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NIOSH INVESTIGATORS:
Anne T. Fidler, Sc.D.
Mitchell Singal, M.D.
Steven A. Lee, C.I.H.

I. SUMMARY

On October 11, 1985, the National Institute for Occupational Safety and Health received a request from the United Rubber Workers to evaluate a perceived excess of heart disease among employees at the Uniroyal- Goodrich tire manufacturing plant in Opelika, Alabama. An on-site survey was done on January 23, 1986, and a follow-up survey was performed on August 19-20, 1986, at which time environmental sampling was done to evaluate heat stress in the Tire Curing Department, carbon monoxide (CO) exposure among forklift drivers, and carbon disulfide (CS_2) exposure in several areas of the plant. In addition, personnel and medical records were abstracted to allow a standardized morbidity ratio (SMR) study (based on a 10-percent sample) and a case-control study to evaluate a possible association between heat stress and incidence of myocardial infarction (MI), used as an indicator of heart disease.

Wet bulb globe temperature (WBGT) readings throughout the Curing Department ranged from 84-89° F. The NIOSH recommended limit for exposure to heat stress under conditions of work in the Curing Department is 82-84° F, assuming the workers are acclimatized to heat. Two forklift drivers were exposed to 4 and 11 parts per million (ppm) of CO; short-term CO measurements taken in general areas of operating forklifts ranged up to 15 ppm. The NIOSH recommended exposure limit is a time-weighted average of 35 ppm and a ceiling limit of 200 ppm. No CS_2 was detected in any of the six personal or two area samples collected (limit of detection: 0.06 mg/m^3).

Thirty-four cases of MI were identified through the Sickness and Accident reports and Death Benefit Claims from 1973-1985. A 10-percent sample of the personnel records of the entire workforce yielded a total of 4229.6 person-years worked in that time period. Using the incidence rate for "recognized" MI from the Framingham Heart Study as a comparison, the overall SMR was not elevated (0.62), nor was there an elevation in the SMR for any age stratum. There was no trend in the incidence of MI by calendar year or by month of year. The case-control study showed no evidence of an association between myocardial infarction and working in the Curing Department.

Based on the results of this study, NIOSH investigators documented excessive heat stress in the Curing Department. There was no evidence, however, of an increased risk of myocardial infarction among Uniroyal employees or an association between MI and work in the Curing Department. No hazards from over-exposure to carbon monoxide or carbon disulfide were present at the time of the NIOSH visit. Recommendations to minimize the risk of heat-related illness and injury are found in Section VIII of this report.

KEYWORDS: SIC 3011, tire manufacturing, heat stress, carbon monoxide, carbon disulfide, myocardial infarction, heart disease

II. INTRODUCTION

On October 11, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Rubber Workers to evaluate a perceived excess of heart disease among employees at the Uniroyal-Goodrich (then Uniroyal) tire-manufacturing plant in Opelika, Alabama. A previous health hazard evaluation had been conducted in 1983 at the same facility (HETA 83-221-1438). A proportional mortality ratio (PMR) study performed at that time revealed no pattern of excess mortality from cardiovascular disease among former employees.

On January 23, 1986, NIOSH investigators conducted an initial site visit of the Opelika facility. Medical and personnel records maintained by the company were assessed for utility in an epidemiologic study of the plant. In addition, company environmental records were reviewed for the presence of known or suspected causative agents of cardiovascular disease. Findings from this visit were presented in letters dated February 10, 1986 and May 29, 1986.

A follow-up visit was made on August 19-20, 1986, at which time environmental sampling was done to evaluate heat stress in the Curing Department, carbon monoxide exposure among forklift operators, and carbon disulfide exposure in several areas of the plant. Epidemiologic data were also collected to allow standardized morbidity ratio (SMR) and case-control evaluations of the occurrence of myocardial infarctions (heart attacks), as a measure of cardiovascular disease. Industrial hygiene results and recommendations resulting from this visit were provided to union and company representatives in a letter dated October 23, 1986.

III. BACKGROUND

The Uniroyal-Goodrich plant in Opelika, Alabama began production of radial passenger tires in 1963 and currently employs approximately 1200 workers. Figure 1 shows the production stages in the manufacture of tires; occupational title groups in tire manufacturing are listed in Appendix 1. A NIOSH publication, "Control of Air Contaminants in Tire Manufacturing," provides detailed descriptions of all major processes of tire manufacturing and their potential for producing worker exposure to air contaminants.[1]

Tire curing presses apply heat and pressure to vulcanize the rubber components in the final tire product. The green tire is placed over a bladder bag which is inflated inside the tire. When the press is closed, the tread and sidewall are forced by the bladder into the mold. Each Curing Department worker at Uniroyal-Goodrich operates 60-65 presses at a time, with each press curing about 3 tires per hour. Thus, each worker loads and unloads approximately 200 tires per hour. Radiant heat is emitted from the steam lines that heat the tire molds.

The Uniroyal-Goodrich plant uses about 200 forklifts and has been gradually replacing propane-operated forklifts with battery-operated forklifts. At the time of the NIOSH follow-up visit, there were 119 battery-operated and 74 propane-operated forklifts.

Carbon disulfide is not used as a rubber additive at this plant, but the requester was concerned that it could be formed during the manufacturing process or present as an impurity in additives.

IV. METHODS AND MATERIALS

A. Environmental

On August 19-20, 1986, 64 dry bulb, wet bulb, globe thermometer, and wet bulb globe thermometer (WBGT) measurements were collected throughout the Curing Department, using two WIBGET Model R55-2110 heat stress monitors.

Estimates of metabolic heat were made according to the table provided in Appendix 2 in order to calculate a recommended heat-stress exposure limit for heat-acclimatized tire-curing workers (Figure 2).

Long-term and short-term colorimetric detector tubes were used to assess potential carbon monoxide (CO) exposure during the use of propane-operated forklifts and during use of the break rooms where cigarettes are smoked. Two personal breathing-zone air samples on forklift drivers and two area air samples in break rooms were collected for about six hours using battery-powered sampling pumps operating at 20 cc/min. Twenty short-term CO tubes were used for general area air sampling when forklifts were operating, for direct sampling of forklift exhaust, and for sampling break room air.

Eight air samples for carbon disulfide were collected in extruding, calendaring, and curing departments, using charcoal tubes sampled at a flow rate of 100 cc/min for about six hours. The samples were desorbed with 10 ml of toluene and analyzed by gas chromatography with a flame photometric detector (sulfur mode) and a fused silica capillary column (splitless mode).

B. Medical/Epidemiological

Indicators of heart disease include mortality data, symptomatic disorders (angina pectoris, myocardial infarction, and congestive heart disease, for example), and asymptomatic conditions (for example, electrocardiographic abnormalities). We chose myocardial infarction for this study because it is a relatively specific and objective diagnosis, virtually always results in hospital admission, and, if not fatal, is followed by a substantial period of time off work. Thus, unlike other symptomatic or asymptomatic heart problems, a myocardial infarction in an active Uniroyal-Goodrich employee would inevitably result in an insurance claim and a Sickness and Accident (S & A) report. (Similar arguments could be made for coronary bypass surgery, but this is a treatment procedure, not a diagnosis. Therefore, its incidence is dependent on trends in medical practice and availability of facilities, as well as on the occurrence of the medical conditions for which it is used.)

In order to estimate the incidence rate of myocardial infarction (MI) experienced at the Opelika, Alabama Uniroyal-Goodrich plant, it was necessary to obtain estimates of both the numerator (number of MIs) and the denominator (number of person-years experienced by workers at this plant). The number of MIs was obtained by review of the company's S & A reports and Death Benefit Claims files. This review, which took place on August 19-20, 1986, allowed identification of workers at Uniroyal-Goodrich who had suffered an MI from 1973 (first available year of S & A reports) through 1985. If an individual experienced more than one myocardial infarction, only the first event was included as a case, and the individual was then removed from the "at-risk" population.

In order to estimate the number of person-years experienced at this plant, company employment records were reviewed and a 10-percent sample was abstracted. Employment records were in the form of New Hire Sheets, which catalogued employees by the date of hire. From these lists, every tenth employee was chosen and the following information was obtained: worker identification number, name, race, sex, date of birth, date of hire, and date of termination. Date of termination for current employees was recorded as 12/31/85, the end date of the study. Due to peculiarities of the personnel records system, date of termination was provided on the New Hire Sheets only for employees who terminated prior to 1977. In order to estimate the date of termination for other employees, the company provided "Wage Employee Seniority Reports" for the years 1977 through 1985 (for some years, quarterly records available; for other years, only annual records available), which provide a list of all persons employed on a given date. From these reports, the last known date of employment was determined and the date of termination was estimated to be the mid-point of the interval between that date and the date of the next seniority report. For example, if a person was included on the list dated 12/31/84, but was not found on the next list (6/30/85), his date of termination was estimated as 3/31/85.

These data were entered into the NIOSH Life Table Analysis System[2] for tabulation of the number of person-years experienced at the Opelika facility. Although all person-years beginning with the opening of the plant in 1963 were considered, only person-years accrued since 1973 were counted in the final number, because only myocardial infarctions occurring after that date were included. The resulting person-years were then stratified by age, duration of employment, and latency since first employment.

The comparison incidence rate of myocardial infarction in a general (non-exposed) population was obtained from the Framingham Heart Study 30-year follow-up.[3] This study of risk factors associated with the annual incidence of cardiovascular disease provided incidence rates, stratified by age and gender. These rates were available for both "recognized" and "unrecognized" MIs. An unrecognized MI was considered to be an event which involved evidence of electrocardiographic changes consistent with a past MI, but not identified by other clinical manifestations either by the patient or the patient's physician. Because this type of MI would not have appeared in the S & A reports, only the rates of recognized MIs were used as comparisons.

Additionally, in order to examine more closely possible associations between the occurrence of MIs and indicators of heat stress, a case-control evaluation was undertaken of the cases of MI and controls matched on sex, race, date of birth (within 5 years), and date of hire. The matching procedure is described in Appendix 3. The cases and controls were compared as to whether they worked in the Curing Department (the department with the highest heat stress) at the time of the case's MI (acute effect of exposure), the duration employed in the Curing Department (chronic effect of exposure), and whether they ever worked in the Curing Department.

V. <u>EVALUATION CRITERIA</u>

A. <u>Environmental Criteria</u>

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of airborne exposure to which most workers can 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 if 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 evaluation criterion. These combined effects are not often considered in the evaluation criterion. 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 Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. The OSHA standards may be required to take into account the feasibility of controlling exposures in various industries where the agents are used, whereas the NIOSH recommended exposure limits are based primarily on concerns relating to the prevention of occupational disease.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- t0 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

B. Hot Work Environments

Heat stress is defined as the total net heat load on the body with contributions from exposure to external environmental sources and from metabolic heat production.[4] Four environmental factors which influence the interchange of heat between the human body and the environment are: 1) air temperature, 2) air velocity, 3) moisture content of the air, and 4) radiant temperature. Industrial heat problems involve a combination of these factors which produce a working environment that may be uncomfortable or even hazardous because of an imbalance of metabolic heat production and heat loss.

When heat loss fails to keep pace with heat gain, the body's core temperature begins to rise. Certain physiologic mechanisms begin to function in an attempt to increase heat loss from the body. First, there is a dilation of the blood vessels of the skin and subcutaneous tissues with diversion of a large part of the body's blood supply to the body surface and the extremities. An increase in circulating blood volume also occurs through the withdrawal of fluids from body tissues. The circulatory adjustments enhance heat transport from the body core to the surface. Simultaneously, the sweat glands become active, spreading fluid over the skin. This removes heat from the skin surface by evaporation. Evaporative cooling must balance metabolic plus environmental heat load to maintain thermal equilibrium. If this fails, heat storage begins with the resultant strain of increased body temperature. Prolonged exposure to excessive heat may cause increased irritability, lassitude (weariness), decrease in morale, increased anxiety, and inability to concentrate.

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

1. Heat rash (prickly heat) may be caused by unrelieved exposure to hot and humid air. The openings of the sweat ducts become plugged due to the swelling of the moist keratin layer of the skin; this leads to inflammation of the glands. There are tiny red vesicles visible in the affected skin area and, if the affected area is extensive, sweating can be substantially impaired. This may result not only in discomfort, but in a decreased capacity to tolerate heat.

2. Heat cramps may occur after prolonged exposure to heat with profuse perspiration and inadequate replacement of salt. The signs and symptoms consist of spasm and pain in the muscles of the abdomen and extremities. Albuminuria (protein in the urine) may also occur.

3. Heat exhaustion may result from physical exertion in a hot environment when vasomotor control (nerves governing muscular control of the blood vessel walls) and cardiac output are inadequate to meet the increased demand placed upon them by peripheral vasodilation or the reduction in plasma volume due to dehydration. Signs and symptoms include pallor, lassitude, dizziness, syncope (fainting), profuse sweating, and cool moist skin. There may or may not be mild hyperthermia (increased body temperature).

4. Heat stroke is a serious medical condition. An important factor is excessive physical exertion. Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin because of cessation of sweating, very high body temperature (usually 106°F (41°C) or higher), confusion, delirium, and coma. Often, circulation is compromised to the point of shock. If cooling of the body is not started immediately, irreversible damage to vital organs may develop leading to death.[4]

Chronic heat illnesses are after-effects of acute heat illnesses, those brought on by working in excessively hot jobs for a period of time without the occurrence of acute effects. Chronic after-effects associated with acute heat illnesses can include reduced heat tolerance, dysfunction of sweat glands, reduced sweating capacity, muscle soreness, stiffness, reduced mobility, chronic heat exhaustion, and cellular damage in different organs, particularly in the central nervous system, heart, kidneys, and liver.[4]

Chronic heat illnesses not associated with acute effects of heat can fall into one of two categories, depending upon the duration of exposure. After several months of exposure to a hot working environment, chronic heat exhaustion may be experienced. Symptoms include headache, gastric pain, sleep disturbance, irritability, tachycardia (rapid heart beat), vertigo (dizziness), and nausea. After many years in a hot job, cumulative effects of long-term exposure that may develop are hypertension (high blood pressure), reduced libido, sexual impotency, myocardial (heart tissue) damage, nonmalignant diseases of the digestive organs, and hypochromia (a condition in which the red blood cells have an abnormally low percentage of hemoglobin).[4]

NIOSH originally defined hot environmental conditions as any combination of air temperature, humidity, radiation, and wind speed that exceed wet bulb globe temperature (WBGT) of 79°F (26°C).[5] In its revised criteria for occupational exposure to hot environments, NIOSH provides figures showing WBGT exposures versus duration of exposure and activity level which are not to be exceeded for work in hot environments.[6]

The revised NIOSH criteria and the ACGIH TLV present a permissible heat exposure for different work-rest regimes and work loads at different WGBT values.[6,7] Figure 2 presents these criteria, which assume that the workers are acclimatized, fully clothed in summer weight clothing, are physically fit, have good nutrition, and have adequate salt and water intake. Additionally, they should not have any pre-existing medical conditions that may impair the body's thermoregulatory mechanisms. Alcohol use and certain therapeutic and social drugs will also impair the body's heat tolerance.[5,6]

Modifications of the NIOSH and ACGIH evaluation criteria should be made if the worker or conditions do not meet the previously defined requirements. The following modifications have been suggested:[8]

1. Unacclimatized or physically unconditioned - subtract 4°F (2°C) from the permissible WBGT value for acclimatized workers. Increased air velocity (above 1.5 meters per second or 300 feet per minute) - add 4°F (2°C). This adjustment cannot be used for air temperatures in excess of 90-95°F (32-35°C). It also does not apply if impervious clothing is worn.

   A criticism of this WBGT modification is that an adjustment for increased air velocity is unwarranted since the WBGT index is adequately responsive to wind velocity.[9]

2. Impervious clothing which interferes with evaporation:

   a. Body armor, impermeable jackets - subtract 4°F (2°C).

   b. Raincoats, firefighter coats, full-length coats - subtract 7°F (4°C).

   c. Completely enclosed suits - subtract 9°F (5°C).

3. Obese or elderly - subtract 2-4°F (1-2°C).

4. Female - subtract 1.8°F (1°C). This adjustment, which is based on the supposedly lower sweat rates for females, is questionable since the thermoregulatory differences between the sexes in groups that normally work in hot environments are complex.[10] Seasonal and work rate considerations enter into determining which sex is better adapted to work in hot environments.[11]

C. <u>Carbon Monoxide</u>

Carbon monoxide (CO) is a colorless, odorless gas, slightly lighter than air. It is produced in the presence of incomplete combustion of carbon-containing compounds, such as in propane. The combination of incomplete combustion and inadequate venting often results in over-exposure.[12]

The danger of this gas derives from its affinity for the hemoglobin (Hb) of red blood cells, which is 300 times that of oxygen. The hazard of exposure to CO is compounded by the insidiousness with which high concentrations of CO-Hb can be attained without marked symptoms. Intermittent exposures are not cumulative in effect and, in general, symptoms occur more acutely with higher concentrations of CO.[13] The myocardium is more sensitive than any other muscle tissue to the decreased amount of available oxygen in blood, as is caused by exposure to CO. Not surprisingly, therefore, there is substantial evidence of an association between exposure to CO and disturbances of the cardiovascular system,[14] including some limited evidence of an increased risk of myocardial infarction among persons living in environments with high CO levels.[15]

The OSHA standard, as well as the ACGIH TLV, for CO is 50 ppm averaged over an 8-hour workshift.[9,16] NIOSH recommends an 8-hour TWA exposure limit of 35 ppm, with a ceiling level of 200 ppm.[17]

D. <u>Carbon Disulfide</u>

Exposure to carbon disulfide has been shown to cause a number of adverse health effects. Among these are damage to the peripheral and central nervous system, reproductive disorders (impaired sperm production, menstrual irregularities, and spontaneous abortion), ocular (eye) changes, gastrointestinal disturbances, renal (kidney) impairment, and liver damage.[18] In addition, there is evidence that exposure to carbon disulfide may accelerate the development of or worsen coronary heart disease. The first epidemiologic evidence of the association between CS_2 and heart disease was a proportional mortality study of viscose rayon workers by Tiller, et al, in 1968.[19] Since then, several other investigators have supported these findings.[20-22]

The current OSHA permissible exposure limit is 20 ppm (62 mg/m^3) for an 8-hour TWA, with a ceiling concentration of 30 ppm (93 mg/m^3). The acceptable peak concentration for an 8-hour shift is 100 ppm (310 mg/m^3) for 30 minutes and this maximum peak must be included in the 8-hour TWA calculation.[16]

NIOSH has a recommended exposure limit of 1 ppm (3 mg/m^3) over a workshift of up to 10 hours (in a 40-hour workweek), with a ceiling of 10 ppm (30 mg/m^3) averaged over a 15-minute period. The NIOSH recommended exposure limit is considered to be below levels at which serious health effects would generally be found, especially those involving the cardiovascular and central nervous systems. Acute toxicity can be avoided by applying the recommended ceiling limit.[18]

VI. RESULTS AND DISCUSSION

A. Environmental

WBGT readings throughout the Curing Department ranged from 84 to 89° F on August 19-20, 1986. Moderately heavy work while walking, according to the calculations from Appendix 2, produces 300 to 400 kcal/hour of metabolic heat in the average (70 kg) tire-curing worker. Therefore, the NIOSH recommended heat-stress exposure limit for 45 minutes per hour of tire-curing work is 82-84° F WBGT (Figure 2), assuming the workers are acclimatized to heat.

An air-conditioned cool room near the Curing Department had a WBGT reading of 76° F. Refrigerated drinking water fountains were located near the work areas and Gatorade[R] was available upon request.

Two propane forklift drivers were exposed to time-weighted average concentrations of 4 parts per million (ppm) and 11 ppm of carbon monoxide (CO) during their shift. Ten short-term CO measurements taken in general areas of operating forklifts ranged from less than 5 ppm to 15 ppm. Five forklift exhaust CO levels ranged from 100 to 2000 ppm. The average CO level throughout the day in the lunchrooms was 3 ppm, with levels ranging up to 10 ppm during heavy use. The NIOSH recommended exposure limit for CO is 35 ppm averaged over an 8 to 10-hour workshift.

No carbon disulfide was detected in any of the personal breathing zone (PBZ) air samples or process source air samples (Table 1). The sampling and analytical limit of detection was approximately 0.06 mg/m^3 and the NIOSH recommended exposure limit for carbon disulfide is 3 mg/m^3.

B. Medical/Epidemiological

Thirty-four cases of myocardial infarction (MI) were identified through S & A reports and Death Benefit Claims. Of these, the personnel records for 30 were located. The 10-percent sample of personnel records yielded data on 357 persons, with a total of 4,229.59 person-years worked between 1973 and 1985. Of the 357 persons included in the sample, 189 (53%) were white, 52 (14.5%) were black, and 116 (32.5%) had no information on race. For this reason, and because the comparison rates from the Framingham Heart Study are not stratified by race, race was not evaluated as a possible confounder in this study. In addition, virtually all workers for whom gender was known were male; therefore, all subjects were assumed, for epidemiologic purposes, to be male. There were 27 individuals for whom no date of birth was provided. It was assumed that their birth dates were 20 years prior to the date of hire.

The age-stratified standardized morbidity ratio (SMR) for this population is presented in Table 2. The number of observed MIs for the entire group is 34, with an expected number of 54.7, resulting in an SMR of 0.62. Not only was there no increased risk of MI overall, there was no increase in the SMR for any age group. Confidence intervals are not provided for the SMR point estimates because, since the SMRs are calculated from a 10-percent sample, the underlying statistical assumptions necessary in inference testing may not be valid.

The incidence of MI by calendar year was not remarkable. From 1974 through 1985, there was no clustering in time (Figure 3). It should be noted, however, that five MIs occurred during 1985, a fact that may have contributed to the perceived excess. There is also little seasonal variation (Figure 4). In fact, the incidence of MI is no higher than expected in the summer months (7/34 (20%) observed vs. 8.5 (25%) expected), a time when an increase would be expected if there were an association with increased heat stress.

To evaluate the influence of specific variables of exposure to heat at this plant on the incidence of MI, a case-control analysis was performed on the 30 cases and 29 controls, matched on age, date of birth, and date of hire. (One case had no available control.) A stratified analysis was not done because of the small number of case/control pairs.

There was no association between MI and work in the Curing Department at the time of the MI. Of the five discordant pairs, there were 3 matched pairs in which the control worked in the Curing Department at the time of the MI, and only 2 pairs in which the case worked in curing at the time of his MI (McNemar's X = 0.45; p > .10). Similarly, there was no association between myocardial infarction and whether a worker had ever worked in the curing department. There were 6 matched pairs in which the control had ever worked in curing and the case had not, and only 3 matched pairs in which the case had ever worked in curing and his control had not (McNemar's X = 1.0; p > .10).

Because of incomplete or unclear personnel records, in several instances the duration of employment in the curing department had to be estimated; therefore, any analysis using this variable is not precise. Although there is a significant association between MI and duration of employment in the Curing Department, it was the controls who worked longer than their matched cases (Wilcoxon matched-pairs signed ranks test: p=0.04).

There are two predominant potential sources of error in these studies: (a) possible underascertainment of cases, and (2) sampling error in the 10-percent sample used to estimate the number of person-years in the plant. However, it is unlikely that either of these sources contributed in a major way towards biasing the results. First, as discussed previously, it is improbable that a recognized MI in a current employee would not be recorded in the S & A reports. Second, it is appropriate to evaluate the incidence of MI among current employees, rather than terminated or retired employees, since the temporal relationship between heat stress (the exposure of interest) and MI is more likely to be acute than chronic. Furthermore, the 10-percent sample yields an estimate with a larger variance than a complete sample; therefore, the SMR will have a lower statistical precision. However, this would result in a random error, and there is no reason to suspect a systematic bias occurred which could have yielded a spuriously low SMR. Therefore, from both the standardized morbidity ratio (SMR) and the case-control analyses, there is no evidence of an association between myocardial infarction and exposure to heat.

VII. CONCLUSIONS

This study documented excessive heat stress in the Curing Department. It did not document, however, either an increased risk of myocardial infarction among Uniroyal-Goodrich employees or an association between MI and work in the Curing Department. No hazards from over-exposure to carbon monoxide or carbon disulfide were present at the time of the NIOSH visit.

VIII. RECOMMENDATIONS

1. Much of the heat in the Curing Department is radiant heat from the tire molds; globe temperatures ranged from 99-105° F. Therefore, it is important to make sure that radiant heat blankets are kept in place. A few of the blankets were removed from operating molds during our visit; this resulted in nearby globe temperatures and WBGTs ranging up to 109° and 93°, respectively.

2. Worker education and training is probably the most important precaution for minimizing the risk of heat injury and illness. Workers should be kept informed of:

    (a) Predisposing factors and relevant signs and symptoms of heat injury and illness,

    (b) Potential health effects of excessive heat stress and first aid procedures,

    (c) Proper precautions for work in heat stress areas,

    (d) First aid procedures for heat-related injury and illness, and

    (e) Control procedures to help protect the health and provide for the safety of themselves and their fellow workers, including instructions to report immediately the development of signs or symptoms of heat stress over-exposure to the appropriate supervisory and health personnel.

3. Propane-fueled forklifts that are used frequently should have their exhausts measured for carbon monoxide (CO). We found a wide range of exhaust CO levels among forklifts during our visit. The newer trucks tended to exhaust about 100 ppm CO, whereas older trucks had up to 2000 ppm of CO in their exhaust. Frequent tuning and maintenance should be used to minimize CO levels.

4. Due to the large area of the plant (40 acres under one roof) and the general openness due to very few walls, a massive amount of dilution ventilation is available to prevent excessive CO exposures during the normal operation of forklifts in open areas of the plant. However, drivers and their supervisors should be careful to avoid any forklift activity that may occur in more enclosed spaces where CO can build up to hazardous levels.

5. The break rooms were found to have sufficient ventilation during our visit, but conditions may differ during winter weather. Break room CO levels should again be measured during peak usage to ensure that, in those areas where smoking is permitted, there is enough ventilation to prevent the excessive build-up of cigarette smoke.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Investigators:	Anne T. Fidler, Sc.D. Supervisory Epidemiologist Medical Section
	Mitchell Singal, M.D. Supervisory Medical Officer Medical Section
	Steven A. Lee, C.I.H. Industrial Hygiene Section
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies

XI. DISTRIBUTION AND AVAILABILITY

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1. Uniroyal-Goodrich
2. United Rubber Workers
3. NIOSH Atlanta Region
4. OSHA, Region 4

Table 1

Carbon Disulfide Air Samples
August 19-20, 1986

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

Location/Job	Sample Time	Concentration
Reader #4, PBZ	930-1407	ND*
Calendar Operator, PBZ	938-1442	ND
Tuber #1 Operator, PBZ	942-1423	ND
Sidewall #3, process area	950-1550	ND
Cure Line Operator, PBZ	810-1450	ND
Calendar Operator, PBZ	816-1430	ND
Sidewall #3 Operator, PBZ	820-1515	ND
Old Curing Line Roof Exhaust, Process Area	830-1405	ND

*ND = none detected <0.06 mg/m^3
Evaluation Criterion, NIOSH REL 3 mg/m^3

Table 2

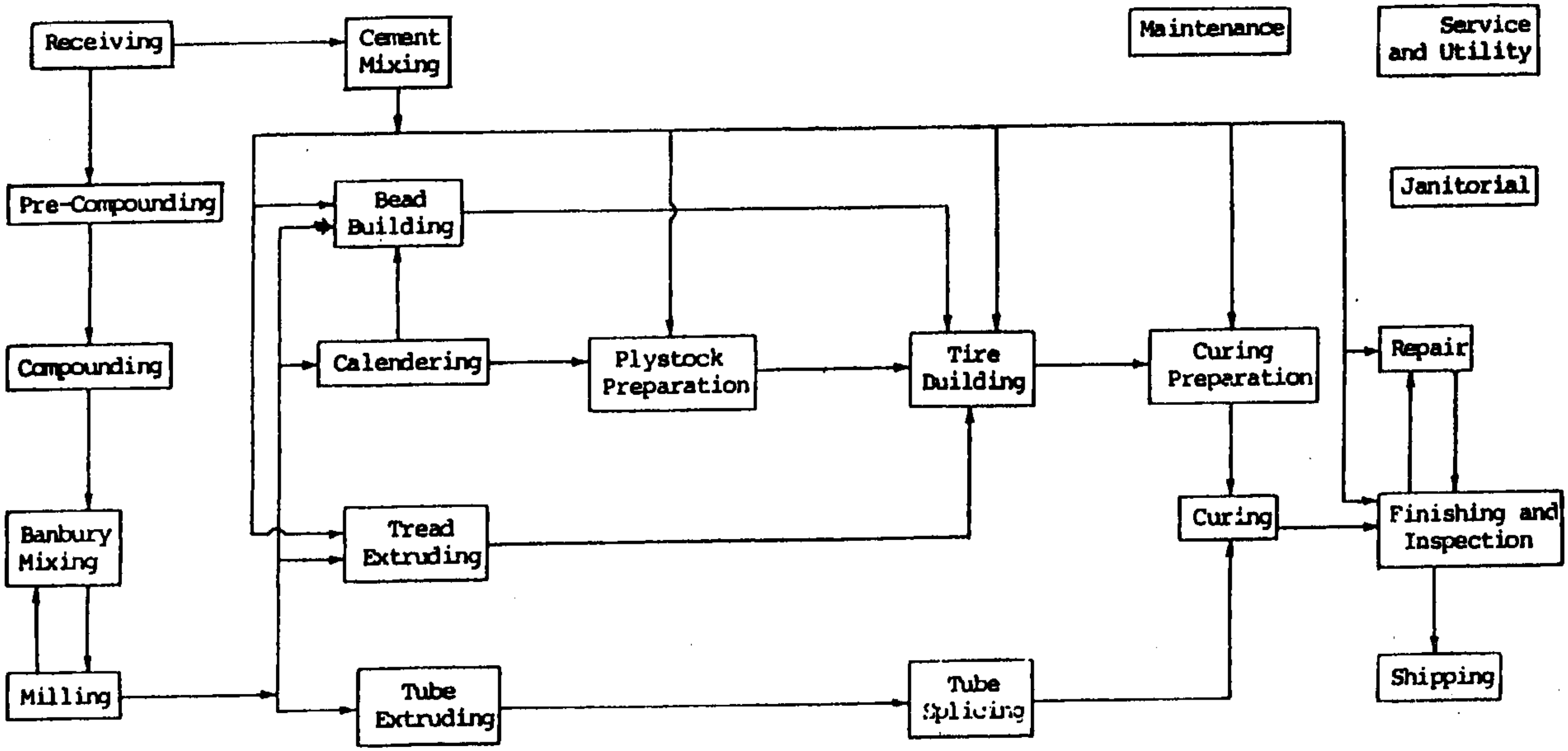
Standardized Morbidity Ratio (SMR) Analysis

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

Age	"Recognized" MI * Ann. Incidence Rate	# person-years	Expected MIs	Observed Mis	SMR
< 35	------	2159.67	-----	1	----
35-44	2/1000	1527.86	3.06 X 10=30.6	13	0.42
45-54	4/1000	425.98	1.70 X 10=17.0	12	0.70
55-64	6/1000	106.82	0.64 X 10= 6.4	4	0.62
65-74	8/1000	9.26	0.07 X 10= 0.7	0	0.00
75-84	10/1000	0.00	0.00 X 10= 0.0	0	----
Age unknown				4	
		4229.59	54.7	34	0.62

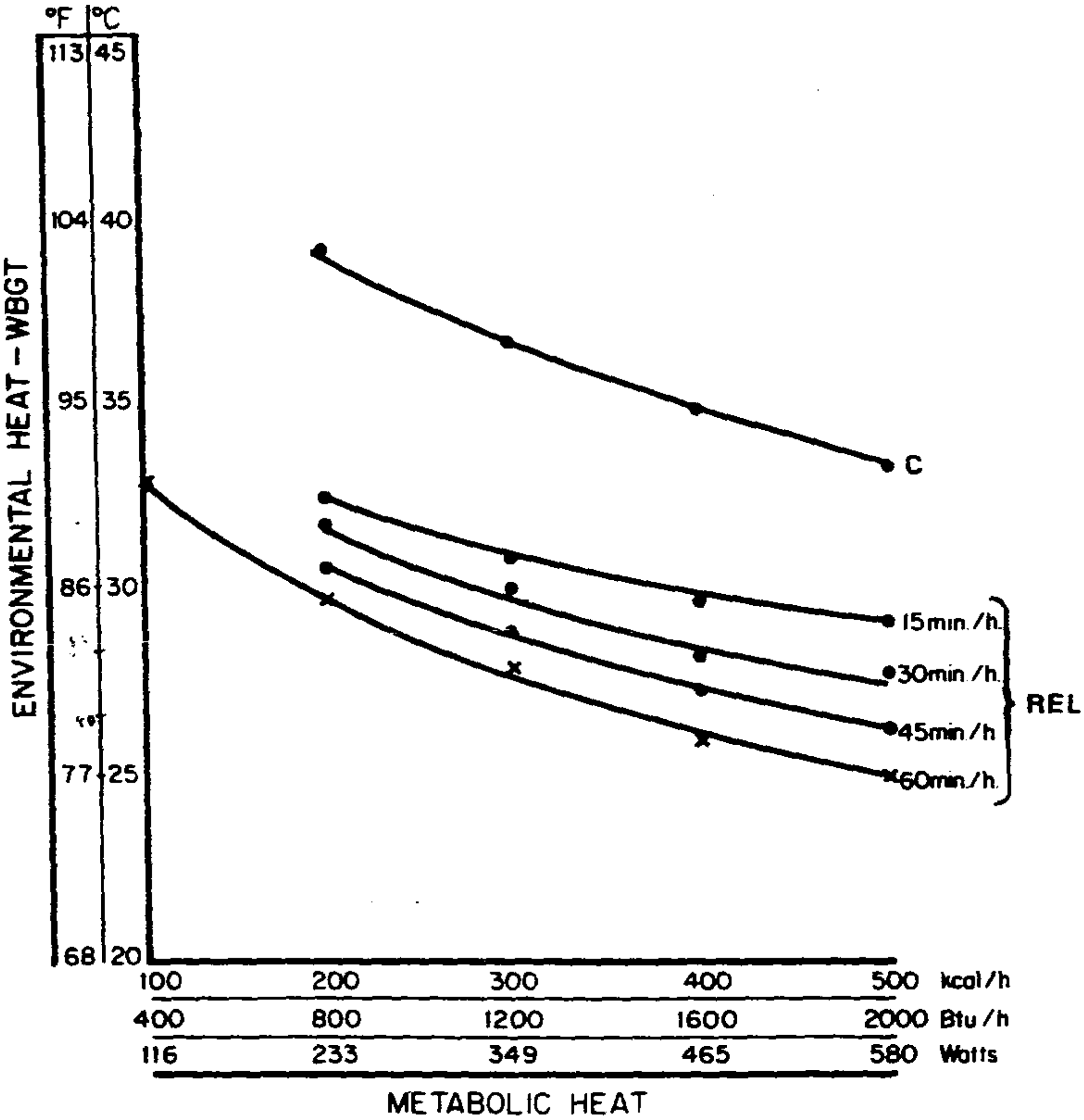
* Expected rates from Framingham Heart Study[3]

Figure 1



Production Stages in the Manufacture of Tires and Tubes.

Figure 2



Recommended Heat-Stress Exposure Limits
Heat-Acclimatized Workers *

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

Figure 3

Myocardial Infarctions by Year
HETA 86-015: Uniroyal - Opelika, Alabama

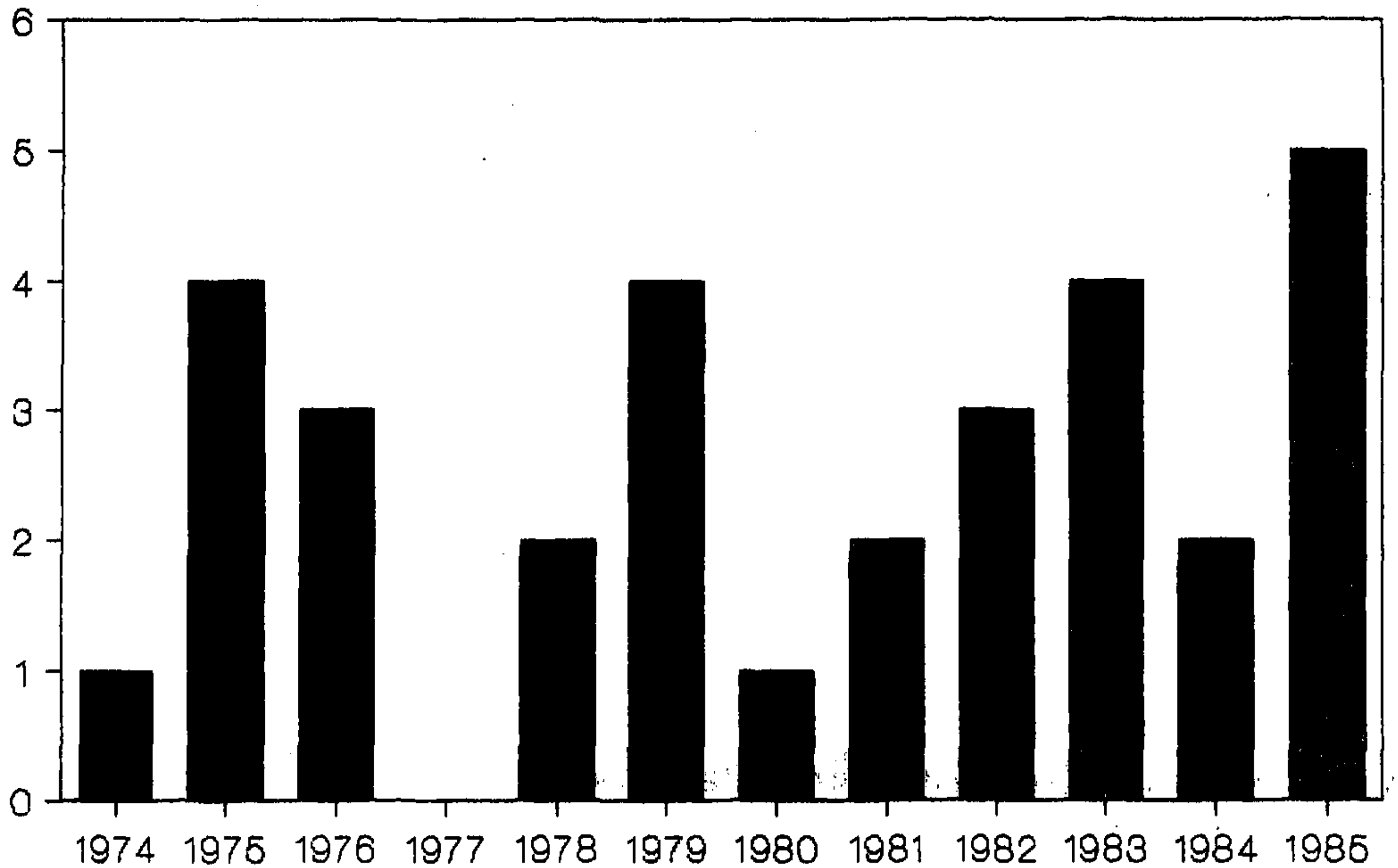
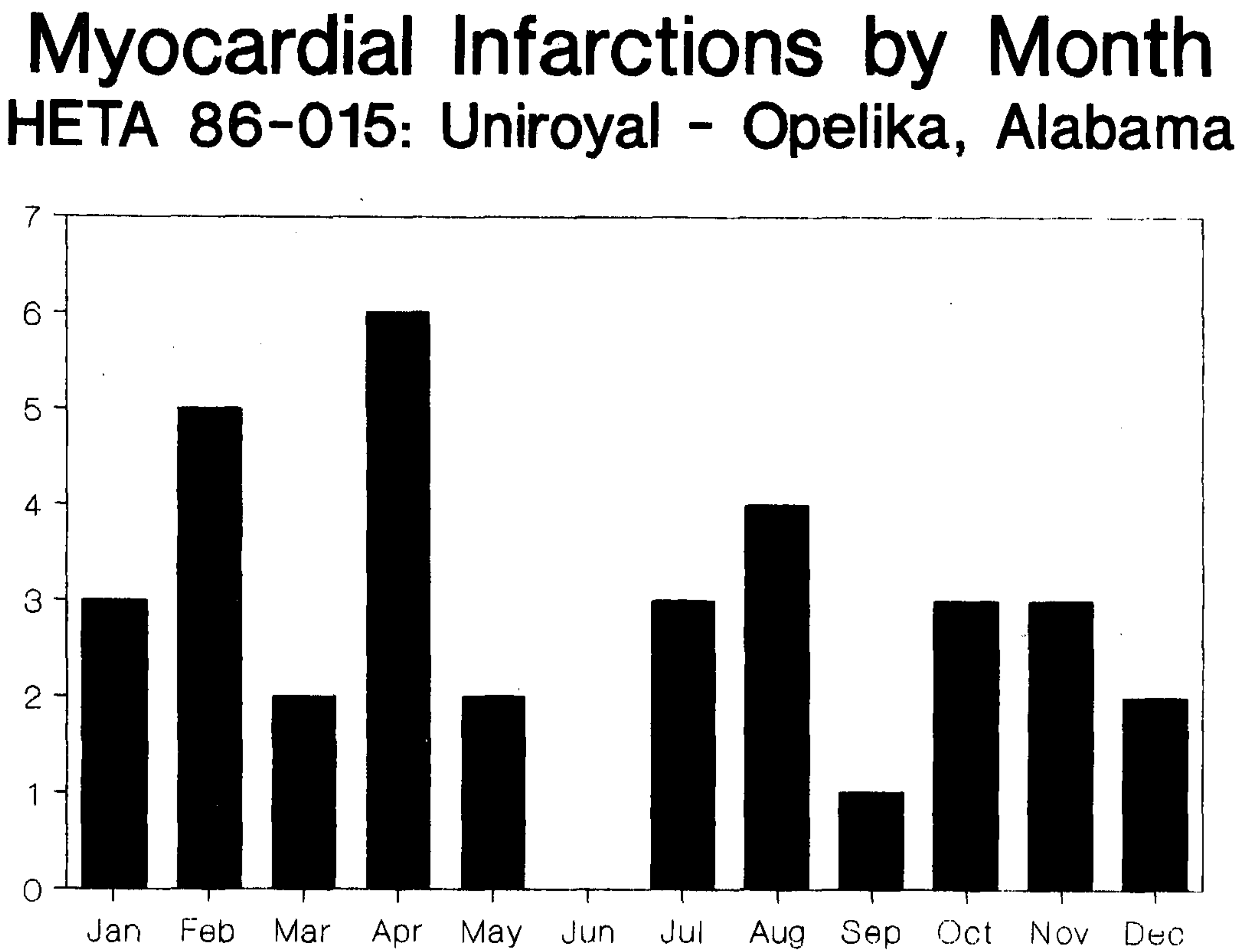


Figure 4


Myocardial Infarctions by Month
HETA 86-015: Uniroyal - Opelika, Alabama
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Appendix 1

Description of Occupational Title Groups
in Tire and Tube Manufacturing[1]

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

Occupational Title Group	Description of Process
Compounding	Batch lots of rubber stock ingredients are weighed and prepared for subsequent mixing in Banburys; solvents and cements are prepared for process use.
Banbury Mixing	Raw ingredients (rubber, filler, extender oils, accelerators, antioxidants) are mixed together in a Banbury mixer. This internal mixer breaks down rubber for thorough and uniform dispersion of the other ingredients.
Milling	The batches from the Banbury are further mixed on a mill, cooled, and the sheets or slabs coated with talc so that they are not tacky. The stock may return to the Banbury for additional ingredients, or go on to breakdown or feed mills prior to extrusion or calendaring.
Extrusion	The softened rubber is forced through a die forming a long, continuous strip in the shape of tread or tube stock. This strip is cut is appropriate lengths, and the cut ends are cemented so as to be tacky.
Calendaring	The softened rubber from the feed mill is applied to fabric, forming continuous sheets of plystock by the calendar (a mill with three or more vertical rolls and much greater accuracy and control of thickness).
Plystock Preparation	The plystock from the calendar is cut and applied to the correct size for tire building, and so the strands in the fabric have the proper orientation.
Bead Building	Parallel steel wire is insulated with rubber vulcanizable into a semi-hard condition and covered with a special rubberized fabric. The beads maintain the shape of the tire and hold it on the steel rim in use.

Appendix 1 (cont.)

Description of Occupational Title Groups
in Tire and Tube Manufacturing[1]

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

Occupational Title Group	Description of Process
Tire Building	The tire is built from several sheets of calendared plystock, treads, and beads.
Curing Preparation	The assembled green or uncured tire is inspected, repaired, and coated with agents to keep it from sticking to the mold in vulcanization.
Tube Splicing	Assembly of tube stock; i.e. tube building
Curing	The green tire or tube is placed in a mold and vulcanized under heat and pressure.
Final Inspection and Repair	The cured tire is trimmed, inspected, and labeled; repairable tires or tubes that do not pass initial inspection are repaired.

Appendix 2

Estimating Energy Cost of Work by Task Analysis[6]

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

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 1.8m^2 body surface (19.4 ft^2)

** Example of measuring metabolic heat production of a worker when performing initial screening.

Appendix 3

Case-Control Matching Procedure

Uniroyal-Goodrich Plant
Opelika, Alabama
HETA 86-015

Cases were identified on the New Hire Sheets, which were ordered by date of hire. A control was considered an eligible match if of the same sex and race, and born within 5 years of the case. We then sought to identify the eligible match with the nearest date of hire (not to exceed one year). If there was a tie, the control was chosen whose date of hire preceded that of the case; if ties still existed, the control with the closest worker identification (badge) number was chosen (if a tie, the lower badge number was used). If there were no eligible matches, the eligibility criterion for age was expanded to 6 years, then to 7, etc. A control, once chosen, became ineligible to be chosen again.) In addition, a control had to have continued employment at Uniroyal-Goodrich at least through the time of the MI experienced by his case.