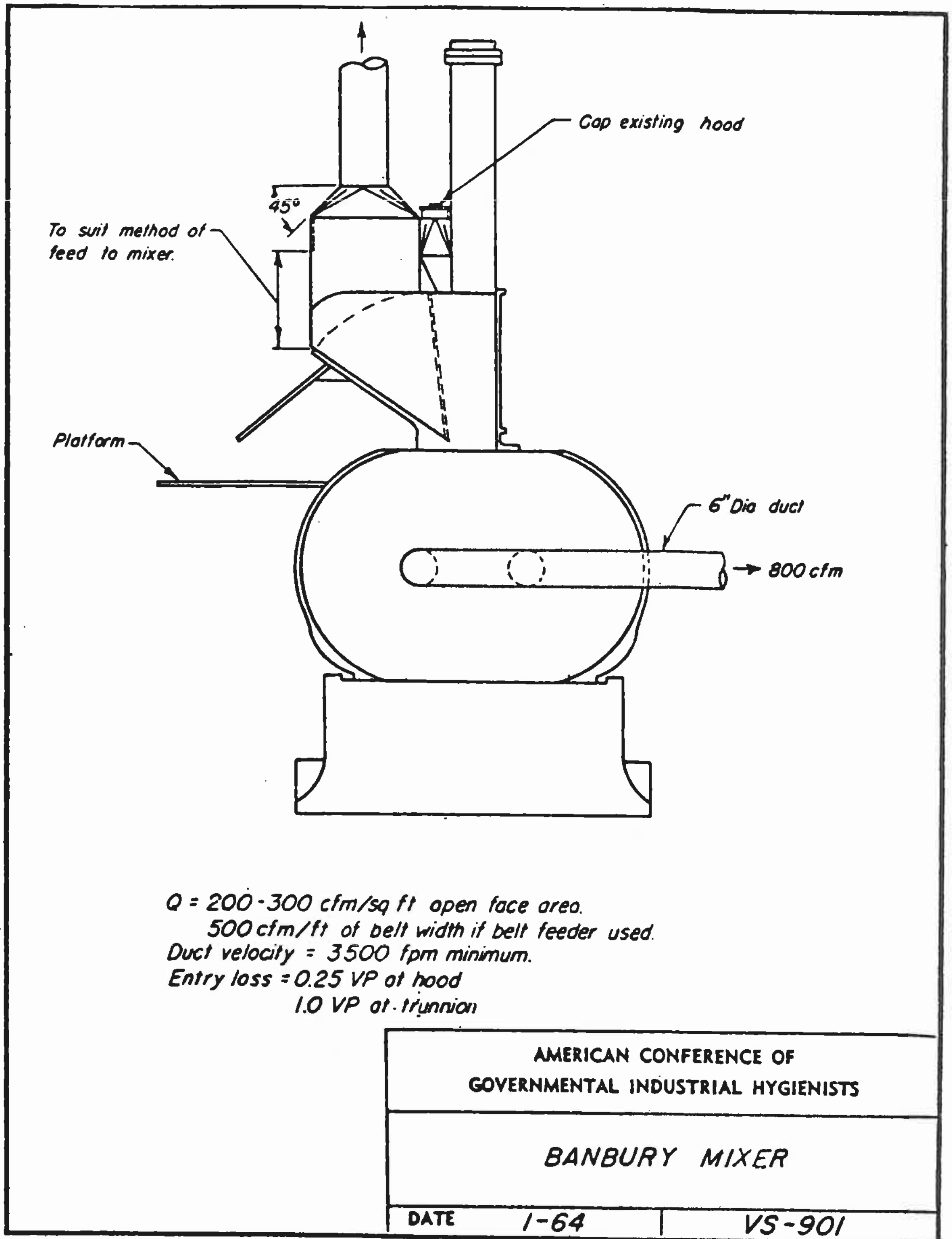
LEV was generally provided for vents on the mixer's hopper and on the carbon black charge chute. Ventilation for mixer vent holes is needed to capture dusts created by the movement of mixer parts. Vents on the mixer are needed to prevent pressurization of internal spaces by movement of internal parts. Occasionally, these vents and the ducting for these vents were observed to be plugged.

Dust ring hoods were observed in a number of plants. These hoods are intended to capture the particulates emitted from a failed dust ring. A dust ring is a mechanical seal that is intended to prevent leakage from the mixer. During this study, the dust rings were not observed to leak.

Table 8. Observed mixer ventilation rates.

Ref.	Charge Door Total Flow (cfm)	Charge Door Face Velocity (fpm)	Discharge Door Total Flow (cfm)	Discharge Door Face Velocity (cfm)	Dust Ring Hood (4) Total Flow (cfm)	Internal Vents Total Flow (cfm)	Carbon Black Vent Total flow (cfm)
24	3900	300	400	Enclosed	NP	400	NP
25	4200	250	NP*	NP	NP	NP	NP
26	4800	850	Enclosed	--	800	NP	700
27	3100	300	3300	--	NP	130	--
28	3600	600	700	90	400	NP	90
23	6700	620	1100	150	830	Plugged	800

* - NP indicates not present.



COURTESY: COMMITTEE ON INDUSTRIAL VENTILATION,
POST OFFICE BOX 16153, LANSING, MICHIGAN.

Figure 8. Banbury mixer ventilation.

Observed Control Effectiveness

The plant with the lowest particulate exposures (plant 1, based on Table 9) used production techniques which minimized contaminant generation, and also completely isolated workers from the dust generation caused by other operations. An automated batching system eliminated the dust generated by manual batching and by charging rubber chemicals into the mixer. The ventilation system associated with the automated batching system completed the isolation of the worker from the dust.

This plant also used Sealdbins(R) to charge carbon black into the mixer. Sealdbins(R) are constructed of rubber and are filled by the carbon black manufacturer with approximately 7,000 pounds of carbon black.[29] These rubber bins are set directly on top of a tilt stand. The tilt stand and vibratory conveyors feed the carbon black through the automatic batching system and into the mixer. In comparison with other systems, this approach minimized the amount of carbon black handled by vibratory feeders and screw conveyors, which tend to leak. This reduced the amount of carbon black dispersion. The small particle size and dustiness of carbon black suggests that closed systems should be used for this material.

In the plants studied, the LEV effectively controlled emissions from the mixer. Because this control was quite good, the operation of the mixer did not contribute significantly to the worker's exposure. The personal sampling results show considerable plant-to-plant variation in the mixing area, but these are due to factors such as background dust levels which affect the workers' particulate exposures.

Process configuration and the use of certain anti-tack agents on the master batch sheet stock seemed to significantly affect contaminant generation. This point can be illustrated by examining the statistics of the personal sampling results for mixer operators at different plants. The total particulate concentration data in Table 8 were tested for significant differences among the geometric means obtained at different operations. An ANOVA of the log-transformed data showed that, at a level of confidence greater than 99.99 percent, there are significant concentration differences. Under Total Particulate Concentration, the column labelled "Grouping Code" presents the results of Duncan's Multiple Range Test.[30] This statistical test is one of many multiple range tests developed to evaluate the significance of differences between pairs of means. Duncan's test controls the comparison-wise error rate to an overall level of confidence of 95 percent. For example, the GM for the total particulate concentration of plant 3 differs significantly from that of plant 1.

In addition to using automated batching and Sealdbins(R), plant 1 replaced kaolin with a soap anti-tack agent on the rubber. The soap did not come off the rubber and create a dust exposure.

Plant 2 appeared to minimize dust generation to a greater extent than the other plants. At plant 2, the mixer operator's total particulate exposure was not significantly different from the area sampling results. This suggests that dusts from other operations, such as manual compounding, caused the worker's dust exposure.

Plants 4 and 5 had the highest total particulate exposure for mixer operators; at both plants, the mixer operator's exposure was significantly higher than the area sampling results. Rigid containers that the worker used to charge powdered materials into the mixer at one of these plants appeared to elevate the worker's total particulate exposure above the background contamination.[28] At the other plant, a clay-type anti-tack agent was dispersed from sheeted rubber when the operator fed the rubber onto the charging conveyor. This appeared to create puffs of dust in the worker's breathing zone.[27] Apparently, the dust adhered to the conveyor and was redispersed when the worker dropped bales of rubber onto the conveyor.

Table 9. Summary of personal sampling results from mixer operators at different plants.

Plant	Total Particulate Concentration GM*	N**	Grouping Code***	Respirable Particulate Concentration GM	N	Comments
1	0.08	8	A	0.06	8	Automated handling of rubber chemicals. Sheeted rubber coated with soap.[24]
2	0.35	6	B	0.11	6	Emptying plastic bags containing rubber chemicals into mixer.[25]
3	0.75	5	B-C	0.14	5	Plastic bags containing rubber chemicals dropped into mixer; background contamination from compounding areas.[26]
4	1.22	8	C	0.27	8	Automatic handling of rubber chemicals. Clay-type anti-tack used to coat rubber stock is dispersed when stock loaded onto charging conveyor.[27]
5	1.54	3	C	0.34	3	Worker emptying rigid containers or paper sacks into mixer mouth.[28]

* - Geometric mean concentrations (mg/m^3).
** - number of samples.
*** - Plants with different grouping codes have significantly different sampling results. Plants which contain the same grouping code are not significantly different.

MILLING

A mill is defined in the present document as any machine which uses rollers to convert the output of a mixer into rubber sheet stock. The rubber is normally hot and fuming when dropped from the mixer. The shearing of the rubber on the mill creates more heat and generates even more fumes. These fumes can normally be controlled by LEV. Although open-mill compounding without LEV was not observed in this study, such a practice would be an extremely potent emission source and would represent a very poor operation. After milling, the rubber sheets are fed through a dip tank to cool the rubber and to apply an anti-tack agent.

Observed Engineering Controls

Based on site observations, the use of Transfer Mixers(R) to complete the mixing process and a sheeter mill to continuously form rubber into sheets almost eliminated the need for the worker to stand in front of the mill. As a result, the worker merely observed the process from a less contaminated work station and avoided direct exposure to the fumes. Thus, isolation was an effective control method in this case.

At some plants, master batch rubber is dropped from the mixer into a pellet extruder. The freshly extruded pellets emit a fume. The application of an anti-tack clay slurry to the pellets and the drying of these pellets can cause the emission of water vapor and a mist containing the anti-tack material.

The fumes are generally controlled by local exhaust ventilation. The mill described by Figure 9 and IV-7, pp. 36 and 108, and in Table 10 provided good control of the fume. If the workers' job requires him to place his head in the enclosure, his exposure will, of course, be elevated.

Design and operating parameters for a successful hood are presented in Table 10 and Figures 9 and IV-7.

Table 10. Design parameters for milling described by Figures 9 and IV-7.

Parameter	Design	Notes
Type of hood	Canopy type enclosure see Figure 9, p. 36	
Face velocity	300 fpm observed to be adequate	ACGIH[9] recommendation for active generation into zone of rapid air motion is 200 - 500 fpm.
Hood location	1. Located so material is not pulled through worker's breathing zone.	
	2. Located so face area can be reduced to a minimum using sheet metal or drapes.	
	3. Located for uniform flow.	Face velocity variation of ±30 percent common for hoods in this study.
Worker comfort	Cooling and heating air must be tempered.	Airflow should be into hood as part of makeup air.
Job design	Isolate worker from fume.	

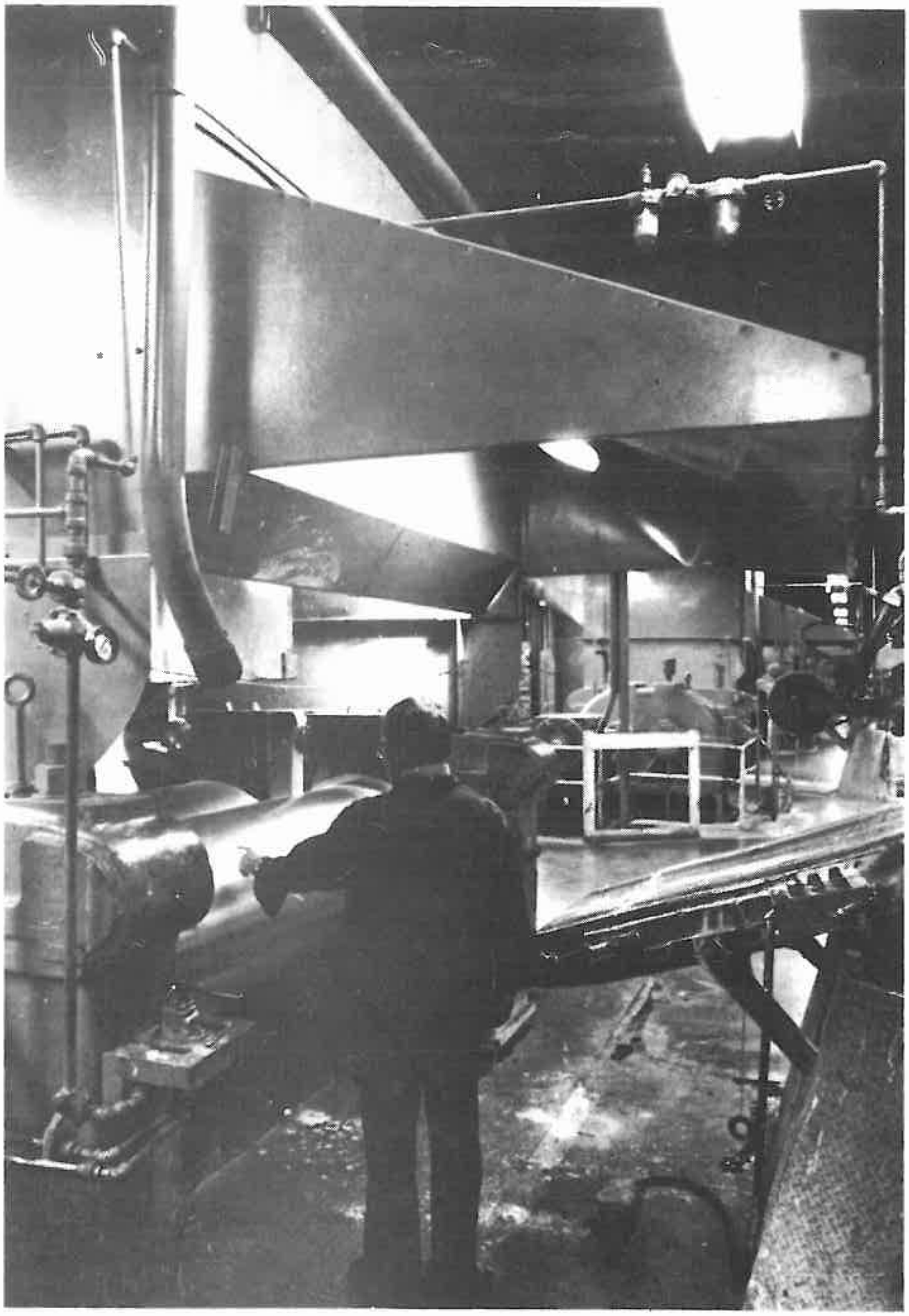


Figure 9. Drop mill hood below mixer.

A simple canopy hood was observed to capture the fumes from a sheeter mill operation. The details of this hood are presented in Figures 10 and 11 and in Table 11. This canopy hood is open on all four sides and functions as a receiving hood with a side take off. Although this particular hood was observed to function when there were no drafts, it is less desirable than the type of hood described by Figure 9.

Table 11. Design parameters for sheeter mill hood, Figures 10 and 11, pp. 37 and 38.

Parameter	Quantity	Note
Volumetric flow	100 $ft^3/min/ft^2$ (area under canopy)	In VS 902, ACGIH[9] specifies 125 $ft^3/min/ft^2$
Distance between rollers and bottom of canopy	4 ft	Minimize distance

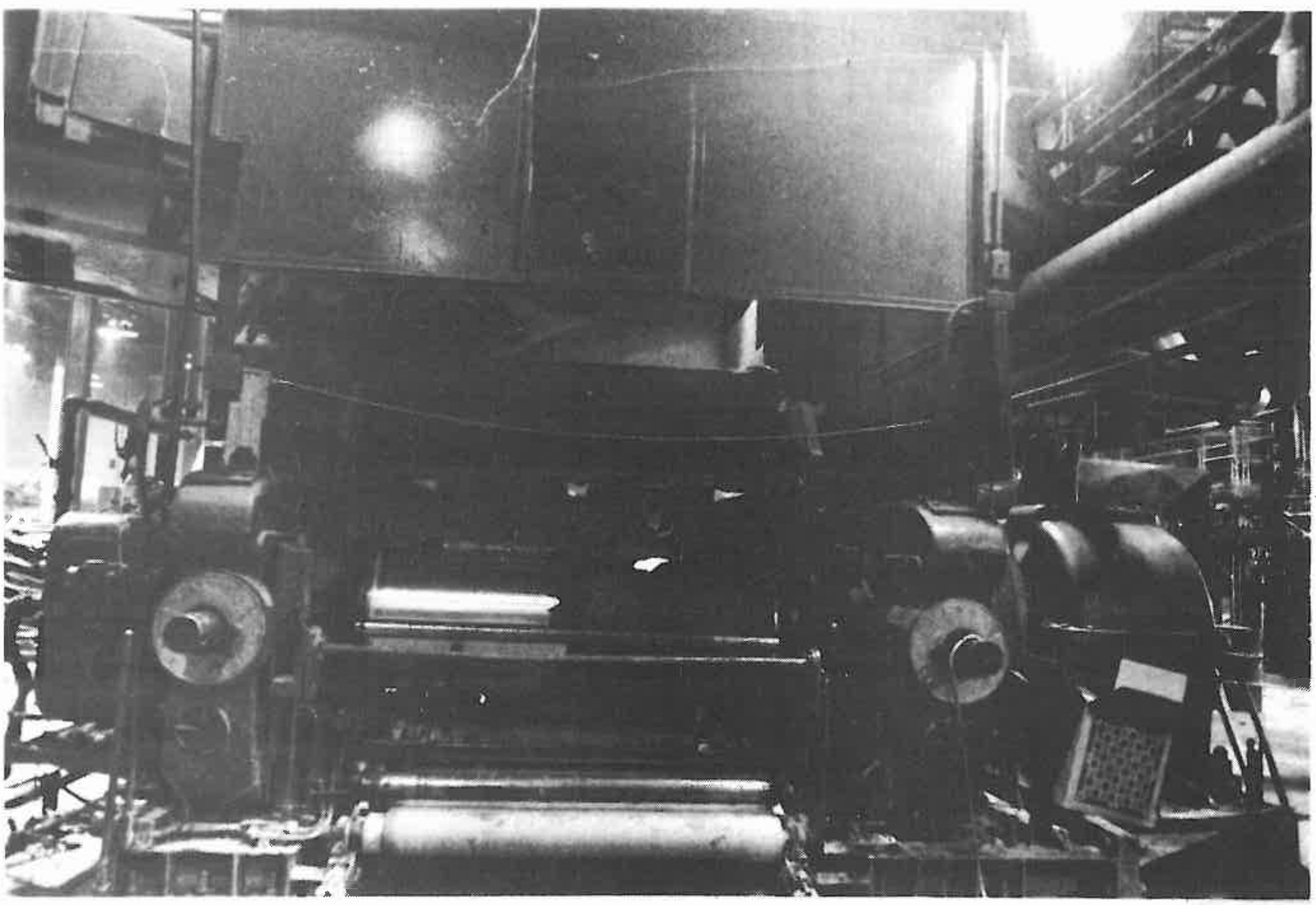


Figure 10. Sheeter mill hood.

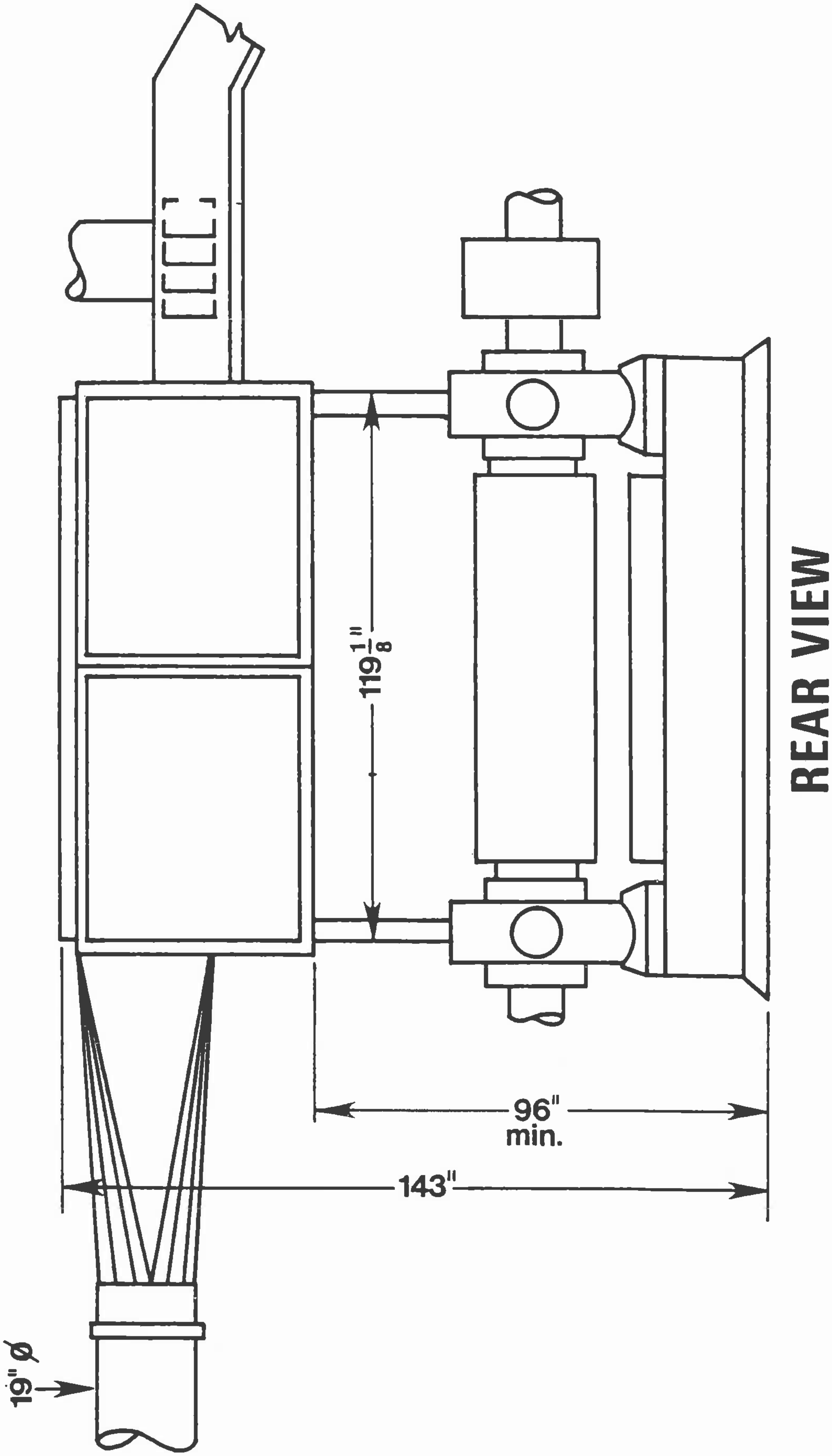


Figure 11. Drawing of sheeter mill hood.

During the study of batch-off systems, the ventilation systems noted in Tables 10 and 11 for a sheeter mill, roller die mill, and a drop mill were studied. A Transfer Mixer(R) continuously fed rubber into a sheeter mill. The sheeter mill continuously formed this rubber into sheet stock. A roller die mill is fed by an extruder which pushes the rubber into the bite of the mill. Drop mills are fed by opening the slide gate or drop gate of a mixer and dropping the rubber into the mill's hopper.

Observed Control Effectiveness

Ventilation was used on all of the mills that were studied in order to control the fumes generated during their operation. Based upon ventilation measurements and observations of fume leakage from hoods, the application of the ventilation to the sheeter mills and to the roller dies was deficient. The drop mill hood was the only mill hood among those studied which contained the fume. However, worker proximity to the mill allowed higher personal exposure than other mills. Sheeter mills and roller dies may be easier to ventilate because the workers do not have to work as close to these types of mills. As illustrated by the results in Table 12, this drop mill hood did not provide the worker with the lowest exposure. The operator of this mill was required to stand in front of the mill and manipulate the stock. Consequently, the operator's time-weighted average (TWA) concentration for total particulate had a geometric mean value of 0.75 mg/m^3. Stationary samples collected close to the mill indicated total particulate concentrations below 0.2 mg/m^3.

Table 12. Summary of personal sampling results for mill operators.

Total Particulate* GM	N**	Respirable Particulate* GM	N**	Comment
0.20	6	0.08	8	Transfer Mixer(R) feeding the horizontal sheeter mill did not require worker to stand in front of mill.[31]
0.75	3	0.34	3	This horizontal drop mill required the worker to manipulate the rubber on rollers. Personal exposures were therefore higher because of this proximity to the mill. This hood did control the fumes and kept the area relatively uncontaminated.[32]
1.22	8	0.40	8	This is a vertical roller die mill with a canopy hood. Cross drafts caused obvious fume leakage. The worker was located outside the hood.[33]

* - Geometric mean concentrations (mg/m^3).
** - Number of samples.

CALENDERING

Stock for tire cords and belts are formed by calendering rubber onto various types of steel cord and fabrics, i.e., rayon, nylon, polyesters, and fiber glass. The fabric is then fed into a friction calender which uses rollers to impregnate and coat the fabric with the proper amount of rubber to form a ply stock. The 3-roller calender coats one side of the fabric at a time, while the 4-roller calender coats both sides of the fabric in one operation. The ply stock is cut to proper length, spliced, and transferred to the tire building area.

Observed Engineering Control Techniques

Calendering rubber onto fabric results in the generation of a fume (see page 88 for information on fumes). Generally, canopy hoods are used to control these fumes, Figure IV-10, p. 111.

Observed Control Effectiveness

Table 13 summarizes the personal sampling results for the calender hoods studied. The two lowest concentrations were from 4-roll calenders that had the canopy hood 5 feet from the stock. Because the control panels for the 4-roll calenders were located away from the fuming stock, the workers' exposure probably reflects background contamination. The calender operator with the highest exposure worked a 4-roll calender and spent most of his time at the control panel which was located next to the take-off rollers. Because the canopy hood was 15 feet above the fuming stock on these rollers, the rubber fumes still contaminated the work station.

Table 13. Summary of personal sampling results for calendering operators.

Total Particulate GM*	N**	Grouping code***	Respirable Particulate GM	N	Comment
0.10	7	B	0.12	7	Canopy hood 4 to 5 feet above stock.[34] Total Particulate and Respirable Particulate GM's are not significantly different.
0.07	4	B	0.05	4	Canopy hood 4 to 5 feet above stock.[35]
0.40	6	A	0.30	6	Work station under canopy hood over 4-roll calender. Fume leaking from canopy hood about 15 feet above fuming stock.[36]

* - Geometric mean concentration (mg/m^3)
** - Number of samples
*** - GM's with different letters are significantly different. From ANOVA, probability of a larger F = 0.0002.

CEMENTING OPERATIONS

Undertread and tread end cementing is usually accomplished in exhaust ventilated enclosures. Cementing is done to help keep the tire together during the building process. Solvents from the evaporating cement are the main air contaminant in this process.

Observed Engineering Control Techniques

In undertread and tread end cementing operations, local exhaust ventilation was used to control the solvent emissions.

Observed Control Effectiveness

Tables 14 and 15 summarize the sampling results for the controls studied. With the exception of one inadequately maintained system, most of the controls maintained petroleum distillate (refined petroleum solvent) concentrations below the NIOSH recommended level[39] of 350 mg/m^3.

Table 14. Summary of petroleum distillate area concentrations for undertread cementing.

Range of Area Concentration GM*	N**	Comment
29-82	20	Partial enclosure.[37] Range of three geometric means.
350-800	20	Total enclosure, drying fan blowing contaminated air out of enclosure. Exhaust air less than 50 percent of design. Range of three geometric means.[6]
37-117	12	Partial enclosure.[38] Range of three geometric means.

* - Geometric mean concentration (mg/m^3)
** - Number of samples

Table 15. Summary of petroleum distillate area concentrations for tread end cementing.

Area Concentration GM*	N*	Comment
210	7	Manual with side draft hood[40]
50	8	Automatic[41]

* - Geometric mean concentration (mg/m^3)
** - Number of samples

CEMENT HOUSE OPERATIONS

Mixing and distribution of cement and green tire mold release agent are done at the cement house, Figure IV-8, p. 109. Occupational exposures to solvents in the cement house are controlled by local exhaust ventilation, dilution ventilation, good fittings and seals, and good work practices. The worker's primary exposure is to petroleum distillate, usually a naphtha. This solvent is used to make the various rubber cements used in tire production.

Observed Engineering Control Techniques

In the cement house, the workers' exposure to solvent vapors can be controlled by a variety of methods. LEV can be used to control petroleum distillate exposure while charging and draining mixing tanks. Work practices are also very important (see Section III). General dilution ventilation is needed to control workers' exposure to solvents evaporating from minor spills and leaking valves in 55-gallon drums.

Observed Control Effectiveness

Table 16 summarizes the results of sampling at the cement houses studied. The differences in concentration are not significant (Probability of a larger F = 0.4). Failure to provide adequate exhaust ventilation during these operations resulted in peak solvent exposures of 400 and 3,700 mg/m^3 at one plant.[40]

Table 16. Summary of cement house operator exposure to petroleum distillate vapors.

Concentration GM*	N**	Reference
169	7	42
157	3	43
147	7	44
92	4	45

* - Geometric mean concentration (mg/m^3)
** - Number of samples

CURING

Tires are cured in a tire curing press like the one shown in Figure IV-11, p. 113. Tire curing is the operation where specific temperature and pressure are applied for a period of time to vulcanize the rubber components in the final tire product. All the plants studied used automatic curing presses and a form of general ventilation to control worker exposure to curing fumes.

Observed Engineering Controls

A canopy hood/make-up air system or a dilution/make-up air system is often used to control fumes from the freshly cured tires. Make-up air is usually introduced by diffusers 10-15 feet above the floor, although some plants use floor vents. They are usually located just outside of the two press rows which are on both sides of a trench. They direct the airflow toward the floor at a 45-degree angle and parallel to the press row. The air flows under the curtains and passes the presses. Sometimes a rigid curtain is used to segregate the fresh make-up air from the air which has been contaminated with curing fumes, this is shown schematically in Figure 12. These curtains are extended from the ceiling to within 10 feet of the floor. When curtains are used, the roof and the curtains function as a large canopy hood.

The ventilation measurements made at these curing rooms are summarized in Table 17. Practically all of the curing rooms used about 6,000 cfm/press of dilution ventilation. When 3,000 cfm per press was used, curing fume was observed to accumulate in the space between the roof and the curing presses. However, this fume "cloud" did not affect the personal sampling results.

Table 18 summarizes typical design parameters. About 6,000 cfm per press of exhaust and make-up air, adequately controls fume. Make-up air diffusers located outside the press rows should provide a minimum of 3,000 cfm/press to avoid cross drafts from disrupting canopy hood performance. If adequate make-up air is not provided, the ventilation system's efficiency will be reduced and the worker's exposure might increase. It should be noted that the location of the exhaust stacks in relation to the make-up air intakes is crucial - the make-up air must not be contaminated by plant exhausts.[52,53,54]

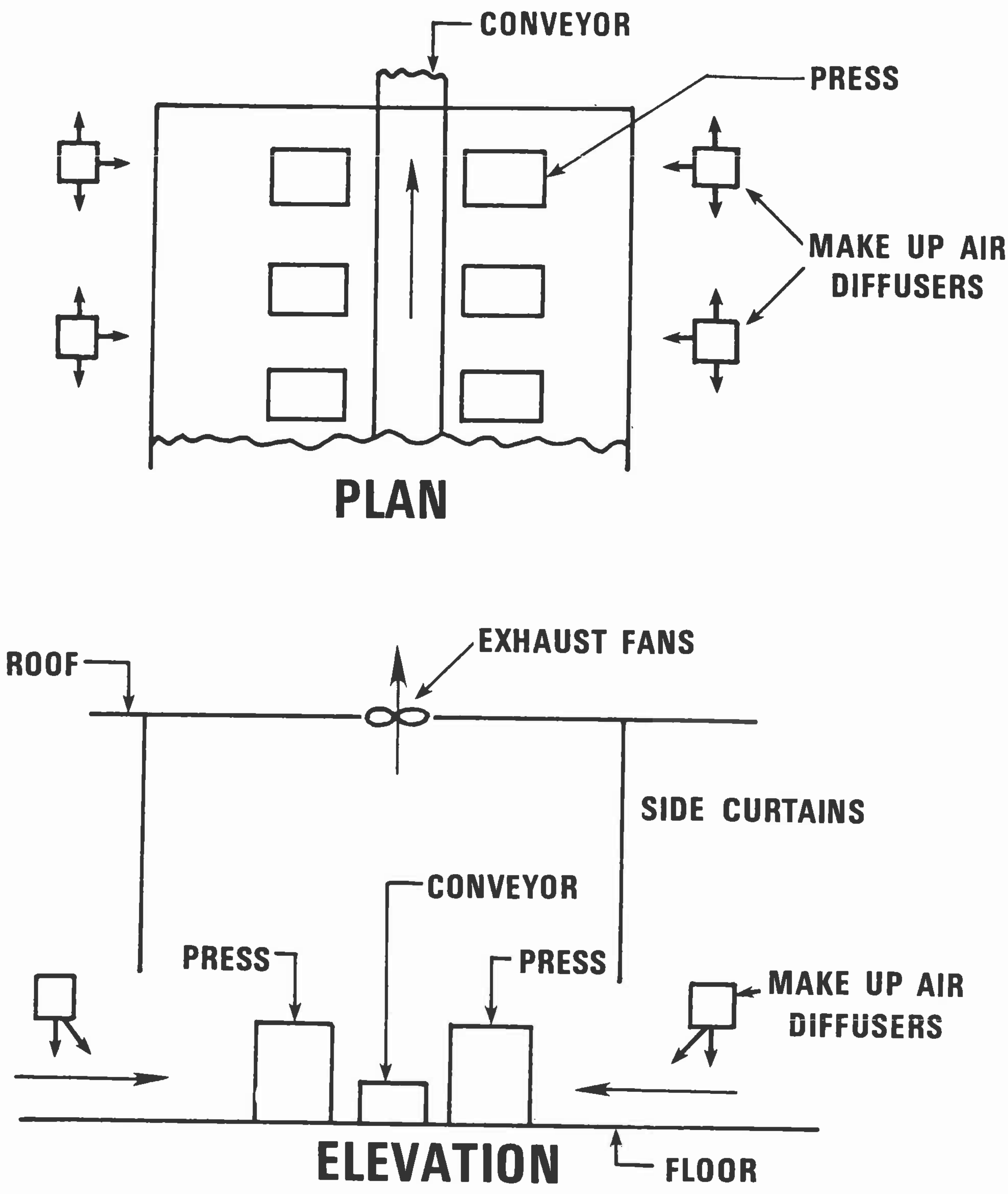


Figure 12. Schematic of ventilation layout for curing operations.

Table 17. Curing room ventilation measurements.

Ref.	Total Partic-ulate GM*	CFM/press** X10^3	Curtains	Notes
46	0.10	6	Present	
47	0.11	6	Present	1. Air velocities of 75-100 fpm were measured between curtains and floor.
				2. Make-up air diffuses every 30 feet along length of press row.
				3. Area sampling results were higher when make-up air units were off.
48	0.17	5	Canopy hood	1. Canopy hood over press row instead of curtain.
				2. Make-up air duct every 4 feet.
				3. Air velocities of 50 fpm between floor and edge of canopy hood.
49	0.19	6	Not present	
50	0.22	3	Not present	Make-up air supplied from floor.
51	0.22	7	Present	1. Fumes observed to escape from under curtains.
				2. Air velocities averaged 30 fpm around press row.
51	0.22	12	Not present	

* GM - Geometric mean (mg/m^3)

** Ventilation rates were measured; however, because of the complexity of the systems it was necessary to estimate the volumes.

Table 18. Design parameters for a curing press row.

Parameter Exhaust Rate	Specification 6,000 CFM/press	Comment
Exhaust Rate	6,000 CFM/press	
Make air from: (a) diffusers (b) other parts plant	 At least 50 percent of exhaust No more than 50 percent	 This reflects current practice.
Curtains	Location: 2 ft. outside of press row. Distance between floor and bottom of curtain: 9-10 ft.	

Observed Control Effectiveness

During the in-depth studies, personal sampling was done for both total and respirable particulate; Table 19 summarizes these results.

Manual presses were not observed in this study since the surveys were directed toward plants with better controls. Manual presses would, however, be expected to produce higher exposures than the automatic presses.[55]

Peak respirable particulate concentrations (measured with a TSI Model-3500 respirable aerosol monitor) frequently exceeded 1.0 mg/m^3 at the front of the curing presses when they opened. To eliminate or reduce this exposure, the job design and specified work practice should be formulated to ensure that workers will not be in front of newly opened curing presses. Aside from this, work practices appeared to have little effect upon worker exposures to curing fume at automatic presses.

Using the data in Table 19, its estimated that the geometric mean of the curing press operator's particulate exposure will remain below 0.3 mg/m^3. ANOVA showed that there were marginally significant differences in concentration among the different operations studied (Probability of a larger $F = 0.07$). Duncan's test showed that the curing fume concentration at one plant was significantly lower than the results at other plants. The reason for this is unclear. It is possible that the data reflect random variation about a single mean. The data and the statistical analysis do indicate that several approaches can be used to keep the geometric mean of the curing fume (Total Particulate) concentrations below the 0.3 mg/m^3 level.

Table 19. Summary of curing press operator exposures to aerosols.

Total Particulate GM*	Grouping N**	Grouping Code***	Respirable Particulate GM	N	Comment
0.10			0.05	1	Curtains.[46]
0.11	7	A	0.09	7	Curtains.[47]
0.17	8	A-B	0.15	8	Canopy hood over press row.[48]
0.19	8	B	0.15	8	General dilution ventilation.[49]
0.22	7	B	0.17	8	General dilution ventilation; make-up air supplied from floor.[50]
0.22	8	B	0.12	8	Curtains (only a few press rows curtained).[51]
0.22	8	B	0.13	8	General dilution ventilation.[51]

* - Geometric mean concentration for all plants studied (mg/m^3).
** - Number of samples.
*** - Plants with different grouping codes have significantly different sampling results. Plants which contain the same grouping code are not significantly different.

TIRE REPAIR - FINAL FINISH

During tire repair operations, workers use grinders to remove defects from the tire. Then, the tire is repaired and painted with a naphtha-based paint. Occasionally, the tire is spot-curred to correct a defect. These operations results in some solvent, noise, and particulate exposures.

Observed Control Effectiveness

Cured tire repair and final finish operations, shown in Figure 13, usually result in worker air contaminant exposures such as petroleum distillate, which evaporates from the cement, and particulate and fume generated by grinding and/or branding the tires. A ventilated tire repair table can be used to capture the grindings and the petroleum distillate which evaporates from the tire on the repair table. Table 20 summarizes the aerosol exposures of these workers. The differences in concentration in Table 20 were not significant (Probability of a larger F = 0.6).

Table 20. Worker exposure to particulate air contaminant during tire repair.

Total Particulate Concentration GM*	N**	Comment
0.17	8	Exhaust ventilation supplied from tires center on inclined table.[56]
0.18	8	Booth.[57]
0.17	8***	Exhaust ventilation supplied from center of tire.[58]
0.26	7***	Hood partially encloses tire which sits on rotating table.[59]

* - Geometric mean concentration, mg/m^3.
** - Number of samples.
*** - One value judged to be an outlier.

Figure 13. Photo of tire repair station.

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SECTION III. WORK PRACTICES

The process technology that is currently used in many operations of the tire building industry is labor intensive. Hopper/bin filling, weighing and batching, and other operations usually involve substantial amounts of manual materials handling with close worker proximity to dusts and fumes. In the long run, both productivity and occupational health may be aided by automating these potentially hazardous operations. For the present, work practices play an important role in reducing occupational exposure to dust and fumes from these operations.

RECOMMENDED WORK PRACTICES

General Work Practices

During the detailed studies, approximately 40 operations were observed. Based upon NIOSH observations, general work practice recommendations that could minimize a worker's dust exposure in these and other operations are:

1. Spills should be cleaned up promptly by wet cleaning or vacuuming. Dry sweeping or the use of compressed air creates airborne dust. Failure to adequately clean up spills can result in additional airborne dust due to normal work activities and can substantially add to personal dust exposures. If vacuuming is used, exhaust air should be adequately cleaned[1,2] or remotely exhausted.

2. Powdered chemicals should be handled carefully, using slow, even movements to avoid generating dust.

3. Work should be located, relative to the ventilation, so the clean air flows past the worker and into the hood. The farther the work is from the hood, the less effective the ventilation is at capturing dust (capture velocity decreases by the square of the distance).

4. If a ventilation system has access doors, they should be closed when they are not in use, as specified by the system design. Leaving these doors open reduces the exhaust volume to other locations. Other provisions of monitoring and maintenance (as discussed in other parts of this report) should be implemented to assure adequate ventilation.

5. Eating and food storage, drinking, smoking, and application of cosmetics in the work areas should be prohibited. Clean isolated areas should be provided for these activities.

6. Potential health effects associated with rubber chemicals should be posted or made available in the workplace.

7. Workers should wash up when leaving the work area to eat or take a rest break.

8. Protective clothing and equipment should be worn as prescribed. Provision for commercial cleaning or laundering of these items should

be made, and contaminated items should not be allowed to leave the plant except to be cleaned in the prescribed manner.

Criteria which can be used by non-technical persons for determining whether problems may exist in work practices or malfunctioning engineering controls are:

1. Employees' clothes are visibly contaminated with chemicals.

2. Smoke and haze is visible in the workplace air.

3. Local exhaust ventilation is not working satisfactorily, based on visible emissions from the equipment.

4. Chemicals are lying on the workplace floor.

5. Material is delivered to the worksite in broken or punctured bags.

6. Workers complain of eye, nose, skin, or throat irritations.

Bin Filling

The precise means of emptying a bag into a hopper will vary with the design of the hopper. The following represent examples of good methods that were used in a number of plants:

1. Bags containing chemicals should be gently lowered to or lifted from the floor. Rough handling can result in puffs of dust or in broken bags.

2. Powdered materials should be carefully poured into bins to minimize spillage. Spills should be cleaned up as they occur, preferably by vacuuming.

3. Bags should be emptied in well-ventilated enclosures. Provision should be made for disposal of the bags, preferably within a ventilated enclosure.

4. Empty bags should be handled gently. Throwing, dropping, squeezing, or violently crushing these bags disperses dust into the air and probably into the worker's breathing zone.

5. Areas where chemicals are handled should be kept clean and uncluttered.

Transfer and Weighing

Good handling procedures are a critical control parameter when transferring material from bins to the weighing scale. During manual weighing operations, the practices listed above and below are appropriate:

1. Dermal contact with chemicals should be avoided. Chemicals should be transferred with some type of scooping device so the worker does not

have to use his hands, bare or gloved. If chemicals become trapped on the inside of gloves, the gloves should be immediately removed, hands washed, and clean gloves put on.

2. When transferring chemicals with a scoop from a larger container to a bag, the scoop should be oriented so the material is dropped the minimum distance.

3. Smooth, even motions should be used in scooping rather than harsh, quick, or jerky motions. In order to avoid spilling chemicals when pouring them into containers, the forward motion of the scoop needs to be even and controlled.

4. When assembling batches of chemicals into a single bag, non-dusty material such as flaked wax should be put in the bag last. This technique will help suppress dust during transport and subsequent handling.

5. Responsibilities for keeping work areas clean should be clearly assigned, so that spills are cleaned up promptly. This may involve production, cleanup, or maintenance personnel. One effective option may be to provide the responsibility, the time, and the accountability for individuals to clean their own work areas.

The size and shape of the containers into which chemicals are placed appear to affect the dust exposure of the workers loading the mixer and, to a lesser extent, workers weighing out the batches of chemicals. Of the three types of containers observed (plastic bags, paper bags, and rigid containers, such as tote boxes), the plastic bags subjectively appeared to cause the least air contamination. These plastic bags could easily be twisted shut or the top of the bag could be folded under the bag, thus minimizing dust dispersion during transport. In some instances the worker could charge the unopened bags into the mixer, eliminating the need for bag opening, dumping, and disposal. The increased use of chemically compatible bags for weighing is a beneficial option. Flexible containers such as plastic garbage cans may pose a greater risk of lifting injuries than rigid containers with handles.

Mixer Loading Stations

In addition to the bag handling recommendations made earlier, the following practices apply:

1. Grates or grills over mixer exhaust ventilation system inlets should be kept clean. Although the local exhaust ventilation appears adequate, its performance can be impaired by a build-up of material on the grates or grills.

2. Access doors near drop gates and slide gates should be kept closed when not in use. Leaving these doors open reduces contaminant capture at the mixer.

3. The mixer charging and weighing conveyors should be kept clean. Dirty conveyors can create airborne dust.

Cement Houses

In cement houses, good solvent transfer systems are needed to minimize exposures to solvent vapors. Specific recommendations are:

1. Keep all solvent mixing vessels tightly closed. Empty containers often contain some residual solvent which can evaporate into the work room air.

2. Provide local ventilation for dispersing or withdrawing material from cement mixing tanks. If local exhaust ventilation is not provided, an industrial hygienist should be consulted to determine what ventilation or NIOSH-approved respirators should be provided.

3. Eliminate leaky spigots. Replace or repair leaking drums, vessels, valves, or spigots. Spigots should be of the "dead man" design. Use an enclosed or partially enclosed metal bucket, grounded to the drum, to catch drips.

4. Do not let open cans of solvent sit on the floor. Use approved safety containers where possible.

5. Follow fire safety rules and other safety practices. These should include (but not be limited to) proper containers, grounding of any pouring and/or receiving containers to prevent sparks, non-smoking areas, and explosion-proof equipment and non-sparking tools (especially floor scrapers).[3,4]

Hot Processes

Hot processes such as milling, extruding, calendering, and curing are generally less labor intensive than material handling operations. However, there are a few procedures which can also help minimize dust, vapor and fume exposure:

1. If possible, locate the work station away from the points of contaminant generation.

2. Avoid direct exposure at open curing presses. If a worker must be close to an open curing press, he should avoid the fume plume or use a NIOSH-approved respirator.

IMPLEMENTATION OF WORK PRACTICES

Effective implementation of work practice controls involves a number of elements. The following general items must be considered on a more specific, case-by-case basis for each situation:

1. Positive involvement of both workers and supervisors which lead to hazard recognition and control, as a daily objective, must be on the same level as production.

2. Engineering measures (process, ventilation, and ergonomic) should be explored as first levels of control to reduce direct workplace exposures.

3. Specific work tasks need to be identified, and standard operating procedures developed for performing these tasks (dust control and ergonomics).[5,6]

4. Adequate time during the production schedule must be allocated to perform production, maintenance, and cleanup activities as specified above.

5. Training must be provided so that production personnel know what they are expected to do and the reasons good work practices are important. They also need to be trained to recognize proper (and improper) operation of production equipment and ventilation systems.

6. Adherence to good practices must be consistently reinforced and the lack of adherence discouraged through appropriate motivational techniques.

7. A clear responsibility/accountability for keeping work areas clean needs to be established. Worker/supervisor cooperation should be stressed.

8. Continued monitoring of engineering, behavioral, and exposure parameters is necessary to ensure that the controls are functioning as intended. This may also require the establishment of target values or criteria and acceptable ranges for these values or criteria. For example, the use of a simple manometer to monitor pressure drop across filters in a spray booth.

The continued use of labor intensive materials handling operations may be undesirable from several viewpoints; strict adherence to specified procedures may be time consuming, difficult to enforce, and easy to defeat. These procedures may represent a recurring operating expense and an erosion of productivity. They may also result in substantially increased future costs due to long-term morbidity and mortality associated with higher exposures. Investment in improved process technology can avoid many of these problems. A good preventive health program can help produce long run medical cost containment. The use of reduced dusting formulations; pre-measured, containerized additives, product-compatible packaging; and automation are possible control approaches.

OBSERVED IMPORTANCE OF WORK PRACTICES

During compounding, bin filling, and mixer loading operations, many workers who (based on our observations) took special care to avoid generating dust had significantly lower dust exposures than other less careful workers who did the same job on different shifts with the same equipment. This conclusion is drawn from a series of detailed plant studies, in which dust exposures of pairs of workers doing the same job on different shifts were measured.[7,8,9] There were two pairs of workers emptying rubber chemicals from paper bags into hoppers and bins, and six pairs of workers were doing manual compounding.[10,11,12,13] In three of these eight pairs, there was a significant shift-to-shift difference in the workers' dust exposure which indicated that normal in-plant variability in work practices substantially affected dust exposures. For 13 of 14 workers, exposures were significantly higher than background dust measurements. This indicated that the task itself was an appreciable cause of dust exposure. Redesign of this task could perhaps reduce this exposure.

A review of the three cases where there were significant shift-to-shift differences in the workers' dust exposure illustrates the importance of good work practices. In two cases, workers were transferring chemicals from a portable hopper to a plastic bag mounted on a weighing scale. The workers with lower dust exposures appeared to take steps conscientiously which minimized dust dispersion. When transferring chemicals from the bin to the bag, they were more careful in their motions and appeared to spill less material than the other workers. Before emptying the scoop or shovel into the bag, they placed the scoop or shovel in the bag as far as possible. In contrast, the worker with higher exposures poured the chemicals from a few feet above the bag and was generally less careful. As a result of these work practices, the average dust exposure experienced by workers using better work practices was 1 mg/m^3. The other workers were exposed to 3.0 mg/m^3. Material handling procedures were apparently responsible for a 3-fold increase in the workers' dust exposure over a full shift.[12,13]

There was a significant variability in materials handling operations. This observed variation in worker exposure points to a need for both better implementation of work practices and for production systems which depend less on behavior for controlling exposures.

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SECTION IV. RESEARCH RECOMMENDATIONS

During the literature review and field studies conducted to develop this document, it became apparent there are a number of research and/or information needs relative to the rubber industry.

A. Hazard Recognition and Evaluation

1. A comprehensive review of health hazards in the rubber industry should be conducted.

   In Appendix III, a brief review of the health hazards in the rubber industry show a discrepancy between historically reported health effects and relevant standards and current extent of exposure data. The extent of exposure data shows that this industry is essentially in compliance with OSHA chemical health standards. However, only a few (approximately 4%) of the chemicals used in tire manufacturing have Federal OSHA health standards. The historical health effects literature reports excessive cancer and respiratory disease among rubber workers. Current epidemiology and continued hazard evaluation (including toxicology and bioassay studies) are needed to reconcile this apparent discrepancy.

2. Methods for evaluating exposures to the fume and vapor components of the total fume generated should be developed.

B. Hazard Control

1. Engineering

   a. Evaluation of methods for transporting (including materials of construction) "tacky" aerosols from the work area.

      At one plant, heavy accumulations of material in ducts for a pelletized dewatering hood and for a calendering hood were found.[1] The deposited materials appeared to be sticky and to adhere to the walls of the duct.[1,2]

   b. Capture velocity formulas in the ACGIH Ventilation Manual should be reviewed and revised, if necessary.[4]

      At a compounding operation,[5] the capture velocities predicted by the equation for a flanged slot hood in the ACGIH manual were considerably different from the observed measurements. This suggests that the equations for flanged slot hoods may need improvement.

   c. Better information regarding flow of powdered or granulated materials in bins and other equipment is needed. This information would be useful both to designers and to production personnel. This was a major problem in many plants and created numerous exposure problems for process workers and maintenance crews due to plugging, bridging, or equipment failure.

d. Controls for noise should be evaluated.

Based upon OSHA compliance data, the control of noise exposure is a problem in the tire manufacturing industry. A study of noise controls used in this industry would identify the best controls in use and would allow for the formation of more specific research recommendations to fill needed gaps.

e. A better method for measuring the "dustiness" of solid materials should be developed.

If a standardized test were developed, companies ordering materials could specify some unit of "dustiness" that could be accepted and thereby reduce the dust generated in specific operations.

Assuming this can be accomplished, then work with suppliers of powdered additives to develop reduced dusting formulations should be encouraged.

f. Other methods of dust control in hopper/bin filling and manual weigh-out and transfer operations should be investigated.

This may involve a combination of automated/isolated work stations as well as other techniques such as push-pull ventilation, good work practices, and reduced dusting formulations.

2. Work Practices

a. Techniques which motivate workers and their supervisors to use good work practices should be evaluated.

b. Techniques to determine specific work practices which reduce air contaminant exposures need to be standardized. Specific recommended work tasks and/or work station design procedures need to be validated.

REFERENCES - SECTION IV

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APPENDICES

APPENDIX I

RESULTS OF PRELIMINARY STUDIES

During the thirteen preliminary surveys, observations were made and air samples were collected and analyzed. The observations served as a basis for selecting plants for inclusion in a detailed study. The seven plants selected for detailed surveys exhibited significant variation in control approach and manufacturing methods.

Tire plants with good controls are able to maintain relatively low dust, fume, and solvent concentrations. Table I-1 summarizes median air contaminant concentrations that were expected during the detailed studies. The amines which had been reported as contaminants in rubber chemicals were not detected in the five plants where samples were taken. Consequently, sampling for these amines was terminated. Table I-2 presents the results of polycylic aromatic hydrocarbons (PAH) sampling and lists the detection limits for each analyte. The detection limit presumes a nominal sample volume of 360 liters. Actual sample volumes ranged between 330 and 370 liters.

Table I-1. Expected geometric mean air contaminant concentrations for detailed studies.[1]

Location	Contaminant	Mean Concentration
Processing areas including compounding, banbury loading	Total particulate	1-2 mg/m^3
Milling, curing	Total particulate	Below 0.5 mg/m^3
Cement house and tread cementing	Petroleum distillate Benzene	Below 300 mg/m^3 Below 1 ppm

Table I-2. General area PAH concentrations (ng/m^3).

Sample Number	Location	Fl	Py	B(a)A	CHR	B(k)F	B(a)P	Cyclohexane Solubles mg/m^3
		CONCENTRATIONS* - ng/m^3						
1	Curing	ND	16.6	ND	25	ND	ND	0.34
2	Milling	ND	ND	30	180	ND	ND	0.40
3	Milling	ND	ND	27	133	ND	15	0.11
4	Curing	ND	ND	ND	12	ND	ND	0.27
5	Curing	212	ND	ND	ND	ND	ND	0.20
6	Curing	ND	ND	ND	ND	ND	ND	0.26
7	Curing	38	ND	ND	ND	ND	ND	0.19
8	Milling	ND	ND	ND	16.7	ND	5.8	0.37
9	Milling	16.7	ND	ND	ND	ND	ND	0.13
10	Curing	11.6	ND	17.2	80	ND	22.9	0.34
11	Milling	149	ND	ND	31	ND	ND	0.067
12	Milling	ND	ND	9	ND	ND	5.8	0.59
13	Curing	ND	22.9	ND	ND	ND	17.2	0.63
14	Curing	ND	22.9	ND	ND	20	ND	0.12
15	Curing	ND	ND	ND	ND	ND	ND	0.20

Detection limits (ng/m^3) based on 360 liter samples are below in parenthesis.

Fl = Fluoranthene (11)
Py = Pyrene (8.3)
B(a)A= Benz(a)anthracene (5.5)
ND = Not Detected

CHR = Chrysene (11)
B(k)F = Benzo(k)fluoranthene (11)
B(a)P = Benzo(a)pyrene (5)

During the preliminary surveys, air samples were collected to ensure that the samples collected during the detailed studies would be meaningful and appropriate. The literature review suggested that workers might be exposed to potential carcinogenic amines such as n-nitrosomines, alpha- and beta-naphthylamine and 4-aminobiphenyl and to PAH. In Britain, these amines were reported by Munn[1] to be contaminants in rubber chemicals (see Table III-6 for summary of findings). The PAH's are adsorbed onto the carbon black and are dissolved in extender oils, both of which are used in tire manufacturing. Possibly, hot operations such as curing or milling might desorb the PAHs from the stock.

The control of occupational exposures to the PAH's and the amines mentioned above as air contaminants fall within the scope of this study. The literature summarized in Appendix III suggests that these compounds might be contaminants in the tire manufacturing industry. To determine whether these compounds are present as air contaminants in tire plants, air samples for these compounds were collected during preliminary surveys.

In tire manufacturing, air contaminant concentrations are usually reported in terms of total particulate or specific organic compounds found in naphtha. Contaminant concentrations are generally lower in areas where controls are very good, therefore, preliminary air samples for total particulate and solvent vapor were taken to determine an appropriate sample size.

Tables I-3 and I-4 summarize the types of samples collected, analytes, and the sampling and analytical procedures used during the preliminary studies. Time limitations required that these samples be taken over a 4-hour period at locations where a control appeared to work well enough to be part of a detailed study.

DISCUSSION

The preliminary studies show that the concentration of total solvent, benzene, and total particulate should be measured during the detailed studies. The solvent samples should be collected with a 20 to 30 liter sample volume. The sample volume for the total particulate samples should be increased to 0.75 m^3 in order to collect an 0.5 mg sample.

The total solvent samples showed that specific compounds such as n-hexane, n-heptane, n-pentane, toluene, and benzene were only 25-40 percent of the total solvent present. Analysis by gas chromatography and mass spectroscopy showed that the solvent used in the cement house and tread cementing operations was basically a naphtha composed of C_4 - C_8 alkanes with a few aromatics.

Table I-3. Substances sampled and analytes from preliminary studies.

Substance Sampled	Analyte
Total particulate	Total weight of material collected on filter
Solvent vapor	Total solvent collected
	Benzene Xylene Toluene Pentane Hexane Heptane
Rubber chemical contaminant	4-Aminobiphenyl Alpha-naphthylamine Beta-naphthylamine
Polycyclic aromatic hydrocarbons	Cyclohexane solubles Fluoranthene Pyrene Benz(a)anthracene Chrysene Benzo(k)fluoranthene Benzo(a)pyrene

Table I-4. Summary of sampling and analytical methods used during preliminary studies.[2]

Substance	Sampling and Analytical Method
1. Total particulate	360 liters of air are drawn through a preweighed, 37-mm Gelman DM 800 filter. NIOSH Sample Data Sheet 29.02.
2. Solvent vapors	20-30 liters of air are drawn through a charcoal tube containing a 100 mg and a 50 mg section of charcoal. The analysis described by Grote and Holtz consisted of desorption in carbon disulfide gas chromatography and detection by a mass spectrophotometer.
3. Rubber chemical contaminants	Alpha naphthylamine NIOSH method 264 Beta naphthylamine NIOSH method 264 4-Aminobiphenyl NIOSH method 269
4. Polynuclear aromatic hydrocarbons	A 360 liter sample of air is drawn through a fiberglass filter mounted on top of a silver membrane filter. These filters are backed-up by an SKC porous polymer tube. The analysis for specific PAH's was done with a high performance liquid chromatograph and a fluoresence detector.

Fifteen samples, collected at four tire plants during preliminary visits, were analyzed for total cyclohexane solubles and for six specific PAH's, Table I-2. The reason for this analysis was to determine whether the analysis of PAH's should be considered for the in-depth study.

A variety of PAH's have been detected in the air. Because of its strong carcinogenic properties, benzo(a)pyrene B(a)P has been the most extensively monitored. Unfortunately, outdoor air pollution concentrations are not widely available for the other PAH's listed in Table I-2. The samples were collected by the National Air Surveillance Network (NASN) method and analyzed for B(a)P.[3] The national annual average of the B(a)P concentration, evaluated from these data, is 1.42 ng/m^3 in 1970 and 0.7 ng/m^3 in 1977. Seasonal and local variations caused individual values in 1970 to range between 0.1-41 ng/m^3 and in 1977 this range was 0.2 to 3 ng/m^3.

The data, obtained from the air sampling network, is based on high volume sampling. While studying PAH's in coal tar and coke oven emissions, White[4] found high volume sampling results in B(a)P concentrations that are eleven times lower than those obtained using a personal sampling pump or a low volume. To compare high volume sampling results to low volume sampling results, the values for B(a)P using the high volume samples should be multiplied by a correction factor of 11.7. After applying the correction factor, the corrected annual average concentration of B(a)P will be 8 ng/m^3 (0.2 to 34 ng/m^3) in 1977 and 17 ng/m^3 (1 to 480 ng/m^3) in 1970. Therefore, B(a)P concentration values found experimentally are comparable with those found in the ambient air.

The proposed standard for the allowable concentration of B(a)P, recommended by the Standard Advisory Committee on coke oven emissions,[5] calls for a maximum limit for employee exposure of 200 ng/m^3 of B(a)P of air averaged over an 8-hour period. This limit sets a level above which no employee exposure is permitted. Obviously, the limits of detection for B(a)P's listed in Table I-2 are well below these recommended TWA's. The proposed standard[5] also suggests that some samples collected for B(a)P evaluation shall be analyzed for PAH, such as benz(a)anthracene, chrysene, benzo(b)fluroanthene, etc. by methods with a sensitivity of at least 50 ng.

The data shown in Table I-2 indicate that in most cases the concentration of PAH's is below their detection limit. The concentration of B(a)P, for which much ambient data is available, are comparable with those obtained from the analysis of the ambient air. Consequently, PAH sampling was not included in the detailed studies.

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APPENDIX II

AIR SAMPLING CONSIDERATIONS - DETAILED STUDIES

During the detailed studies, the time weighted average concentration of total suspended particulate, respirable dust, and various solvents were measured using a 7- to 8-hour sampling period. Area samples were collected to determine background concentrations and to indicate important sources of air contamination. Personal samples were collected to determine the effectiveness of a control at limiting the worker's exposure to air contaminants. In order to quantitatively determine the effect of work practices upon the workers, exposure samples were collected on two shifts for four days.

The concentration differences between workers and between sampling locations and workers were used to judge the importance of good work practices, the importance of the sources of emissions, and the effectiveness of a control. Area samples were collected near the control, near the emission sources, and away from the operation under study. For an ideal operation, all concentrations should be low and there should be no difference between personal and area sampling results. The lack of differences indicates that the job tasks do not contribute to worker exposure. A significant difference between the concentration measurements, suggests that an emission source is not being controlled adequately. Because the experimental data has considerable variability, the significance of the concentration differences was evaluated by analysis of variance (ANOVA) and Duncan's Multiple Range Test.

METHODOLOGY

The total particulate and respirable dust concentration were measured by using personal sample pumps to draw air through preweighed filters. The details of the sampling procedures are described by NIOSH Sampling Data Sheet 29.02.[1] The filters and blanks were returned to the laboratory for post weighing. The weight gain, after applying a blank correction, is presumed to be the weight of contaminant collected on the filter. The blank correction was based upon at least six filters which were handled the same as the sample filters with the except the plugs were not removed from the filter cassette and no air was drawn through the blank filters. Typically, blank filters lost an average of 0.05 mg with a standard deviation of 0.01 to 0.02 mg. Each filter was preweighed and postweighed twice.

Solvent vapors at the tread lines and in the cement houses were sampled by drawing 20 to 30 L of air through standard charcoal tubes, at a known rate between 50 and 150 mL/min. The charcoal tubes have a 4-mm inside diameter and contain a 100 mg section and a 50 mg section of coconut shell charcoal. As described by NIOSH method P&CAM 127,[2] these samples were analyzed quantitatively for benzene, toluene, xylene, and naphtha by desorption in 1 mL of carbon disulfide, and subsequent analysis in a gas chromatograph equipped with a flame ionization detector. Naphtha standards were prepared from a bulk sample of the naphtha collected at each plant. The chromatograms obtained from the bulk samples matched the chromatograms obtained from the charcoal tubes.

In areas such as the compounding department, banbury, and final repair stations,the particulate is presumed to be a dust. Consequently, MSA's FWS-B filters were used in these areas to collect the dust. The FWS-B filter is a PVC membrane filter with a nominal pore size of 5 microns. In areas where a rubber fume was being generated, such as curing, milling and calendering, the Gelman DM-800 filter was used for particulate collection. This filter is made of a PVC acrylonitrile co-polmer material with a 0.8 micron pore size. Unfortunately, some lots of these filters lost weight when they were used for sampling. Weight losses of 1 to 2 mg were observed by NIOSH researchers for filters obviously loaded with particulate. All DM-800 filters used in this study were from lots which did not exhibit this weight loss. Because a limited number of filters from these lots were available the number of fume samples was restricted.

FILTER COMPARISON

Unfortunately during the first detailed study, the supply of good DM-800 filters was exhausted. Consequently fume samples were collected with the MSA FWSB filters. In milling and calendering areas, this is probably not a serious error. Based upon simultaneous total and respirable dust samples, usually less than half the mass of the fume is respirable.

Samples taken between two curing presses were used to compare the Gelman DM-800 and the MSA FWSB filters. Three filters of each type were connected by three separate pieces of tubing to three critical orifices. The critical orifices were connected to a manifold. The manifold was maintained at 25 inches of mercury vacuum by a carbon vane pump. The experiment was replicated once. The results are presented in Table II-1. This data was transformed by taking the common logarithms and analyzing them by analysis of variance techniques using day as a classification variable. These results are presented in Table II-2. This analysis indicates that day was highly significant and that the filter and filter-day interaction was significant at a level of confidence between 90 and 95 percent. Duncan's Multiple Range Test, at a 95 percent level of confidence, shows that on Day 2 the FWSB filters collected significantly less material than the Gelman DM-800 filters. For Day 1, this was not significant.

Table II-1. Comparison of filter samples.

	Total Particulate Concentrations (mg/m^3)	
Day	DM 800 Filters	FWSB Filters
1	0.150	0.156
	0.157	0.137
	0.130	0.149
2	0.119	0.074
	0.115	0.102
	0.115	0.099

Table II-2. Analysis of variance of filter data.

Source of Variation	Degrees of Freedom	Mean Square	F	Probabiltiy of Larger F
Days	1	7.013×10^{-2}	32.5	4.5×10^{-4}
Filters	1	7.822×10^{-3}	3.6	9.3×10^{-2}
Day - Filter (interaction)	1	9.66×10^{-3}	4.5	6.7×10^{-2}
Error	8	2.16×10^{-3}		

This data indicates that the FWSB filters collected curing fume concentrations were 90 percent of those found by the Gelman DM-800 filters. This is consistent with the results of Liu.[3] Liu reported that the efficiency of 5.0 micron pore-size Teflon(R) membrane filters fell from 100 percent for 1.0 micron aerosols to 80 percent for 0.01 micron aerosols. For 1.0 micron pore size Teflon(R) membrane filters, the efficiency remained for all practical purposes at 100 percent. This suggests that the curing fume can penetrate the MSA FWSB filters while this fume does not appreciably penetrate the Gelman DM-800 filters.

Although there was some indication the MSA FWSB filters may not be an appropriate filter to sample curing fumes, this filter was used in one curing room. The 20 percent bias that this might introduce into the sampling results would be relatively minor compared to the day-to-day and position-to-position sampling variability observed in this study. Based upon the least significant range from the Duncan's Multiple Range Test used to analyze the log-transformed concentration data, two geometric medians would need to be different by at least a factor of 1.8 in order for the difference to be significant. Occasionally this factor reached 3.0.

STATISTICAL ANALYSIS OF THE DATA

The concentration data for a given control was analyzed by analysis of variance and Duncan's Multiple Range Test.[4,5] Before the data is analyzed, the individual data is log transformed. Following transformation the data is analyzed by analysis of variance to determine whether there are any important shift, sampling location, or shift sampling location interaction effects. A typical analysis of variance table is shown in Table II-3. The last column in this table is the alpha error associated with assuming that there is a difference. The sources of variation were assumed to be significant when the alpha error was 0.05 or less. This determined whether a main effect or an

Table II-3. Typical analysis of variance.

Source of Variation	Degrees of Freedom	Mean Square	F	Probability of Larger F
Shift	1	0.459	20.2	1.59×10^{-4}
Location	4	0.779	34.4	10^{-6}
Shift-Location	4	0.155	6.8	1.8×10^{-3}
Error	30	2.26×10^{-2}		

interaction was significant. Then difference in means of the different treatment cells were examined by Duncan's Test to determine which differences were significant. If either the shift-term or the shift-location term was significant at an alpha error of 0.1 or less, treatment cells consisted of the concentration data collected on a given shift at a given location. When the shift-term and the shift-location interaction term were both insignificant, treatment cells consisted of all the sampling data collected at one location.

The data indicated relatively high amounts of background variability. The geometric standard deviations computed from the ANOVA mean square error (MSE) were between 1.4 and 2.0, in order for the difference to be considered significant. The application of Duncan's Test showed that two geometric means needed to be different by a factor of 1.8 to 3.0, depending upon the MSE, degrees of freedom, and number of medians to be examined. These results are consistent with the observations of Leidel et al.[6] They examined data from NIOSH health hazard evaluations and found industrial hygiene air sampling data to be log-normally distributed with geometric standard deviations ranging between 1.2 and 2.5.

Duncan's Multiple Range Test requires some explanation. It is used to test a group of means for significant differences at an overall level of confidence of 95 percent. In the present study, the means are the means of log-transformed concentration data. The least significant ranges determine whether there are significant differences among a group of means. To make these numbers somewhat more understandable, the mean, least significant range, and standard deviation are transformed by taking their inverse logarithms. The means become geometric medians. The least significant ranges become least significant ratios. The ratio of a large median to a smaller median must exceed this value in order for the difference to be significant. The square root of the MSE becomes a geometric standard deviation (GSD).

The least significant ratio is affected by the MSE from the ANOVA of the number of medians to be compared and the number of data points used. Figure II-1 shows the effect of the latter values upon the least significant ratio for comparing four median values. In this figure, if you have the means from four groups (sampling locations) and the pooled GSD, from the ANOVA, is 2.0 then the sample size is very improtant in determining the statistical significance of the differences. In this case, if there are only 2 replications per mean then a difference of 700 percent would be necessary before the difference could be due to something other than chance. In contrast, if there are 8 concentrations per mean, a difference of only 200 percent would be necessary before the difference could be due to something other than chance. The sensitivity of Duncan's Test to detect differences between medians will vary among the different case histories in the plant reports.

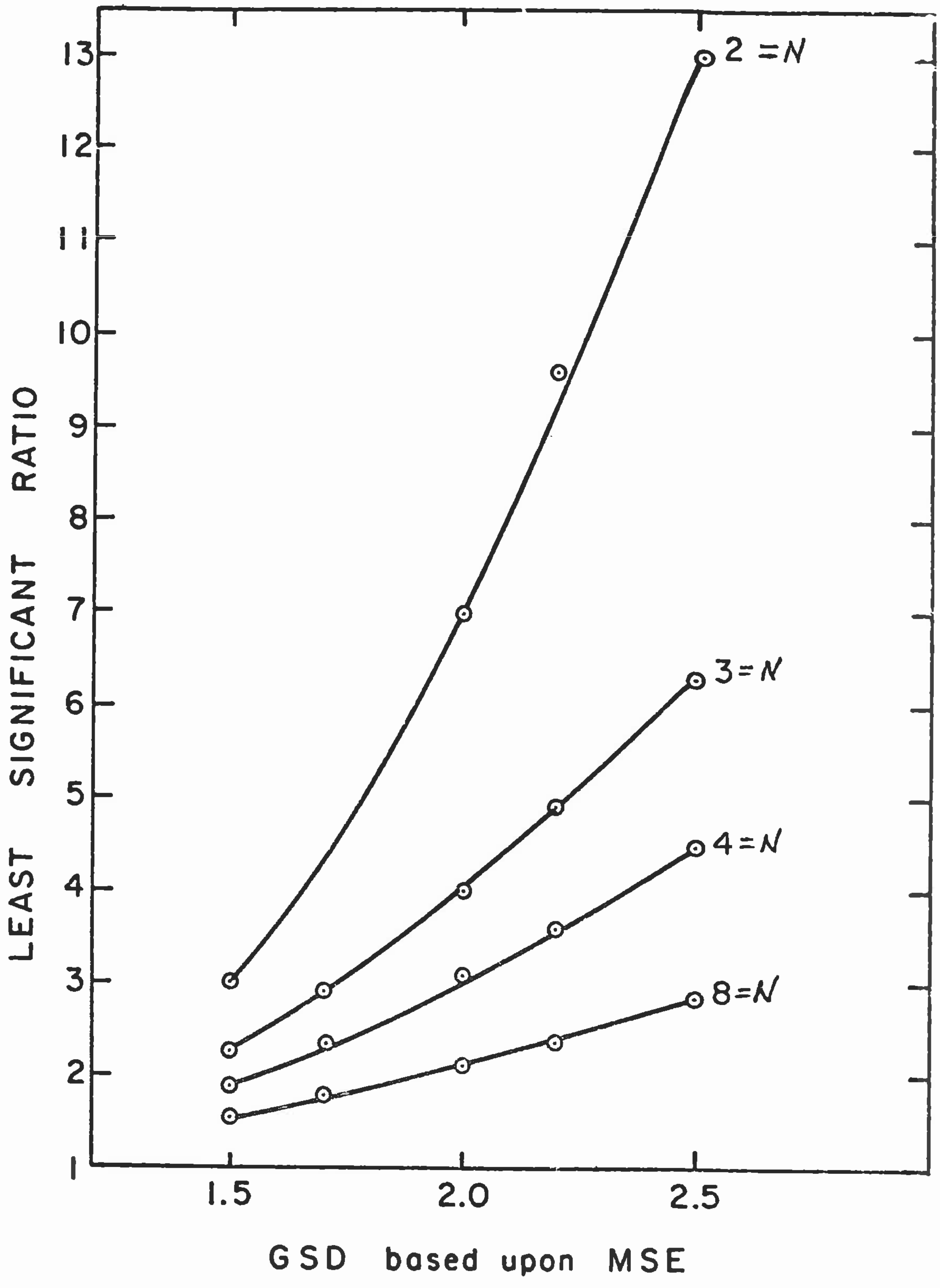

Figure II-1. Least significant ratio for evaluating the ratio of the largest to the smallest geometric mean for a group of four means with N replications per mean.

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APPENDIX III

REVIEW OF HEALTH HAZARDS IN THE RUBBER INDUSTRY

Although this report deals with the tire manufacturing industry, the health hazards present in many aspects of the rubber industry are reviewed in this appendix. In the occupational health literature, the distinction between tire and non-tire rubber workers is not always made. For example, the first 10 references in this appendix largely deal with the tire industry. However, the word "tire" is not mentioned in any of the titles for these references. As a result, this section deals with health hazards in the rubber industry which includes tires.

During rubber manufacturing, workers are exposed to a variety of hazardous chemical substances and harmful physical agents. Exposures to these stresses are reported to result in serious health hazards. Although standards, recommended standards, and threshold limit values (TLV's) exist for few of these substances, there are many health hazards for which no recommended or suggested standards exist. The latter hazards are beyond the scope of this work.

REPORTED HEALTH EFFECTS

Increased incidences of respiratory disease and cancer have been reported among tire workers.[1,2] Lednar found workers in curing preparation, curing and finishing, or inspection had an increased incidence of pulmonary disability retirement.[1]

Fine and Peters[3,4,5,6] reported increased respiratory morbidity among rubber workers in curing rooms and processing areas, and among workers exposed to talc. Among curing room workers, they reported increased prevalence of chronic and acute bronchitis and chronic obstructive lung disease (COLD). Workers exposed to curing fumes for more than a 10-year period were found to have statistically significant and "excessive" losses of their forced expired volume ($FEV_{1.0}$). In one year, these workers lost 173 mL of $FEV_{1.0}$ as opposed to 40 mL for controls. Because people typically have an $FEV_{1.0}$ between 2.0 and 2.5 L and because a $FEV_{1.0}$ of 1.5 L is indicative of COLD, Fine and Peters characterized such losses as excessive. Because of the small sample sizes involved, they were unwilling to estimate the future incidence of COLD among curing room workers.

Among processing workers with 10-years experience, Fine and Peters[5] found increased respiratory morbidity. Limited sampling showed that these workers were exposed to respirable dust concentrations of 1 to 5 mg/m^3. Based upon pulmonary function tests, Fine and Peters concluded that 40-years exposure to processing dusts would result in clinically apparent and disabling dyspenea. Based upon an average exposure concentration of 2 mg/m^3 which related to definite decreases in pulmonary function, they suggested an 8-hour TLV of 0.5 mg/m^3 of respirable dust.

Among rubber workers exposed to talc for 10-years, Fine and Peters[6] found a significantly greater prevalence of productive cough and positive criteria for

COLD. Based upon analysis of pulmonary function tests, they predicted current talc exposures would cause some workers to have significant dyspnea and pulmonary disability. Consequently, a TLV between 0.5 and 0.25 mg/m^3 for respirable talc was recommended.

Gamble[7] and Peters[8] observed the association of excess cancers (stomach, lung, and bladder) with occupational titles. Manson and Nakano[9] studied the mortality of rubber workers and found excess cancer deaths in specific sites and job classifications. They found "processing workers" had excess cancers of stomach and large intestines; "tire builders" had excess cancers of brain and lymphatic system; excess lung cancers were observed in the curing room workers; and excess leukemia occurred among all tire workers. However, in a case control study of lung cancer among rubber workers, Delzell, et al,[10] observed that curing room workers did not have an excess risk of developing lung cancer relative to other workers. In a case-control study of leukemia in the U.S. rubber industry, Wolf[11] reports a significant excess of lymphatic leukemia among compounding and mixing workers at one out of four companies studied. In the British tire industry, excess stomach and lung cancer have also been reported.[12]

In reviewing the world literature on cancer in the rubber industry, the World Health Organization (WHO)[13] concluded that there are definite excesses of bladder, stomach, and lung cancer and leukemia in the rubber industry. Furthermore, they stated bladder cancer was causally associated with aromatic amine exposure and leukemia was associated with solvent exposure. Limited evidence was available to casually associate stomach cancer with compounding, mixing, and milling.

The International Research Agency on Cancer of the WHO[13] prepared and published the following summary:*

> "Evidence of increased cancer rates in rubber workers arose when Case reported a substantial excess of bladder cancer among rubber workers in the UK, particularly in Birmingham. Among British rubber workers, the death rate from bladder cancer during 1936-1951 was almost double that of the general population. A subsequent study of workers in the British cable-making industry also indicated an increase in bladder cancer risk. A study of bladder cancer incidence in two British tyre manufacturing plants showed a doubling of the rates:

*"Reproduced, with permission, from IARC (1982) <u>IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans,</u> Vol. 28, <u>The Rubber Industry</u>, pp. 219-221.

excesses were related particularly to exposures in milling, mixing, calendering and maintenance jobs. In two further mortality follow-up studies in the UK it was reported that excesses of bladder cancer mortality were virtually confined to workers first employed before 1950.

Subsequent to preliminary observations of cancer in the rubber industry by Mancuso in the US, follow-up studies of mortality were carried out among rubber workers in the Akron, Ohio, factories of three large rubber companies; these showed either an overall deficit of bladder cancer (one factory) or a small excess (two factories). In the largest of the three factories, the excess was greatest among workers first employed before 1935 and among those who had worked for more than 35 years. A case-control study of bladder cancer in rubber workers in Akron, Ohio, showed an approximate doubling in risk for milling and calendering workers in one factory.

In the follow-up studies of rubber workers in both the US and the UK, excess mortality from a number of other cancers has been reported. Some excesses were found in an entire factory population, and others in rubber workers in specific job categories. Within the US, these follow-up studies prompted a number of site-specific case-control studies of cancer within the same population of rubber workers.

Each of three US follow-up studies of male rubber workers within specific factories revealed more deaths than expected from cancers of the stomach and of the large intestine. In one of the studies, the excesses were noted primarily in workers in jobs early in the production line, where exposures are chiefly to particulates but also to some fume from uncured rubber. A case-control analysis of stomach cancer in the second of these studies showed a positive association with work early in the production line and with that in curing preparation and in maintenance. Further analysis, according to estimated exposure to specific agents, showed a positive association with exposure to talc. In one study in the UK, mortality from stomach cancer was increased among all workers, but particularly among men in jobs early in the production process. In a second study in the UK, excess mortality from stomach cancer was also observed among all workers, but not among particular occupations.

Excess mortality from lung cancer was found in one UK study in workers primarily in the non-tyre sector. In a second UK study, an excess of lung cancer was found among workers in many occupations in the tyre and non-tyre sectors. Excess cases of lung cancer in the US follow-up studies were associated with work in compounding and mixing, extrusion, tyre curing, rubber reclaim, and fuel-cell and de-icer manufacturing. Cancer of the prostate was associated with compounding and mixing and with calender operation in one US study and with general service and maintenance jobs in two. A case-control study on one factory revealed an excess of prostatic cancer in "batch preparation jobs" within the compounding and mixing area.

Mortality from brain cancer was increased in tyre-building workers in one of three US study populations; a case-control study within another of these populations showed no such association.

Excesses of cancers of the lymphatic and haematopoietic systems were noted in the US, and an excess of leukemia was noted in one of the UK studies. In one of the three US study populations, an excess of leukemia was highest in workers in compounding and mixing, tyre inspection and synthetic rubber manufacture; in a second US population, the excess was highest in workers in calendering, tyre building and tyre curing. Similar, though weaker, associations were found for lymphomas. A case-control study of malignancies of the lymphatic and haematopoietic systems, drawing upon all seven US plants of one company, showed an increased risk of lymphatic leukemia in workers in jobs entailing exposure to solvents.

An association was found between tyre building and the incidence of cancer of the skin in the one study in which incidence data were obtained.

Excesses of cancer at the following sites have been reported among rubber workers: thyroid, oesophagus, liver, pancreas and cervix. These excesses were isolated findings, were inconsistent or were based on observation of small numbers of exposed workers.

Most of the epidemiological evidence comes from studies in the United Kingdom and the United States. Studies carried out in Canada, Finland, Sweden and Switzerland were either not specifically related to the rubber industry or were based on small numbers of subjects. Their results are in general in accordance with those of the British and US studies."

EXTENT OF EXPOSURE

Reports of occupational exposure to air contaminants are summarized in Tables III-1 and III-2. The air contaminants found vary with location in the tire plants and, with few exceptions, these numbers are well below current OSHA permissible exposure limits (PEL's). The data summarized in these tables were reported by Williams et. al and Van Ert et. al.[14,15]

Table III-1. Summary of University of North Carolina (UNC) Rubber Workers Exposure Data for Aerosol[14,15]

Occupational Title Group	Exposure	Median Concentration (range of medians) mg/m^3	Number of Medians
Compounding	total aerosol	3.1 (1.27-4.99)	3
	respirable aerosol	0.69 (0.37-1.57)	9
Banbury	total aerosol	1.9 (1.4-5.8)	4
	respirable aerosol	0.64 (0.33-1.47)	10
Milling	total aerosol	0.76 (0.22, 1.31)	2
	respirable aerosol	0.48 (0.1-0.88)	10
Tire curing	total aerosol	1.33 (0.62, 2.05)	2
	respirable aerosol	0.43 (0.03-1.0)	3
Tire finishing, inspection & repair	respirable aerosol	0.22 (0.04-0.58)	11

Table III-2. Summary of UNC rubber worker solvent exposure data.[14,15]

Occupational Title Group	Pentane median (range) n* ppm	Hexane median (range) n ppm	Heptane median (range) n ppm	Benzene median (range) n ppm	Toluene median (range) n ppm
Compounding (cement mixing)	3.9(0.2-109)7	15.7(0.7-134.7)8	2.8(0.1-14.8)8	0.5(0.2-4.8)8	3.1(1.2-7.7)8
Extrusion	1.4(0.1-5)9	5.9(3.7-32.5)9	13.6(2.8-23)9	0.8(0.1-5.1)9	9.5(2.9-22.1)9
Tire building	1.8(0.1-11.2)10	11.2(1.2-43)10	5.7(0-18)9	1.4(0.1-2.4)10	1.5(0.6-3.8)10
Curing preparation	0.8(0.1-17.5)8	7.5(2.3-153)9	4.9(0.1-73)7	0.8(0.1-5.9)9	1.2(0.2-5.0)9
Inspection and repair	1.5(0.1-10.8)3	6.0(4.3-7.6)3	2.1(1.3-3.6)3	1.1(0.1-1.9)3	0.8(0.6-2.2)3

NOTE: Pentane, hexane, and heptane refer to the n-alkane and its isomers.
* - n is the number of samples

Exposures to noise and heat stress do occur in the tire industry. The University of North Carolina (UNC); as part of a tripartite agreement between UNC, the United Rubber Workers, and the participating company; reported finding areas where the sound pressure levels exceeded 85-90 dBA. Typical values are reported in Table III-3. Apparently, the tire manufacturing industry has noise problems which deserve attention.

Reportedly, heat stress is a problem in the tire industry. Several UNC reports supplied by the URW indicate that the WBGT exceeded 79°F in some plant areas.[17]

Table III-3. Sound pressure levels observed in tire plants.

Departments	Levels (dBA)
Compounding	76-78
Cement house	90
Banbary	75, 80-87, 85, 81, 93
Milling	86, 87, 97
Tread extrusion	90
Cutting	86-96
Green tire preparation	84-92
Curing	89, 90, 94
Grinding	79-80
Inspection	84, 85
Conveyor	86-94

POSSIBLE HEALTH HAZARDS

In addition to the occupational exposures cited in the literature, potential exposures to other hazardous chemical substances are suggested. PAH's are reportedly present in carbon blacks, extender oils, and softners used in the manufacture of tires.[18,19] Nau[20] reported PAH's are so tightly bound to the carbon black that no hazard exists. Nutt[21] found B(a)P in a tire manufacturing plant at concentrations not different from the outside ambient levels. In the carbon black criteria document,[18] NIOSH summarized the work of another researcher who found PNA's on carbon black. The identified chemical species are listed in Table III-4. The criteria document noted that all of the listed compounds have not been identified as carcinogens or suspected carcinogens.

Table III-4. PNA's found in carbon black.[18]

Type of Black	Chemical Species
Oil furnace black	1,2-benzpyrene 1,12-benzperylene 3,4-benzpyrene Anthanthrene Chrysene Pyrene Coronene Fluoranthene
Thermal black	3,4-benzpyrene Coronene
SRF carbon black	Anthracene Phenanthrene Fluoranthrene Pyrene 1,2-benzanthracene Chrysene 1,12-benzperylene Phenylene Anthanthrene Coronene 9,10-dimethyl,2-benz-anthracene 1,2-benzpyrene 3,4-benzpyrene O-phenylene pyrene

Exposures to known or suspected carcinogens as tire ingredients or contaminants of tire ingredients has been reported. Monson and Fine[19] reported that several of the antioxidents and accelerators used in tire manufacturing are suspected carcinogens. These are listed in Table III-5. Over a million pounds of phenyl-naphthylamine, a metabolic precursor of alpha or beta-naphthylamine, was used in 1975 as a rubber antioxident.[22] Table III-6 lists known carcinogens which Munn[23] found as contaminants in rubber additives, but not as air contaminants in the work place. The carcinogen beta-naphthylamine had been used in the rubber industry but its use was discontinued.[24] However, it still may be a contaminant in chemicals used by the industry.

Table III-5. Antioxidents and accelerators
Examples of suspected carcinogens.[19]

Compound	Reason
4-isopropoxydiphenylamine	Animal studies
N,N-diphenyl-p-phenylene diamine	Mutagenic in bacterial systems
phenyl-beta-naphthylamine	Carcinogenic metabolite
2-mercaptobenzothiazole	Animal studies
N-oxydiethylene-2-benzothiazole	Animal studies
Hexamethylenetetramine	Animal studies
Bis (dimethyldithiocarbamate) zinc	Animal studies

Table III-6. Some carcinogenic impurities in rubber additives.[23]

Additive	Impurity
Diphenylamine	4-Aminodiphenyl
beta-Naphthol	beta-Naphthylamine
Di-beta-naphthyl-p-phenylene-diamine	beta-Naphthylamine
alpha-Naphthol	alpha-Naphthylamine

Because tire curing "fumes" cause respiratory disease, these "fumes" or off-gas products have been studied by several researchers. By mass, these "fumes" are a relatively minor emission from the tire plants. About 1 percent of the organic emissions are thought to be from rubber decomposition products and volatiles;[25] the rest were solvents.

Several researchers have made efforts to identify the chemical components of curing fumes. The findings of Grote[16] and Rappaport[26] are summarized in Table III-7. Gold and Grote carried out their studies by heating uncured rubber stock in the laboratory. Rappaport did conduct field sampling in a tire vulcanization area. The concentrations of individual chemical species was found by Rappaport to be below 1.1 ppm.

Table III-7. Components of curing fumes.

Identified by Grote[16]	Identified by Rappaport[26]
C_5-C_8 alkanes	Styrene
Alkyl substituted benzenes	Toluene
Toluene	Ethyl benzene
Tetrachloroethylene	Oligomers of 1,3-butadiene

N-nitroso compounds which have been identified as air contaminants near processes involving hot rubber are often found to be potent animal carcinogens. Although the carcinogenic risk to man has not been determined, Fine and Rounbehler[27] speculate that man alone is not resistant to the carcinogenic properties of these compounds. The sampling results of Fine and Rounbehler are summarized in Table III-8.

Table III-9, which was developed by Harris,[28] shows the solvents used in tire building during 5-year-intervals between 1921 and 1975. This list includes solvents for which no exposure data is available in the published literature. Many of these solvents are basically naphthas.

Reported exposures are minimal to chemical substances for which there are standards. However, the workers are exposed to a variety of chemicals whose toxicity has not been evaluated. There are no standards for these compounds.

Table III-8. Some n-Nitrosamine concentrations found in four tire plants.[27]

LOCATION	Concentrations of n-Nitrosamines in ug/m^3		
	n-Nitroso-morpholine	n-Nitroso-dimethylamine	n-Nitroso-diethylamine
Banbury drop mill	0.9, 0.41*	0.1	
Warm-up mill	2.8 0.97 0.73 0.17		
Calendar	0.17 0.34 0.85	 0.16	
Tread tuber, extruder	22.0, 0.49 9.2, 3.9 2.4, 8.5 3.1	0.13 2.0, 0.15 1.7, 1.7 1.8	1.41
Curing room	6.6, 0.52 1.5 1.5	0.24 0.03 0.08	
Warehouse	3.7	0.38	

* - Two values on a line mean both values are from one plant

Table III-9. Tire building solvent use by 5-year intervals for one plant* (1921-1975).[28]

Solvent	1921-1925	1926-1930	1931-1935	1936-1940	1941-1945	1946-1950	1951-1955	1956-1960	1961-1965	1966-1970	1971-1975
Carbon disulfide		X	X	X							
Benzene	X	X	X								
Xylenes				X							
Naphtha	X	X	X	X	X	X	X	X	X	X	X
Rubber solvent	X	X	X	X							
Gasoline low-test		X									
Carbon tetrachloride		X	X	X	X						
Gasoline	X	X	X	X	X	X	X	X	X	X	X
Naphtha-aliphatic	X	X	X								
Aromatic solvent					X	X	X	X	X	X	X
Hexane				X	X	X	X	X	X	X	X
Isopropanol					X	X	X	X	X	X	X
Trichloroethylene								X	X	X	X
Perchloroethylene									X	X	X
Heptane								X	X	X	X
Naphtha-Hi flash							X	X	X	X	X
Naphtha-Shell					X	X	X				
Naphtha-Lt. fraction									X	X	X
Solvent-Shell 140									X	X	X

* Use based on hard-copy files of materials ordered by the plant.

SUMMARY OF HEALTH EFFECTS FROM RECOGNIZED HAZARDS

Health hazards for which there are recommended standards include solvents, carbon black, heat stress, and noise. The standards, recommended standards, and ACGIH TLV's for these are listed in Table III-10. These standards are based upon health effects and deserve brief attention.

Carbon black exposures occur in the compounding and Banbury areas of a tire plant. Excessive exposure to carbon black causes irritation dermatitis and reduced pulmonary function. The following lung diseases are reported: pneumoconiosis, pulmonary fibrosis.[18] PAH's, which have been implicated as carcinogens in coke ovens, are absorbed onto carbon black. Based on professional judgement, NIOSH recommended a limit of 0.1 mg/m^3 of cyclohexane extractable material.[18]

Solvents commonly used in the tire industry include: refined petroleum solvents such as naphtha; C_5-C_8 alkanes such as pentane, hexane and heptane; isopropyl alcohol, toluene, benzene, trichloroethylene, and perchloroethylene. These were identified from Harris' list (Table III-9) or from industrial hygiene studies. Many of these solvents cause dermatitis, and eye and throat irritation.[29,30,31,32,33,34] n-Hexane causes polyneuropathy.[28] In addition to the effects previously listed, perchloroethylene, trichloroethylene and xylene can cause liver and kidney damage. Benzene is a known cause of leukemia and aplastic anemia,[35] and has been found as a contaminant in various paraffin solvents.[28,36]

In the tire industry noise is a wide-spread problem. Excessive noise can cause permanent and temporary hearing shifts, speech interference, and masking which impairs human performance, and causes degradation of jobs requiring high vigilance.[37,38]

Heat stress has been reported to be a problem in tire curing rooms. The consequences of over-exposures to heat stress range from minor ones, such as prickly heat and fatigue, to major ones ranging from water and electrolyte imbalance, to heat exhaustion, heat cramps, heat stroke, and death.[39]

Table III-10. Occupational exposure limits for some common air contaminants found in tire plants.

Air Contaminant	OSHA[40] TWA	NIOSH[41] TWA	ACGIH[42] TLV
Benzene	10 ppm	1 ppm	10 ppm
Carbon black	3.5 mg/m^3	3.5 mg/m^3	3.5 mg/m^3
Heptane	500 ppm	--	400 ppm
Hexane	500 ppm	--	100 ppm
Pentane	1000 ppm	--	600 ppm
Toluene	200 ppm	100 ppm	100 ppm
Xylene	100 ppm	100 ppm	100 ppm
Talc	20 mpp/cf	--	20 mpp/cf
Alkanes C_5-C_8	--	350 mg/m^3	--
Rubber solvent	--	--	1600 mg/m^3
Nuisance dust	10 mg/m^3	5 mg/m^3	10 mg/m^3
Asbestos	2 f/cc*	0.1 f/cc*	2 f/cc*
Petroleum distillate	2000 mg/m^3	--	--
Refined petroleum solvents	2950 mg/m^3	350 mg/m^3	--

* - fibers longer than 5 microns

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APPENDIX IV

TIRE MANUFACTURING OPERATIONS

INTRODUCTION

Tire manufacturing makes up a major portion of the rubber industry. This part of the rubber industry is classified under the Standard Industrial Classification (SIC) Code 3011 and includes "establishments primarily engaged in manufacturing pneumatic casing, inner tubes, and solid and cushion tires for all types of vehicles; airplanes, farm equipment, and children's vehicles; tiring and camel back, tire repair; and tire and retreading materials".[1]

Based on a rubber product index from 1975,[2] the tire and inner tube production represents approximately 48 percent from the total production of seven rubber product industries, the other production relationships can be seen in Table IV-1.

Table IV-1. Production of rubber products in 1975[2].

SIC CODE	Industry Segment	Metric Tons Produced[a] Production X10[3]	% of Total
3011	Tires	2,038[b,c]	48
3021	Rubber footwear	140	3
3041	Rubber hose and belting	400	10
3069	Fabricated rubber products N.E.C.	997[d]	23
3293	Gaskets, packing, and sealing devices	160	4
3357	Nonferrous wire drawing and insulating	51[d]	1
7534	Tire retreading and repair	475[b]	11

a. Based on product weight except otherwise noted.
b. Average weight of a tire is 10.9 kg.
c. Inner tubes and other tire materials, which constitute approximately 7 percent of the industry, are not included.
d. Based on amount of rubber compound consumed.

The figures in Table IV-1 illustrate the dominant position of tire production in the rubber industry. The manufacture of tires and inner tubes consistently consumes about 65 percent of all new synthetic or natural rubber production each year.[3]

In order to understand the health problems associated with this industry, a review of the rubber chemicals and manufacturing operations is needed.

RUBBER ADDITIVES

The properties of the various tire components and the processing properties are not only controlled by the rubber mixture itself, but by chemical additives. Based on their various functions, the chemical additives are known as vulcanization agents, accelerators, activators, pigments, softeners and plasticizers.

VULCANIZATION AGENTS

Sulfur is the principal curing agent used with natural rubber and with some of the synthetic polymers. Some organic compounds containing sulfur, may be substituted for sulfur in this process. The generally known vulcanization agents are listed in Table IV-2.

Table IV-2. Vulcanizing agents.[3]

P-quinone dioximes	Sulfur
Sulfur monochloride	Polysulfide polymers
Selenium*	Zinc oxide
Tellurium*	Magnesium oxide
Thiuram disulfides	Organic peroxides
alkyl phenyl sulfides	

* Limited use in tire manufacturing, but may be used for other rubber products.

ACCELERATORS

These chemicals increase the rate of the cure, when the sulfur is used as the vulcanization agent. A number of organic compounds have been tried as accelerators, but few are in active use, i.e., thiazoles and activated thiazoles. Other types also used are: aldehydes, amines, carbamates, sulfides and guauidine compounds. Some of the more common, commercially used, accelerators are listed in Table IV-3.

Table IV-3. Accelerators.[3]

Aldehyde-amine reaction products	Arylguanidines
Dithiocarbamates	Thiuram Sulfides
Thiazoles	Sulfenamides
Xanthates	Thioureas

ACTIVATORS

The activators are used in small amounts, usually in combination with the accelerators, to achieve a good curing reaction. A list of the more common activators is provided in Table IV-4.

Table IV-4. Organic activators.[3]

Composition	Trade Name
Primary fatty amines	Alamine 7, 46
Mono-and dibenzylamines	DBA
Diphenylguanidine phthalate	Guantal
Zinc salts of a mixture of fatty acids	Laurex
Mixture of organic and inorganic acetates	MODX
Dibutyl ammonium oleate	Barak
Normal lead salicylate	Normasal
Fatty acids and metal soaps	--

SOFTENERS, PLASTICIZERS, EXTENDERS

The function of these chemicals is to soften or plasticize the uncured rubber material. The softners also support the pigment dispersion and can be used as extenders.

Plasticizers decrease the viscosity of the rubber stock. Some softeners and plasticizers are listed in Table IV-5.

Table IV-5. Typical softeners and plasticizers used in rubber compounding.[4]

Rubber Type	Softener/plasticizer
Natural rubber and SBR	All petroleum fractions
	Pine tars and resins
	Coal tar fractions
	Pentachlorothiophenol (RPA-6, Renacit VI) and its activated zinc salt (Endor)
	Thioxylenols (Pitt-Consol 640)
	2, 2' - Dibenzamidodiphenyldisulfide (Pepton 22)
	Zinc 2-benzamidothiophenoxide (Pepton 65)
Neoprene	Naphthenic petroleum fraction
	Coal tar fractions
	Esters
	Dioctyl sebacate
	Butyl oleate
	Monomeric polyether
	Triethylene glycol caprylate-caproate
	Trioctyl phosphate
Nitriles	Coal tar fractions
	Monomeric esters
	Adipates
	Sebacates
	Tributoxyethyl phosphate monomeric
	Fatty acid ester
	Di(butoxyethoxyethyl) adipate (TP-95)
	Triglycol ester of vegetable oil fatty acid
	Coumarine - indene resins
	Rosins
	Modified phenolics
	Tetrahydronaphthalene
	Dibutyl phthalate
	Dibutyl sebacate

In tire manufacturing, a compound is a mixture of elastomers and additives. The composition of a compound will vary with its use. Typical compounds for a part of a tire are listed in Table IV-6.

Table IV-6. Typical compound composition.[3]

Compound	Parts by Weight
Rubber	100
Carbon black	25
Zinc oxide	3
Stearic acid	2
Softener	5
Antioxidant	1
Sulfur	2.8
Primary accelerator	0.75
Secondary accelerator	0.15

The majority of the chemical compounds which are used to make tires have no manditory or recommended standards. Consequently, particulates in the rubber industry are often erroneously classified as nuisance dust.

TIRE MANUFACTURING OPERATIONS AND CONTAMINANT GENERATION

Tire manufacturing operations involve a series of chemical and mechanical operations and have the potential for exposing workers to many air contaminants. Figure 1, p. 5, "Production Stages in the Manufacture of Tires and Tubes," illustrates the sequence of these operations. During these operations a variety of air contaminants are released into the workroom air. The type of air contaminant varies with the operation. Dusts are generated in receipt and transfer of raw materials and during hopper/bin filling, weighing an batching, mixing, and the finishing of cured tires. During operations such as mixing, milling, extrusion, calendering, and curing a "fume" is often emitted from the hot rubber. Operations which involve the use of organic solvents, cement house operations, under and end tread cementing, green tire spraying, and tire building and repair result in occupational exposures to solvents.

From the standpoint of air contaminant generation and the tire manufacturing process, a number of operations can be described. The areas described do not address all tire manufacturing operations. Only operations which were observed or reported to generate air contaminants are described.

Hopper/bin filling

Hopper/bin filling refers to the transfer of rubber chemicals and carbon black into containers, such as bins, hoppers, or totes, in preparation to weigh out

Figure IV-1. Hopper/bin filling hood.

Hopper/bin filling results in dust generation which is usually controlled by local exhaust ventilation, Figure IV-1. Rubber or weighing and batching operations. chemicals commonly arrive at the plant in 50 pound paper bags. The contents of these bags are typically emptied into hoppers, bins, or portable totes. The inlet for these and bins are typically located above the weighing and batching station. The use of portable totes is associated with the practice of blending large batches of chemicals prior to weighing and batching.

The act of bag emptying can result in a dust exposure to the worker. Usually, local exhaust ventilation is used to control dust generated from pouring the chemicals into a bin or hopper. Dust associated with handling the empty bag cannot be controlled by this local exhaust ventilation without special provisions.

Carbon black is generally handled in bulk quantities in tire plants. In some plants, carbon black is fed from silos into totes. These totes are used to feed specific carbon blacks into mixers. In a few plants, Sealdbins(R) are used to feed carbon black, zinc oxide, or amorphous silica directly into the mixer. These collapsible Sealdbins(R) are made of heavy gauge rubber, filled by the supplier. With this system, fewer mechanisms are needed to transport the carbon black or amorphous silica to the mixer, and fewer exposures result from these screw conveyors.

Weighing and batching

Weighing and batching refers to the preparation of batch lots of rubber chemicals for charging into the mixer. This operation consists of weighing precise amounts of material into batches for transfer to the mixer. This operation can be conducted manually or automatically.

During manual weighing and batching, Figure IV-2, chemicals are transferred from a bin or a tote to a weighing scale. The contents of the pan are poured into containers and emptied into the mouth of a mixer. In some instances, plastic bags are set on the scale and the chemicals are poured directly into the bag.

Figure IV-2. Manual weighing and batching.

When pouring chemicals into the container or transfering material between the bin or tote and the scale, the worker inevitably creates dust. The work practices can affect the quantity of dust generated. Weighing booths and ventilated weighing scales are typically used to help control the dust generated during the pouring operations.

Some companies use automated weighing and batching systems[5] to add precise amounts of rubber chemicals directly into the mixer. This equipment eliminates the worker dust exposure caused by manual weighing and batching. This is a example of a process change which minimizes dust dispersion.

Mixing

During this operation, rubber elastomers and various rubber chemicals are combined into a homogeneous mixture which is necessary for a uniform curing reaction thoroughout the tire. Based upon observations and case studies, these operations generally require multiple passes through an internal mixer and a mill. The general configuration is illustrated in Figure IV-3. Banbury and Intermix mixers are widely used in this industry.

The rubber is passed through the equipment at least two times. During the first pass, referred to as a master batch, bales of rubber, pigments, oils, carbon black, and rubber chemicals, with the exception of the curing agents, are mixed. During subsequent passes through the mixer and mill, additional materials are added according to a specific plan or they are added to correct the composition of the rubber stock. This stock is often called "remill". During the final pass through the mixer and mill, curing agents are added. Rubber undergoing its final pass is called a final batch.

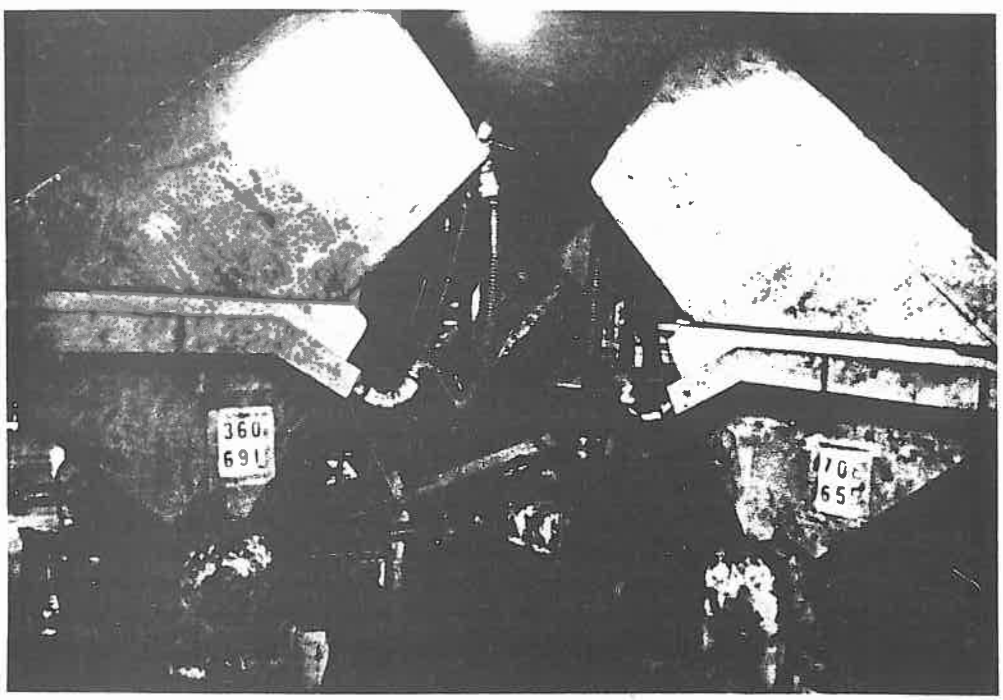

Figure IV-3. Bulk carbon black in metal totes.

The operations and equipment used to charge materials into the mixer vary significantly, from plant to plant. Methods used to charge powdered ingredients into the mixer also vary widely. In some, batches of powdered chemicals are weighed into rigid containers or plastic or paper bags which were either emptied or dropped into the charge door. Emptying these containers produce dust exposures. Others used computer-controlled weighing systems to charge the proper amount of a chemical into the mixer. This eliminates the dust generated from manually weighing out chemicals into batches and charging these batches into the mixer.

Carbon black is charged into the mixers by a remote controlled system. Carbon black is transported to the weighing scale for the mixers and into the mixer from a variety of starting points. Some manufacturers store carbon black in silos and use screw conveyors to transport the carbon black to the weighing system. Others feed the carbon black into metal totes which contain several thousand pounds of carbon black, Figure IV-3. The carbon black is fed by gravity and screw conveyors into the weighing system and then into the mixer. When these systems are poorly sealed and maintained, they are a source of carbon black air contamination. One tire producer received carbon black directly in rubber containers called Sealbins(R), Figure IV-4. This minimizes the handling of carbon black in screw conveyors.

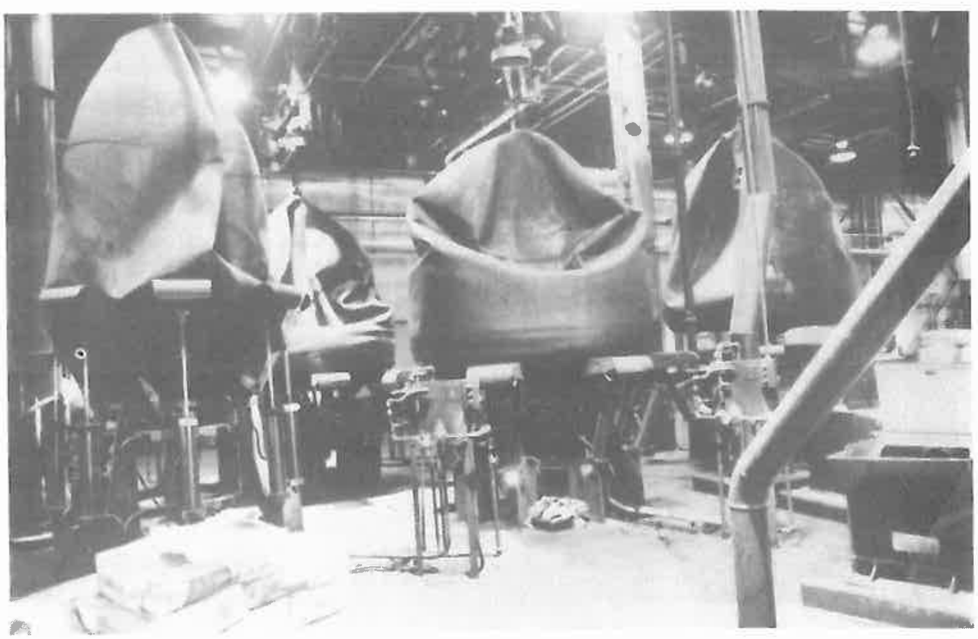

Figure IV-4. Sealdbins(R) and dispensing stations.

The methods used to charge oils and masterbatch rubber into the mixer are relatively consistent among plants. Oils which may contain oil soluble rubber chemicals are weighed automatically or manually or by remote control and pumped into the mixers. Bales of natural rubber and elastomers are weighed on a conveyor and the conveyor charges the rubber into the mixer.

The manner in which masterbatch rubber was handled during subsequent passes through the mixer and mill depended upon the output of the masterbatch mill. Some masterbatch mills produced sheets of rubber which were fed by rollers onto the final batch mixer conveyor. Other masterbatch mills, called pelletizers, produced rubber pellets. These were fed into the masterbatch mixer by a computer controlled or remote controlled weighing system.

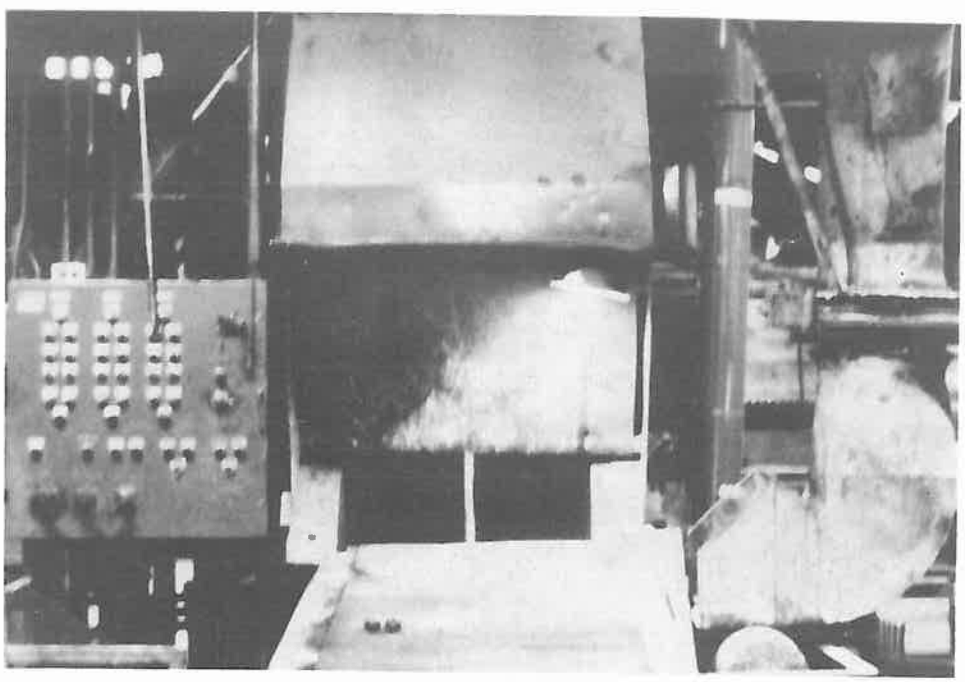

Figure IV-5. Mixer loading.

Milling

The type of mills used under the mixers varied with the type of batch and the plant. In some plants, the mill is preceded by a secondary mixer such as a Transfer Mix(R) (Figure IV-6) or a single screw extruder. Mills used to process master batches include sheeter mills and drop mills. Under final batch mixers, sheeter mills, drop mills, and roller die mills are used to produce sheets of rubber. Drop mills, Figure IV-7, produce sheets of rubber from batches of rubber dropped onto the two horizontal rollers. An operator has to manually manipulate the rubber on the rollers for proper mixing and to form the rubber into a sheet. Sheeter mills used in conjunction with a Transfer Mix(R) continuously formed the rubber into a sheet. Using two vertical rollers, a roller die mill, with the help of a screw extruder, continuously formed the rubber into sheets. Regardless of the type of mill used, the sheeted rubber was always fed through a dip tank for cooling and coating with an "anti-tack agent" usually kaolin, soapstone, or soapstone/soap-slurry.

In the mixer, and on the mills, the friction generated by shearing the rubber with rotors and rollers is used to heat and mix the rubber. Masterbatch rubber is generally allowed to get hotter than final batch rubber. Because rubber will cure if the temperature gets too high, the mixers and mills are water cooled. This equipment gets hot enough to cause the stock to fume, however. This is a significant source of air contamination which is usually controlled by ventilating the mixer and mill. When the hot rubber stock is cooled in the dip tank, steam is generated which entrains some of the anti-tack agents as a mist. In addition, the kaolin or soapstone antitack agents appeared to be emitted as a dust when the dry rubber was handled.

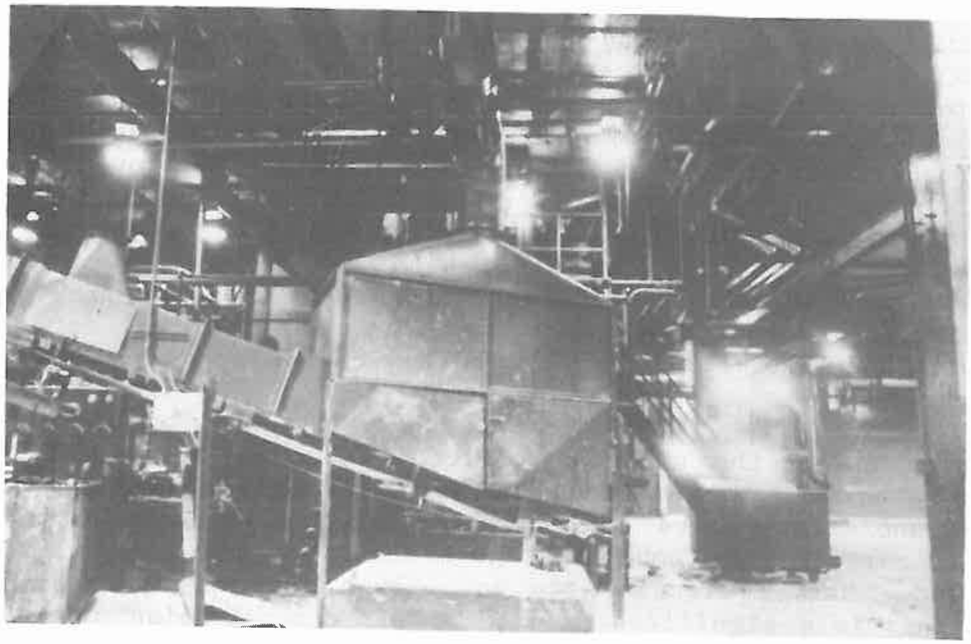

Figure IV-6. Ventilation on transfer mix(R).

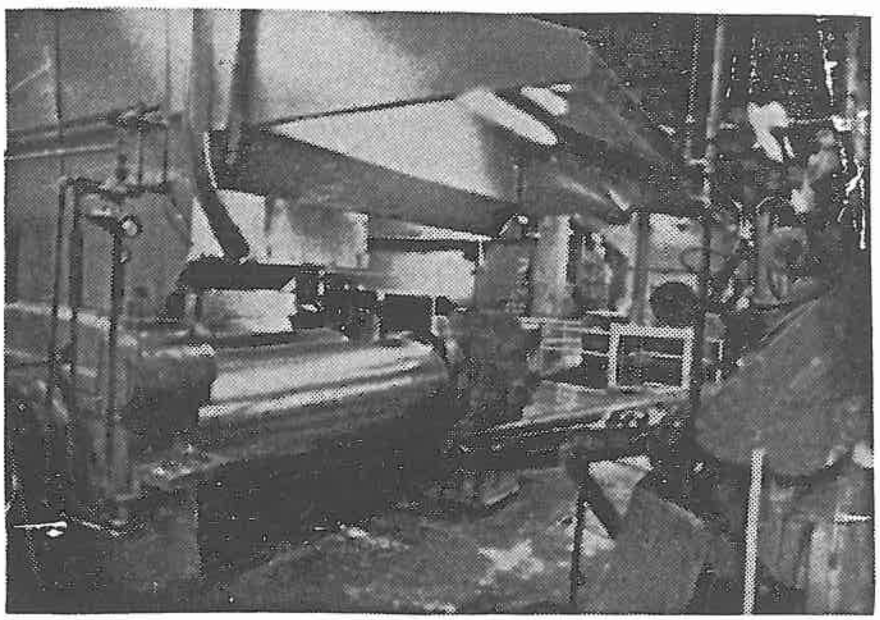

Figure IV-7. Drop mill below mixer.

Cement House Operations

Mixing and distribution of cement and green tire mold release agent are done at the cement house, Figure IV-8. Occupational exposures to solvents in the cement house are controlled by local exhaust ventilation, dilution ventilation, good fittings and seals, and good work practices. The worker's primary exposure is to petroleum distillate, usually a naphtha. This solvent is used to make the various rubber cements used in tire production.

Solvents and other ingredients are generally mixed in 200 to 400 gallon mixers to produce rubber cements. Leaks can occur from the seals of these tanks and from access lids. Local ventilation around the access lids was found to control solvent vapors. Generally, the tanks are well-sealed and do not leak; however, general exhaust ventilation is needed in the area should a leak occur. The cement can either be pumped to the cementing stations or drained into portable tanks. For these operations, local exhaust ventilation is necessary to control vapors from evaporation and from pump seal leaks.

Cements are also mixed in 50 to 55 gallon portable tanks or drums. These containers should be covered.

Minor amounts of specified solvents such as acetone, toluene, xylene, isopropyl alcohol, and special naphthas are usually obtained from spigots in drums set on their sides. Occasionally these spigots leaked into a can set below the spigot.

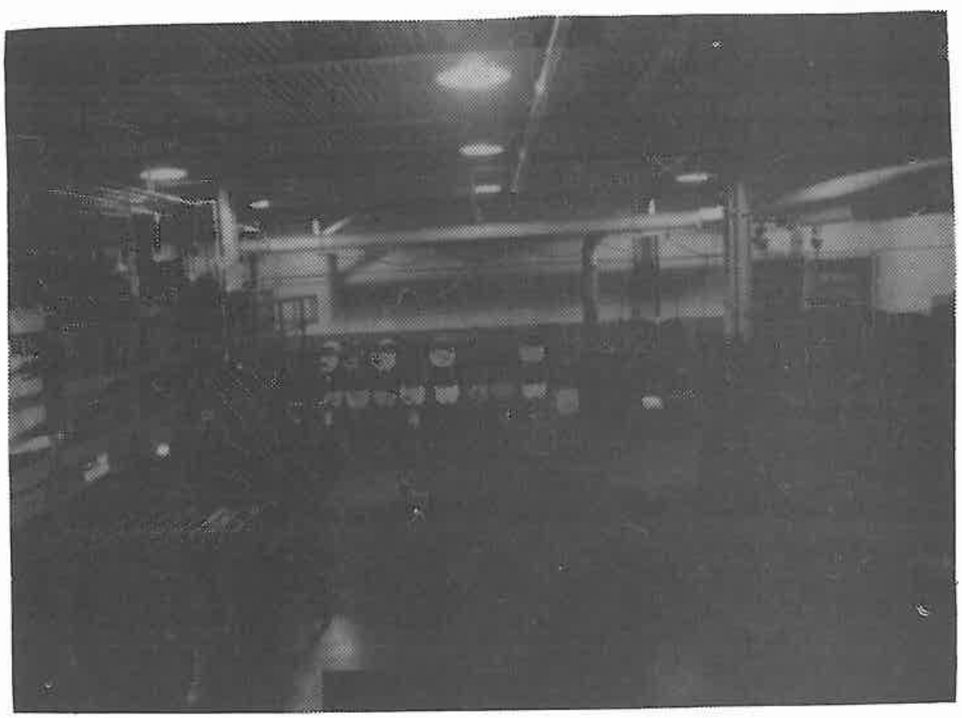

Figure IV-8. Cement house.

Tire Tread

Tire treads are made by extruding sheeted rubber through mills which heat the rubber and into a screw type extruder. This produces a continuous ribbon which is fed through an undertread cementer where cement is applied to the bottom of the tread base. Then this ribbon is sliced into individual tread lengths and cement is applied manually or automatically to the ends of the tread, Figure IV-9.

Extrusion is a relatively hot process which can cause the rubber to "fume". The cementing operation results in solvent vapors escaping into the work environment.

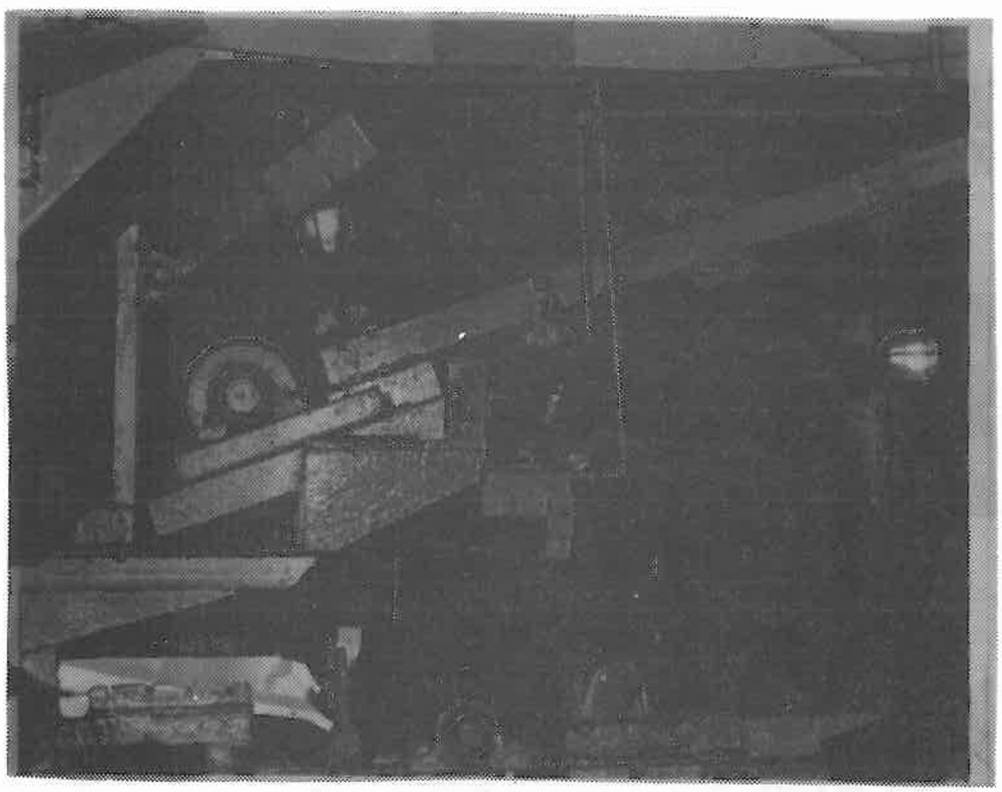

Figure IV-9. Undertread cementing.

Tire Bead Manufacturing

The tire bead is composed from steel wires coated with rubber material. Before rubber coating, the steel wires are electrically plated with a non-ferrous material. The rubber coating is performed by extruding the rubber onto the wire. The bead is wrapped with a rubberized fabric tape and then rewrapped in a way that the second layer could be fixed into the sidewall of the tire.

After the beads are formed, they are occassionally dipped in a solvent-based cement so that the beads stick to the tire during building. When the beads are allowed to dry in the open, the work place air is contaminated with the petroleum distillate which is the base solvent for the cement.

Calendering Operations

Ply stock for tire cords and belts are formed by calendering rubber onto various types of steel cord and fabrics, i.e., rayon, nylon, polyesters, and fiber glass, Figure IV-10. The fabric is spliced by means of high speed sewing machines. To provide a firm and properly cured bond of the fabric to the rubber, the fabric is pretreated by using a water based dip solution. This pretreatment (which may involve resourcinol/formaldehyde solutions) is generally done by the textile manufacturers. The pretreated fabric is then fed into a friction calender which uses rollers to impregnate and coat the fabric with the proper amount of rubber to form a ply stock. The 3-roller calender coats one side of the fabric at a time, while the 4-roller calender coats both sides of the fabric in one operation. The use of rollers to apply the rubber to the fabric results in "fumes" which are generally controlled with local exhaust ventilation. The ply stock is cut to proper length, spliced and transferred to the tire building area.

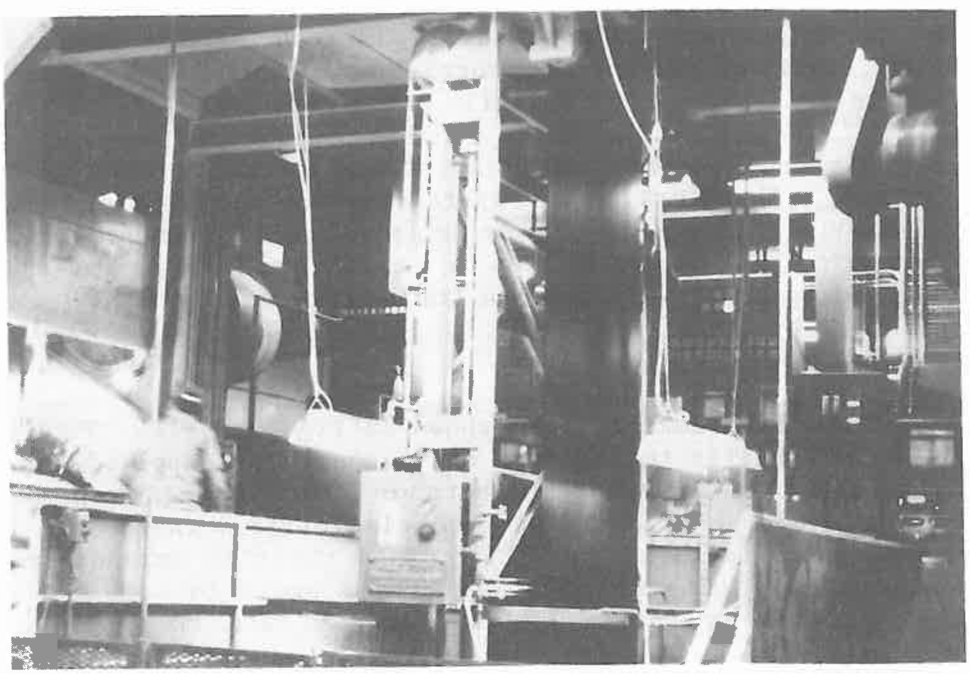

Figure IV-10. Calendering.

Tire Building

The tire is basically built from the inside out on a steel or inflated rubber drum. First, the inner liner is applied around the drum; then the ply stock is wrapped around in a specific angle. The beads are located at the ends of the cylinder and the ply stock turned back to wrap around the bead. A chafer, a strip of rubber coated fabric, may be attached around the bead. The belt (if used) is applied on the top of the last ply. Then the tread and the sidewalls are attached. Finally, the drum is collapsed and the green tire released from the drum. While assembling the tire, some naphtha is used to assemble the individual tire components. This usually results in a low concentration of naphtha vapors in the tire building area. The assembled tire is called a green tire.

Green Tire Spraying

After the green tire is assembled, a mold release agent is sprayed on the inside and outside tire surfaces. The mold release agents are dissolved in either water or a naphtha. The coating prevents the tire from sticking to the mold during vulcanization.

The green tires are placed in a booth sprayed and then are removed and placed on a rack for drying. If the tires are removed from the rack too soon, the carrier solvent evaporates into the workplace air. When a petroleum distillate is the carrier solvent, about 0.34 pounds of solvent is used per tire. Between 27 and 35 percent of this solvent is believed to evaporate into the workplace air.[6,7]

The water-based spray solutions contain fewer organic solvents than the previously used organic spray solutions. They are basically an aqueous system containing 30 to 60 percent silicone solids, 3 to 4 percent emulsifiers and bactericides and less than 1 percent corrosion inhibitors. The use of the water-based sprays will reduce the volatile emissions.

At the time of this study, steps were being taken by most plants to switch to water-based sprays. Therefore, this operation was not studied because the change would obviously eliminate worker exposure to solvents, and the mold release agents were not identified as a health hazard in the literature. Unfortunately, this trend has reversed in the last several years.

Tire Curing

Tires are cured in a tire curing press shown in Figure IV-11. Tire curing is the operation where specific temperature and pressure are applied for a period of time to vulcanize the rubber components in the final tire product. The green tire is placed over a bladder bag which is inflated inside the tire. As the press closes steam inflates the bladder and the tire expands against the downward pressure of the closing mold. When the press is completely closed, the tread and sidewall is forced by the bladder into the mold before the vulcanization starts.

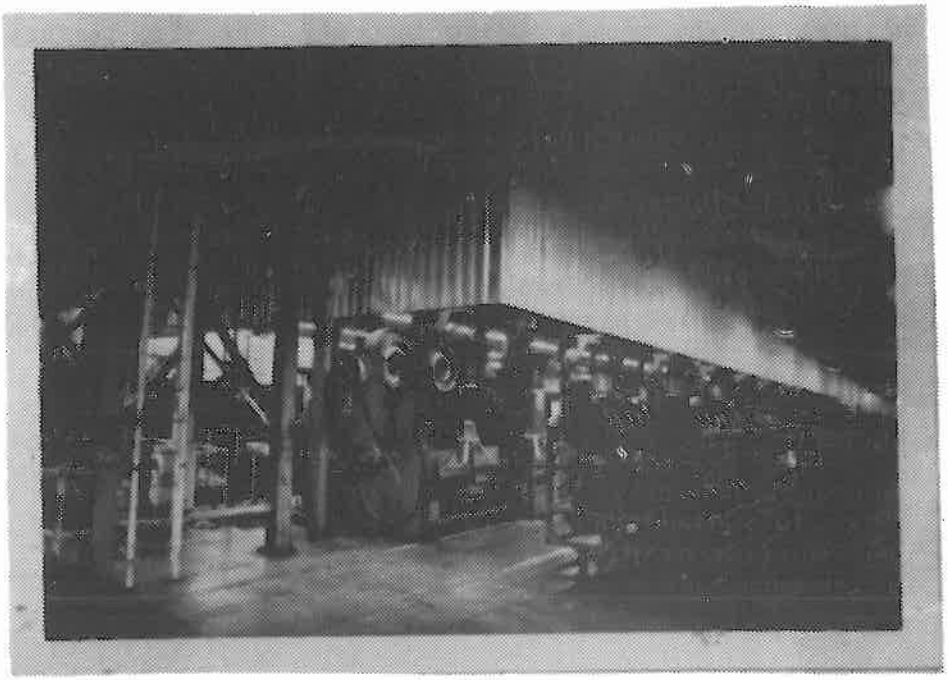

Figure IV-11. Curing room.

At a pre-set time, the bladder is deflated and the mold is opened. Then the tire is moved to a post cure inflation stand where the tire is inflated and cooled in the open atmosphere. As the freshly cured hot tire cools it emits a fume referred to as curing fume.

Tire curing presses are generally located on both sides of a pit. The pit refers to the area between the two press rows which contain take-off conveyors and utilities for the operation of the presses.

Grinding Operation

When the tire is cool, the excess rubber material, which escaped through the mold vent holes, has to be removed by grinding and/or a final buffing to balance the tire. These operations may be completed on automatic machines or by hand. The dust generated by these operations is normally controlled by local exhaust ventilation.

White Sidewall Tire Production

After the grinding operation, the white sidewalls are painted, usually in a ventilated spray booth, with a water based paint. The paint protects the white sidewalls during shipment.

Inspection

This is a final step in the manufacturing process. The tire is inspected and shipped to the storage room or transported back to the repair station for final repair.

Tire Repair

During tire repair operations, workers use grinders to remove defects from the tire. Then, the tire is repaired and painted with a naphtha based paint. Occasionally, the tire is spot-curred to correct a defect. These operations results in minimal solvent and particulate exposures.

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APPENDIX V

EFFICIENCY DETERMINATIONS USING TRACER GAS TECHNIQUES

INTRODUCTION

During the detailed surveys, exhaust hood efficiencies were evaluated using tracer gas techniques. The use of tracer gas for this purpose constituted a "feasibility" study to determine the utility of the tracer gas techniques for this purpose and, therefore, the results should be viewed accordingly.

Theoretically, local exhaust hood efficiency can be determined by a ratio of the quantity of air contaminant captured by the exhaust system to the total quantity of contaminant generated by the process per unit time. This efficiency determination requires the measurement of two parameters: total emission generation rate and hood capture rate or contaminant escape rate. While the measurement of hood capture rate is relatively simple, the measurement of the total contaminant generation rate is extremely difficult without laboratory type conditions.

Normally, the performance of a ventilation system is determined by measuring the various hood ventilation parameters, i.e. face or slot velocities, total air flow, etc., and by using standard industrial hygiene sampling techniques. Although these techniques have been used for years, they present several problems. It is not always easy to measure flow rates and velocities and it is even harder to obtain and analyze valid industrial hygiene samples. Therefore, an alternative method for determining hood efficiencies is needed. A review of the literature and some preliminary laboratory work suggest strongly that tracer gas techniques may indeed offer that alternative.

Based on what had been learned through our literature review and our limited laboratory tests it was decided that a field evaluation of this technique would be extremely valuble to the engineering and industrial hygiene communities. Therefore, it was determined that this technique should be evaluated during this control technology assessment.

EQUIPMENT AND METHOD

Sulfur hexafluoride (SF_6) was selected as the tracer gas. It is odorless, colorless, non-explosive, chemically stable, relatively non-toxic, and has an extremely low detection limit. The lowest concentration detectable is 0.001 parts per billion (ppb) using a gas chromatograph with an electron capture type detector (ECD).

A Baseline Industry Inc. gas chromatograph equipped with an ECD was used for this field test. The chromatograph had its own vacuum system and was microcomputer controlled allowing continous sampling.

The following procedures were used for each field measurement:

1. The sample probe was positioned in the duct to avoid airflow disturbances, where possible.

2. Several samples were run prior to the release of the SF_6 to determine whether there were interfering compounds in the system.

3. SF_6 was then released at a controlled rate in the hood duct inlet and its concentration in the duct continuously analyzed. This concentration was then designated as the 100 percent capture concentration.

4. The SF_6 point source was then moved to various locations in and around the hood while the duct concentrations were analyzed to determine the hood's control capability. Several determinations were made at each point to assure statistical accuracy.

5. The ratio of the concentration for the 100 percent capture versus the concentrations determined for other locations was considered to be the "hood efficiency."

These evaluations were completed at several local exhaust hood locations controlling various types of contaminants.

SUMMARY

The data obtained during this feasibilty experiment revealed that the tracer gas technique worked well in determining capture efficiency for the SF_6. The efficiency data developed during the survey correlated very well with the industrial hygiene sampling data and the ventilation measurements made during the survey.

Although the results of this field experiment were positive, extensive research is still needed to solve some of the problems which were recognized prior to or during this investigation but could not be adequately addressed. Some of these areas are:

1. Determine the minimum distance from where the tracer gas is released to the point where the SF_6 concentration becomes uniform and measurements may be taken.

2. Determine the relationship between efficiencies based on gas versus those based on the use of particulate tracer compound.

3. Develop a method of introducing the tracer gas into the actual emission area and a sampling stratagy for determining efficiency.

4. Develop a statistical strategy for the sampling required.

A detailed technical report regarding this tracer gas experiment has been prepared. Interested individuals may contact the NIOSH Technical Information Office for further information on this report.

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