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HETA 96-0169-2637
Kokoku Rubber, Inc.
Richmond, Kentucky

John A. Decker, C.I.H.
Douglas Trout, M.D.

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by John A. Decker, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Greg Kinnes, C.I.H.. Desktop publishing by Pat Lovell.

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Health Hazard Evaluation Report HETA 96-0169-2637
Kokoku Rubber, Inc.
Richmond, Kentucky
May 1997

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SUMMARY

In June 1996, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) concerning exposures to chemicals released in the vulcanizing department at Kokoku Rubber. The request indicated several employees were experiencing allergic reactions, breathing problems, and skin rashes. In response to this request, NIOSH conducted a site visit on July 12, 1996, during which industrial hygiene sampling and medical interviews were conducted.

Industrial hygiene sampling was conducted for nitrogen oxides (5 process samples), aldehydes (3 personal and 3 area samples), and nitrosamines (5 personal and 1 area sample). Qualitative analyses for airborne chemicals (primarily organic) were conducted with thermal desorption tubes. Heat stress monitoring was also conducted. Low concentrations of nitrogen dioxide (below the analytical limit of quantification) were detected. No nitrosamines were found. Various aldehydes were detected on the thermal desorption tubes, but none could be detected by the aldehyde screening method because of a higher limit of detection for the method. The thermal desorption tube monitoring found 30 additional airborne contaminants, including acetophenone, methyl styrene, carbon disulfide, and sulfur dioxide. Although not monitored, several amines were present in the rubber formulations and could have been present as airborne contaminants. A heat stress hazard was not identified on the day of the survey, but the recommended heat-stress exposure limit could potentially be exceeded on hot days exceeding the climatological norms.

The NIOSH medical officer interviewed 11 employees, including 8 employees who requested an interview. Nine of the 11 interviewed employees either currently worked or had worked in the vulcanizing department. Of these 9 employees, 7 reported intermittent respiratory symptoms including shortness of breath, chest tightness, and nose and throat irritation while working in the vulcanizing department. There were no specific parts or formulations identified that caused similar symptoms among 2 or more of the employees interviewed.

Several low-concentration respiratory irritants were found in the vulcanizing department. Although no single chemical was implicated in the reported health effects, it is possible that the combined effects of these irritants may be contributing to health complaints reported among some employees. Recommendations were made regarding local exhaust ventilation, medical surveillance, and the implementation of a heat stress program.

Keywords: SIC 3016 (Automotive mechanical rubber goods), neoprene rubber, nitrogen oxides, nitrosamines, aldehydes, heat stress.

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INTRODUCTION

In June 1996, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) concerning exposures to chemicals released in the vulcanizing process at Kokoku Rubber. The request indicated several employees were experiencing allergic reactions, breathing problems, and skin rashes. In response to this request, NIOSH conducted a site visit on July 12, 1996, during which industrial hygiene sampling and medical interviews were conducted. Although rubber is also formulated at this facility, the HHE request included only the vulcanizing area and the quality control inspection trailer.

BACKGROUND

Kokoku Rubber produces approximately 150 different precision rubber parts primarily from polyisoprene (Neoprene®) rubber at the Richmond, Kentucky, facility. The parts are formed by compression molding and are used in the automotive industry (about 50% of volume), electronics industry (40%), and health care industry (10%). Examples of items produced include valves for fuel and exhaust gas control, fuel tubes, piston boots, seal stoppers for use with chemical condensers, vibration isolator gaskets, TF rubber for keyboard switches, rubber stoppers for vials, and multi-tip rubber stoppers for vacuum blood-collection devices.

Individual pieces of unvulcanized rubber are placed in the molds by hand; then the press closes and heat and pressure are applied for a pre-set time. The rubber undergoes a physicochemical change known as vulcanization, which involves the cross-linking of unsaturated hydrocarbon chains with sulfur. At a pre-set time, the mold is opened and the parts are removed and cooled in the open atmosphere. As the freshly-cured part cools, it emits a vapor/particulate substance referred to as "curing fume." The parts are then inspected by hand in an inspection trailer apart from the rubber vulcanizing building.

The Kokoku facility has fifteen 500-ton presses and twelve 200-ton vulcanizing presses. The cycle time for the presses generally ranges from 3 to 8 minutes at temperatures ranging from 150 - 200ºC. For the 500-ton presses, the source of heat is stream, whereas the 200-ton presses use electrically-heated oil. None of the machines are equipped with local exhaust ventilation. Kokoku management has considered installation of exhaust ventilation, but changes have not been made because of concerns about creation of a fire hazard. Contaminant removal is via dilution ventilation from building fans. Since the presses produce substantial steam and heat, there are also concerns about heat stress. Ambient dry bulb temperatures reportedly reach 100-110ºF inside the plant on hot summer days.

Approximately 125 full-time employees and 30 part-time employees work at Kokoku Rubber. According to the company, the average duration of employment is 2.7 years. For the vulcanizing area, approximately 30-40 employees work during the first shift (A shift), 25 employees work during second shift (B shift), and approximately 10-12 employees work during the third shift (C shift). Approximately 30 employees (all female) work in the inspection trailer. Overall, the workforce is approximately 60% female.

The employees are given a 10-minute break in the morning, a 40-minute lunch break, and another 10-minute break in the afternoon. On hot days, the company reportedly provides an additional 10-minute break in the afternoon. The break room is air-conditioned, and cold water and drinks are available. The inspection trailer is air-conditioned. In the vulcanizing area, employees use heat-resistant gloves when removing hot molds.

The "recipe" for the rubber varies depending on the strength and elasticity needed for the part being produced. The chemicals used in compounding include fillers (carbon black), oils, alcohols, zinc oxide, stearic acid, antidegradants (to limit oxidation), sulfur (for vulcanizing), and accelerators (to speed the cross linking process). Over 100 chemicals for rubber compounding were in use at the time of the NIOSH visit, and the complete MSDS list included 400 chemicals that may be used depending on the rubber application. Several amine chemicals were also being used. These included stearylamine, N-isopropyl-N-phenyl-p-phenylene diamine, 4,4'-dimethylbenzyl-diphenylamine, and "octylated"-diphenylamines. A silicone-in-water emulsion die-release agent is used for parts that are difficult to remove from the molds.

METHODS

Industrial Hygiene

Industrial hygiene monitoring was conducted to assess airborne concentrations of nitrogen oxides, nitrosamines, and aldehydes. Nitrogen oxides and aldehydes, which can cause eye and respiratory irritation, were monitored because of employee concerns about possible over-heating of the rubber during curing. Nitrosamines, many of which are carcinogens, can be produced from the reaction of various amines and nitrite. Qualitative analyses for airborne chemicals (primarily organic) were conducted with thermal desorption tubes. Since the presses produce significant build-up of heat in the plant, heat stress monitoring was also conducted.

Nitrogen Oxides

Five process area air samples for nitrogen dioxide (NO_2) and nitric oxide (NO) were collected in the vulcanizing area (sampling locations are indicated in the results section). The Filtec oil filter mold and the GTI lower seal were being produced in the areas sampled. The sampling and analysis were conducted according to NIOSH method 6014, except that an air flow rate of 200 milliliters per minute (mL/min) was utilized at the recommendation of NIOSH chemists.[1] The sampling train was assembled as follows:

Tube A: 400 milligram (mg) triethanolamine-coated molecular sieve (SKC® #226-40)
Tube B: 800 mg chromate oxidizer to convert NO to NO_2
Tube C: Same as tube A

Tubes A and C were analyzed for Nitrite ion (NO_2^-) by visible absorption spectrophotometry. The limits of detection and quantification for NO were 0.8 and 2.7 micrograms (μg) per sample, respectively. This corresponded to air concentrations of approximately 9 and 32 micrograms per cubic meter air (μg/m^3), respectively. The limits of detection and quantification for NO_2 were 1 and 4.2 μg/sample, respectively, corresponding to air concentrations of approximately 12 and 49 μg/m^3, respectively.

For each location sampled above, a short-term sample was collected with Draeger® 0.5a "nitrous fumes" (NO + NO_2) detector tube. These tubes are designed to detect total nitrogen oxide concentrations between 0.5 and 10 parts per million (ppm).

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 1.0 liters per minute (L/min).[1] The samples were collected from press operators producing the following parts: B-D 1cc syringe, Filtec oil filter mold, Honda head cover packing, ITW Isolator, and the Stanley Drain Tube. In addition, one area sample was collected in the inspection trailer (many different parts were being inspected). The samples were analyzed by gas chromatography using a thermal energy analyzer. The seven analytes included in the analyses are *N*-nitrosodimethylamine, *N*-nitrosodiethylamine, *N*-nitrosodipropylamine, *N*-nitrosodibutylamine, *N*-nitrosopyrrolidine, *N*-nitrosopiperidine, and *N*-nitrosomorpholine. The limit of detection was approximately 0.02 μg/m^3 for all nitrosamines, except nitrosomorpholine, which was 0.06 μg/m^3.

Thermal Desorption - Gas Chromatography/Mass Spectrometry

Four area samples for qualitative analyses of airborne chemicals were collected using thermal desorption tubes. Three samples were collected in the curing department, and one sample was collected outside as a control. The specific sampling locations and parts produced were as follows: the 500-ton B1 press (GTI lower seals), the 200-ton A1 press (ITW Nifco isolator), and the 200-ton E2 press (HP black wiper). Sampling was collected at a nominal airflow rate of 45 mL/min for approximately 1.5 hours.

Stainless steel thermal desorption tubes containing three beds of sorbent materials were used-- a front 90 mg layer of Carbopack Y®, a middle 115 mg layer of Carbopack B®, and a back 150 mg layer of Carboxen 1003®. Prior to field sampling, each tube was conditioned at 375ºC for 2 hours.

The samples were analyzed using the ATD 400® automatic thermal desorption system. The thermal unit was interfaced directly with a Hewlett Packard 5890A® gas chromatograph and a Hewlett Packard mass selective detector. A higher desorption temperature (375ºC versus the "normal" 300ºC) was used to facilitate removal of high molecular weight rubber additives from the sorbent materials. Since steam and humidity were present during sampling, all sample tubes were purged of excess water, prior to analyses, by drawing helium through the tubes for 30 seconds at 100 mL/min.

Aldehydes, Screening

Three process samples and three personal samples for aldehydes were collected and analyzed according to NIOSH Method 2539, "Aldehydes, Screening."[1] This method is primarily a qualitative screening method for aldehydes, and is typically not recommended for quantification of contaminants. The samples were collected on a solid sorbent tube containing 10% 2-(hydroxymethyl)piperidine on XAD-2 media (SKC® #226-118) at an airflow rate of approximately 40 mL/min for approximately 2 hours. This length of sampling yielded a air sample volume of approximate 5 liters as recommended for the method. The samples were then analyzed by gas chromatography with flame ionization detection.

The samples were analyzed for the following aldehydes: acetaldehyde, formaldehyde, valeraldehyde, hexanal, heptanal, butyraldehyde, propisonaldehyde, acrolein, and iso-valeraldehyde. The limits of detection and quantification for formaldehyde were 2 µg/sample and 7.4 µg/sample, respectively. For acetaldehyde, valeraldehyde, and iso-valeraldehyde, the limits of detection and quantification were 0.4 µg/sample and 1.4 µg/sample, respectively. For hexanal, heptanal, butyraldehyde, propionaldehyde, and acrolein, the limits of detection and quantification were 0.9 µg/sample and 3 µg/sample, respectively.

Heat Stress Monitoring

Area heat stress monitoring was accomplished with two Reuter-Stokes RSS 214 WibGet® monitors. One monitor was placed between the 500-ton D1 and D2 presses. The other monitor was placed in the aisle between 200-ton A1 and C1 presses.

The WibGet monitor assesses environmental heat by the Wet Bulb Globe Temperature (WBGT) method. The WBGT is the accepted standard method for determining environmental heat stress.[2,3,4] Due to the impracticality of monitoring a worker's deep body temperature, the measurement of environmental factors that correlate with a worker's deep body temperature and other physiologic responses to heat is necessary. The WBGT combines the effect of humidity, air movement, air temperature and radiant heat into a single measurement. The monitors were operated in the automatic logging mode and were programmed to record the measured parameters at 5-minute intervals. Specifications provided by the manufacturer for the Reuter-Stokes RSS 214 monitor are as follows:

Accuracy: ±0.3°C
Sensor Range: 0-100°C

WBGT measurements, in conjunction with metabolic heat production rates, can be used to estimate total heat exposure for comparison to guidelines. During this evaluation, metabolic heat production rates in kilocalories per hour (kcal/hr) were estimated via observation of body position and work activities, and compared to standard tables. WBGT and metabolic heat rates are expressed as 1-hour time-weighted averages. These recommended standards were developed to prevent workers from exceeding a deep body (core) temperature of 38°C (100.4°F).[2,3,4,5] The evaluation criteria for heat stress can be found in Appendix A. Note that the NIOSH criteria and American Conference of Governmental Industrial Hygienists (ACGIH) criteria are identical for acclimated workers.

The WibGet® units were placed as close as possible to the workers. The monitors were also placed so that there was no restriction of free air flow around the thermometer bulbs. Before sampling, the wick of the wet-bulb thermometer was moistened with demineralized water and the thermometer reservoir filled. The monitors were allowed to equilibrate 20 minutes in each area monitored prior to recording readings.

Medical

The NIOSH medical officer interviewed 11 employees, including 8 employees who requested an interview, 2 who were chosen at random, and 1 who had been identified as having a specific health problem. Six of them employees were from the quality inspection department, two from the vulcanizing plant, and three had other job duties; all worked on the first shift. In addition, the OSHA Injury and Illness logs (Form 200) for 1995 - 1996 (to date) were reviewed by the NIOSH medical officer.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number 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 per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing 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 level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[6], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[7] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[8]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Although the products and by products of tire and nondairy rubber manufacturing contain hundreds of chemicals, only a small proportion of them are covered by applicable Federal occupational health standards.

Nitrogen Oxides

Nitric acid (NO) and nitrogen dioxide (NO_2) can cause eye, nose, and respiratory irritation.[9] The NIOSH REL for NO_2 is 1 part per million (ppm) (1.8 mg/m^3) as a 15-minute short-term exposure limit (STEL).[6] The OSHA PEL is 5 ppm (9.4 mg/m^3) as a Ceiling limit.[8] The ACGIH recommends a 3 ppm (5.6 mg/m^3) 8-hour TWA with a 5 ppm (9.4 mg/m^3) STEL.[7] The NIOSH REL, ACGIH TLV, and OSHA PEL for NO is 25 ppm (30 mg/m^3) as a 10-hour TWA.[6,7,8]

Most reported cases of severe illness from nitrogen oxide exposures have been from accidental exposure to combustion products of nitroexplosives, nitric acid, arc or gas welding in confined spaces, or entry into unvented agricultural silos.[10]

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.[11] Compounds of the *N*-nitrosamine group of *N*-nitroso compounds are considered to be among the most potent of animal carcinogens.[12] Epidemiologic evidence of human carcinogenicity, however, remains inadequate despite sufficient experimental evidence of carcinogenicity in animals.[13,14]

In the past, NIOSH investigators have found airborne nitrosamines in a number of tire manufacturing facilities.[15,16,17,18] During rubber processing, nitrosamines can be formed by nitrosation of amines or amine derivatives in accelerators, retarders, promotors, and blowing agents.[19,20] The highest concentrations of nitrosamines found in tire manufacturing facilities were those of *N*-nitrosomorpholine, with a maximum concentration of 250 µg/m^3 at one plant.[21] 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.[21] Subsequent substitution of raw materials and ventilation improvements resulted in significantly reduced exposure to airborne nitrosamines.[17,21]

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.[20,22] 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.[20,22,23,24]

NIOSH considers 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.[25] 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.[26]

Additional Selected Chemicals

Acetophenone: The primary hazard associated with acetophenone exposure is irritation of the skin and eyes.[27] The low volatility generally limits the exposure by the pulmonary route.

α,α-dimethylbenzenemethanol: This substance is an eye and skin irritant. Animal experiments suggest it can be absorbed into the body through the skin. Prolonged inhalation to high concentrations of vapor can cause central nervous system depression.[28]

α-methyl styrene: This substance is an irritant to the eyes, skin, and upper respiratory tract. Skin contact may cause dermatitis, and prolonged inhalation to high concentrations may cause central nervous system depression.[29]

Carbon disulfide: This chemical can affect a variety of body systems, including the central nervous system, eyes, kidneys, liver, and skin. Reported symptoms from over-exposures include neuropsychiatric changes, visual disturbances, and dermatitis from contact with vapor or liquid.[30]

Cyclohexylisothiocyanate: No health information was found for this substance. Other members of this chemical family (i.e. methylisothiocyanate) have been used as pesticides and are eye and respiratory irritants.[31]

Sulfur Dioxide: The majority of health effects from sulfur dioxide are on the upper respiratory tract. Sulfur dioxide can cause nose and throat irritation, and it has been associated with bronchoconstriction in sensitive individuals.[26]

Aliphatic aldehydes: Aldehydes, in general, have been implicated in respiratory irritation, and direct contact can cause dermatitis. Some aldehydes, especially formaldehyde, have been implicated in sensitization (allergic) reactions.

Heat Stress

Heat stress is the total net heat load on the body that results from exposure to external sources (environmental heat) and internally generated heat (metabolic heat) minus the heat lost from the body to the environment.[32,33,34] The environmental factors of heat stress are air temperature and movement, humidity, and radiant heat. Exposure to heat stress conditions produces physiological responses referred to as heat strain and characterized by an increase in: "core" or deep body temperature; heart rate; blood flow to the skin, and; water and salt loss due to sweating.[34,35] These conditions can occur when the physical work is too heavy and/or the environment is too hot.

The body normally maintains a deep body temperature within narrow limits (about 37°C) by means of various adaptive mechanisms to either produce more heat, or rid the body of excess heat. This continuous heat regulation is an essential requirement for continued normal body function. The most important physiologic responses to heat include changes in blood flow to the skin, muscular activity, and sweating. Under excess heat conditions, blood flow to the skin increases, where heat dissipates into the environment. Muscular activity will increase if more heat is necessary (e.g., shivering), and will, if possible, decrease when less heat is needed. Sweating is a major heat dissipation mechanism that depends on the evaporation of sweat to produce a cooling effect. The rate and amount of evaporation is a function of humidity and the speed of air movement over the skin.

The major heat exchange mechanisms between the human body and the environment are convection, radiation, and evaporation.[32]

1. Convection heat exchange (C) is the gain or loss in heat as a function of the rate of air movement over the skin and the difference in temperature between the ambient air and the skin. When the dry bulb air temperature is lower than the skin

temperature (about 35°C), heat is lost from the body. When ambient temperatures exceed the skin temperature, heat is gained by convection.

2. Radiant heat exchange (R) is the gain or loss in heat by radiation from warmer surfaces to cooler surfaces

3. The evaporation (E) of water (sweat) from the skin is an important cooling mechanism and always results in a net heat loss. In hot-moist environments, evaporative heat loss may be limited by the capacity of the ambient air to accept additional moisture.

The basic equation describing heat balance is: $S = M \pm C \pm R - E$, Where:

> S = The net body heat gain or loss
> M = Metabolic heat production
> C,R,E are described above

Heat acclimatization is the enhanced tolerance to heat acquired by working in a hot environment.[36] The body's heat adaptive mechanisms can, through regular exposure to hot environments, significantly increase the ability to tolerate work in heat. This heat acclimatization process can usually be induced in 7-10 days of exposure to a hot environment.[35] Acclimatized workers can perform with less increase in core temperature and heart rate, and less salt loss, then unacclimatized workers.

At this time, OSHA has not promulgated regulations or standards covering heat stress. OSHA has, however, issued a directive to OSHA field staff that provides technical information regarding the investigation of heat stress issues in industry.[37] This document draws heavily on NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) criteria. The NIOSH RELs and ACGIH Threshold Limit Values (TLVs) present recommended heat exposure limits (WBGT) for a variety of work-rest regimens and worker energy costs (metabolic heat generation).[32,33,34] This criteria, presented in Figure 1, applies for the following conditions:

a. Healthy workers who are physically and medically fit
b. Workers who are heat-acclimatized to working in hot environments
c. An average worker size of 154 pounds (70 kilograms)
d. Workers who are wearing light summer clothing

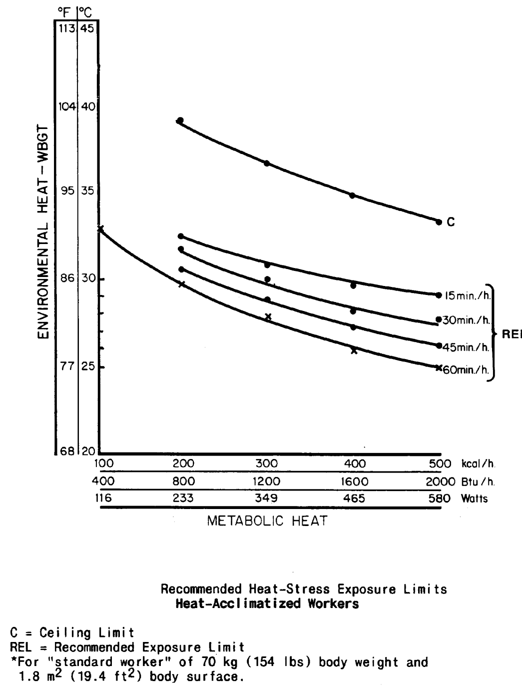
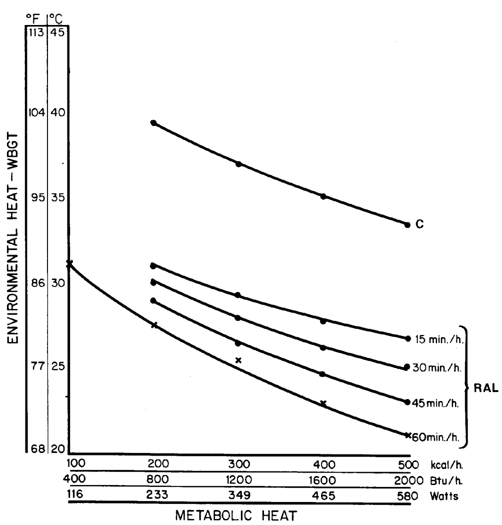


Figure 1

If any of these parameters change, modifications must be made to the heat exposure evaluation criteria. Values are available for adjusting for worker weight and additional clothing.[32,34] In special cases where vapor-impermeable clothing (e.g., chemical protective suits) is worn, the WBGT is not the appropriate method for measuring environmental heat stress.

NIOSH has also established Recommended Alert Limits (RALs) for healthy workers who are not acclimatized to working in hot environments.[32] These limits are presented in Figure 2. A ceiling level has been recommended by NIOSH, for both acclimatized and un-acclimatized workers. Workers should not be exposed to temperatures reaching or exceeding this ceiling limit without adequate heat-protective clothing and equipment. These ceiling levels are indicated with a C in Figures 1 and 2.

These evaluation criteria have been established to prevent exposed workers from exceeding a deep-body or core temperature of 38°C (100.4°F). This temperature is considered to be a consensus among work physiologists and standard setting organizations as the value below which the body temperature must be maintained to reduce the risk of heat illness.[32, 33,34,35]



Recommended Heat-Stress Alert Limits
Heat-Unacclimatized Workers

C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

Figure 2

Due to the impracticality of monitoring a workers deep body temperature, the measurement of environmental factors that correlate with a workers deep body temperature and other physiologic responses to heat is necessary. As mentioned, the WBGT is the accepted standard method for measuring these environmental factors for most situations. For indoor use only two measurements are needed: the natural wet bulb (nwb) and black globe temperatures (g). The calculation for the indoor WBGT is as follows:

$$WBGT = 0.7t_{nwb} + 0.3t_g$$

These measurements of environmental heat are expressed as 1-hour time-weighted averages (TWAs).

As both metabolic and environmental heat together determine the total heat load, the work load category of each task must be established to determine the applicable heat exposure limit. For this evaluation, metabolic heat rates for each task monitored were estimated from established references (Table 1).[32,34] This was accomplished by observation of the worker performing the task, and categorizing body position, type of work, and degree of work-rest regimen (e.g.

Table 1

Estimating energy cost of work by task analysis

A. Body position and movement	kcal/min*	
Sitting	0.3	
Standing	0.6	
Walking	2.0-3.0	
Walking uphill	add 0.8 per meter rise	
B. Type of work	**Average kcal/min**	**Range kcal/min**
Hand work		
light	0.4	0.2-1.2
heavy	0.9	
Work one arm		
light	1.0	0.7-2.5
heavy	1.8	
Work both arms		
light	1.5	1.0-3.5
heavy	2.5	
Work whole body		
light	3.5	2.5-9.0
moderate	5.0	
heavy	7.0	
very heavy	9.0	
C. Basal metabolism	1.0	
D. Sample calculation**		**Average kcal/min**
Assembling work with heavy hand tools		
1. Standing		0.6
2. Two-arm work		3.5
3. Basal metabolism		1.0
Total		5.1 kcal/min

* For standard worker of 70 kg body weight (154 lbs.) and 1.8 m^2 body surface (19.4 ft^2).
**Example of measuring metabolic heat production of a worker when performing initial screening.

continuous, 50%, etc.). Metabolic heat production was then estimated in kilocalories per hour (kcal/hr). The WBGT measurements, estimates of metabolic heat production (kcal/hr), and the degree of work-rest regimen were used to determine the appropriate REL for each task monitored.

Heat Stress: Health Effects

When heat gain exceeds the ability of the body to compensate through heat loss mechanisms, the core temperature will begin to rise and heat stress disorders are possible. There are a variety of outcomes that could occur, ranging from somewhat mild behavioral disorders (heat fatigue) to very severe health problems such as heat stroke. In addition to the environmental temperatures and metabolic rates, there are numerous other factors that will influence the potential for a heat related disorder to occur. These include the following:

1. Fluid intake and electrolyte replenishment
2. Degree of acclimatization
3. Diet
4. Age
5. Gender
6. Body Fat
7. Alcohol and drug (therapeutic and social) use
8. Individual variation
9. Physical fitness

The primary physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.[30]

Heat Rash

Heat rash ("prickly heat") occurs as a result of unrelieved exposure to humid heat with the skin continuously wet with unevaporated sweat. This often occurs when clothing traps moisture against the skin. The sweat gland ducts can become plugged which leads to inflammation of the glands. This causes profuse, visible, tiny red vesicles in the affected skin area and can substantially impair sweating. Therefore, it is not only a nuisance due to discomfort but can diminish the workers' capacity to tolerate heat.

Heat Cramps

Heat cramps can occur after prolonged exposure to heat with extensive perspiration and inadequate replacement of salt. Cramps usually occur in the abdomen and extremities.

Heat Exhaustion

Predisposing factors for heat exhaustion include sustained exertion in a hot environment, lack of acclimatization and failure to replace water and/or salt lost in sweat. These factors can result in dehydration, depletion of circulating blood volume and circulatory strain from competing demands for blood flow to the skin and active muscles. Signs and symptoms include fatigue, nausea, headache and giddiness. There may be an increase in body temperature. The affected individuals skin will be clammy and moist.

Heat Stroke

Heat stroke is considered a serious medical emergency. A major predisposing factor is excessive physical exertion in a hot environment. Classical heatstroke includes (1) major disruption of the central nervous function (convulsions, unconsciousness); (2) a lack of sweating; and (3) a very high body temperature (>105°F). Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin (due to cessation of sweating), confusion, collapse, delirium, and coma. If cooling of the victim's body is not started immediately, irreversible damage to vital organs may develop.

In addition to the above, prolonged exposure to excessive heat may cause increased irritability and anxiety, decreased morale and an inability to concentrate. This often results in a general decrease in production efficiency and quality.

RESULTS

Industrial Hygiene

Nitrogen Oxides

NO was not detected on any full-shift samples (limit of detection: approximately 9 $\mu g/m^3$). NO converts spontaneously in air to nitrogen dioxide (NO_2). NO_2 was found at levels below the limit of quantification (approximately 49 $\mu g/m^3$ - see Table 2 below). The detector tube sampling results were non-detected for total nitrogen oxides in all locations sampled. It is possible that the NO_2 found was not produced during the vulcanizing process. Some ambient NO_2 is often present due to other pollution sources (i.e. automobiles). For perspective, the National Ambient Air Quality Standard for NO_2 is 100 $\mu g/m^3$.

Table 2
Nitrogen Dioxide Area Samples
Kokoku Rubber - Vulcanizing Department

Sampling Location	Sampling Time (minutes)	Nox Conc. (Ug/m^3)
B2 - 200 ton	425	(33)
E-line - 200 ton	379	(34)
Between C1 and C2	436	(30)
Inspection table	435	(25)
B-line	432	(21)

The results in parentheses indicate the values are between the limits of detection (9 $\mu g/m^3$) and quantification (49 $\mu g/m^3$). The accuracy of the analytical method at these low concentrations is subject to greater variability compared to higher concentrtions over the limit of quantification. The NIOSH Recommended exposure limit for NO_2 is 1800

N-Nitrosamines

No analyzed nitrosamines (*N*-nitrosodimethylamine, *N*-nitrosodiethylamine, *N*-nitrosodipropylamine, *N*-nitrosodibutylamine, *N*-nitrosopyrrolidine, *N*-nitrosopiperidine, and *N*-nitrosomorpholine) were detected on any of the samples. The limit of detection was approximately 0.02 $\mu g/m^3$ for all nitrosamines, except nitrosomorpholine, which was 0.06 $\mu g/m^3$.

Thermal Desorption - Gas Chromatography/Mass Spectrometry

More than thirty chemicals were found on the thermal desorption tubes (see Table 3 below). The major chemicals detected on all three samples were acetophenone, α,α-dimethylbenzenemethanol, α-methyl styrene, carbon disulfide, and siloxane compounds. Other substances of significance included sulfur dioxide and cyclohexane isothiocyanate. The isothiocyanate compound may have been formed from its corresponding amine (cyclohexylamine) and carbon disulfide during the thermal desorption process or during curing. Very small peaks (implying low concentrations) of aliphatic aldehydes were found; however, aldehydes more frequently associated with thermal decomposition (i.e. acrolein) were not found. Many of these chemicals are classified as respiratory or skin irritants.

Table 3
Substances found on Thermal Desorption Tubes
Kokoku Rubber - Vulcanizing Department

Sulfur Dioxide	Propane	Butane and butene
Ethanol	Acetone	Isopropanol
2-methyl-2-propanol	Carbon disulfide	1-propanol
Trimethylsilanol	Acetic acid	Butanal*
Methyl cellosolve	Hexene	Toluene
C_8-C_9 aliphatic hydrocarbons	Hexamethylcyclotrisiloxane	α-methyl styrene
Aliphatic aldehydes (C_7-C_{10})	Phenol	Octamethylcyclotetrasiloxane
Acetophenone	α,α-dimethylbenzenemethanol	1-methoxy-2-methylethylbenzene*
Decamethylcyclopentasiloxane	2-(2-butoxyethoxy)ethanol	Cyclohexane isothiocyanate
Ethylene dimethacrylate	Dibutylformamide*	Multiple siloxane compounds

Chemicals indicated with asterisks indicate that the substance listed is the most likely chemical to match the mass spectrometry output.

Aldehydes, Screening

Because of the higher detection limit in NIOSH method 2539 (aldehydes, screening) compared to the analytical method for the thermal desorption tubes, aldehydes were not detected on any of these samples. As discussed for the thermal desorption tube results, low levels of various aldehydes were detected, but their concentrations are so low as not to be detected by this analytical methodology.

Heat Stress Monitoring

The results of heat stress monitoring on the 500-ton D-Line press can be found in Figure 3. The Wibget placed between the A1 and C1 200-ton presses malfunctioned, and no useful data are available for this location. For the work conditions observed on the day of the NIOSH survey, the WBGT recommended heat-stress exposure limit (REL-- referred to as the TLV in the ACGIH criteria) was estimated to be approximately 28.0ºC. A metabolic rate of approximately 270 kilocalories per hour (kCal/hr) for the workers was calculated from the values recommended in the American Conference of Governmental Industrial Hygienists (ACGIH) and NIOSH criteria (see Table 1 in Evaluation Criteria):

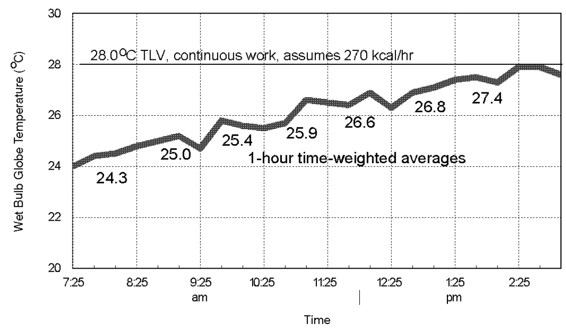
A. Standing/walking: 1.5 kcal/minute
B. Moderate work with both arms: 2.0 kcal/minute
C. Basal metabolism: 1.0 kcal/minute

Total: 4.5 kcal/minute
= 270 kcal/hr

The 270 kcal/hr metabolic rate was then applied to Figure 3 in the Evaluation Criteria section to give a recommended heat-stress exposure limit of 28ºC.

The WBGT measurements, expressed as 1-hour time-weighted averages (TWAs), did not exceed the 28ºC criterium during the day, although it was approached at the end of the day. These results assume all workers were

Figure 3
Kokoku Rubber, HETA 96-0169
Wet Bulb Globe Temperature, D-Line



heat acclimated. Note that this evaluation consisted of only one day of evaluation. Higher temperatures, changes in work type, addition of unacclimatized workers, extension of work shifts, etc. would result in changes to WBGT measurements and metabolic rates.

On the day of our survey, the outside temperatures ranged from 20.5ºC (66ºF) at 7:00 am to 28.8ºC (84ºF) at 2:00 pm. According to the National Weather Service, the climatological norms (1961-1990) for Lexington, Kentucky, indicate an average high temperature for July of 30ºC (86ºF). Therefore, the afternoon high temperature observed on the day of our survey was slightly below normal for August. The climatological norms for relative humidity were not available for Lexington. On the day of the survey, outside relative humidities ranged from 82% (morning) to 59% (afternoon).

Medical

Nine of the 11 interviewed employees either currently worked or had worked in the past in the vulcanizing department. Of these nine, seven reported experiencing intermittent respiratory symptoms including shortness of breath, chest tightness, and nose and throat irritation while working in the vulcanizing plant. Two of these seven reported specific rubber parts or formulations as being related to their symptoms, while the others did not identify any particular work duties within the vulcanizing plant as being related to the symptoms. Of the six who were working in the quality inspection department at the time of the site visit, three reported intermittent symptoms of shortness of breath and nose and throat irritation while working with certain parts in quality inspection, while three reported no current symptoms. There were no specific parts or formulations identified in the vulcanizing plant or in quality inspection that caused similar symptoms among two or more of the employees interviewed. None of the interviewed employees reported specific diagnoses pertaining to their respiratory symptoms.

Three employees (all from the quality control department) reported intermittent skin rashes after handling specific parts; no individual part was identified which caused a skin rash in two or more employees. None had skin eruptions at the time of the interview, and none (except another employee described below) had been diagnosed with a specific skin condition.

One employee, who had worked in the quality inspection department, the mixing room, and the vulcanizing plant in the past, reported a history of being diagnosed with work-related contact urticaria. After diagnosis this employee was moved to an area of the plant with less exposure to the raw materials and less handling of the finished products; the last episode of urticaria was reported by the employee was approximately one year prior to the interview.

Review of the OSHA 200 logs revealed that 42 entries were made in 1995, and 6 in 1996 (up to the date of our site visit). Of the 1995 entries, 14 were for employees with upper and lower respiratory symptoms related to a single day in October, 1995 when contaminants from roof-repair work entered the plant via the ventilation system. One entry was for the diagnosed work-related urticaria mentioned above. The rest of the entries were for injuries, including musculoskeletal problems, lacerations, burns, foreign bodies, and contusions. The six entries for 1996 included three entries for musculoskeletal problems and one entry each for a laceration, a burn, and a spider bite. Review of the medical department logs did not reveal any pertinent information in addition to that discussed above.

DISCUSSION

Respiratory (lung) and dermatologic (skin) effects among rubber product manufacturing workers have been reported in many publications.[38,39,40,41] Respiratory symptoms reported among rubber workers have included chest tightness and shortness of breath, and have been reported to be more common among workers in the curing, processing, and finishing/inspecting areas of rubber product plants.[38,39] Exposure to agents in the manufacture of rubber tires has been associated with acute and chronic respiratory impairment as measured by pulmonary function studies.[38] Contact dermatitis, which is an inflammatory skin condition caused by skin contact with a substance from the environment, and other skin conditions such as contact urticaria, have been reported frequently among rubber product workers.[39,40] In some rubber manufacturing facilities it has been difficult to determine specific causative agents for these health effects, due in part to lack of adequate toxicity data concerning the many chemical formulations found in rubber product manufacturing.[38]

Many epidemiologic studies have reported excess deaths from bladder, stomach, lung, hematopoietic, and other cancers among tire and nontire rubber products workers. Most of these excess deaths cannot be attributed to a specific chemical because (1) workplace exposures involve many individual chemicals and combinations, and (2) frequent changes occur in chemical formulations. Most of the chemicals found in these industries have not been tested for carcinogenicity or toxicity, nor do they have established occupational limits. One class of potentially carcinogenic compounds, known as nitrosamines, have been studied extensively in rubber plants.[38]

Strategies which can be used in the prevention of potential work-related health problems related to rubber parts manufacturing include: 1) identifying known irritants and allergens which may be present in the workplace and substituting agents that are less irritating/allergenic; 2) establishing and improving engineering controls (such as local exhaust ventilation) to reduce exposure to potential irritants or allergens; 3) utilizing personal protective equipment, such as gloves and special clothing, appropriately; 4) emphasizing personal and occupational hygiene; 5) establishing educational programs to increase awareness of potential health hazards in the workplace; and 6) providing health screening and follow-up as appropriate. Regarding potential respiratory effects, pre-placement examinations and medical surveillance with tests of lung function may be helpful in identifying employees who may require medical follow-up.

CONCLUSIONS

Air sampling in the vulcanizing department revealed several respiratory irritants, including acetophenone, α-methyl styrene, carbon disulfide, and sulfur dioxide. Several of these substances can also cause skin irritation. Additionally, several amine-based chemicals are used extensively in the rubber formulations. Amines can potentially cause respiratory and skin irritation. The health effects of these multiple exposures are difficult to evaluate. Although no single chemical was implicated in the reported health effects, it is possible that the combined effects of these irritants may be contributing to health complaints reported among some employees.

RECOMMENDATIONS

1. Workers should be encouraged to continue reporting all possible work-related health problems to the company. These problems should be investigated on an individual basis by the company and consulting health care providers. Each person with potential work-related health problem should be fully evaluated by a health care professional, preferably one with expertise in occupational health. A complete evaluation would include a full medical and occupational history, a medical exam, a review of exposures, possibly diagnostic tests (such as skin patch tests in the case a skin condition or pulmonary function tests in the case of respiratory symptoms), and complete follow-up to note the progress of the individual. Individuals with definite or possible work-related health problems should be protected from exposures to presumed causes or exacerbators of the problem. In some cases, workers may have to be reassigned to areas where exposure is minimized or nonexistent.

2. To reduce exposures to the curing fume, Kokoku Rubber should further consider the installation of local exhaust ventilation systems on the curing presses. Local exhaust ventilation may also be considered for the tables where the freshly cured parts are placed. An expert in the design of local exhaust ventilation systems should be consulted. Control technologies from the tire industry may have some applications at Kokoku Rubber. Further information can be found in the NIOSH document "Control of Air Contaminants in Tire Manufacturing."[42]

3. Because of high internal heat from presses, radiant heat is considered the primary source of heat load, with ambient temperature a secondary factor. Nonetheless, it is possible that the WBGT recommended heat-stress exposure limit could be exceeded on warmer days. A heat stress program should be implemented. The elements of a program include:

(a) *Training* Employees should be trained in safety and health procedures for work in hot environments, including the signs and symptoms of impending heat illness and initiation of first aid and/or corrective procedures. Additionally, the effects of non-occupational factors such as drugs, alcohol, obesity, etc., on tolerance to occupational heat stress should be covered. The need for fluid replenishment, and that reliance on the thirst mechanism is insufficient, are other important elements of worker heat stress training.

(b) *Acclimatization* Kokoku Rubber should ensure all workers are fully acclimatized for working in hot environments. Acclimatization efforts should begin at the start of the hotter months of the year, and should include both new employees and employees returning from vacation or newly transferred to a hot area. Note that there is a wide difference in the ability of people to adapt to heat. In general, for workers who have had previous experience with the job, the acclimatization regimen should be exposure for 50% on day 1, 60% on day

2, 80% on day 3 and 100% on day 4. For new workers the schedule should be 20% on day 1 and a 20% increase on each additional day.

(c) Heat-Alert Program (HAP) This program should be used to alert workers of impending hot spells, and initiation of heat control efforts (e.g. additional breaks, increased ventilation, shorter work cycles).

(d) *Medical Screening* Workers with low heat tolerance should be medically evaluated by a health care professional. The capacity to tolerate heat has been shown to be related to physical fitness (the higher the degree of physical fitness, the greater the ability to tolerate heat) and physical work capacity (those with low physical work capacity are more likely to develop higher body temperatures than are individuals with high physical work capacity). Medical screening should also include a history of any previous heat illness. Workers who have experienced a heat illness may be less heat tolerant.

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