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KELLY-SPRINGFIELD TIRE COMPANY
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## SUMMARY

In response to a request from the United Rubber Workers, the National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation at the Kelly-Springfield Tire Company in Freeport, Illinois, to evaluate the curing departments. The request stated that employees were potentially exposed to nitrosamines and other chemicals released during tire curing. The request also stated that employees were concerned about long-term health effects, such as cancer, as well as the acute irritant effects of exposure. An industrial hygiene and medical investigation was conducted on February 18-19, 1992.

Full-shift personal breathing-zone monitoring was conducted for *N*-nitrosamines, polycyclic aromatic hydrocarbons (particularly the benzene-soluble fraction), and total particulates. Five samples were collected for each analysis. Additionally, five area samples were collected for total hydrocarbons.

No *N*-nitrosamines were detected in any samples. With the exception of one sample with no detectable benzene-soluble fraction, concentrations of benzene-soluble fraction ranged from 0.20 to 0.78 mg/m$^3$ as time-weighted averages (TWAs). All were at or above the criteria for coal-tar pitch volatiles (NIOSH Recommended Exposure Limit [REL] of 0.1 mg/m$^3$ as a 10-hour TWA and Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.2 mg/m$^3$ as an 8-hour TWA). However, the criteria for coal-tar pitch volatiles are not directly applicable to curing fume results because of differences in polycyclic aromatic hydrocarbon (PAH) content. Anthracene, benzo[*a*]pyrene, phenanthrene, chrysene, and pyrene, which are included in the OSHA definition of coal-tar pitch volatiles, were not detected in the Kelly-Springfield samples. Only three PAHs (naphthalene, acenaphthene, and fluorene) were detected. Naphthalene concentrations ranged from less than 0.5 µg/m$^3$ (the minimum detectable concentration) to 3.6 µg/m$^3$ as TWAs, and were well below the NIOSH REL of 50,000 µg/m$^3$. Acenaphthene concentrations ranged from 1.8 to 6.9 µg/m$^3$ as TWAs. Fluorene was detected at concentrations below the limit of quantification. NIOSH has not set RELs for acenaphthene or fluorene. The concentrations of hexane isomers, heptane, and methylcyclohexane were well below their respective criteria.

Total particulate concentrations ranged from 0.05 to 1.25 mg/m$^3$ as TWAs, below the evaluation criteria for nuisance (inert or nontoxic) particulates. No specific criteria for curing fume particulates have been established in the United States. However, criteria for nuisance particulates may not be applicable because curing fume may contain toxic substances.

Because of the historic potential for exposure to carcinogenic substances in the rubber industry and the uncertainty of epidemiologic study results, employee concerns about cancer risks are not unexpected. Cancer, however, is the second leading cause of death in the United States, accounting for about one-fourth of deaths among adults in recent years; and lung cancer is the most common cause of cancer deaths in men. Company records of employee and retiree deaths for the years 1964 through 1991 show that cancer was the cause of death in 12 (14%) of 88 deceased hourly employees.

In confidential medical interviews, eye, nose, or throat irritation, headache, and fatigue were reported by over half of 25 randomly selected first-shift employees. Approximately one-third reported cough, and one-fifth reported chest tightness, wheezing, or shortness of breath.

The available records did not reveal an unusual number of cancer deaths at Kelly-Springfield. The most frequent cancer site, found in three individuals, was the trachea, bronchus, or lung. No other cancer site was observed in more than one individual.

Because many of the frequently reported symptoms are consistent with exposure to the large variety of potential contaminants in the workplace, control of exposures to air contaminants may reduce the numbers of symptoms that employees experience. Recommendations for the installation of local exhaust ventilation are provided.

KEYWORDS: SIC 3011 (Tire Manufacturing), curing fume, *N*-nitrosamines, polycyclic aromatic hydrocarbons, benzene-soluble fraction, total particulates, hydrocarbons, respiratory irritation, cancer.

## INTRODUCTION

In February 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the United Rubber Workers Local 745 to evaluate employee exposures in the curing departments at the Kelly-Springfield Tire Company in Freeport, Illinois. The request stated that employees were potentially exposed to nitrosamines and other chemicals released from presses in the curing departments. The request also stated that employees were concerned about long-term health effects, such as cancer, as well as the acute irritant effects of exposure. In response to this request, NIOSH investigators conducted a site visit on February 18-21, 1992, after completion of an unrelated Occupational Safety and Health Administration (OSHA) investigation in early 1992.

## BACKGROUND

The Kelly-Springfield Tire Plant, a large one-story structure in Freeport, Illinois, was built in 1963. Tire production began in December that year. The plant currently operates around the clock with three shifts per day. Eighty-nine employees work in Department 514 (passenger-tire curing area), and sixty-seven in Department 534 (rear-farm-tire curing area). Approximately 21,000 tires are produced per day in Department 514, and 1,750 tires are produced per day in Department 534. Each type of tire is manufactured with various rubber formulations (generally styrene-butadiene). In the tire-building Climate Control Area, 21 employees work in Department 530 (strip lamination), 9 in Department 531 (farm-machine strip lamination), and 25 in Department 532 (rear-farm strip lamination).

Tire curing is the operation where curing presses apply heat and pressure to "green" tires to vulcanize the rubber components in the product. The green tire is placed over an inflatable bladder in the mold of the curing press. When the press is completely closed, the steam-inflated bladder forces the green tire against the mold to form the tread and sidewalls. After the vulcanization process is complete, the bladder is deflated, and the press is opened. The temperature and curing time vary, depending on the type of tire being processed. Vapors, particulates, and other byproducts of the vulcanization process, referred to as curing fume, are emitted from freshly cured tires. At the Freeport plant, curing fume is removed only by general dilution ventilation.

Large rear tractor tires generate more curing fume than the smaller passenger tires, and off-gas for up to an hour after removal from the curing presses. After curing, the tractor tires are transferred to an inflation stand, inflated, then cooled in the open curing-room environment. Tractor-tire curing presses are individually controlled by employees who may be assigned to several presses. Therefore, these employees often work near off-gassing tires. Passenger-tire curing presses are located on both sides of pit areas containing take-off conveyors and utilities for operation of the presses. These presses are automated, but employees assigned to them must ensure that the machinery is functioning properly. Therefore, these employees also work near off-gassing tires.

In the Climate Control Area (Departments 530, 531, 532), a trade-secret process is used to apply rubber to the tire's inner carcass to form the tread. The area has no local exhaust ventilation to control fume emitted from heated rubber during the process. The purpose of the controlled climate is to produce a high quality tire, not necessarily to control employee exposures. On the day of the survey, the temperature was 76.7°F with a relative humidity of 22.7%.

## METHODS – ENVIRONMENTAL

An industrial hygiene investigation of the curing areas (Departments 514 and 534) and the Climate Control Area (Department 530) was conducted on February 18-19, 1992. All air sampling was performed during the first shift on February 19.

### *N*-NITROSAMINES

Five personal breathing-zone (PBZ) samples for *N*-nitrosamines were collected with Thermosorb/N® sorbent tubes according to NIOSH Method 2522 at a flow rate of 2.0 liters per minute (L/min).[1] Four samples were collected in the curing departments and one sample was collected in the Climate Control Area. No area samples were collected. A detailed description of the analysis can be found in Appendix A. The samples were analyzed by gas chromatography/mass spectrometry (GC/MS).

The seven analytes were *N*-nitrosodimethylamine, *N*-nitrosodiethylamine, *N*-nitrosodipropylamine, *N*-nitrosodibutylamine, *N*-nitrosopyrrolidine, *N*-nitrosopiperidine, and *N*-nitrosomorpholine.

### POLYCYCLIC AROMATIC HYDROCARBONS

Five PBZ samples were collected according to NIOSH Method 5506, utilizing a 2-micrometer (μ) pore size, 37-mm Zeflour® (Membrana, Pleasanton, CA) filter in series with a washed XAD-2 (100 mg/50 mg) sorbent tube.[1] The samples were collected at a flow rate of 1.4 to 2.0 L/min. The samples were wrapped in aluminum foil and stored in an insulated container with bagged refrigerant.

The Zeflour® filter samples were analyzed for polycyclic aromatic hydrocarbons (PAHs) according to NIOSH Method 5515 with modifications, benzene-soluble fraction according to NIOSH Method 5023, and total nuisance dust according to NIOSH Method 0500 with modifications.[1] The XAD-2 Tubes were analyzed for PAHs according to NIOSH Method 5515.[1] A detailed description of the sample analysis can be found in Appendix B.

The seventeen PAH analytes were naphthalene, anenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*Θ*]pyrene, benzo[*a*]pyrene, indeno (1,2,3-cd) pyrene, dibenz[*a,h*]anthracene, benzo[*g,h,i*]perylene.

### HYDROCARBONS

Five area samples for hydrocarbons were collected on charcoal tubes (SKC 100 mg/50 mg) at a flow rate of 200 mL/min. Following sampling, each charcoal tube was desorbed in 1 mL carbon disulfide. Three of the samples were analyzed qualitatively by GC/MS.

Based on the results of the GC/MS analysis, the five samples then were analyzed quantitatively for hexane, heptane, methylcyclohexane, and total hydrocarbons by gas chromatography according to NIOSH Method 1500.[1]

## METHODS – MEDICAL

Confidential medical interviews were conducted with 25 first-shift employees from Departments 514 (10 of 31 employees), 530 (2 of 7), 531 (2 of 3), 532 (3 of 9), and 534 (8 of 22). These employees were randomly selected by the NIOSH medical officer from each of the job titles with potential for exposure to curing or rubber fume. The interviewer asked for information about job tasks, work exposures, and symptoms. Nine other employees were interviewed in person or by telephone, either at their request or because they were reported to have possible work-related health effects.

Kelly-Springfield provided the NIOSH medical officer with a list of employee and retiree deaths for the years 1964 through 1991. The list contained names of salaried and hourly employees who died while actively employed at or after retirement from the Freeport facility. The list also contained each individual's date of death and International Classification of Diseases (ICD) codes for primary and secondary causes of death. The ICD codes were translated into diagnoses using the eighth and ninth editions of the ICD.

During the confidential medical interviews, several employees provided names of co-workers who were reported to have cancer or who had died from any, including non-cancer, cause. These names were compared with the names of deceased employees and retirees provided by Kelly-Springfield.

## EVALUATION CRITERIA

*General Guidelines*

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours/day, 40 hours/week for a working lifetime without experiencing adverse health effects. It is important to note, however, that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the limits set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of evaluation criteria for the workplace are the following: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[2] the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs),[3] and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] Because of a recent court decision, the OSHA effective exposure limits are those specified as "Transitional Limits" in the air contaminant standard 29 CFR 1910.1000.[5] These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over the entire 8- to 10-hour workday. Concentrations are usually expressed in parts per million (ppm) or milligrams per cubic meter ($mg/m^3$). In addition, for some substances there are short-term exposure limits (STELs) or ceiling limits which are intended to supplement the TWA limits where there are recognized toxic effects from short-term exposures.

The OSHA standards are required to take into account the feasibility of reducing exposures in various industries where the agents are used; whereas the NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. In evaluating worker exposure levels and NIOSH recommendations for reducing exposures, it should be noted that employers are legally required to meet the requirements of OSHA PELs and other standards.

Although no specific criteria for curing fume particulates have been established in the United States, both OSHA and ACGIH have established exposure limits (15 and 10 $mg/m^3$, respectively) for total nuisance (inert or nontoxic) dust. OSHA also has an occupational limit for respirable nuisance dust (5 $mg/m^3$). However, these criteria may not be applicable because curing fume may contain toxic substances.

## *N*-NITROSAMINES

*N*-nitroso compounds contain a nitrosyl group ( −N=O) bonded to a nitrogen atom. Of more than 120 *N*-nitroso compounds tested, approximately 80% have demonstrated carcinogenicity in animals. The more potent compounds have shown cancer induction at low doses in all species tested, including primates.[6] Compounds of the *N*-nitrosamine group of *N*-nitroso compounds are considered to be among the most potent of animal carcinogens.[7] Epidemiologic evidence of human carcinogenicity, however, remains inadequate despite sufficient experimental evidence of carcinogenicity in animals.[8,9]

In the past, NIOSH investigators have found airborne nitrosamines in a number of tire manufacturing facilities.[10,11,12,13] During rubber processing, nitrosamines can be formed by nitrosation of amines or amine derivatives in accelerators, retarders, promotors, and blowing agents.[14,15] The highest concentrations of nitrosamines found in tire manufacturing facilities were those of *N*-nitrosomorpholine, with a maximum concentration of 250 $\mu g/m^3$ at one plant.[16] The reaction of the nitroso group from thermal decomposition products of a retarding agent, *N*-diphenylamine, with other rubber additives containing preformed morpholine compounds was considered the source of *N*-nitrosomorpholine.[16] Subsequent substitution of raw materials and ventilation improvements resulted in significantly reduced exposure to airborne nitrosamines.[12,16]

Nitrosamines are also found outside the workplace. Exogenous exposures occur when preformed nitrosamines enter the body by inhalation (breathing), ingestion (eating), or skin absorption. In addition, endogenous exposures occur when nitrosamines are formed within the body. Tobacco and tobacco smoke, including smokeless tobacco and side-stream smoke, represent the largest nonoccupational source of exposure to preformed nitrosamines.[15,17] Other potential nonoccupational sources of nitrosamines and precursor compounds (such as nitrates or nitrites) include cured meat products, alcohol beverages, cosmetic products, and some vegetables.[15,17,18,19]

NIOSH recognizes substances that cause increased rates of tumors in mammals to be potential occupational carcinogens. NIOSH recommends that occupational exposures to these substances, including nitrosamines, be reduced to the lowest feasible level.[20] OSHA recognizes, and thus regulates, *N*-nitrosodimethylamine, a nitrosamine, as a potential occupational carcinogen. The OSHA standard does not include a PEL, but it requires strict control of exposure.[21]

## POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are chemical species that consist of two or more fused aromatic rings. They are often associated with the combustion or pyrolysis of organic matter, especially coal, wood, and petroleum products. The mineral oils and tar products used in the rubber industry contain preformed PAHs. In addition, PAHs may be generated when mineral oils and tars are heated during the manufacture of rubber products.[22] Although mineral oils and tar products vary in composition, they are known to induce carcinogenic effects in mammals, including humans. Their carcinogenicity may be dependent on the presence of carcinogenic PAHs, such as benzo[*a*]pyrene.[22 28}] Occupational exposures to coal-tar and petroleum products, which contain PAHs, have been associated with increased risk of cancer, such as cancers of the skin, lung, and bladder.[23,24,25] Mineral oils containing different amounts of PAHs have also been found to be mutagenic in some mutagenicity tests.[22,25] Tobacco smoke contains PAHs, including naphthalene, phenanthrene, anthracene, pyrene, benz[*a*]anthracene, and benzo[*a*]pyrene.[26]

NIOSH considers coal-tar products (coal-tar, coal-tar pitch, creosote, or mixtures of these substances) to be carcinogenic. Therefore, NIOSH recommends that occupational exposures to coal-tar products be controlled so that employees are not exposed to the benzene- (or cyclohexane-) extractable fraction of coal-tar products at a concentration greater than 0.1 $mg/m^3$, determined as a TWA concentration for up to a 10-hour work shift in a 40-hour work week.[20] Both OSHA and ACGIH set their standards at 0.2 $mg/m^3$ for a normal 8-hour workday or 40-hour work week. OSHA defines coal-tar pitch volatiles as the fused polycyclic hydrocarbons (such as anthracene, benzo[*a*]pyrene, phenanthrene, acridine, chrysene, and pyrene) that volatilize from the distillation residues of coal, petroleum, wood, and other organic matter.[3,20]

The criteria for coal-tar pitch volatiles, however, are not directly applicable to curing fume results because of differences in PAH content. These criteria are presented because the extraction method for the benzene-soluble fraction of curing fume uses a method developed for coal-tar pitch. The curing-fume compounds extracted by the method, however, cannot be interpreted to be the same as those extracted from coal-tar products.

Naphthalene, a PAH, is not considered a potential occupational carcinogen, and its NIOSH REL is 50,000 $\mu g/m^3$ as a TWA.[20] NIOSH has not set RELs for acenaphthene or fluorene. The International Agency for Research on Cancer (IARC) included fluorene in a list of agents that were not classifiable as to their carcinogenicity in humans. Evidence for the carcinogenicity of fluorene in animals was considered insufficient, and data in humans were not adequate to draw conclusions.[27]

## HYDROCARBONS

Many hydrocarbons, including hexane isomers, heptane, and methylcyclohexane can cause drowsiness or dizziness at high concentrations. Other hydrocarbons are associated with respiratory and mucous membrane irritation.[28] The relevant occupational exposure limits are listed with the sample results.

## RESULTS – ENVIRONMENTAL

### *N*-NITROSAMINES

No nitrosamines were detected in any of the samples collected. All seven nitrosamines were confirmed in the quality assurance sample. The limit of detection was estimated to be less than 0.05 µg/m$^3$ for *N*-nitrosopiperidine, *N*-nitrosopyrrolidine, and *N*-nitrosomorpholine; and less than 0.02 µg/m$^3$ for all other analytes. Detection limits were based on a signal-noise ratio of 3:1 for the $NO^+$ ion at m/z 29.998. No mass spectral interferences were detected in the analyses of the three sample blanks.

Although a peak was detected at the appropriate retention time for *N*-nitrosomorpholine, mass spectral analysis indicated that the substance was not *N*-nitrosomorpholine or any other nitrosamine.

### POLYCYCLIC AROMATIC HYDROCARBONS

The sampling results for total particulates and benzene-soluble fraction samples are shown in Table 1. Total particulate TWA concentrations ranged from 0.05 to 1.25 mg/m$^3$, below the criteria for nuisance particulates. However, these criteria may not be applicable to curing fume, which may contain toxic substances.

With the exception of one sample with no detectable benzene-soluble fraction, benzene-soluble fraction concentrations ranged from 0.20 to 0.78 mg/m$^3$ TWA. All were at or above the criteria for coal-tar pitch volatiles (NIOSH REL of 0.1 mg/m$^3$ TWA and Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.2 mg/m$^3$ TWA). However, anthracene, benzo[*a*]pyrene, phenanthrene, chrysene, and pyrene (PAHs included in the OSHA definition of coal-tar pitch volatiles) were not detected in the Kelly-Springfield samples.

Three PAHs (naphthalene, acenaphthene, and fluorene) were detected. The sampling results are shown in Table 2. The naphthalene concentrations ranged from less than 0.5 µg/m$^3$ (the minimum detectable concentration) to 3.6 µg/m$^3$ TWA, and were well below the NIOSH REL of 50,000 µg/m$^3$. Acenaphthene concentrations ranged from 1.8 to 6.9 µg/m$^3$ TWA. Fluorene was detected at concentrations below the limit of quantification. NIOSH has not set RELs for acenaphthene and fluorene. The limits of detection and quantification were 0.5 and 1.7 µg/sample for each of the PAHs.

Smoking was permitted in break areas during the NIOSH visit. As discussed earlier, tobacco smoke contains a number of PAHs. Naphthalene is found in tobacco smoke; however, acenaphthene and fluorene are not listed by the Environmental Protection Agency as PAHs found in tobacco smoke.[26]

### HYDROCARBONS

The concentrations of hexane isomers, heptane and methylcyclohexane, which were well below their respective criteria, are shown in Table 3. Because all the hydrocarbon sampling consisted of area samples, the results may not be representative of actual employee exposures. However, the concentrations of total hydrocarbons were typical of concentrations found previously in other tire plants.[29]

## RESULTS – MEDICAL

The annual average employment at Kelly-Springfield was 1,523 in 1990 and 1,572 in 1989, as reported on the OSHA Form 200-S for those years.

Eighty-eight deaths among hourly employees and sixteen deaths among salaried employees were reported for the years 1964 through 1991 (Table 4) on the list provided by Kelly-Springfield. Twelve of the eighty-eight deaths among hourly employees were related to malignancies. The most frequent primary cancer site in three individuals was the trachea, bronchus, or lung. No other primary cancer site occurred in more than one individual.

The requester and confidentially interviewed employees provided names of 10 salaried and 26 hourly employees reported to have died (not necessarily of cancer) or reported to have cancer. Fifteen of the individuals were on the list of deceased employees provided by Kelly-Springfield. Only one of the nine diagnoses provided by co-workers was confirmed by the company's list. Four individuals died of causes other than cancer. The 20 individuals who were not on the Kelly-Springfield list were presumed either to have died after termination of employment or to be still alive in 1991.

The symptoms reported by the randomly selected employees during confidential medical interviews are shown in Table 5. Eye, nose, or throat irritation, headache, and tiredness were reported by over half of those interviewed. Approximately one-third of the interviewed employees reported cough, and one-fifth reported chest tightness, wheezing, or shortness of breath. Workplace and environmental factors reported to aggravate symptoms are shown in Table 6. In Departments 514 and 534, employees attributed their eye, nose, and throat irritation, headache, and tiredness to curing fume or gas-burner emissions. In Departments 530, 531, and 532, employees attributed these symptoms to curing fume or environmental conditions resulting from the climate-control system.

## DISCUSSION

Epidemiologic studies have shown that rubber workers may be at increased risk of developing cancer. Rarely, however, have causative agents been identified. In 1949, free naphthylamine in an antioxidant was linked to bladder cancers in British rubber workers, prompting the removal of the antioxidant from use in the industry.[30] British rubber workers who entered the industry after 1949 did not show evidence for a continued excess risk of bladder cancer.[31] Cancer excesses, however, continue to be found in the rubber industry. Known occupational carcinogens, such as asbestos and benzene, or potential occupational carcinogens, such as nitrosamines and PAHs, might have contributed to the excess risks. Chemical exposures, however, have varied over time, as well as from process to process. In addition, cancers are not detected until years after cancer cells first begin to multiply; the time between exposure and recognition of the cancer (by symptoms or medical findings) is typically 10 to 20 years. Thus, excess cancer risks due to occupational exposures may be difficult to detect, and specific cancer-causing agents may be difficult to identify with certainty. This difficulty can be illustrated by the epidemiologic evidence of lung cancer risk among tire-curing workers. Some studies have shown excesses in lung cancer rates among tire-curing workers,[32,33,34] while other studies have not found the same excesses.[35,36] A more recent case-control study found elevated lung cancer rates in curing preparation, but not in curing.[37] The elevated lung cancer rates in curing preparation, however, did not increase as duration of exposure increased. The association between exposure and disease may be questioned when disease rates do not rise as exposure potential increases. A study of curing workers also found an excess of cancers of the pancreas and leukemia, but the causes for these excesses could not be determined.[34]

Because of the historic potential for exposure to carcinogenic substances in the rubber industry and the uncertainty of epidemiologic study results, employee concerns about cancer risks are not unexpected. Cancer, however, is the second leading cause of death in the United States.[38] Therefore, except for large cancer excesses, work-related causes of cancer are difficult to demonstrate. When multiple types of cancer are reported and the number of each type of cancer is small, such as was found in the Kelly-Springfield workforce, it is difficult to attribute the cancers to workplace exposures.

Known carcinogens, such as certain PAHs and nitrosamines, were not detected in air samples collected in the Kelly-Springfield curing departments by NIOSH investigators. Concurrent sampling by Kelly-Springfield, however, revealed airborne *N*-nitrosomorpholine in the curing departments. This discrepancy may be related to differences in analytic methods. Kelly-Springfield reportedly does not perform mass-spectral analysis, the method used for the NIOSH samples, during analyses for nitrosamines. Their method of analyte identification was based solely on retention time. This method may result in misidentification of the analyte because many other substances can elute at the same time as nitrosamines.

In 1976, Fine and Peters reported the results of their study of respiratory symptoms and pulmonary function in curing workers.[39,40] Increased rates of respiratory problems were seen in curing workers when compared to workers who were not exposed to curing fume. Although current and former smokers were more symptomatic than nonsmokers, within smoking categories, curing workers had higher rates of acute bronchitis and a two-fold greater prevalence of chronic bronchitis compared with other workers.[39] Workers with heavy exposure to curing fume also showed greater decreases in lung function after a work shift than workers with light exposure to curing fume.[40] Curing workers with more than 10 years of exposure showed greater decreases in lung function over a one-year period compared with curing workers with less than 10 years exposure and workers not exposed to curing fume.[40] In these studies, exposure to curing fume was represented by respirable particulates (particles small enough to be inhaled deep into the lungs) collected on personal samplers. The mean exposure to respirable particulates was 1.63 $mg/m^3$ in the heavily exposed group and 0.24 $mg/m^3$ in the lightly exposed group. The mean exposure to respirable particulates in the heavily exposed group was higher than the highest concentration (1.25 $mg/m^3$) of total particulates found in Kelly-Springfield curing departments. Because respirable particles comprise only a fraction of total particulates, exposures to respirable particulates in the Kelly-Springfield curing departments are probably lower than those of the curing workers studied by Fine and Peters.

Curing fume contains sulfur compounds, amines, and other air contaminants that could explain the symptoms of eye, nose, and throat irritation, as well as the respiratory symptoms reported by Kelly-Springfield curing department employees. Symptoms of headache, lightheadedness or dizziness, and tiredness are consistent with exposures to organic solvents, even though specific hydrocarbons were not detected in concentrations above the NIOSH RELs. Because many of the frequently reported symptoms are consistent with exposure to the large variety of potential contaminants in the workplace, control of exposures to air contaminants may reduce the numbers of symptoms that employees experience.

## RECOMMENDATIONS

The following recommendations are offered as prudent measures to reduce exposures to curing fume.

### CURING DEPARTMENT

Kelly-Springfield should consider installing local exhaust ventilation in its passenger- and farm-tire curing departments. In-house expertise already exists at Goodyear, Kelly-Springfield's parent company. The Goodyear Engineering Department has designed and installed ceiling-mounted hoods that have successfully controlled airborne contaminants in curing rooms at several Goodyear plants. In addition, NIOSH provides information on control technologies in the publication, "Control of Air Contaminants in Tire Manufacturing."[12] At Kelly-Springfield, local exhaust ventilation should greatly reduce potential exposures to known irritant substances, such as amines released during the curing process. The effectiveness of local exhaust hoods could be tested on a limited number of presses before full-scale installation.

The design of receiving hoods is critical for proper operation of the hoods. The bottom edges of each hood should be as close to the floor as possible. The distance from the front of the presses to the sides of the hood should be large enough to assure containment of the fume plume. In addition, each hoods' size and exhaust rate should be adequate to contain the fume and air inducted into the hood by convection.

Make-up air should be supplied to the curing departments in a manner that provides cooling for the employees, but does not create jets of air which could disrupt air flow into the hoods or pull contaminated air out of the hood. Contaminated air should be exhausted far enough above the plant roof to prevent circulation back into the plant.

Plant personnel indicated that the truck- and tractor-tire press rows did not have hoods because of the machinery used to load tires onto the presses. Push-pull hoods should be considered for these rows. The bottom edges of these hoods should be as close to the floor as possible. A manifold jet or series of jets can be used to direct and augment the flow of fume into the hood. Design of the jets should follow the general design guidelines already published in the literature and the ACGIH Ventilation Manual for push-pull hoods.[41] The effectiveness of push-pull hoods could be tested on a limited number of presses before full-scale installation.

### CLIMATE CONTROL AREA

Kelly-Springfield should investigate the Climate Control Area to identify sources of potential emissions. Sources of rubber-fume emissions should be enclosed or placed under local exhaust enclosures or hoods, whenever possible. Transparent, scratch-resistant, non-yellowing, shatter-proof material, such as Lexan, can be used if operators must view the process. Enclosures should have adequate openings so that the transport velocity in the ducts is maintained when doors to the enclosure are closed.

Horizontal runs of duct should be minimized because the sticky nature of rubber emissions can lead to plugging of ductwork. Routine inspection of ductwork for accumulation should be included in the preventive maintenance program.

**SAMPLE ANALYSIS**

Because reliance on retention time alone for the analysis of nitrosamines may result in misidentification of analytes, mass spectral analysis should be used to confirm the presence of nitrosamines.

**TOBACCO SMOKE**

Workers should not be involuntarily exposed to tobacco smoke. The best method for controlling worker exposure to environmental tobacco smoke is to eliminate tobacco use from the workplace and to implement a smoking cessation program. Until tobacco use can be completely eliminated, employers should protect nonsmokers from environmental tobacco smoke by isolating smokers. Methods for eliminating tobacco use from the workplace and isolating smokers can be found in the NIOSH Current Intelligence Bulletin 54, Environmental Tobacco Smoke in the Workplace, Lung Cancer and Other Health Effects.[42]

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Copies of this report have been sent to:

1. Kelly-Springfield Tire Company
2. Employee representative
3. United Rubber Workers Local 745
4. OSHA Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Total Particulates and Benzene Soluble Fraction
Kelly-Springfield Co.
HETA 91-0123
February 19, 1992

| **Sample Type** | **Sample Volume** (liters) | **Total Particulates** ($mg/m^3$)[a] | **Benzene Soluble Fraction** ($mg/m^3$) | **Limit of Detection**[b] ($mg/m^3$) |
|---|---|---|---|---|
| Personal[c] | 666 | 0.65 | 0.45 | 0.08 |
| Personal[d] | 896 | 0.93 | 0.78 | 0.06 |
| Personal[d] | 232 | 0.60 | 0.21 | 0.21 |
| Personal[e] | 506 | 0.05 | ND[f] | 0.10 |
| Personal[c] | 488 | 1.25 | 0.20 | 0.10 |
| NIOSH REL[g]<br>OSHA PEL[i]<br>ACGIH TLV[k] | | none<br>15[j]<br>10[j] | 0.1[h]<br>0.2[h]<br>0.2[h] | |

[a] $mg/m^3$ = milligrams per cubic meter air.
[b] For the benzene-soluble fraction.
[c] Mold-and-bladder operator.
[d] Cure-line operator.
[e] Laminator operator, a smoker.
[f] ND: Not detected.
[g] NIOSH Recommended Exposure Limit, time-weighted average over 10 hours.
[h] Criteria for coal-tar pitch volatiles. These criteria are not directly applicable to curing fume results because of differences in composition and potential differences in toxicity. See comments in text.
[i] OSHA Permissible Exposure Limit, time-weighted average over 8 hours.
[j] Criteria for nuisance particulates. These criteria are not directly applicable to curing fume results because of differences in composition and potential differences in toxicity. See comments in text.
[k] ACGIH Threshold Limit Value, time-weighted average over 8 hours.

Table 2
Polycyclic Aromatic Hydrocarbons
Kelly-Springfield Co.
HETA 91-0123
February 19, 1992

| **Sample Type** | **Sample Volume** (liters) | **LOD/LOQ** ($\mu g/m^3$)[a] | **Naph-thalene** ($\mu g/m^3$) | **Acenaph-thene** ($\mu g/m^3$) | **Fluorene** ($\mu g/m^3$) |
|---|---|---|---|---|---|
| Personal[b] | 506 | 1.0/3.4 | 3.6 | 6.9 | (2.5)[c] |
| Personal[d] | 666† | 0.8/2.6 | (2.1) | (1.8) | (1.8) |
| Personal[e] | 232† | 2.1/7.3 | ND[f] | (3.0) | (2.6) |
| Personal[e] | 896 | 0.6/1.9 | 2.4 | 2.6 | (1.7) |
| Personal[d] | 488† | 1.0/3.5 | (1.4) | (2.0) | (1.2) |
| NIOSH REL[g]<br>OSHA PEL[h]<br>ACGIH TLV[i] | | | 50,000<br>50,000<br>52,000 | none<br>none<br>none | none<br>none<br>none |

[a] LOD/LOQ: Limit of detection and limit of quantification based on sample volume. $\mu g/m^3$ = micrograms per cubic meter air.
[b] Laminator operator, a smoker. PAHs, including naphthalene, are released in tobacco smoke, but acenaphthene and fluorene are not primary constituents of cigarette smoke.
[c] Note: The values in ( ) represents a quantity between the LOD (0.5 µg/sample) and the LOQ (1.7 µg/sample), and should be considered a trace concentration with limited confidence in its accuracy.
[d] Mold-and-bladder operator.
[e] Cure-line operator.
[f] ND: Not detected.
[g] NIOSH Recommended Exposure Limit, time-weighted average over 10 hours.
[h] OSHA Permissible Exposure Limit, time-weighted average over 8 hours.
[i] ACGIH Threshold Limit Value, time-weighted average over 8 hours.
†Sampling pump failed.

Table 3
Hydrocarbons
Kelly-Springfield Co.
HETA 91-0123
February 19, 1992

| **Sample Type** | **Sample Volume** (liters) | **Hexane Isomers** ($mg/m^3$)[a] | **Heptane** ($mg/m^3$) | **Methyl-cyclohexane** ($mg/m^3$) | **Total Hydrocarbon** ($mg/m^3$) |
|---|---|---|---|---|---|
| Area[b] | 76 | 3.4 | 3.7 | 10.3 | 27.1 |
| Area[c] | 108 | (0.03)[d] | 0.4 | 1.3 | 3.0 |
| Area[e] | 71 | (0.10) | 0.1 | 0.4 | 1.1 |
| Area[f] | 69 | 1.0 | 0.5 | 1.7 | 5.0 |
| Area[g] | 96 | 3.0 | 2.0 | 6.4 | 17.4 |
| NIOSH REL[h] | | 350 | 350 | none | none |
| OSHA PEL[i] | | 500 | 1640 | 1600 | none |
| ACGIH TLV[j] | | 500 | 1640 | 1610 | none |

[a] $mg/m^3$ = milligrams per cubic meter air.
[b] Climate Control Area (Dept. 530), strip laminator #1.
[c] Passenger-tire curing (Dept. 514), row E.
[d] Values in ( ) are between the limit of detection and limit of quantification.
[e] Farm-tire curing (Dept. 534), press B-3.
[f] Passenger-tire curing (Dept. 514), row J.
[g] Farm-tire curing (Dept. 534), press F-2.
[h] NIOSH Recommended Exposure Limit, time-weighted average over 10 hours.
[i] OSHA Permissible Exposure Limit, time-weighted average over 8 hours.
[j] ACGIH Threshold Limit Value, time-weighted average over 8 hours.

Table 4
Summary of Deaths Among Active or Retired Hourly Employees, 1964-1991
Kelly-Springfield Company
HETA 91-0123

| **Cause of death**[a] | **Number of employees** | **Age of employees (years)** |
|---|---|---|
| All causes | 88 | 18-79 (mean = 46.6) |
| Accidents, poisonings, violence | 31 | 18-69 (mean = 30.5) |
| Heart disease | 29 | 29-79 (mean = 57.8) |
| Malignancies, all sites | 12 | 36-70 (mean = 56.8) |
| Trachea, bronchus, lung | 3 | |
| Stomach | 1 | |
| Rectum | 1 | |
| Kidney | 1 | |
| Bladder | 1 | |
| Lymphosarcoma | 1 | |
| Myelofibrosis | 1 | |
| Brain | 1 | |
| Melanoma | 1 | |
| Disseminated cancer, primary not specified | 1 | |

[a] International Classification of Diseases, eighth edition.

Table 5
Symptoms Reported During Interviews With 25 Employees
Kelly-Springfield Co.
HETA 91-0123
February 19 - 21, 1992

| **Department**<br>Number interviewed | **All**<br>25 | **514**<br>10 | **530, 531, 532**<br>7[a] | **534**<br>8 |
|---|---|---|---|---|
| Headache | **13 (52)**[b] | 6 (60) | 3 (43) | 4 (50) |
| Lightheadedness or dizziness | **5 (20)** | 3 (30) | 1 (14) | 1 (13) |
| Tiredness | **14 (56)** | 7 (70) | 2 (29) | 5 (63) |
| Any eye, nose, or throat irritation | **17 (68)** | 5 (50) | 5 (71) | 7 (88) |
| Eye irritation | **15 (42)** | 4 (40) | 4 (57) | 7 (88) |
| Nasal irritation | **10 (40)** | 4 (40) | 3 (43) | 3 (38) |
| Throat irritation | **6 (24)** | 1 (10) | 1 (14) | 4 (50) |
| Cough | **9 (36)** | 3 (30) | 2 (29) | 4 (50) |
| Lower respiratory symptoms | **5 (20)** | 2 (20) | 1 (14) | 2 (25) |
| Chest tightness | **1 (4)** | 1 (10) | 1 (14) | 1 (13) |
| Chest wheezing | **2 (8)** | 2 (20) | 0 | 1 (13) |
| Shortness of breath | **2 (8)** | 2 (20) | 1 (14) | 2 (25) |
| Chest pain or palpitations | **2 (8)** | 1 (10) | 0 | 1 (13) |
| Nausea or vomiting | **0** | 0 | 0 | 0 |
| Skin rashes | **4 (16)** | 2 (20) | 0 | 2 (25) |

[a] Two from Department 530, two from 531, and three from 532.
[b] Number and (%) of those interviewed.

Table 6
Factors Reported by 25 Employees
Responsible for Worsening Symptoms
Kelly-Springfield Co.
HETA 91-0123
February 19 - 21, 1992

| **Factor** |
|---|
| Climate Control<br>(in order of reported severity)<br><br>Department 530<br>Department 532<br>Department 531 |
| Curing fume according to type of tire<br><br>Radial tires<br>Certain bias ply tires |
| Curing fume from certain stock materials<br><br>Code #1720<br>Code #1552 |
| Increased smoke attributed to changes in the past ten years<br><br>Higher curing temperatures<br>Shorter curing times<br>Increased number of processes |
| Outside environmental conditions<br><br>Dry air, especially in winter<br>Winter<br>Summer |

## **APPENDIX A**: *N*-NITROSAMINE SAMPLE ANALYSIS

The samples and blanks were prepared for analysis by backflushing the Thermosorb/N® tubes with 2 milliliters (mL) of a solution containing 25% dichloromethane and 75% methanol. A standard solution containing the analytes in methanol/dichloromethane at the concentration of 10 micrograms per milliliter (µg/mL) each was purchased from Thermedics Inc., Woburn, MA. The quality assurance sample was prepared by injecting 20 microliters (µL) of the standard directly onto a fresh Thermosorb/N® tube. The tube was allowed to stand overnight and then desorbed for analysis. An additional 0.1 µg/mL standard was prepared for use in determining detection limits. The samples then were analyzed by gas chromatography/mass spectrometry (GC/MS). The mass spectrometer was operated in the selected-ion-monitoring (SIM) mode at a resolution of 3000. Specific *N*-nitrosamines were detected by monitoring the characteristic $NO^+$ ion at m/z 29.998 during the expected chromatographic elution time of the analyte. If a mass spectrometer response occurs at the correct retention time, an additional confirmation step is carried out. In this instance, the mass spectrometer is set to monitor the molecular ion of the analyte during analysis. A positive response confirms the presence of the analyte. The gas chromatograph was equipped with a 30 meter by 0.25 millimeter (mm) DB-5.625 capillary column. The oven was temperature programmed from 60°C to 200°C at 12°C/min. GC/SIM analysis conditions were optimized with 1-µL injections of the 10-µg/mL standard. The area response obtained during analysis was compared to the areas from standards to estimate the concentration.

**APPENDIX B**: POLYCYCLIC AROMATIC HYDROCARBON ANALYSIS

The filter samples first were analyzed for particulate total weight by gravimetric analysis. The filters and backup pads were not vacuum desiccated; instead they were subjected to room conditions (21 ± 3°C, 40 ± 3% relative humidity) for a long duration for stabilization. The total weight of each sample was determined by weighing the sample plus the filter on an electrobalance and subtracting the previously determined tare weight of the filter. The instrument precision is 0.01 mg. Due to variable factors such as hygroscopicity of the sample, the actual precision may be considerably poorer.

The filters were then sonicated for 60 minutes in 5 mL of benzene. The extract was analyzed for polycyclic aromatic hydrocarbons by gas chromatography using a 30 meter X 0.32 mm fused silica capillary column with 1.0 μ of DB-5. The oven conditions were 100°C for 5 minutes up to 300°C for 15 minutes at a rate of 5°C per minute.

The benzene extract was also analyzed for the benzene soluble fraction in the following manner. The extract was filtered through a 0.5-μ teflon filter and collected in an additional test tube. One mL of each sample was then transferred into a tared Teflon cup and evaporated to dryness in a vacuum oven at 40°C. The Teflon cups were again weighed and the difference recorded, and weight gain of the cup being one-fifth the total benzene solubles per sample.

The washed XAD-2 sorbent tubes were desorbed in 1.0 mL of benzene with 60 μg/mL trisosane as an internal standard and were analyzed by gas chromatography in the same manner as the Zeflour® filters.