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16. Abstract (Limit: 200 words)

A mortality survey among gray-iron (11097157) foundry (SIC-3321) workers was conducted. The cohort consisted of 278 male hourly workers having at least 10 years of experience who died between January 1, 1970 and December 31, 1981. The cohort was traced from company records, death certificates, and interviews with union officials or other retirees. Proportionate mortality ratios (PMRs) were computed and categorized according to job title of the deceased workers. Among 221 white males, the principal causes of death were: nonmalignant respiratory disease, PMR 177; lung cancer, PMR 148; and leukemia, PMR 284. Workers in the finishing department had significant excess mortality due to nonmalignant respiratory disease (PMR 279) and lung cancer (PMR 179). A PMR of 321 for nonmalignant respiratory disease occurred among core room workers. Significant and insignificant correlations between deaths due to nonmalignant respiratory disease and lung cancer, respectively, and employment in the finishing department occurred. Among nonwhite workers, a significant excess of circulatory disease mortality (PMR 143) occurred for those 60 or more years old at the time of death. The authors conclude that the excess malignant and nonmalignant respiratory disease mortality cannot be explained by age or smoking. Iron foundries are extremely hazardous work environments.

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PREFACE

This is the first in a series of six mortality reports conducted under the terms of NIOSH contract #210-81-5104.

We would like to acknowledge the important contributions to this work by Leonard Faith and other officials and members of UAW Local Union 579, Danville, Illinois.

We also are grateful for the time, effort and concern contributed by Carole Rogers and Margaret Auch who shouldered the clerical and secretarial tasks on this project.

MORTALITY AMONG FERROUS FOUNDRY WORKERS

NIOSH Contract #210-81-5104
International Union, United
Automobile Workers (UAW)

SUMMARY

Mortality analyses were carried out by the International Union, UAW for 278 male hourly workers employed for at least 10 years at a gray iron foundry and who died between January 1, 1970 and December 31, 1981. Statistically significant excess proportional mortality due to nonmalignant respiratory disease (SPMR=177), lung cancer (SPMR=148) and leukemia (SPMR=284) was found among the 221 white males. White males in the **Finishing** exposure classification experienced a significant excess of proportional mortality due to nonmalignant respiratory disease (SPMR=279) and lung cancer (SPMR=179). White males in the **Core Room** exposure classification experienced an excess of proportional mortality due to nonmalignant respiratory disease (SPMR=321). Case-control studies, using stratification and logistic regression, further demonstrated a significant association between nonmalignant respiratory disease and the **Finishing** exposure classification after controlling for the effects of age, prior occupations in coal mining or foundries, and smoking. A positive but nonsignificant association between lung cancer and **Finishing** was also found after controlling for age, prior work history, and smoking in case control studies.

Among non-white males there was significant excess in proportional mortality due to circulatory diseases (SPMR = 143). Case-control analyses further indicated that circulatory disease mortality was associated with **Foundry** exposure classification (OR = 11; p = .06) among decedents aged 60 or more at death. This finding has not been previously reported and requires confirmation in follow up studies.

Breathing zone dust measurements averaged 10 mppcf plantwide between 1947 and 1976, with 11% of samples exceeding 20 mppcf. Measurements in foundry, finishing and core making were similar. The average personal exposure and prevalence of high exposures to workers was probably lower than the measurements show because of sampling strategy. The suggests that a foundry dust exposure limit of 10 mppcf was inadequate to protect against mortality from respiratory cancer and nonmalignant respiratory disease.

This study confirms earlier reports and provides additional new information demonstrating the hazardous nature of the ferrous foundry environment. It supports the need for full implementation of currently available control technology to reduce exposures of danger to workers.

MORTALITY AMONG FERROUS FOUNDRY WORKERS

BACKGROUND

Origins of Study

This report is the result of an investigation of mortality patterns among hourly workers at the Danville Central Foundry (DCF), General Motors Corporation in Danville, Illinois. The investigation was undertaken by the International Union, United Automobile Workers (UAW) in response to concerns expressed by the local union. An additional basis for concern was a series of epidemiologic investigations [3,8,14,18,23,34,40] which reported excess mortality from nonmalignant and malignant lung disease in United States and European foundry workers. Of particular interest was that the present study might provide mortality information relating to American foundry conditions in the post World War II era.

Foundry Process[1,4]

Foundry work involves the pouring of molten metal into molds to produce cooled, shaped and cleaned metal castings.

The plant in this study was a ferrous foundry, melting scrap iron to produce both gray iron and malleable iron castings. Cast iron contains iron, carbon, silicon and other elements in smaller quantities. Gray and malleable iron differ primarily in their carbon content; gray iron contains 3-4% and malleable iron 1.75-2.5%. The foundry processes used to produce malleable and gray iron differ in that malleable iron is innoculated with additives to purify the metal. Malleable iron castings are heated for 3-4 days in annealing ovens at 1500-1800° F.

Several furnace types have been used commercially in the past 50 years. Cupolas are vertical cylinders lined with refractory material and charged with alternating layers of coke, limestone or other fluxes, and iron. Electric furnaces use either induced current or electric arcs to heat the iron without added coke and limestone.

Molten iron is transported in ladles by overhead conveyer to pouring areas where mold cavities are filled with hot metal. These molds are typically made of sand which has been shaped by compression around a re-usable pattern. The most common mold material is "green sand", a mixture of silica sand, sea coal, bentonite or other clay binders, various cereals and water. Other mold ingredients less commonly used include furan resins, sodium silicate and linseed oil.

Cores are solid pieces which are set inside mold cavities prior to pouring and which create the internal hollows in finished castings. Cores are generally made of silica sand held in shape with a variety of oil or synthetic resin binders.

Solidified castings are removed from molds in a shakeout, followed by knockout of cores and breaking of sprue. Finishing involves abrasive blasting to remove surface sand, and grinding and chipping to remove excess metal.

Description of Plant and Exposures

History

A history of the plant and its processes was reconstructed through discussions with local union representatives with supplemental information and validation from management personnel and company documents. Quantitative exposure information, described in Appendix 1, was derived from company industrial hygiene survey reports for foundry dust, carbon monoxide and other air contaminants.

The facility opened in 1944 as a malleable iron foundry in Danville, Illinois for the U.S. Defense Corporation. Heavy truck axle castings were produced for military vehicles until 1946. Approximately 600 persons were employed. After the war the plant closed. It was reopened in early 1947 by General Motors as a gray iron foundry.

In about 1950, a malleable iron foundry was opened adjacent to the gray iron plant and operated until 1981. Numerous expansions and additions to the physical plant have been made over the years. The plant layout in 1982 is shown in Figure 1. Schematics of physical plant changes over time are presented in Figure 2.

The plant has produced a variety of iron castings including intake and exhaust manifolds, crankshafts, valve bodies, oil and water pumps, brake rotors, and power steering gears. The peak employment of hourly workers was 2,100 in 1977. The hourly employment in 1982 was about 950.

Core Making

Since the 1940's, a core room has been located at each end of the plant. Core making operations were not separated from the rest of the plant by physical barriers. Oil sand, shell core, hot box and cold box core making processes have been used.

The oil sand process mixed sand in mullers with binders of vegetable oils, cereals and probably pitch. These cores were then hardened by baking in a gas fired oven. The shell core system was introduced in the early 1950's to make thin walled, hollow shell cores. Shell core binder systems typically contain phenol-formaldehyde resins with hexamethylenetetramine as catalyst. Shell cores were produced until 1981. In the late 1960's, the hot box process was introduced. Furan binders which typically contain furfuryl alcohol, formaldehyde, urea and ammonium chloride were cured in gas fired core boxes. Phenol-formaldehyde-urea systems have also been used at this plant. "Cold box" coremaking was added in the mid 1970's. In this process resins harden in the core box by a reaction using isocyanate resins (methylene bisphenyl diisocyanate) and amine catalysts (triethylamine, dimethylethylamine).

Foundry Area

Molding sand, a mixture of sand, sea coal, clay and corn flour, was prepared in mullers located near the shakeout area. The wet sand was transported by conveyor to automatic molding machines. Molds were then transported to the pouring lines by conveyor.

Cupolas melted scrap metal in the gray iron foundry. Arc furnaces were used in the malleable iron foundry. Hot metal cranes transported the molten metal to the pouring area in non-lidded ladles. Prior to 1973, there were eight manual pouring lines with three or four pourers per line. By 1973, six of the eight lines were mechanized. Once the metal was poured, molds proceeded through a cooling tunnel. Castings were removed from molds through shakeout and then moved by conveyor to the basement for cooling.

Finishing

Malleable iron castings proceeded to annealing ovens. Gray iron castings went directly to the finishing area by way of pan conveyor. The finishing area was located approximately 200-250 feet from the foundry area, not separated by physical barriers. Castings moved on conveyors through sprue, removal, shot blasting, grinding, testing, and repair.

Other

There were several operations physically removed from the major production areas. These include power house, the yard (raw materials handling), cafeteria, shipping and locker room. The pattern shop has been close to the foundry area but enclosed.

Several types of workers, such as maintenance, housekeeping, inspection and time clerks were not limited to specific areas of the plant.

Quantitative Exposures

Air samples of foundry dust, carbon monoxide and other contaminants were obtained during 17 industrial hygiene surveys conducted at 1 to 3 year intervals between 1947 and 1976. Arithmetic means for individual contaminants were calculated for each survey (survey mean). Survey means were averaged to provide an overall mean for the period (period mean).

Period mean dust levels in mppcf were as follows for major work areas:

Core Room	-	8.8
Finishing	-	9.2
Foundry		
Melting	-	14.0
Molding	-	9.4
Sand Systems	-	18.4
Plant-wide	-	10.0

The survey median for carbon monoxide in cupola and pouring areas ranged from 20 ppm to over 100 ppm. Additional industrial hygiene data are reviewed in Appendix 1.

Prior Employment

Many of the decedents had work experience prior to employment at the study plant. Local union representatives provided the following description of key non-GM employers.

During the first decades of the 20th century, underground bituminous coal mining was an important economic activity in the Danville area. The local decline in coal mining contributed to a labor surplus in the 1930's and 1940's, making former miners available for employment in the study plant.

In approximately 1947, an important local employer, Hegeler Zinc Company, went out of business. Hegeler Zinc produced rolled zinc for flashlight battery casings. Coke and zinc ore were brought in from off-site and crushed. The coke and zinc ore were mixed with copper powder in open hearth furnaces or retort ovens. The molten zinc was poured into ingots and rolled. Hygienic conditions were reported by former employees to be very poor. "Fume fever" was reported to have occurred.

Other facilities that may have employed workers in this study include a small number of other ferrous foundries, a munitions works operated by the Dupont Company for war production, and refractories and brick works.

MATERIALS AND METHODS

Study Population

The study population includes all those hourly employees who worked at Danville Central Foundry for 10 or more years* and who died during he period from January 1, 1970 through December 31, 1981. Efforts were made to include deaths among active workers, retirees, and terminated employees.

Information regarding deaths came from 5 sources (Table 1). The local union maintains a death benefit fund and requires that a death certificate be presented by beneficiaries prior to payment. Membership in the fund is optional. Between 70-90% of workers were enrolled. Reports of death were also recorded in files maintained by the local union benefits representative and the International Union pension system. Enrollment in the benefits or pension system is nonvoluntary and contractual. All names in International Union pension records, but not listed as dead were submitted to a Social Security Administration vital status determination. This group included workers who terminated with pension rights before retirement age (Deferred Vested Pension). The last source of death ascertainment was plant records of the employer. Plant management learned of deaths generally from life and health insurance records, although death reports from funeral homes, newspapers, or phone calls from the beneficiary/family were also used.

A total of 288 hourly workers meeting the study criteria was identified. Death certificates were obtained from 282 (98%). Work history records were available for 278 decedents (Figure 3). Catchment from all union sources combined (98%) was approximately equal to that of all company sources (97%). The number and percent of study group discovered by source and concordance measures between various combinations are given in Table 1.

Nosology

Death certificates were used as the source for cause of death, age at death, year of death, sex, and race of decedents. Death certificates were coded by a certified nosologist for underlying cause of death according to the 8th revision of the International Classification of Diseases (ICD).

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*Length of Service was defined as cumulative time of employment exclusive of layoffs, quits, discharge, sick leave, or other leaves.

Work Histories

Three types of company personnel records were used as the source of employment information: 1) employment jackets 2) job history file cards and 3) employment application.

Employment jackets recorded departments worked, date of department or employment status changes, and a transaction code (department transfer, quits, layoff, discharge, etc.). The plant employment supervisor provided a dictionary of department codes and transaction codes. The dictionary was verified and supplemented in one case by local union officials and retirees.

Employment jackets were the primary employment records from 1944 to 1969. After 1969, employment jackets were less complete but still provided the last date worked or retirement date. Total employment duration was therefore calculable for each decedent, including those who completed 10 years of service between 1970 and 1981.

Job history index cards provided department number, job classification and dates of job or employment status changes from 1960 to 1969.

These plant personnel records provided a reasonably complete and accurate record of work histories from 1944-1969. Computerized daily labor records were introduced in the 1970's. However, these printouts were discarded for the period 1973-1977 inclusive, and were apparently unretrievable for the period 1970-1973. Therefore, employment records after 1970 were fragmentary and not suitable for use. One hundred and sixty-five (54%) of the study group with work histories averaged 4.3 years of service after 1970.

Generally, up to 4 jobs held immediately prior to study plant employment were recorded on the employment application. The information included employer name, job description, dates of employment, and reason for leaving.

A written protocol was developed for abstracting the following information from the employment jacket and job history card: department code and date (month, year) of department transfer or job status change for all jobs ever-worked. From the employment application, 4 categories of prior jobs were coded with beginning and ending date (month, year) of each job: coal mining, zinc foundry work, non-zinc foundry work, and all other jobs. Categories were assigned on the basis of employer name and/or job description keywords.

Exposure Classification

Five mutually exclusive exposure classifications were constructed by grouping together departments with presumed common operations and exposures (Table 2). Finishing classification jobs were presumed to share substantial exposures to respirable silica dust, smaller exposures to metal dusts, and possible exposure to polycyclic aromatic hydrocarbons (PAHs). **Foundry** classification exposures were presumed to have included silica, pyrolysis products (including PAHs), iron oxide fumes, carbon monoxide, noise and heat. **Core Room** exposures would vary depending on the particular core making process, but in general would include mixtures of gases or vapors (phenol, formaldehyde, amines, carbon monoxide) and silica dust. The **Mixed** classification represents workers with high mobility jobs with multiple exposures including silica and metal dusts, PAHs, and solvents. The **Other** classification was presumed to offer the least opportunity for exposure to recognized foundry hazards. The work areas included in **Other** were generally enclosed or physically separated from the production areas.

Three measures of exposure duration were determined for each decedent*: 1) the exposure classification of longest cumulative duration, 2) less than or greater than 5 years in a given exposure classification, and 3) the exposure classification of longest duration 15 years prior to death. These three measures yielded highly correlated assignments of workers to exposure categories. Separate mortality analyses were carried out using each of the three exposure measures. The risk estimates were essentially the same using any of the three measures. In order to eliminate redundancy, only results based on the exposure classification of longest duration will be presented. This measure was chosen because it has conceptual and computational simplicity and yields a unique classification for each individual.

Smoking History

Tobacco smoking histories were obtained by interviews of 3 independent groups of co-workers, local union officials and members of the local union retiree association. In total, 10 participants from various departments of the plant were asked whether each decedent ever smoked tobacco. The options were yes (ever-smoker), no (nonsmoker) and unknown (unknown as smoker or decedent unknown to interviewee). The definition of smoker included ex-smokers, pipe and/or cigar smokers, individuals who smoked for even brief periods, as well as regular cigarette smokers.

Decedents were classified as smokers if they were reported as a smoker in any one of the three interviews. For decedents not classified as a smoker, at least one report of nonsmoking was necessary for classification as a nonsmoker. Individuals with unknown smoking status in all 3 interviews were considered unknown smokers.

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*Because specific department assignments after 1970 were not known, duration in exposure classifications was slightly truncated for decedents with post-1970 employment.

Interviewees were not informed of the cause of death of decedents or of the exposure classification scheme.

Statistical Analyses

Standardized Proportional Mortality

Standardized proportional mortality ratio analyses (SPMR) and standardized proportional cancer mortality ratio analyses (SPCMR) were performed using the Monson Program[29], which uses indirect standardization to adjust for age, sex, race, and calender year of death. The referent population was the U.S. death registry[29]. U.S. white male proportional mortalities were revised to include National Center for Health Statistics (NCHS) mortality data through 1978 (see Appendix 2). Although not used, Illinois white male proportional mortalities were computed for the major causes of concern to this study and were quite similar to U.S. figures for 1970 - 1974 (Appendix 5). The statistical significance of the SPMRs was assessed by Mantel-Haenszel chi square procedures[25].

SPMRs were calculated for subgroups defined by length of service, age at death, prior employment, and exposure classification of longest duration.

Standardized proportional mortality analyses of lung cancer were also performed for the subgroup of ever-smokers, using lung cancer mortality data for smokers from the U.S. Veterans Study[9,21] for comparison. Details of the procedures are given in Appendix 3. Standardized proportional mortality analysis for the subgroup of nonsmokers was also performed using the U.S. standard population.

Case-Control

Case-control analyses were performed to test the hypothesis that there was no association between nonmalignant respiratory disease and specific exposure classifications. Cases of nonmalignant respiratory disease were defined as decedents with ICD death codes 460-519. Controls included all other deaths with the exclusion of lung cancer (ICD 162). Based on prior knowledge of foundry exposures [10,26] and the general processes of respiratory disease, decedents with lung cancer as the underlying cause of death were judged to be inappropriate controls and were excluded from case-control studies of nonmalignant respiratory disease. Stratification and logistic regression were used to control for potentially confounding factors of race, age, smoking, and prior occupational exposures in coal mining and foundries. Because the number of black nonmalignant respiratory disease deaths was small, the analysis was restricted to white males.

A second case-control study was carried out to test the hypothesis that there was no association between lung cancer and specific exposure classifications. Cases were defined as decedents with ICD code 162 as the underlying cause of death. Based on prior knowledge of foundry exposures[10,26] and the general processes of respiratory disease and carcinogenesis, controls included all other causes with the exclusion of nonmalignant respiratory disease (ICD 460-519) and non-lung cancers (ICD 140-161, 163-209). Stratification and logistic regression were used to control for potential confounding by age, prior occupation in foundries, and smoking. Because the number of black lung cancer deaths was small, the analysis was restricted to white males.

A third case-control study was done to test the hypothesis that there was no association between circulatory disease and specific exposure classifications. Cases were defined as decedents with ICD codes 390-458 as the underlying cause of death. Controls were defined as decedents with all other ICD codes as the underlying cause. Stratification was used to control potential confounding by age and prior occupation. The analysis was restricted to black males.

Strata-specific odds ratios were used as the measure of association in stratified case-control studies. Statistical significance of stratum specific odds ratios was assessed with the Fisher Exact Probability.[13]

Unconditional multiple logistic regression[6] was used to assess the association between lung cancer and nonmalignant respiratory disease with exposure classification, simultaneously adjusting for age, prior occupation, and smoking. A forward algorithm was used, first adjusting for the main effects of age, prior foundry exposure, and smoking. The main effect of exposure classification was tested for inclusion in the model using the -2*log likelihood statistic[6]. All 2x2 interactions between exposure measures and covariates were also tested if a statistically significant main effect of exposure was found.

In addition to exclusions based on case or control definitions, these analyses also excluded the 4 decedents with missing work records and 13 decedents whose work histories were inadequate to determine exposure classification of longest duration (see Appendix 4).

Power Calculations

A posteriori power calculations were done using the criterion of detecting a 1.5-fold increase in the measure of association given an α error of .05. The method used in case-control studies was the approximate method for unequal number of cases and controls given by Fleiss [13, pp. 44-46]. For power calculations in SPMR analyses, the normal approximation to the Poisson distribution was used.

The significance level for all statistical analyses was set at $p=.05$ unless otherwise stated.

Quality Control

Formal quality control measures were used during data abstracting, coding, and data entry to computer files. All data was abstracted onto standardized coding forms. The abstracting of work histories was done according to a written protocol. The abstracter was trained and periodically observed throughout the coding process. Work history records and death certificate information were double key punched. Computer files were visually scanned to catch outliers and erroneous values. Computer files containing death certificate information, work history data, and smoking histories were manually checked against original records and corrected. Finally a 10% random sample of death certificates from the study group was resubmitted to the same nosologist approximately 6 months after the original batch was coded. In 22 of 26 cases, there was exact agreement on the first 3 digits of the ICD code. In 25/26 cases (96%) the same placement in the Monson cause of death categories resulted.

RESULTS

Description of Study Group

Demographic and occupational characteristics of the study group are presented in Tables 3 - 8 and Figures 4 - 14. Eighty percent of the study group were white and 99% were male. Mortality data on the 4 white female decedents is included in Appendix 4, but will not be discussed further. Of 57 non-white males, 56 were black and 1 was Asian. The mean age at death was 63 for white males and 58 for black males. The mean age at hire for males, white or black, was 36. Unlike the bell shaped distributions for age at death and age at hire (Figures 4, 5), the frequency distribution for year of hire (Figure 6) was bimodal. Approximately ninety percent, however, were hired in the narrow interval of 1945-1955. The mean length of service for whites and blacks was approximately 20 years.

There was considerable movement between departments. Roughly 20% of individuals accumulated 5 or more years in more than 1 exposure classification (Figure 7). Blacks were disproportionately employed in the **Foundry** classification (Figure 8). The age distribution of the **Finishing** classification was skewed toward older age-at-death in comparison to the 4 other exposure classifications (Figure 9).

71% of males were reported by co-workers to have ever smoked tobacco in any form (Table 5). 27% of males were nonsmokers and 2% were of unknown status. There was a greater percentage of white smokers (75%) than black smokers (52%). White male nonsmokers comprised about 30% of the **Finishing** or **Foundry** classifications, but only 11% of the **Mixed** (Figure 10).

Approximately 20% of the study group was previously employed in coal mining, 13% in a zinc foundry, and 23% in any foundry (zinc, ferrous, steel, unspecified) (Table 6). Former coal miners were overrepresented in the **Finishing** and **Core** compared with all other known departments (Figure 11). Former zinc workers were disproportionately employed in the **Foundry** classification (Figure 12). A similar observation of lesser magnitude was made for decedents formerly employed in any foundry (Figure 13).

Standardized Proportional Mortality Findings

The standardized proportional mortality profile of white and non-white workers is presented in Table 9. White male workers experienced excess proportional mortality due to all malignant neoplasms (O/E = PMR: 61/51.5=118, $p > .05$) and nonmalignant respiratory disease (25/14.2=177, $p < .05$). Non-white male workers had significant excess proportional mortality from all circulatory diseases (30/20.9 = 143).

The excess cancer mortality in whites was mainly a consequence of significant excesses of deaths from cancer of the lung (28/18.9=148) and lymphopoietic cancers (9/4.6=198). Leukemia mortality (5/1.8=284) was the major component of the excess lymphopoietic cancers.

For whites the excess mortality from nonmalignant respiratory disease was accounted for by increases in emphysema deaths (10/3.5=285; $p < .05$) and pneumonia deaths (8/4.4=183; $p > .05$).

These findings were analyzed in more detail by age at death, duration of service, exposure classification, prior work history, and smoking history (Tables 10 - 17).

Lung Cancer

White male workers dying at age 60 or older experienced a significant doubling of proportional mortality from lung cancer (24/11.9 = 202). A deficit was found in the decedents aged less than 60 (4/6.83 = .58). Lung cancer proportional mortality was elevated for white males in each strata of service duration but was statistically significant only for those with less than 20 years (15/9.1 = 166). White males in Finishing experienced a significantly increased number of deaths due to lung cancer cancer (11/6.1 = 179). Nonsignificant excesses also occurred in white males in Foundry (6/4 = 151) and Mixed (6/3.8 = 158). Among white males with no prior employment in coal mining or zinc foundries, the SPMR for lung cancer was 146 (19/12.9; $p > .05$). Using the updated U.S. veteran smokers as the standard population (see Appendix 2), white male smokers aged 35 - 84 at death experienced a 57% excess (p=.13) in lung cancer proportional mortality (Table 14). This excess was greatest (12/5.3 = 227, p = .08) among those smokers 65 - 74 years old at death.

Nonmalignant Respiratory Disease

Statistically significant excesses were found among white males in the following subgroups:

- Less than 20 years service (18/8.0 = 225)
- Age 60 or more at death (22/10.6 = 208)
- Finishing (15/5.1 = 297)
- Core Room (5/1.6 = 321)
- Nonsmokers (7/3.4 = 209)

Greater than expected numbers were also found for white males with no prior employment in coal mines or zinc foundries (11/8.9 = 123).

Lymphopoietic Cancer

Excesses in proportional mortality were present in nearly every subgroup examined. Two fold significant elevations were observed for the following groups of white males:

- Less than 20 years service (5/2.4 = 212)
- Age 60 or more at death (7/2.7 = 255)
- __Mixed__ (3/0.9 = 329)
- No prior mining or zinc foundry work (7/3.1 = 221)
- Nonsmokers (3/1.01 = 297)

Although small in numbers, lymphopoietic cancer deaths among non-whites were elevated (2/.65 = 307; $p > .05$).

Circulatory Disease

Non-white males experienced a significant excess in proportional mortality for all circulatory disease (30/20.9 = 143). This significant excess was also found in several subgroups of non-white males:

- Age 60 or more at death (16/10.49 = 154)
- 20 or more years service (19/9.6 = 197)
- __Foundry__ classification (20/14.5 = 138)
- No prior employment in zinc foundries (24/17.7 = 136).

Case-Control Findings

Nonmalignant Respiratory Disease

Table 18 gives demographic and occupational characteristics of cases and controls for the analyses of nonmalignant respiratory disease among white males. Compared to controls, nonmalignant respiratory disease cases were, on the average, 6 years older at death, 7 years older at hire, served 3 fewer years, and were formerly employed for 2 more years in other foundries. The percentage of ever-smokers was greater among controls (75%) than cases (67%). In the 60 or older strata, only the differences in former employment in foundries and smoking persisted.

Crude odds ratios for associations between nonmalignant respiratory disease among white males and exposure classification are given in Table 19. A strong positive association (OR=3.7, p=.004) was found for the __Finishing__ classification and a weaker one (OR=2.0, p=.17) for __Core Room.__ Nonmalignant respiratory disease was negatively associated with the 3 other exposure classifications.

Stratification was used to control for prior occupation (Table 20), smoking (Table 21), and smoking and prior occupation (Table 22) after restriction of the analysis to the 60 or older age group. In the subgroup of non-coal miners, there was a significant association (OR=3.8) between nonmalignant respiratory disease and Finishing. Further, in the non-coal subgroup with no prior work in zinc or other foundries, Finishing was still associated with nonmalignant respiratory disease (OR=2.5; p = .20). A possible interaction was indicated by an even greater odds ratio (OR=10.5, p=.08) for Finishing and nonmalignant respiratory disease for the subgroup of non-coal miners with prior foundry experience.

The numbers for the analysis of smoking effects were small and limit the statistical reliability of the observed associations. The association between nonmalignant respiratory disease and Finishing was greater among nonsmokers (OR=5.5) than smokers (OR=1.9). This association persisted among the nonsmokers who never had prior coal mine or foundry experience (OR=4.3). Among white male smokers with no prior coal or foundry occupations, there was a slight negative association between nonmalignant respiratory disease and Finishing.

The results for the multiple logistic regression of nonmalignant respiratory disease and duration in Finishing are shown in Table 23 for the white male non-coal miner subgroup. After simultaneously adjusting for age at death, years formerly employed in foundries, and smoking, there was a significant independent association between years in Finishing and nonmalignant respiratory disease. There was also a significant positive interaction between years in Finishing and prior occupation in foundries. For a 10 year and 20 year duration in Finishing, the model predicts odds ratios of 1.9 and 3.7, respectively.

Lung Cancer

Average demographic and occupational characteristics of lung cancer cases and controls (Table 24) were similar. The percentage of ever-smokers was greater among cases (82%) than controls (75%).

Table 25 gives crude odds ratios for the association between lung cancer and exposure classification in white males. Only Finishing was positively associated with lung cancer. None of the crude associations was statistically significant.

Stratified analyses controlling for age, and age and prior foundry occupations are shown in Table 26. A large and significant association (OR=10.1) between Finishing and lung cancer was found in the less than 60 year age at death strata but this finding was based on a small number of cases. No significant positive associations between Finishing and lung cancer were observed in the 60+ subgroup after further stratifying on prior foundry occupation and smoking habit (Table 27 - 28).

The results for the multiple logistic regression of lung cancer and duration in Finishing are shown in Table 29. After adjusting for age at death, years formerly employed in foundries, and smoking, there was a nonsignificant positive association for years in Finishing. For a 10 and 20 year duration in Finishing, the model predicts odds ratios of 1.45 and 2.1, respectively.

Circulatory Disease

Table 30 presents demographic and occupational characteristics of black male circulatory disease cases and controls. Compared to controls, cases were on average 6 years older at death, 4 years older at hire, and were moderately overrepresented as smokers. There was a higher proportion of smokers among those who died at less than 60 years old, and within this stratum proportionately more cases than controls smoked.

Table 31 gives the odds ratio for the association between Foundry classification and circulatory disease stratifying on age and prior occupation in foundries. An association (OR = 11.0, p=.06) was found in the 60 or older age stratum. Elevated odds ratio were also found for those aged 60 or more at death without prior foundry work (p=.13).

Table 32 gives the odds ratio for the association between Foundry and circulatory disease stratifying on age and smoking status. A large association (p=.055) was found among nonsmokers aged 60 or more at death.

DISCUSSION

Findings

The central findings of this investigation are that white male workers experienced significant excess proportional mortality from nonmalignant and malignant disease of the lung and lymphopoietic cancer, and that non-white workers experienced significant excess proportional mortality from circulatory diseases. Further, some of these causes of death are associated with specific work areas within the plant.

Among white males, there was a significant positive association between nonmalignant respiratory disease and work in Finishing departments. This association was strong, stable and apparent in nearly all analyses. It persisted after taking into account smoking, age, and prior occupation. A positive association between nonmalignant respiratory disease among white males and work in Core Room departments was also suggested in the proportional mortality and case control analyses but these findings did not have strong statistical reliability.

Among white males, there was a significant excess of proportional lung cancer mortality among those in Finishing departments. This association was supported in the case control analyses, particularly among those who died at less than 60 years old, but these findings relied upon small numbers and were neither statistically stable nor consistent among various strata.

Among non-white men, there was a positive association between circulatory disease mortality and Foundry department exposures. Although the proportional mortality excess in this subgroup was statistically significant, the case-control associations, while large (OR's from 1.8 to 16.0), were not statistically stable.

The overall excess in proportional mortality from lymphopoietic cancer among white males remained apparent when calculations were restricted to non-smokers and those without prior mining or foundry experience. However, there were no clear in-plant exposure associations identified.

Methodologic Issues

There were several potential limitations to this investigation which might have affected the validity and precision of the findings and conclusions.

Ascertainment of Deaths

Incomplete ascertainment of deaths meeting the study definition might have affected risk estimates if the missing information was systematically associated with specific causes of death or specific exposures for cases and/or controls. Our judgment, however, is that the nature of the records as well as the benefits system which generated them provide a credible basis for a complete and unbiased ascertainment of deaths.

First, the jointly administered employer-union pension plan is independently monitored by the local union benefits representative and employer, and all hourly workers upon completing 10 years of credited service become eligible. Spouses of deceased pensioners have strong economic incentives for reporting deaths so that benefits can be claimed. Second, the employer-union negotiated health and life insurance plan covered active employees, and beneficiaries are moved by strong economic motives to report deaths to the employer and the union. Third, the local union death benefits program, covering active and retired members, was supplemental to and administered independently of other death benefit programs. Finally, for the small group of terminated workers whose pensions were deferred until retirement age, Social Security Administration records were searched for a report of death.

Thus, the records used to find deaths in this study targeted overlapping, but exhaustive categories of workers with 10 or more years of service. Moreover, other researchers(2) have also demonstrated the utility of similar records in mortality investigations.

Misclassification

Misclassification probably occured in this study in the assignment of both exposures and causes of deaths.

Exposures: Decedents shared physical and chemical exposures from different work areas among the 5 exposure classifications. First, the lack of physical barriers between major departments probably permitted widespread cross contamination by airborne pollutants. This is supported by industrial hygiene data (Appendix 1). Second, the rotation of jobs within the plant meant that workers could spend substantial time in more than one exposure classification. For example, about 30% of decedents with 5 or more years in the **Foundry** classification spent 5 or more years in at least one other exposure category (Figure 7). Thirdly, while the classification scheme grouped together operations with common exposures, these exposures were not necessarily unique to each category. For example, free crystalline silica dust was present in **Finishing**, **Core Room** and **Foundry** classifications.

In general the impact of this overlap among exposure classifications would be to reduce risk estimates. In addition the specific design of the case-control analyses in this study probably exaggerated this effect. For example, nonmalignant respiratory disease was associated with both **Finishing** and **Core Room** assignments (Tables 12, 19). This plausibly could be related to common exposures, such as free crystalline silica, in these departments. If decedents with **Core Room** exposure classification were excluded from the analysis of **Finishing** and nonmalignant respiratory disease (Table

19) the odds ratio would increase to 6.9 ($p < .001$). Likewise, excluding decedents with **Finishing** exposure classification from the analysis of **Core Room** and nonmalignant respiratory disease increases the odds ratio to 6.3 ($p=.014$).

Causes of Death: For assigning certain underlying causes of death, death certificates are prone to inaccuracies. To the degree that classification errors are similar for both study and control populations, observed differences in risk will be valid. However, risk differences might not be discovered at all for causes of death which are substantially under-reported on death certificates for both study and comparison populations. Such an effect may have limited the ability of this investigation to determine the full extent and nature of the observed excess in nonmalignant respiratory disease. The absence of recorded deaths from silicosis or pneumoconiosis is particularly suspect in a group with definite silica exposure and substantial respiratory disease.

In an effort to explain this, chest x-rays for 19 workers whose cause of death was nonmalignant respiratory disease were sent to 4 trained B readers for review. The films were of insufficient quality to allow for consistent or reliable interpretations which would have been necessary to resolve this issue.

Confounding by Covariates

This study used several techniques, including standardization, restriction, stratification and multivariate analysis to control for the effects of the factors believed most likely to confound the relationships between disease outcome and work exposures. Age at death, race, smoking history and prior occupational history were judged to be likely confounders based on *a priori* assumptions about their relationships with certain disease outcomes (e.g. cigarette smoking and lung cancer) and on their distribution in the study data (e.g. a relationship between coal mining and subsequent exposure classification, seen in Figure 11).

Our basic conclusion is that none of these factors adequately explains the major study findings described above. However, in some cases they may have played a contributory role. For example, among those white males with no coal mining background and no prior foundry work there was an association between nonmalignant respiratory disease and **Finishing** (OR = 2.5, p = .20, Table 20). The risk was considerably higher (OR = 10.5, p = .08), however, among the non-miners who did have prior foundry experience. This is of particular interest because Blot *et al*[3] reported an interaction between zinc smelter employment and steel industry exposures in a study of lung cancer. Several other possible interactions are suggested by the data, but caution in interpretation is warranted because small numbers seriously limit statistical reliability.

The association between nonmalignant respiratory disease and Finishing is stronger among nonsmokers (OR = 5.5) than smokers (OR = 1.9) (Table 21). While this may be a chance occurrance, another plausible explanation is that among nonsmokers, with a low background rate of nonmalignant respiratory disease, the effect of finishing room exposures is greater relative to the non-exposed than the exposure effects among smokers whose lungs are already impaired. Stated quantitatively, the crude attributable risk percent for the association between **Finishing** and nonmalignant respiratory disease is 82% and 47% for nonsmokers and ever-smokers, respectively. Another possibility is that smokers systematically transferred out of **Finishing** jobs at a greater rate than nonsmokers. This is consistent with the observation that smokers are under-represented in the Finishing classification (Figure 10).

A careful assessment of smoking behavior was desirable because of the well documented[41,42], strong relationships with the diseases of most interest in this study. Although individual smoking histories were obtained and used during analysis, two additional steps were taken to avoid underestimation of possible smoking effects. First, since U.S. population mortality rates include a contribution from nonsmokers, the expected numbers of lung cancers and other respiratory diseases derived from this population might be inappropriately low for comparison with a study group with a considerable proportion of smokers. Therefore an additional comparison was made, using data extrapolated from the experience of smokers in the U.S. Veterans study (see Appendix 2). In this comparison, restricted to smokers, the study group still experienced a proportional excess of lung cancer deaths (Table 14), most apparent among those aged 65 - 74 (PMR = 227, p = .08).

Second, retrospective determination of smoking behavior may not be reliable and it was not possible to assess the magnitude or direction of possible recall bias. Therefore the conservative assumption can be made that all white males in the study had been smokers. Even with this assumption. there was an 80% proportional lung cancer mortality excess (p = .14) in the 65 - 74 year age groups using the extrapolated veteran smokers rates for comparison (Table 33).

Statistical Power

Although a number of positive associations emerged from this study, the small size of the study group limited the likelihood of detecting these, and possibly, others. This may be responsible for our inability to validate some finding of other foundry investigations, e.g. Koskela's finding of lung cancer risks among molders and casters[23,40]. In case-control studies, the statistical power was 13% for detecting a 50% elevation in the odds ratio for the association between **Foundry** and lung cancer (Table 34).

Limitations of Study Design

The proportional mortality method has limitations[2,28,36,44]. PMRs do not directly measure the force of mortality, although in many circumstances, SPMRs have yielded reasonable approximations of Standardized Mortality Ratios (SMRs) obtained from the same population of workers[2,36]. We estimated the all-causes SMR to be 0.98 for a sample of 971 male pensioners from the study plant, alive on January 1, 1970 and followed up through December 31, 1981*. This SMR provides evidence that the SPMRs in this study do not misrepresent the mortality experience of workers at this plant.

As with other methodologies, PMRs are susceptible to biases and distortions based on the choice of the referent population. For example, cancer SPMRs could be elevated among groups with expected cancer death rates, if healthy worker selection operated on cardiovascular disease or other chronic disease mortality. The apparent excess of cancer deaths would be distributed uniformly among cancer sites. However, in this study cancer excesses were confined to the lung and the lymphopoietic system. Further, Standardized Proportional Cancer Mortality Ratios (the ratio of deaths from one type to all cancers) were generally higher for lung and lymphopoietic cancers than other sites, although not significantly so (Table 35).

The choice of U.S. white males as the referent population rather than Illinois white males introduced little error due to geographic variations in proportional mortality from causes of death of concern in this study (Appendix 4). In fact, PMRs for respiratory cancer would have been slightly higher if Illinois white males had been used as the referent population.

Latency

Latency must be considered in the analysis of chronic disease mortality. A commonly held definition of latency period in occupational mortality studies is the time period between hire and death[39]. Using this definition, 11 to 37 years was the range of latency periods for white males in this study. (By definition, the study group included those with at least 10 years of employment from their hire date). Thus the observation window, 1970-1981, was sufficiently wide to observe mortality from diseases with 15 to 36 year latency periods based on the range of hire dates, 1945-1955, when most of the decedents were hired (Figure 6). Additional analyses of mortality by latency were not done to examine specific hypotheses, although latency-exposure interactions would be of interest for further study.

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* This estimate is based on the same pension records used to ascertain deaths for the SPMR study. Pensioners as of January 1, 1970 at the study plant substantially meet the eligibility criteria for members of an at-risk cohort with 10 or more years service.

Significance

Previous Findings

There have been several epidemiologic reports of lung cancer among iron[8,10,14,23,40] and steel[3,15] foundry workers. Egan-Baum[10] reported lung cancer excess of 44% and 77% among white and black workers in an SPMR analysis of 3,000 members of the International Molders Union. Decoufle and Wood[8] found a 2 fold increase in respiratory cancer in the subgroup of male gray iron foundry workers with 5 or more years employment prior to 1938. In a standardized mortality investigation, Koskela[23] found 1.5 to 2.7-fold excesses in lung cancer mortality in a cohort of Finnish iron workers. A nested case-control study further attributed the excess to molders and casters. Recently in a cohort study of English foundrymen, Fletcher[14] found significant excess mortality of 42% and 73% for workers in the foundry work area and fettling shop (finishing) respectively.

Mortality patterns in steel foundries were investigated by Gibson[15] and Blot[3]. Gibson found that crane operators, followed by finishers and core makers, were at greatest risk from lung cancer. Blot reported an excess of lung cancer in decedents with steel foundry occupations, after controlling for age, race, smoking and prior employment in zinc smelting.

Nonmalignant respiratory disease among foundry workers has been previously reported in epidemiologic investigations[10,22,34], vital statistics reports[24] and other studies[26,41]. Silicosis, chronic bronchitis and loss of lung function have all been reported. These studies have provided little information concerning specific associations of illness with particular jobs, exposures or employment patterns.

Greater than expected number of leukemia deaths were observed by Decoufle and Wood[8]; but the numbers were too small to provide strong evidence. To our knowledge excess mortality from cardiovascular disease has not been previously reported in foundry workers.

Causal Role of Occupation

Temporal relationships, dose-response, and biologic plausibility were considered in addition to the statistical associations and consistency with other studies which have already been discussed.

First, the appearance of cancer and pneumoconiosis related to chemical exposure typically follows a lengthy latent period after initial contact. Latency was not examined in detail, but it is noted that the average time between hire and death was 26.3 years for white males and 24.9 years for black males. This would allow adequate time for the appearance of diseases known to have long latency such as lung cancer, although in some situations the full extent of risk might not be apparent until an average of 30-40 years since initial exposure. On the other hand the risk of diseases which may have shorter latent periods, such as leukemia[20], may have been underestimated if some of these deaths occurred prior to the period of observation.

Second, diseases of occupational cause typically increase in frequency with increases in intensity of exposure, determined by dose level and/or duration of exposure. The data available did not permit reliable assignments of exposure levels to individual workers. Nonetheless, logistic regression demonstrated a significant relationship between nonmalignant respiratory disease and years in <u>**Finishing**</u> departments. The proportional excess in nonmalignant respiratory disease, however, was greatest among white males with less than 20 years service. This apparent inconsistency may be explained by a moderate concentration of workers with the longest cumulative years in <u>**Finishing**</u> among those with less than 20 overall years of plant service (Table 36). Logistic regression also demonstrated a relationship between lung cancer and years in <u>**Finishing**</u>, although this was not statistically significant. Among non-white males there was a clear association of circulatory disease proportional mortality with longer length of service. One isolated finding of interest was a 3-fold proportional excess (PMR=280) of large intestine cancer among white males with 20 or more years of service but not present among those with less service.

Third, it is important that these associations between disease and occupation have biologic plausibility:

<u>Lung cancer</u>

Toxicologic studies of foundry exposures implicate polyaromatic hydrocarbons and silica in mutagenesis and carcinogenesis. Gibson[16] demonstrated a correlation between foundry departments with elevated lung cancer SMR's and mutagenic activity in air samples in the Ames bioassay.

Several investigators have proposed that silica in the foundry environment acts as a co-carcinogenic particulate in the foundry. It has been noted, for example, that particulate type affects co-carcinogenicity[11]. Niemeier <u>et.al.</u>[31] have reported respiratory tumors in hamsters exposed to several particulates, including ferric oxide, in combination with benz(a)pyrene. In each case the tumor rate was higher than that found with exposure to benz(a)pyrene alone. Palmer and Scott reported that various polycyclic aromatic hydrocarbons are emitted as pyrolysis products of organic materials in mold binders and additives and are found in high concentrations widely distributed in pouring, shakeout and finishing areas of foundries[33].

Silica has generally not been considered carcinogenic, although Goldsmith[17] has argued that there is considerable evidence supporting a relationship between silica exposure and lung cancer. Recent findings have not been consistent. Davis et al. found no excess lung cancer among a group of Vermont granite workers with documented silica exposures and substantial mortality from silicosis[7]. Finkelstein, however, found excess lung cancer mortality among Ontario miners previously receiving workers' compensation for non-fatal silicosis[11].

Decedents in **Foundry** classifications were the most likely to have been exposed to particulate-PAH combinations, although decedents in **Finishing** may have been exposed to particulate-PAH combinations to a lesser degree. Particulates in **Finishing** may have contained a higher percentage of respirable crystalline silica. However, neither the work history nor industrial hygiene data were detailed enough to characterize the precise nature of these combined exposures in various work areas. The lung cancer findings are consistent with a carcinogenic role for silica, other foundry particulates, and polycyclic aromatic hydrocarbons either alone or, more likely, in combination. This study could not shed new light on the exact nature of such effects and interactions.

Other carcinogens have been found in varying amounts in foundry environments, but cannot readily be associated with epidemiologic findings. These include nitrosamines, aromatic amines, chromium and nickel salts[33]. Formaldehyde, a known animal carcinogen[38] is emitted from hot box core room processes in biologically significant amounts, but probably was not used widely in this foundry until the mid-1960's.

Nonmalignant Respiratory Disease

Nonmalignant respiratory disease among white males was clearly associated with **Finishing** department exposures in this study group. It may also have been associated with core room work. Silica exposures have been widespread in the U.S. foundry industry[27,32] and at this location, and NIOSH has recently identified a series of silicosis cases among active **Foundry** workers.[5] The respiratory toxicity of silica has been well established. However, two features of the data make it at least questionable whether silica exposure alone explains the mortality findings.

First, no death certificate mentioned silicosis or other pneumonoconiosis as an underlying or contributing cause of death. This does not entirely rule out the possibility of silicosis in this population, since death certificates may not accurately identify this illness. A review of x-rays taken prior to death was made in an effort to provide additional information. Unfortunately the quality of these x-rays was poor. Although the four B readers who reviewed the x-rays reported opacities consistent with silicosis on some of the films, their readings were not consistent or reliable enough to reach conclusions about pneumoconiosis in this population.

Second, the industrial hygiene data suggest that silica exposure was widespread throughout this plant and not limited to just the **Finishing** and **Core** areas. The complete characterization of foundry dust should include, in addition to the proportion of crystalline silica, information about particle size, ferric oxide particulate and adsorbed organic chemicals. This study could not determine departmental dust differences which could convincingly explain department differences in nonmalignant respiratory disease. Thus, the absence of nonmalignant respiratory disease excess among **Foundry** classifications is not explained. One hypothesis for further investigation is that silica exposure at levels insufficient to cause fibrosis nonetheless is a substantial contributer to chronic lung disease in combination with other pulmonary toxins in the foundry environment. In the presence of widespread silica exposures, the distribution of illness would reflect the distribution of these other contaminants.

Cardiovascular Disease

The finding of cardiovascular disease mortality among non-white **Foundry** workers is consistent with the fact that workers in these areas were the most likely to sustain substantial exposures to heat and carbon monoxide. In a morbidity study of cardiovascular risk factors among foundry workers, Hernberg et.al.[19] reported increasing prevalence of angina pectoris symptoms with increasing level of carbon monoxide. Elevated systolic blood pressure was also found for the CO-exposed group compared with the non-exposed.

CONCLUSIONS AND RECOMMENDATIONS

The findings of malignant and nonmalignant lung disease are consistent with occupational causation and cannot be explained by age, smoking behavior or prior employment in coal mining or other foundries. Moreover, the pattern of mortality generally conforms to that reported in the scientific literature.

This investigation supports the observation that foundries have been extremely hazardous working environments since World War II. Although the findings reflect historic conditions which may have changed, there is ample recent evidence to suggest that current foundry conditions throughout the country have not changed appreciably enough in the past 25 years to warrant assurance to workers that the period of high risk has ended. The findings suggest that a foundry dust exposure limit of 10 mppcf was inadequate to protect against mortality from respiratory cancer and nonmalignant respiratory disease.

The following activities are proposed:

1. Increased emphasis should be given to the accurate diagnosis of pulmonary disease among active foundry workers, including a comprehensive industry-wide evaluation of the prevalence and incidence of pneumoconiosis and other chronic respiratory disease. Surveillance should include chest x-rays, spirometry and medical history questionnaires using standardized procedures. X-rays should be evaluated by certified "B readers"[30] who have demonstrated ability to recognize pneumoconiosis accurately.

2. A thorough program of toxicologic investigations is necessary to answer questions raised by this study and others concerning the complex chemical environment of the modern foundry. Specific attention should be directed to the presence of PAH's in finishing operations and to possible synergistic relations among respirable silica, iron oxide particulate and polycyclic aromatic hydrocarbons. Additional emphasis should be given to chemical resin systems used in core making along with their pyrolytic degradation products.

3. It has been demonstrated that technologic means are, in general, available and feasible to reduce foundry dust exposures below existing federal OSHA permissible levels[35]. A nationwide effort is necessary to bring this industry in compliance with legal standards. Evidence such as that presented in this study make such a control effort a public health imperative.

4. The finding of increased cardiovascular mortality among non-white males on Foundry jobs has not been previously reported and requires validation.

5. Several specific activities in the study plant are needed:

   a. Prospective surveillance for nonmalignant respiratory disease among all employees, including chest x-rays, pulmonary function testing, and medical history questionnaire using standardized methods.

   b. A thorough industrial hygiene survey, including determination of silica, polycyclic aromatic hydrocarbons, formaldehyde and related core room chemical exposures.

   c. A thorough review of existing ventilation systems and their maintenance schedules.

   d. A prospective record keeping system designed to facilitate ongoing surveillance of mortality and respiratory disease morbidity.

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TABLES

Table 1

Ascertainment of Deaths by Source, 1970-1981

SOURCE	N	%
All Sources	288	100
Union Sources	283	98
Local Union Death Benefit Fund (DBF)	218	76
Local Union Benefits Representative Deceased Member File (BRD)	155	54
International Union Pension Records (IPR)	230	80
Company Sources, Primarily Insurance Records at Plant (CIF)	279	97
Social Security Administration Search of Deferred Vested Pensioners	4	1

Concordance Between Sources of Death Ascertainment, 1970-1981

SOURCES	N	%
DBF x BRD x IPR x CIF	118	41
DBF x IPR x CIF	45	16
DBF x CIF	42	15
IPR x CIF	37	13
BRD x IPR x CIF	23	8
DBF x BRD x CIF	10	3
CIF only	3	1
SSA only	2	.5
All Other Combinations	8	2.5
Total	288	100

Table 2

Exposure Classification, 1970 - 1981

	Exposure Classification	Department (Dept. #)
1.	Finishing	Finishing (16) Annealing (15) Pan Conveyor (14)
2.	Foundry	Foundry (12) (includes shakeout) Melting (11)
3.	Core Room	Core Room (10) Shell Core (17)
4.	Mixed	Maintenance (34) Third Shift Clean-up (35) Inspection (37) Production Accounting (31) Plant Protection (26)
5.	Other	Yard (33) Stock Room (73) Shipping (39) Pattern Shop (20) Power House (38) Cafeteria (23) Management Trainee (40)

Table 3

Demographic Characteristics of Male Study Group By Race, 1970 - 1981

1. All Males*	N	MIN	MAX	MEAN	STD DEV
Age at Death	278	32	88	61.8	10.2
Age at Hire	274	17	55	35.6	9.5
Year of Death	278	70	81	76.0	3.4
Year of Hire	274	44	68	50.0	4.5
Total Years Served	274	10	34	19.7	5.9

2. White Males	N	MIN	MAX	MEAN	STD DEV
Age at Death	221	32	88	62.7	10.2
Age at Hire	217	17	55	36.1	9.3
Year of Death	221	70	81	76.2	3.3
Year of Hire	217	44	68	49.9	4.5
Total Years Served	217	10	33	19.6	5.9

3. Black Males	N	MIN	MAX	MEAN	STD DEV
Age at Death	56	35	79	58.0	9.1
Age at Hire	56	17	54	33.3	9.4
Year of Death	56	70	81	75.5	3.6
Year of Hire	56	43	65	50.6	4.2
Total Years Served	56	10	34	20.0	5.5

*Includes 1 Asian Male

Table 4

Age at Death of Males By Race 1970-1981

Age Category	All Males+ N	All Males+ %	White Males N	White Males %	Black Males N	Black Males %
30-	5	2	4	2	1	2
40-	21	8	14	6	7	13
50-	86	31	60	27	26	46
60-	96	34	82	37	14	25
70-	61	22	52	24	8	14
80+	9	3	9	4	0	0
Total	278	100	221	100	56	100

+ Includes 1 Asian Male.

Table 5

Distribution of Ever-Smoking Tobacco by Race, Males 1970-1981

Smoking Category	All Males+ N	All Males+ %	White Males N	White Males %	Black Males N	Black Males %
Nonsmoker	75	27	50	23	24	43
Ever-Smoker	196	71	167	76	29	52
Unknown	7	2	4	1	3	5
Total	278	100	221	100	56	100

+ Includes 1 Asian Male.

Table 6

Number of Decedents and Mean Duration Ever Employed

in Coal Mining, Foundries, and Other Jobs Prior

to Hire, Males 1970-1981

	All Males+			White			Black		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Coal Mining	51	11.7	9.6	48	11.7	9.4	3	10.3	15.3
Zinc Foundry	35	7.1	6.3	26	8.6	6.5	9	2.8	2/8
All Foundries, Including Zinc	66	5.0	5.5	50	5.4	5.8	16	3.5	5.7
All Other Jobs	170	5.1	5.7	130	5.7	5.7	39	3.3	5.3

+ Includes 1 Asian Male.

Table 7

Number of Decedents and Mean Years Duration

in the Exposure Classification of Longest

Duration by Race, Males 1970-1981

	All Males+			White			Black		
Exposure Classification	N	Mean	SD	N	Mean	SD	N	Mean	SD
Finishing	89	13.7	5.3	75	14.1	5.2	14	11.4	4.9
Foundry	75	14.8	5.1	42	15.3	5.1	33	14.1	5.0
Core Room	29	13.7	6.4	25	13.7	6.6	3	13.8	6.2
Mixed	45	13.4	4.9	44	13.6	4.9	1	6.7	0.0
Other	23	16.8	5.3	23	16.8	5.3	0	0.0	0.0
Unknown	13	12.0	3.0	8	12.4	3.2	5	11.4	2.7

+ Includes 1 Asian Male.

Table 8

Distribution of Years Worked in Exposure

Classifications, Males 1970-1981

Duration in Years	Finish N	Finish %	Foundry N	Foundry %	Core N	Core %	Mixed N	Mixed %	Other N	Other %
None	105	38	117	43	171	62	177	65	221	81
0-	36	13	43	15	44	16	31	11	11	4
1-	34	12	24	9	26	10	15	6	10	4
5-	40	15	29	11	12	4	17	6	11	4
10-	15	6	24	9	8	3	18	6	3	1
15-	34	12	22	8	6	2	10	4	9	3
20+	10	4	15	5	7	3	6	2	8	3
Total	274	100	274	100	274	100	274	100	274	100
Mean	5.1		4.7		1.9		2.5		1.7	
SD	6.8		6.9		4.8		5.4		5.0	

Table 9

Standardized Proportional Mortality of Male

Workers by Race, 1970 - 1981

	Underlying Cause of Death 8th Revision ICD	WHITE MALES OBS.	EXP.	PMR	95% CI LL	UL	NON-WHITE MALES OBS.	EXP.	PMR	95% CI LL	UL
140-209	All Malignant Neoplasms	61	51.49	118	95	147	12	10.23	117	71	193
	Cancer of the Digestive Organs (150-159)	14	13.07	107	64	178	1	2.99	33	6	203
	Cancer of the Large Intestine (153)	6	4.66	129	58	283	1	.61	165	24	1130
	Cancer of the Pancreas (157)	3	2.79	108	35	331	0	.55	0	0	0
	Cancer of Respiratory System (160-163)	29	19.85	146*	104	206	4	3.77	106	42	271
	Cancer of Lung (162)	28	18.85	148*	104	210	3	3.54	85	29	251
	Cancer of Bladder (188)	3	1.43	210	70	631	0	.17	0	0	0
	Cancer of Kidney (189)	2	1.31	152	32	600	1	.16	634*	115	3484
	All Lymphopoietic Cancer (200-209)	9	4.55	198*	105	373	2	.65	307	83	1133
	Leukemia (204-207)	5	1.76	284*	123	655	0	.22	0	0	0
390-458	All Diseases of the Circulatory System	105	113.69	92	81	105	30	20.98	143**	110	186
	Arteriosclerotic Heart Disease (410-414)	81	84.76	96	81	113	17	12.76	133	89	199
	All Vascular Lesions of the CNS (430-438)	9	13.29	68	36	127	4	4.22	95	37	240
460-519	All Nonmalignant Respiratory Disease	25	14.15	177**	122	256	1	2.57	39	6	244
	Pneumonia (480-486)	8	4.36	183	93	360	1	1.37	73	11	501
	Emphysema (492)	10	3.51	285**	158	512	0	.36	0	0	0
520-577	All Diseases of the Digestive System	9	10.69	84	45	159	4	2.70	148	58	380
	Cirrhosis of Liver (571)	3	6.35	47	16	140	3	1.66	181	61	537
900-998	All External Causes	13	15.84	82	50	135	5	4.76	105	47	235
	All Accidents (800-949)	11	9.79	112	64	197	3	2.64	114	38	338
	All Other Causes	8	15.14	53	—	—	5	15.76	32	—	—
1-998	All Causes	221	221	100	—	—	57	57	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$

Table 10

Standardized Proportional Mortality of White Male

Workers by Age at Death, 1970 - 1981

		< 60 YEARS					≥ 60 YEARS				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	18	17.69	102	68	152	43	33.05	130*	100	169
	Cancer of the Digestive Organs (150-159)	9	4.14	300*	117	403	5	8.71	57	25	133
	Cancer of the Large Intestine (153)	3	1.38	217	73	648	3	3.20	94	31	287
	Cancer of Respiratory System (160-163)	4	7.20	56	22	139	25	12.43	201***	140	290
	Cancer of Lung (162)	4	6.87	58	23	146	24	11.87	202***	139	294
	All Lymphopoietic Cancer (200-207)	2	1.74	115	29	451	7	2.74	255**	126	518
	Leukemia (204-207)	1	.63	158	23	1092	4	1.09	366**	147	909
390-458	All Diseases of the Circulatory System	43	35.24	122	98	152	59	76.01	78**	65	92
	Arteriosclerotic Heart Disease (410-414)	33	27.62	119	91	157	47	55.49	85	68	106
	All Vascular Lesions of the CNS (430-438)	2	2.83	71	18	274	6	10.02	60	28	128
460-519	All Nonmalignant Respiratory Disease	2	3.22	62	16	238	22	10.59	208***	140	308
	Pneumonia (480-486)	2	1.16	172	44	670	5	3.06	163	69	385
	Emphysema (492)	0	.69	0	0	0	10	2.74	365	206	647
520-577	All Diseases of the Digestive System	2	5.38	37	10	134	7	5.20	135	65	277
800-998	All External Causes	10	10.64	94	54	162	3	5.10	59	20	176
	All Accidents (800-949)	9	6.34	142	78	260	2	3.37	59	15	229
	All Other Cause	3	5.83	51	—	—	5	9.05	55	—	—
1-998	All Causes	78	.78	100	—	—	139	139	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$
*** Significant at $p < .001$

Table 11

Standardized Proportional Mortality of White Male

Workers by Length of Service, 1970-1981

		10 - 20 YEARS					≥ 20 YEARS				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	28	25.95	108	78	149	33	24.79	133	99	179
	Cancer of the Digestive Organs (150-159)	5	6.73	74	32	173	7	6.12	147	78	276
	Cancer of the Large Intestine (153)	0	2.44	0	0	0	6	2.14	280**	131	598
	Cancer of the Pancreas (157)	3	1.41	213	71	638	0	1.34	0	0	0
	Cancer of Respiratory System (160-163)	15	9.50	158	98	255	14	10.13	138	84	226
	Cancer of Lung (162)	15	9.06	166*	103	267	13	9.68	134	80	225
	All Lymphopoietic Cancer (200-209)	5	2.36	212	91	494	4	2.12	188	73	489
	Leukemia (204-207)	3	.94	318*	110	728	2	.79	254	67	961
390-458	All Diseases of the Circulatory System	56	61.35	91	76	109	46	49.91	92	75	113
	Arteriosclerotic Heart Disease (410-414)	48	44.91	107	86	133	32	38.21	84	64	110
	All Vascular Lesions of the CNS (430-438)	3	8.01	37	13	106	5	4.84	103	44	242
460-519	All Nonmalignant Respiratory Disease	18	8.01	225***	146	346	6	5.80	103	48	224
	Pneumonia (480-486)	6	2.57	234*	109	503	1	1.66	60	9	413
	Emphysema (492)	7	2.02	347***	174	690	3	1.41	213	71	637
520-577	All Diseases of the Digestive System	4	5.19	77	30	199	5	5.39	93	40	217
800-998	All External Causes	7	8.49	82	43	159	6	7.25	83	39	176
	All Accidents (800-949)	5	5.31	94	41	214	6	4.40	136	63	295
	All Other Causes	4	8.01	50	—	—	4	6.86	58	—	—
1-998	All Causes	117	117	100	—	—	100	100	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$
*** Significant at $p < .001$

Table 12

Standardized Proportional Mortality of White Male Workers

by Exposure Classification of Longest Duration, 1970 - 1981

		FINISHING					FOUNDRY				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	21	17.11	123	84	178	11	10.28	107	64	179
	Cancer of the Digestive Organs (150-159)	4	4.40	91	35	235	3	2.57	117	39	349
	Cancer of the Pancreas (157)	2	.93	215	56	824	0	.56	0	0	0
	Cancer of Respiratory System (160-163)	11	6.44	171	98	298	6	4.15	144	68	307
	Cancer of Lung (162)	11	6.14	179*	103	312	6	3.96	151	71	322
	All Lymphopoietic Cancer (200-209)	3	1.53	196	65	589	1	.88	114	16	790
	Leukemia (204-207)	2	.60	333	91	1223	1	.33	305	48	1948
390-458	All Diseases of the Circulatory System	32	38.98	82	65	104	21	21.37	98	73	133
	Arteriosclerotic Heart Disease (410-414)	26	28.80	90	67	122	14	16.29	86	57	129
	All Vascular Lesions of the CNS (430-438)	4	4.84	83	32	212	3	2.17	138	46	412
460-519	All Nonmalignant Respiratory Disease	15	5.04	297***	187	473	2	2.52	79	21	302
	Pneumonia (480-486)	4	1.55	258*	102	656	0	.74	0	0	0
	Emphysema (492)	5	1.30	383**	171	858	1	.63	159	23	1088
520-577	All Diseases of the Digestive System	3	3.41	88	29	264	2	2.19	91	24	351
800-998	All External Causes	3	5.35	56	21	153	3	2.78	108	37	317
	All Accidents (800-949)	2	1.45	138	36	522	2	1.71	117	30	450
	All Other Causes	1	5.11	20	—	—	3	2.86	105	—	—
1-998	All Causes	75	75	100	—	—	42	42	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$
*** Significant at $p < .001$

Table 12 (Cont'd.)

Standardized Proportional Mortality of White Male Workers

by Exposure Classification of Longest Duration, 1970 - 1981

		CORE ROOM					MIXED				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	6	5.77	104	52	209	14	10.27	136	86	215
	Cancer of the Digestive Organs (150-159)	2	1.44	138	36	527	3	2.59	116	39	347
	Cancer of Respiratory System (160-163)	2	2.21	91	24	338	6	3.99	151	71	320
	Cancer of Lung (162)	2	2.11	95	25	355	6	3.81	158	74	336
	All Lymphopoietic Cancer (200-209)	0	.53	0	0	0	3	.91	329*	114	946
390-458	All Diseases of the Circulatory System	13	12.34	105	72	154	19	22.45	85	62	116
	Arteriosclerotic Heart Disease (410-414)	12	9.18	131	84	204	14	16.79	83	55	126
460-519	All Nonmalignant Respiratory Disease	5	1.56	321**	144	713	2	2.70	74	20	281
	Emphysema (492)	4	.36	1117***	517	2413	0	.65	0	0	0
520-577	All Diseases of the Digestive System	0	1.21	0	0	0	3	2.25	134	45	399
	Cirrhosis of Liver (571)	0	.73	0	0	0	2	1.37	146	38	561
800-998	All External Causes	1	2.37	42	8	210	4	3.29	121	49	302
	All Accidents (800-949)	1	1.45	69	12	410	3	2.02	149	50	438
	All Other Causes	0	1.75	0	—	—	2	3.04	66	—	—
1-998	All Causes	25	25	100	—	—	44	44	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$
*** Significant at $p < .001$

Table 12 (Cont'd.)

Standardized Proportional Mortality of White Male Workers by Exposure

Classification of Longest Duration, 1970 - 1981

	Underlying Cause of Death 8th Revision ICD	OTHER				
					95% CI	
		OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	8	5.56	144	79	262
	Cancer of the Digestive Organs (150-159)	2	1.39	144	38	549
	Cancer of Respiratory System (160-163)	3	2.23	134	46	392
	Cancer of Lung (162)	3	2.13	141	48	411
	All Lymphopoietic Cancer (200-209)	2	.48	417*	118	1417
	Leukemia (204-207)	1	.18	556	98	3141
390-458	All Diseases of the Circulatory System	11	11.65	94	62	143
	Arteriosclerotic Heart Disease (410-414)	11	8.86	124	78	197
460-519	All Nonmalignant Respiratory Disease	0	1.38	0	0	0
420-577	All Diseases of the Digestive System	1	1.22	82	12	546
800-998	All External Causes	2	1.60	125	34	466
	All Accidents (800-949)	2	.98	204	55	764
	All Other Causes	1	2.97	34	—	—
1-998	All Causes	23	23	100	—	—

* Significant at $p < .05$

Table 13

Standardized Proportional Mortality of White Male Workers

by Prior Work History and Smoking Status, 1970 - 1981

	Underlying Cause of Death 8th Revision ICD	NON COAL - NON ZINC					NON SMOKERS+				
					95% CI					95% CI	
		OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
149-209	All Malignant Neoplasms	42	35.02	120	92	156	8	11.50	70	38	127
	Cancer of the Digestive Organs (150-157)	11	8.75	126	72	223	1	2.95	34	6	208
	Cancer of the Large Intestines (152)	4	3.08	130	49	341	1	1.06	95	14	657
	Cancer of Respiratory System (160-163)	19	13.67	139	91	213	4	4.37	92	36	233
	Cancer of Lung (162)	19	13.04	146	95	223	4	4.17	96	38	245
	All Lymphopoietic Cancer (200-209)	7	3.16	221*	108	452	3	1.01	297*	102	863
	Leukemia (204-207)	4	1.21	332*	132	832	2	.39	511**	148	1764
390-458	All Diseases of the Circulatory System	75	75.62	99	85	116	29	26.16	111	86	142
	Arteriosclerotic Heart Disease (410-414)	60	56.91	105	86	129	23	19.39	119	86	163
	All Vascular Lesions of the CNS (430-438)	5	8.31	60	26	139	2	3.17	63	17	236
460-519	All Nonmalignant Respiratory Disease	11	8.94	123	70	218	7	3.35	209*	104	420
	Pneumonia (480-486)	5	2.83	176	75	415	2	3.07	186	716	
	Emphysema (492)	3	2.16	139	45	423	3	.79	378	133	1074
520-577	All Diseases of the Digestive System	4	7.94	50	20	128	2	2.29	87	23	336
800-998	All External Causes	13	12.94	100	62	164	4	3.29	121	50	295
	All Accidents (800-949)	11	7.90	139	80	242	4	2.07	193	78	480
	All Other Causes	6	10.54	57	—	—	0	3.41	0	—	—
1-998	All Causes	151	.51	100	—	—	50	50	100	—	—

* Significant at p < .05

** Significant at p < .01

\+ Comparison population U.S. White Males

Table 14

Standardized Proportional Mortality Due to Lung Cancer, Standardizing to US Veteran Smokers*

WM Smokers, 1970 - 1981, Ages 35 - 84

	1970-1974		1975-1981		Total		
Age	O	E	O	E	O	E	PMR
35-	0	.0333	0	.2672	0	.3005	—
45-	1	.7137	2	2.0812	3	2.7949	107
55-	2	1.5865	5	3.8883	7	5.4748	128
65-	2	1.4875	10	3.8147	12	5.2761	227
75-84	1	0.3372	0	0.4711	1	0.8083	124
Total	6	4.1582	17	10.5225	23	14.6807	157

95% CI (87, 282)

X^2 (M-H) = 2.279
p = .13

*See Appendix 3 for details of standardization methods.

Table 15

Standardized Proportional Mortality of Non-White

Male Workers by Age at Death, 1970 - 1981

		< 60 YEARS					≥ 60 YEARS				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	10	5.57	180*	105	309	2	4.66	43	13	139
	Cancer of the Digestive Organs (150-159)	1	1.58	63	10	415	0	1.41	0	0	0
	Cancer of the Large Intestine (153)	1	.27	366	59	2257	0	.33	0	0	0
	Cancer of Respiratory System (160-163)	4	2.28	175	70	442	0	1.49	0	0	0
	Cancer of Lung (162)	3	2.13	141	48	414	0	1.41	0	0	0
	All Lymphopoietic Cancer (200-209)	2	.36	549**	162	1866	0	.29	0	0	0
	Leukemia (204-207)	1	.05	1889	467	7645	0	.10	0	0	0
390-458	All Diseases of the Circulatory System	14	10.59	132	88	198	16	10.39	154*	110	215
	Arteriosclerotic Heart Disease (410-414)	7	6.49	108	57	205	10	6.27	159	96	265
	All Vascular Lesions of the CNS (430-438)	2	1.91	105	28	398	2	2.31	86	24	317
460-519	All Nonmalignant Respiratory Disease	0	1.42	0	0	0	1	1.15	87	13	583
520-577	All Diseases of the Digestive System	4	2.02	198	79	497	0	.67	0	0	0
	Cirrhosis of Liver (571)	3	1.37	219	75	639	0	.28	0	0	0
800-998	All External Causes	3	3.89	77	28	215	2	.88	228	61	850
	All Accidents	2	2.02	99	26	372	1	.62	163	24	1097
	All Other Causes	3	10.51	29	—	—	2	5.25	38	—	—
1-998	All Causes	34	34	100	—	—	23	23	100	—	—

* Significant at $p < .05$

** Significant at $p < .01$

Table 16

Standardized Proportional Mortality of Non-White

Male Workers by Length of Service, 1970 - 1981

		10 - 20 YEARS					≥ 20 YEARS				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	6	5.28	114	56	231	6	4.95	121	60	244
	Cancer of the Respiratory System (160-163)	3	1.87	160	55	470	1	1.90	53	8	331
	Cancer of Lung (162)	2	1.75	114	30	432	1	1.78	56	9	357
	All Lymphopoietic Cancer (200-209)	0	.34	0	0	0	2	.31	647**	196	2137
390-458	All Diseases of the Circulatory System	11	11.36	97	63	149	19	9.63	197***	142	274
	Arteriosclerotic Heart Disease (410-414)	8	6.85	117	65	210	9	5.91	152	88	265
	All Vascular Lesions of the CNS (430-438)	1	2.34	43	7	259	3	1.88	160	55	465
460-519	All Nonmalignant Respiratory Disease	1	1.38	72	11	483	0	1.19	0	0	0
520-577	All Diseases of the Digestive System	3	1.39	216	74	628	1	1.31	76	12	504
800-998	All External Causes	4	2.54	157	65	382	1	2.22	45	8	216
	All Accidents (800-949)	2	1.40	143	38	539	1	1.24	80	12	532
	All Other Causes	3	6.05	50	—	—	2	8.89	23	—	—
1-998	All Causes	28	28	100	—	—	29	29	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$
*** Significant at $p < .001$

Table 17

Standardized Proportional Mortality of Non-White Male Workers with the Longest Duration in Foundry Exposure Classification and with no Prior Employment in a Zinc Foundry, 1970 - 1981

		FOUNDRY					NON ZINC				
					95% CI					95% CI	
	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	LL	UL	OBS.	EXP.	PMR	LL	UL
140-209	All Malignant Neoplasms	7	7.35	95	50	182	11	8.63	127	76	214
	Cancer of Respiratory System (160-163)	3	2.81	107	36	315	3	3.20	94	32	277
	Cancer of Lung (162)	2	2.63	76	20	285	2	3.00	67	18	250
	All Lymphopoietic Cancer (200-209)	2	.46	432*	122	1523	2	.55	361	100	1306
390-458	All Diseases of the Circulatory System	20	14.45	138*	100	191	24	17.70	136*	101	182
	Arteriosclerotic Heart Disease (410-414)	11	8.85	124	75	206	12	10.76	112	69	180
	All Vascular Lesions of the CNS (430-438)	1	2.83	35	6	211	4	3.54	113	45	287
460-519	All Nonmalignant Respiratory Disease	0	1.80	0	0	0	1	2.19	46	7	292
520-577	All Diseases of the Digestive System	2	1.97	101	27	386	3	2.34	128	43	381
800-998	All External Causes	1	3.36	30	5	166	5	4.21	119	53	266
	All Accidents (800-949)	0	.72	0	0	0	3	2.32	129	44	383
	All Other Causes	3	4.07	74	—	—	4	12.93	31	—	—
1-998	All Causes	33	33	100	—	—	48	48	100	—	—

* Significant at $p < .05$
** Significant at $p < .01$

Table 18

Demographic and Occupational Characteristics of Nonmalignant Respiratory Disease Cases and Controls, White Males 1970-1981+

	All Ages		60 or older at Death		Less than 60 at Death	
	Case (N=24)	Control (N=165)	Case (N=22)	Control (N=93)	Case (N=2)	Control (N=72)
Age at Death ($\bar{x} \pm$ SD)	67±9	61±10	69±7	69±7	47±16	52±6
Age at Hire ($\bar{x} \pm$ SD)	42±7	35±9	43±6	41±7	30±9	27±6
Year of Hire ($\bar{x} \pm$ SD)	1951±4	1950±5	1950±3	1949±3	1960±11	1951±6
Years of Service ($\bar{x} \pm$ SD)	17±5	20±6	17±5	19±6	14±3	21±6
Years Former Coal ($\bar{x} \pm$ SD)	4±6	3±7	4±7	5±9	0±0	.3±2
Years Former Foundry ($\bar{x} \pm$ SD)	3±6	1±3	3±6	1±4	0±0	.6±2
Number (%) Ever-Smoked	16 (67)	124 (75)	4 (64)	69 (74)	2 (100)	5 (76)

Age Distribution of Nonmalignant Respiratory Disease Cases and Controls, White Males 1970 - 1981+

	Cases		Controls	
Age at Death	N	%	N	%
30-	1	4	3	2
40-	0	0	14	9
50-	1	4	55	33
60-	11	46	54	33
70-	10	42	32	19
80+	1	4	7	4
Total	24	100	165	100

±Excludes 4 decedents with missing work records.

Table 19

Crude Association Between Exposure Classifications of Longest Duration

and Nonmalignant Respiratory Disease, White Males 1970-1981*

	Case	Control	OR	95% CI	p
Finishing	15	49	3.7	(1.5,9.0)	.004
Non-Finishing	9	108			
Foundry	2	34	0.3	(.1,1.5)	.10
Non-Foundry	22	123			
Core	5	18	2.0	(.7,6.1)	.17
Non-Core	19	139			
Mixed	2	36	0.3	(.1,1.4)	.08
Non-Mixed	22	121			
Other	0	20	—		.05
Non-Other	24	137			

*See Appendix 4 for exclusions.

Table 20

Association Between Nonmalignant Respiratory Disease and Finishing Exposure Classification by Prior Occupation, White Males 60 or Older at Death, 1970-1981*

	Never Coal Miner					Ever Coal Miner				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Finish	8	1	3.8	(1.02,14.1)	.04	6	13	1.4	(.3,6.1)	.48
Non-Finish	4	40				4	12			

	Never Coal Miner									
	No Prior Foundry Work					Prior Foundry Work				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Finish	5	17	2.5	(.5,12.1)	.20	3	4	10.5	(.8,130.7)	.08
Non-Finish	3	26				1	14			

*See Appendix 4 for exclusions.

Table 21

Association between Nonmalignant Respiratory Disease and Finishing Exposure Classification by Smoking Status, White Males 60 or more years at death, 1970 - 1981+

	Nonsmoker					Ever- Smoker				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Finishing	6	11	5.5	.6,53.5	.13	7	22	1.9	.6,6.0	.23
Non-Finishing	1	10				7	41			

+See Appendix 4 for exclusions.

Table 22

Association Between Nonmalignant Respiratory Disease and Finishing Exposure Classification by Prior Employment and Smoking Status. White Males 60+ Years Old at Death, 1970-1981+

	Non Smoker								Ever Smoker							
	Never Coal Never Zinc Never Other Foundry				Ever Coal Or Ever Zinc Or Ever Other Foundry				Never Coal Never Zinc Never Other Foundry				Ever Coal or Ever Zinc or Ever Other Foundry			
	Case	Cont.	OR	p	Case	Cont.	OR	p	Case	Cont.	OR	p	Case	Cont.	OR	p
Finishing	3	7	4.3	.26	3	4	3.8	.34	1	10	.7	.61	6	2	2.6	.16
Non-Finishing	0	5			1	5			3	20			4	21		

+See Appendix 4 for exclusions.

Table 23

Logistic Regression of Nonmalignant Respiratory Disease vs Age at death in Years, Smoking Status (ever, never), Years in Prior Foundry Jobs, and Years of Finishing, White Male Non-Coal Miners, 1970-1981 +

Variable	Coefficient, b	STD ERR	e^b	X^2(1 df)
Intercept	5.0746	2.6194	—	
Age-Yrs	.04093	.032020	1.04	
Prior Foundry (Yrs.)	-.77530	.94250	.46	
Smoker (No-Yes)	-.15838	.70365	.85	
Finishing (Yrs.)	.037733	.047276	1.04	5.52
Finishing x Prior Foundry (years x years)	.075993	.066283	1.07	7.62

Fraction explained = .78

+ Final model: $\text{Logit}(p|\bar{X}) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_2X_4$

where X_1 = age,
X_2 = prior foundry employment,
X_3 = smoking status, and
X_4 = years in Finishing.

Table 24

Demographic and Occupational Characteristics of Lung Cancer Cases and Controls, White Males 1970-1981+

	All Ages		60 or Older at Death		Less Than 60 at Death	
	Case (N=28)	Control (N=132)	Case (N=24)	Control (N=74)	Case (N=4)	Control (N=58)
Age at Death ($\bar{x} \pm$ SD)	65±6	61±11	67±5	69±7	52±1	51±6
Age at Hire ($\bar{x} \pm$ SD)	39±7	35±10	40±6	42±7	31±8	27±6
Year of Hire ($\bar{x} \pm$ SD)	1950±3	1950±5	1950±2	1948±3	1952±8	1952±6
Years of Service ($\bar{x} \pm$ SD)	20±6	20±6	20±6	19±5	20±7	21±6
Years Former Coal ($\bar{x} \pm$ SD)	2±5	3±7	2±6	5±9	0±0	.3±2
Years Former Foundry ($\bar{x} \pm$ SD)	2±4	1±3	2±4	1±4	0±0	.5±1
Number (%) Ever- Smokers	23 (82)	96 (73)	20 (83)	55 (74)	3 (75)	41 (71)

Age Distribution of Lung Cancer Cases and Controls

White Males, 1970 - 1981

	Cases		Controls	
Age at Death	n	%	n	%
30-	0	0	3	2
40-	0	0	10	8
50-	4	14	45	34
60-	17	61	39	30
70-	7	25	28	21
80+	0	0	7	5
Total	28	100	132	100

+Excludes 4 decedents with missing work records.

Table 25

Crude Association between Lung Cancer

and Exposure Classification of Longest

Duration, White Males 1970-1981*

	Case	Control	OR	95% CI	p
Finish	11	39	1.4	(.6,3.3)	.27
Non-Finishing	17	86			
Foundry	6	29	.9	(.3,2.4)	.53
Non-Foundry	22	96			
Core	2	14	.6	(.1,2.9)	.40
Non-Core	26	111			
Mixed	6	28	.9	(.3,2.6)	.56
Non-Mixed	22	97			
Other	3	15	.9	(.2,3.3)	.57
Non-Other	25	110			

*See Appendix 4 for exclusions.

Table 26

Association Between Lung Cancer and Finishing

Exposure Classification of Longest Duration by

Age and Prior Work History in Foundries.

White Males 1970-1981*

	$<$ 60 Years at Death					$\geq$ 60 at death				
	Case	Cont.	OR	p	95% CI	Case	Cont.	OR	p	95% CI
Finish	3	13	10.1	.05	1.0,105.5	8	26	.8	.43	.3,2.2
Non-Finish	1	44				16	42			
	Never Prior Foundry									
	$<$ 60 at Death					$\geq$ 60 at Death				
	Case	Cont.	OR	p	95% CI	Case	Cont.	OR	p	95% CI
Finish	3	10	21.0	.02	—	7	22	.8	.49	.3,2.5
Non-Finish	0	35				11	29			
	Ever Any Prior Foundry									
	$<$ 60 at Death					$\geq$ 60 at Death				
	Case	Cont.	OR	p	95% CI	Case	Cont.	OR	p	95% CI
Finish	0	3	1.5	.77	—	1	4	.7	.61	.1,7.3
Non-Finish	1	9				5	13			

*See Appendix 4 for exclusions.

Table 27

Association Between Lung Cancer and Finishing Exposure
Classification of Longest Duration by Smoking Status,
White Males, 60 or older at Death, 1970 - 1981*

	Nonsmoker					Ever-Smoker				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Finishing	1	8	.6	(.1,7.4)	.58	6	17	.8	(.3,2.6)	.49
Non-Finishing	2	9				14	33			

*See Appendix 4 for exclusions.

Table 28

Association Between Lung Cancer and Finishing Exposure Classification of Longest Duration By Prior Employment and Smoking Status, White Males 60 Years or Older at Death, 1970-1981*

	Nonsmoker								Ever-Smoker							
	Never Zinc and Never Other Foundry				Ever Zinc Or Ever Other Foundry				Never Zinc and Never Other Foundry				Ever Zinc Or Ever Other Foundry			
	Case	Cont.	OR	p	Case	Cont.	OR	p	Case	Cont.	OR	p	Case	Cont.	OR	p
Finishing	1	6	1.1	.73	0	2	2.0	.60	5	15	.7	.43	1	2	1.4	.65
Non-Finishing	1	7			1	2			10	22			4	11		

*See Appendix 4 for exclusions.

Table 29

Logistic Regression of Lung Cancer
vs Age in Years, Smoking Status
(ever, never), Years in Prior
Foundry Jobs, and Years of
Finishing, White Males
1970-1980.+

Variable	Coefficient, b	STD ERR	e^b	X^2(1df)
Intercept	5.0354	1.8609	—	
Age-Yrs.	.029401	.022214	1.03	
Prior Foundry, Yrs.	.045938	.057151	1.05	
Smoker (No-Yes)	.76819	.58422	2.1	
Finishing (Yrs.)	.030471	.031062	1.03	.94

Fraction explained = .64

+ Final Model: Logit $(P \mid \overline{X}) = b_o + b_1X_1 + b_2X_2 = b_3X_3 + b_4X_4$

where X_1 = age,
X_2 = prior foundry employment,
X_3 = smoking status, and
X_4 = years in Finishing.

Table 30

Demographic and Occupational Characteristics of Circulatory Disease Cases and Controls, Black Males 1970 - 1981

	All Ages		Less than 60 at Death		60 or older at at Death	
	Case	Control	Case	Control	Case	Control
	N=30	N=26	N=14	N=20	N=16	N=6
Age at Death ($\bar{x}$ ± SD)	61±8	55±9	54±6	51±5	67±5	68±4
Age at Hire ($\bar{x}$ ± SD)	35±9	31±10	28±7	27±6	41±7	46±6
Year of Hire ($\bar{x}$ ± SD)	1950±3	1951±5	1950±3	1952±6	1949±3	1951±2
Years Served ($\bar{x}$ ± SD	21±6	20±5	22±7	20±6	20±5	17±3
Years Coal ($\bar{x}$ ± SD)	1±5	.1±.6	0±0	.2±.7	2±7	0±0
Years Prior Foundry ($\bar{x}$ ± SD)	1±3	2±4	0±0	2±3	2±4	3±7
Number (%) Ever Smoked	17 (57)	12 (46)	12 (86)	10 (50)	5 (31)	2 (33)

Age Distribution of Circulatory Disease Cases and Controls, Black Males 1970 - 1981

	Cases		Controls	
Age at Death	N	%	N	%
40-	3	10	5	19
50-	11	37	15	58
60-	12	40	2	8
70+	4	13	4	15
Total	30	100	26	100

Table 31

Association Between Circulatory Disease and Foundry Exposure Classification of Longest Duration by Age and Prior Work History in Foundries. Black Males 1970-1981*

	< 60 at Death					≥ 60 at Death				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Foundry	9	12	1.8	(.4,8.7)	.38	11	1	11.0	(.9,130)	.06
Non-Foundry	3	7				4	4			
Never Any Prior Foundry										
	< 60 at Death					≥ 60 at Death				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Foundry	9	6	3.0	(.5,16.9)	.20	8	1	16.0	(.7,383)	.13
Non-Foundry	3	6				1	2			
Ever Any Prior Foundry										
	< 60 at Death					≥ 60 at Death				
	Case	Cont.	OR	95% CI	p	Case	Cont.	OR	95% CI	p
Foundry	0	6	—	—	—	3	0	4.0	—	.36
Non-Foundry	0	1				3	2			

* See Appendix 4 for exclusions.

Table 32

Association Between Circulatory Disease and Foundry Exposure Classification of Longest Duration by Age and Smoking Status Black Males, 1970-1981*

	< 60 at Death					≥ 60 at Death				
Nonsmokers	Case	Control	OR	95% CI	p	Case	Control	OR	95% CI	p
Foundry	0	6	-	-	-	8	0	36.0	-	.055
Non-Foundry	0	3				3	4			
Ever-Smokers	Case	Control	OR	95% CI	p	Case	Control	OR	95% CI	p
Foundry	7	6	1.2	(.2,8.1)	.63	3	1	3.0	-	.60
Non-Foundry	3	3				1	1			

* See Appendix 4 for exclusions due to missing work history.

2 cases and 1 control with unknown smoking status excluded.

Table 33

Standardized Proportional Mortality due to Lung Cancer, Standardizing to U.S. Veteran Smokers. All White Males, 1970 - 1981, Ages 35 - 84*

	1970 - 1974		1975 - 1981		Total		
Age at Death	O	E	O	E	O	E	PMR
35-	0	.0333	0	.2672	0	.0667	—
45-	1	1.1102	2	2.5542	3	3.6644	82
55-	2	2.1762	5	4.8853	7	7.0615	99
65-	2	1.9250	10	4.7426	12	6.6676	180
75-84	1	0.3934	0	1.1407	1	1.5341	65
Total	6	5.6381	17	13.5900	23	19.2281	120

95% CI (86, 246)

$X^2(M\text{-}H) = 1.90$

$p > .05$

* See Appendix 3

Table 34

Power Calculations for Detecting a 1.5-Fold

Increase in Risk Measure at α = .05,

One-Sided Test. White Males 1970 - 1981

1. Case Control*

Case	Exposure Classification of Longest Duration	Exposure Rate in Controls	Power (%)
Nonmalignant Respiratory Disease	Finishing	.312 (49/157)	14
Nonmalignant Respiratory Disease	Foundry	.217 (34/157)	10
Nonmalignant Respiratory Disease	Core Room	.115 (18/157)	3
Lung Cancer	Finishing	.312 (39/125)	15
Lung Cancer	Foundry	.232 (29/125)	13

2. Standardized Proportional Mortality Due to Lung Cancer (Normal Approximation to Poisson)

Study Group	Population	Expected	Power (%)
WM Smokers Ages 35-84	U.S. Veteran Smokers	14.68	59

*Method of Fleiss (9, pp. 44-46)

Table 35

Standardized Proportional Cancer Mortality,

White Males 1970 - 1981

	Underlying Cause of Death 8th Revision ICD	OBS.	EXP.	PMR	95% CI LL	95% CI UL
140-209	All Malignant Neoplasms	61	61	100	100	100
	Cancer of the Digestive Organs (150-159)	14	15.43	91	58	143
	Cancer of the Large Intestine (153)	6	5.48	110	51	235
	Cancer of the Pancreas (157)	3	3.32	90	30	271
	Cancer of Respiratory System (160-163)	29	24.17	120	91	159
	Cancer of Lung (162)	28	23.89	121	91	162
	Cancer of Bladder (188)	3	1.64	183	61	548
	Cancer of Kidney (189)	2	1.58	127	32	496
	All Lymphopoietic Cancer (200-209)	9	5.21	173	93	320
	Leukemia (204-207)	5	1.98	252*	110	579

* Significant at $p < .05$

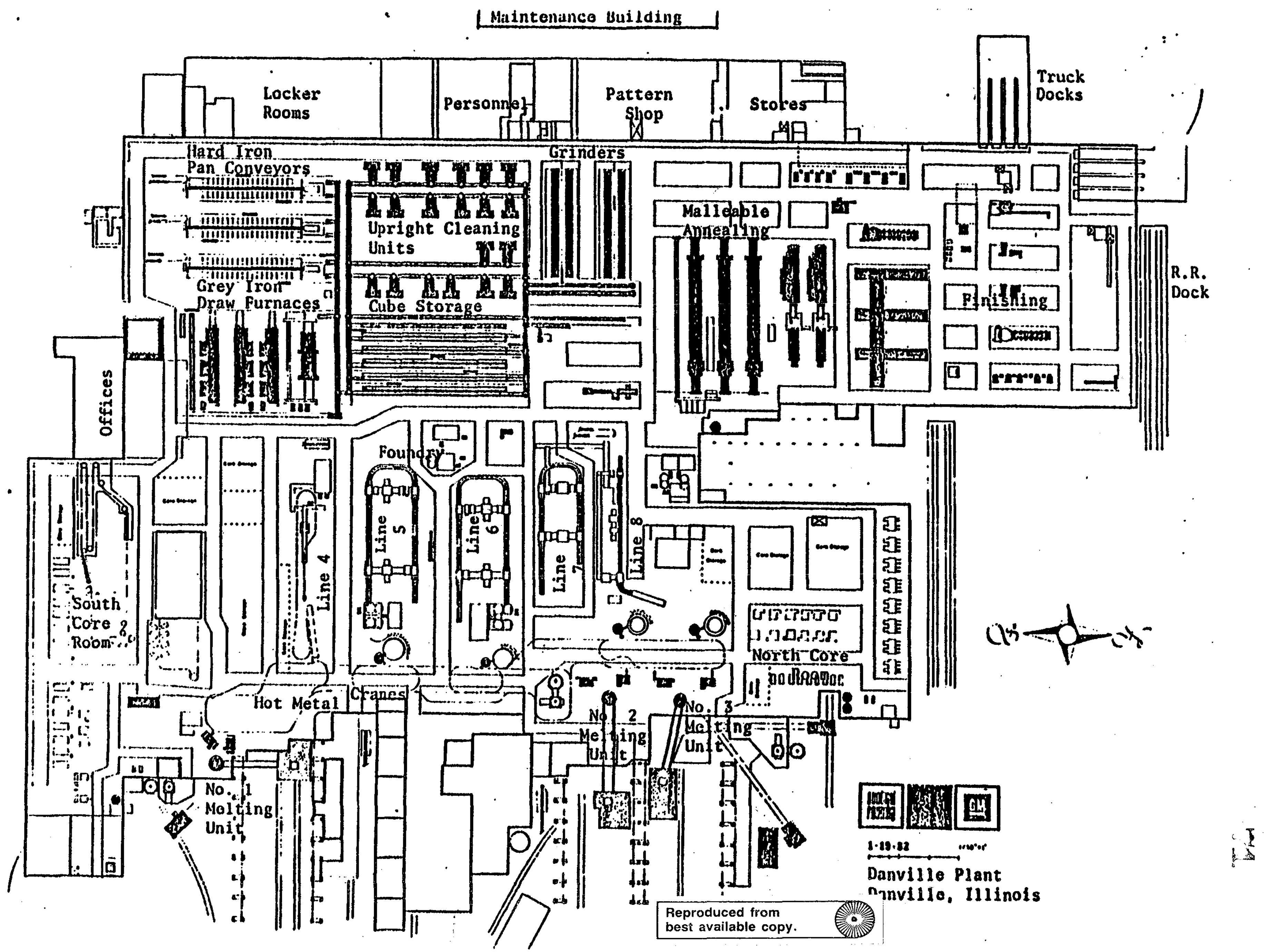
Table 36

Mean Years in Finishing Exposure Classification
by Total Years of Service and Age
at Hire, White Males 1970 - 1981

Age at Hire	10-		15-		20-		25+		Total	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
< 30	8	1.6	7	4.6	12	6.4	27	2.2	54	3.4
30-	15	4.8	16	6.5	33	8.0	20	3.1	84	6.0
40+	35	5.3	36	8.3	7	4.0	1	0.0	79	6.5
Total	58	4.7	59	7.4	52	7.1	48	2.6	217	5.5

(Columns 10- through Total are under the spanning heading YEARS OF SERVICE.)

FIGURES



Maintenance Building
Locker Rooms
Personnel
Pattern Shop
Stores
Truck Docks
R.R. Dock
Hard Iron Pan Conveyors
Grinders
Upright Cleaning Units
Cube Storage
Grey Iron Draw Furnaces
Malleable Annealing
Finishing
Offices
Foundry
Line 4
Line 5
Line 6
Line 7
Line 8
North Core Room
South Core Room
Hot Metal
Cranes
No. 1 Melting Unit
No. 2 Melting Unit
No. 3 Melting Unit
1-19-82
Danville Plant
Danville, Illinois

FIGURE 2

SCHEMATIC OF PHYSICAL PLANT CHANGES, 1943 - 1982

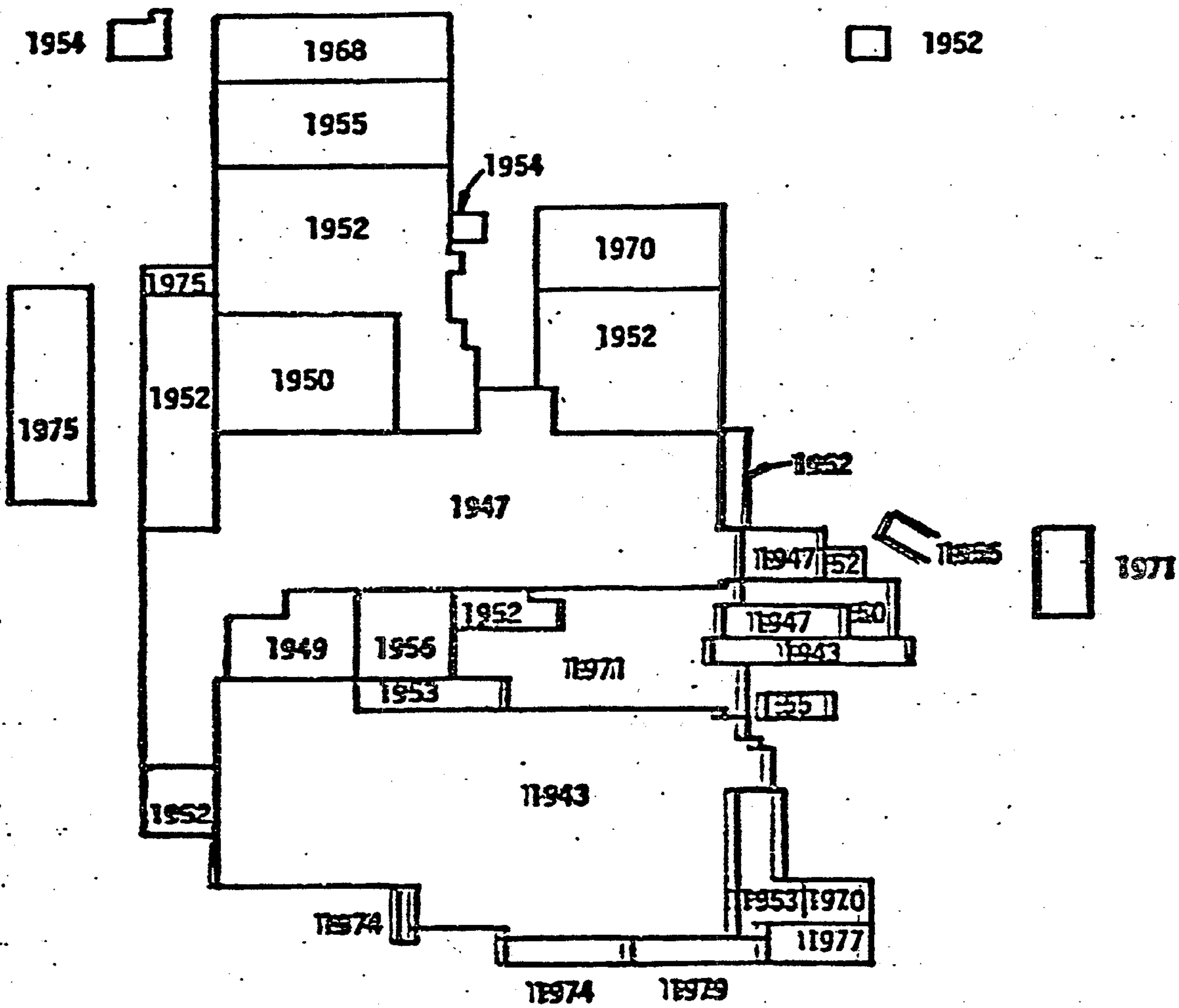


Figure 3

Flow Diagram of Deaths 1970-1981,

10 or more Years of Service

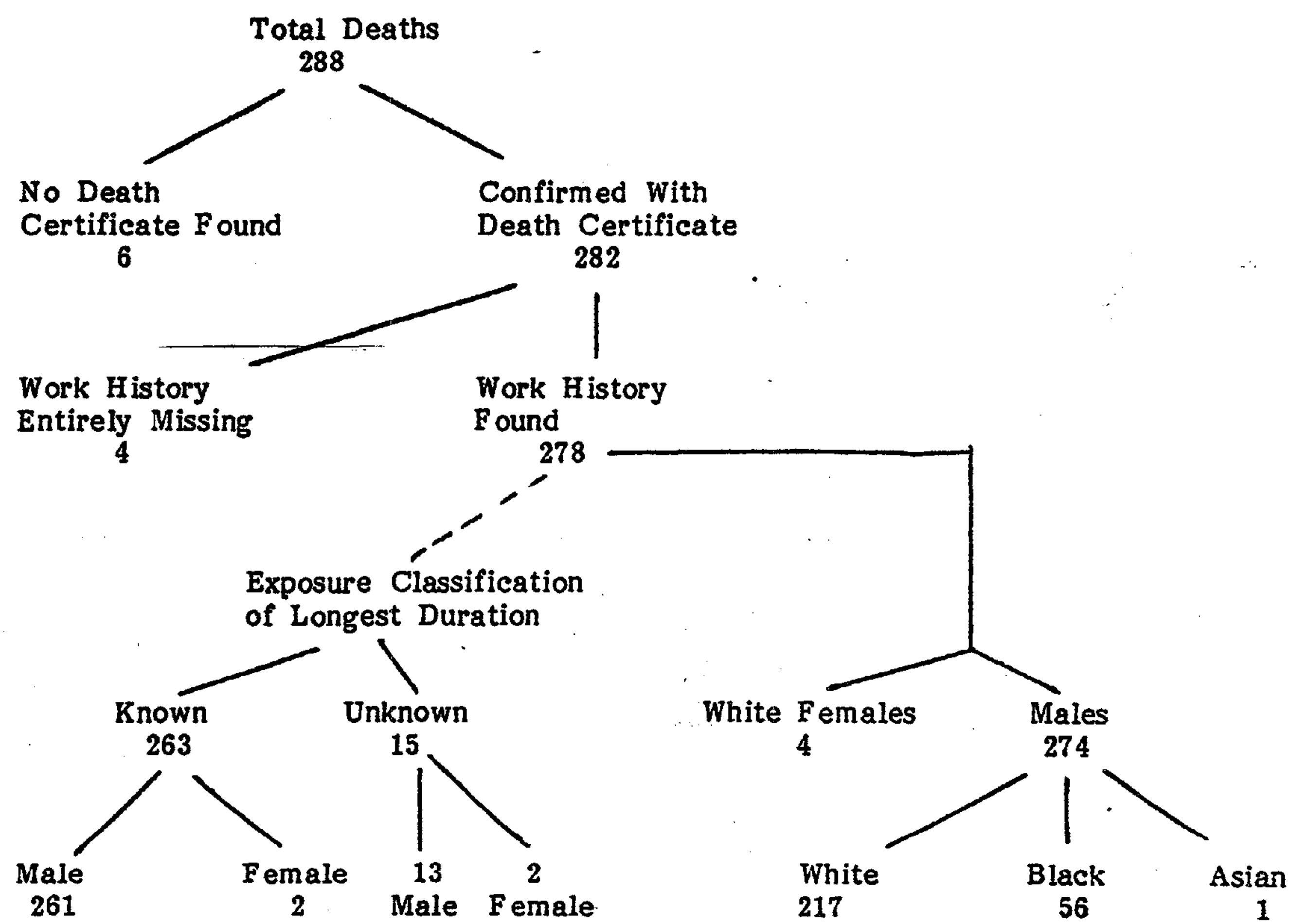


FIGURE 4

FREQUENCY DISTRIBUTION OF AGE AT DEATH

MALES 1970 - 1981

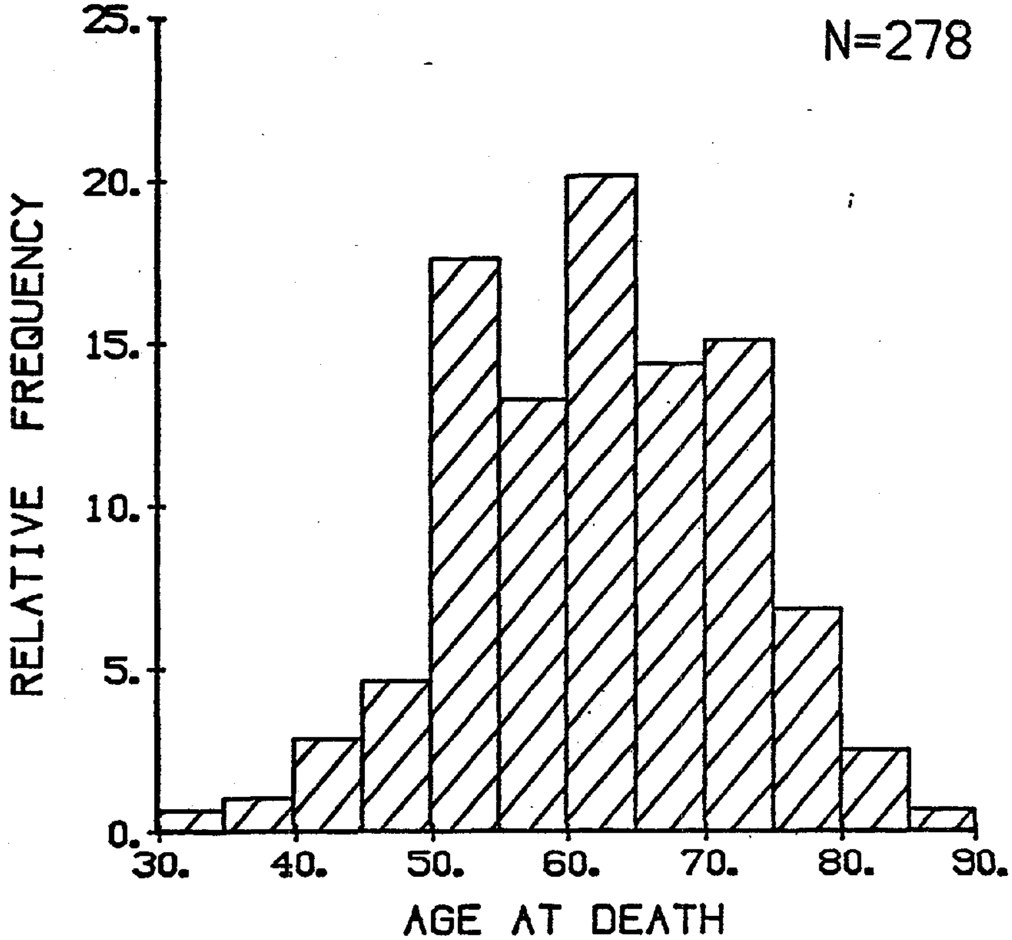


FIGURE 5

FREQUENCY DISTRIBUTION OF AGE AT HIRE

MALES 1970 - 1981

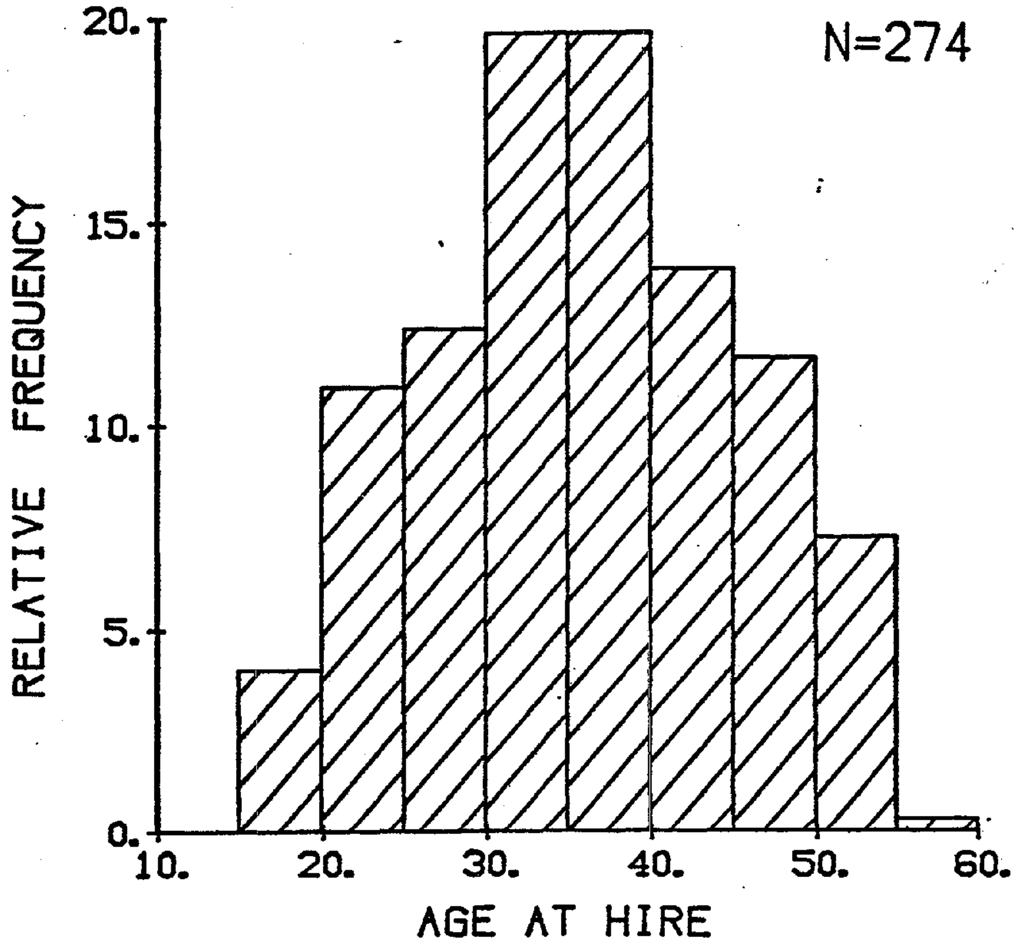


FIGURE 6

FREQUENCY DISTRIBUTION OF YEAR OF HIRE

MALES 1970 - 1981

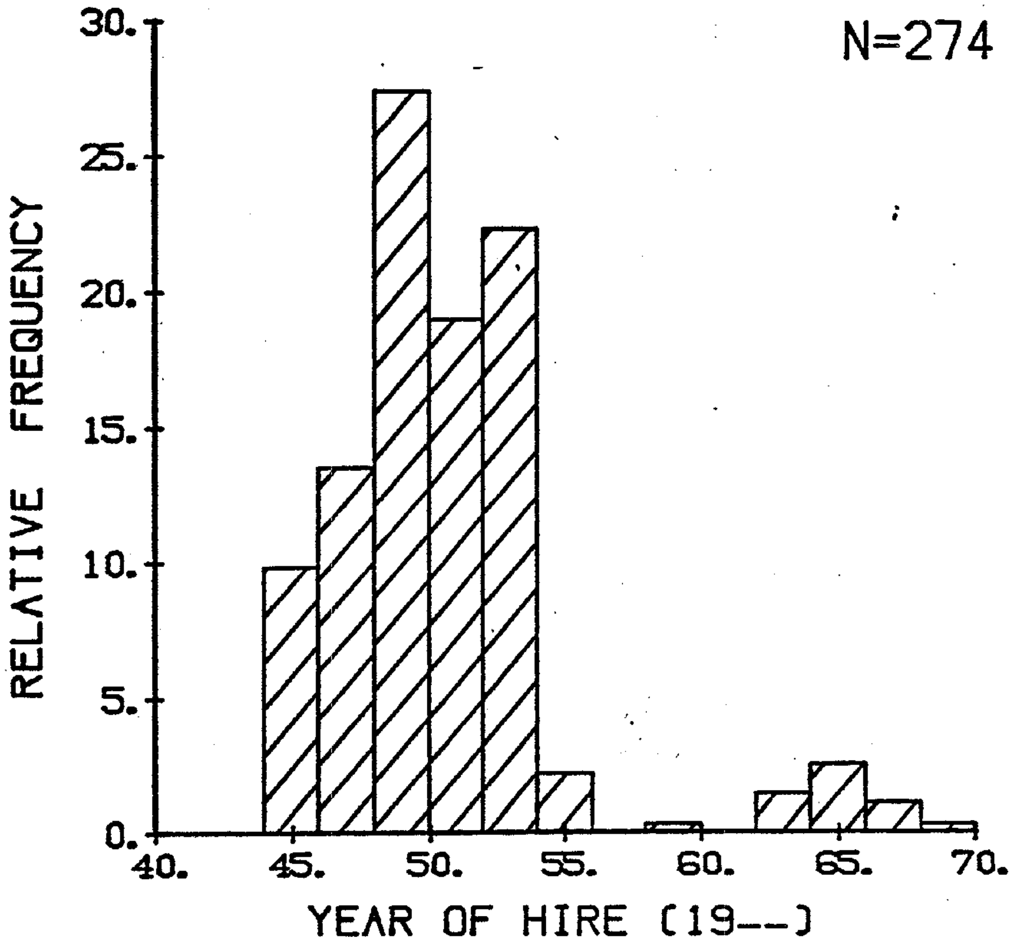


FIGURE 7

DISTRIBUTION OF COMBINATIONS OF EXPOSURE CLASSIFICATIONS

EACH CLASSIFICATION WORKED 5 OR MORE YEARS

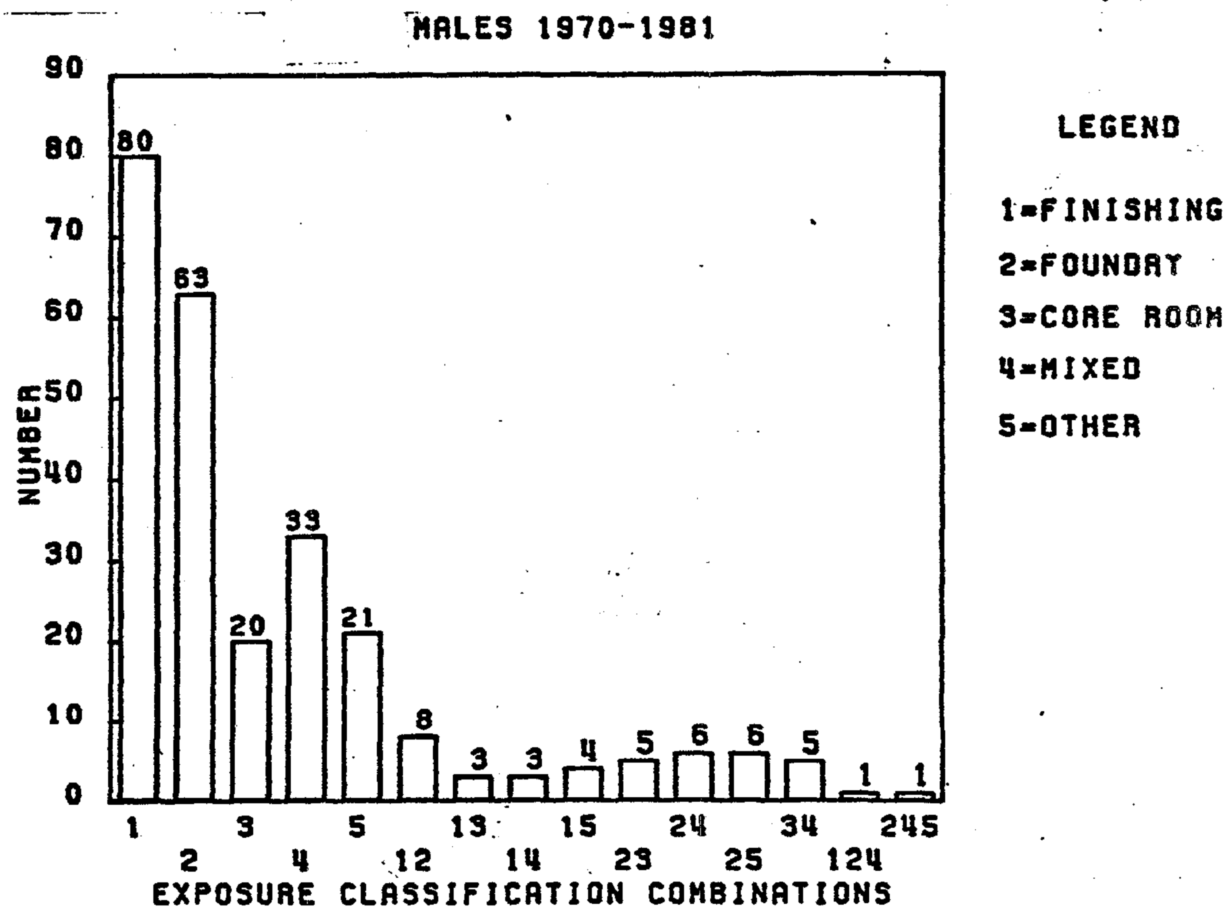


FIGURE 8

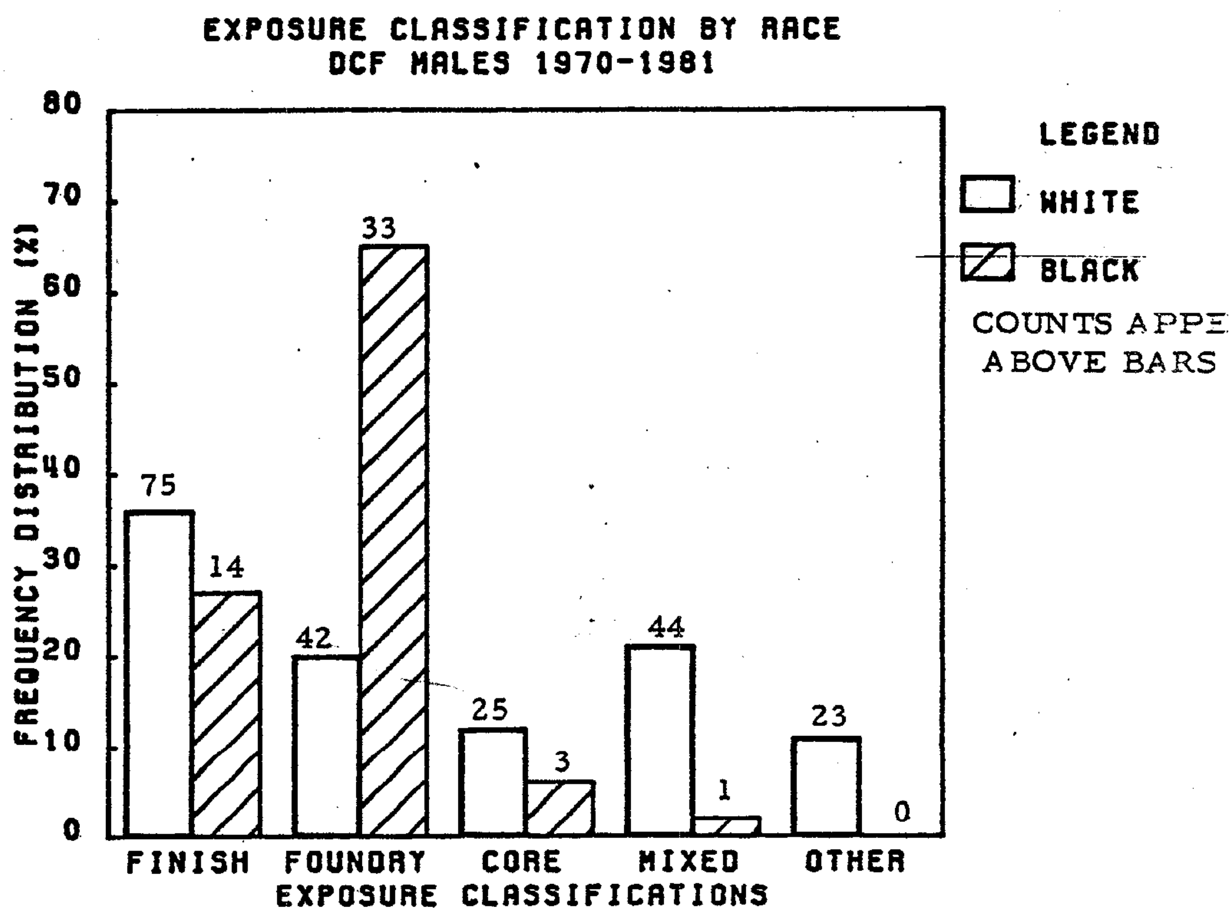

EXPOSURE CLASSIFICATION BY RACE
DCF MALES 1970-1981
FREQUENCY DISTRIBUTION (%)
0
10
20
30
40
50
60
70
80
75
14
42
33
25
3
44
1
23
0
FINISH
FOUNDRY
CORE
MIXED
OTHER
EXPOSURE CLASSIFICATIONS
LEGEND
WHITE
BLACK
COUNTS APPE
ABOVE BARS

FIGURE 9

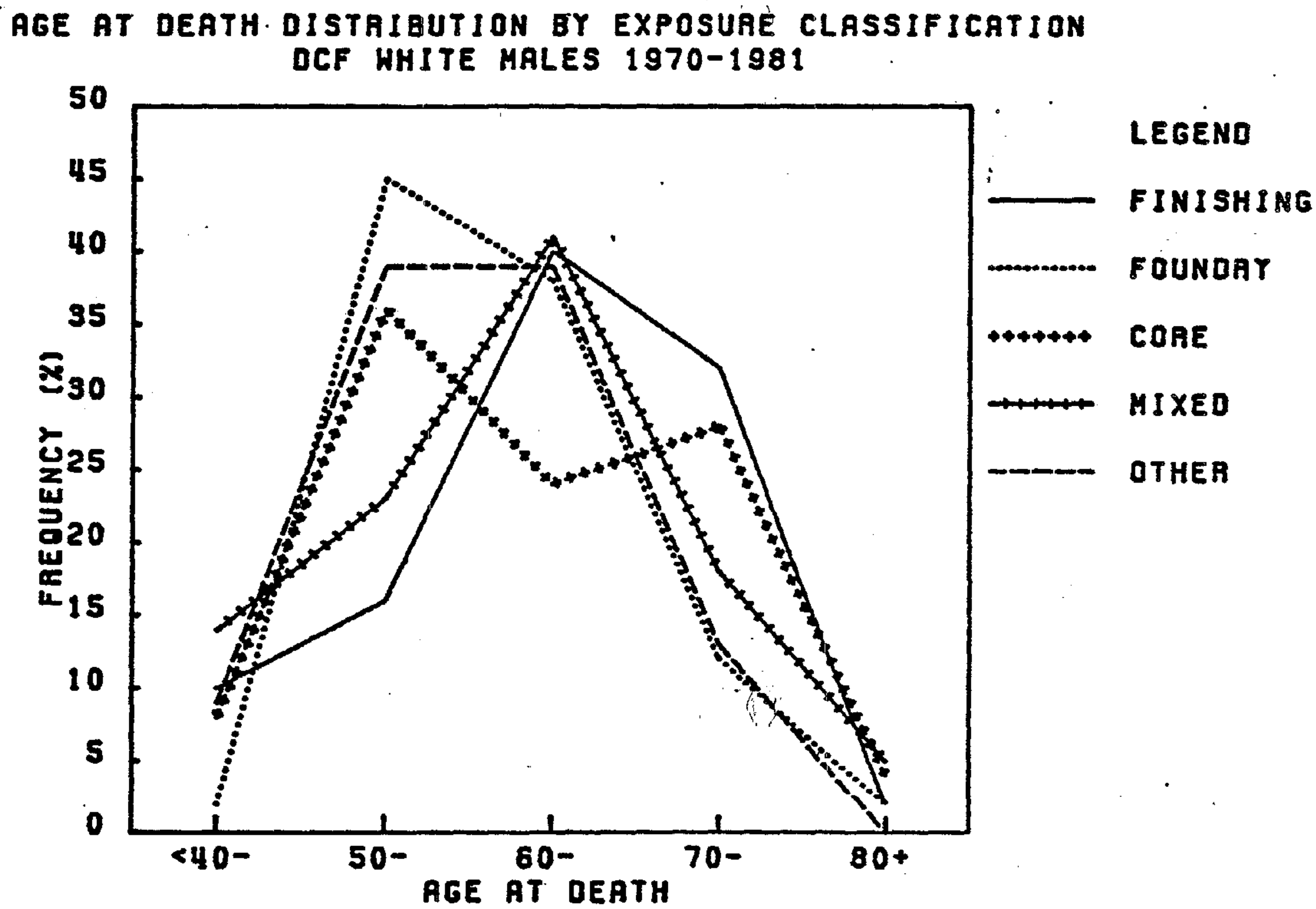

AGE AT DEATH DISTRIBUTION BY EXPOSURE CLASSIFICATION
DCF WHITE MALES 1970-1981
FREQUENCY (%)
50
45
40
35
30
25
20
15
10
5
0
<40-
50-
60-
70-
80+
AGE AT DEATH
LEGEND
FINISHING
FOUNDRY
CORE
MIXED
OTHER

FIGURE 10

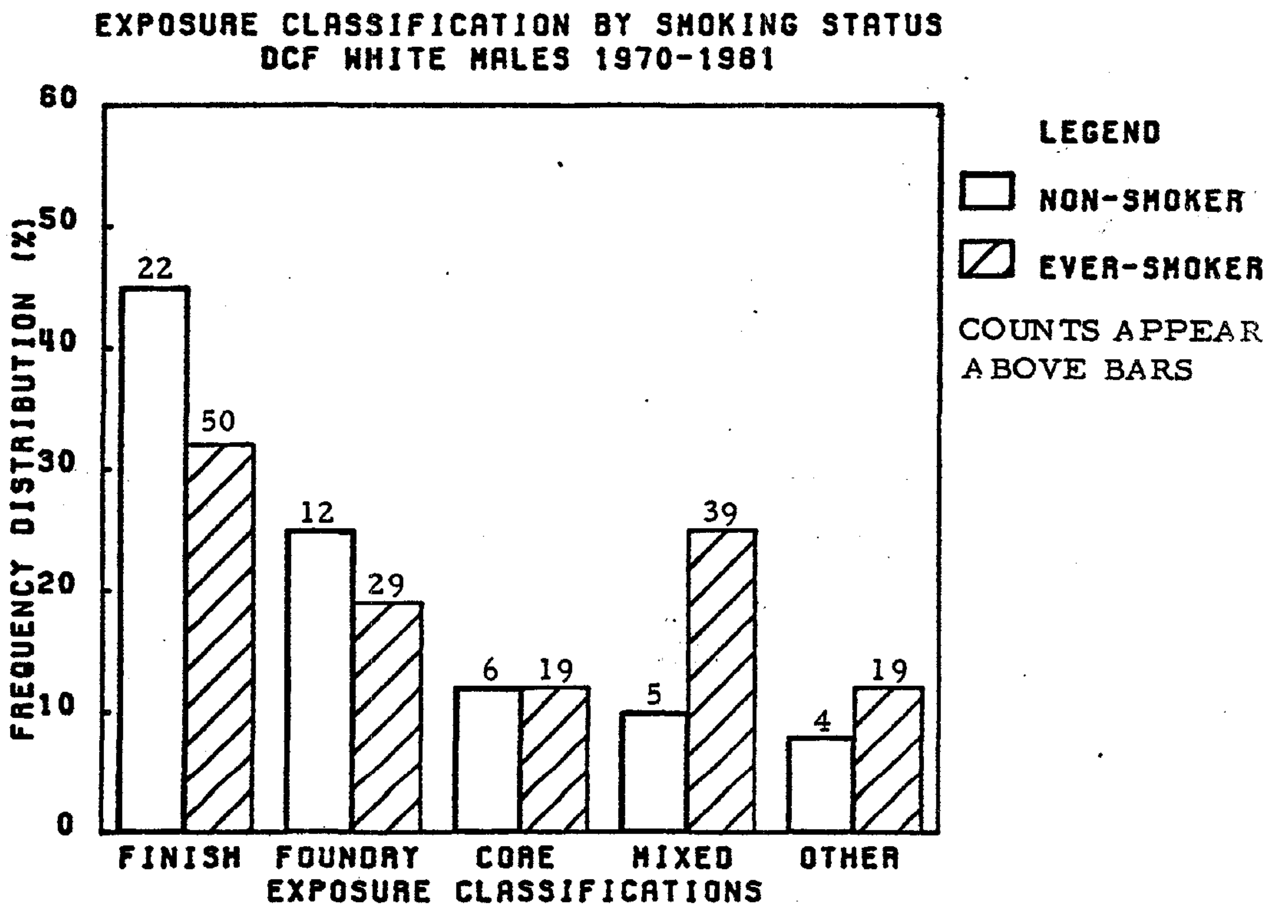

EXPOSURE CLASSIFICATION BY SMOKING STATUS
DCF WHITE MALES 1970-1981
FREQUENCY DISTRIBUTION (%)
60
50
40
30
20
10
0
22
50
12
29
6
19
5
39
4
19
FINISH
FOUNDRY
CORE
MIXED
OTHER
EXPOSURE CLASSIFICATIONS
LEGEND
NON-SMOKER
EVER-SMOKER
COUNTS APPEAR
ABOVE BARS

FIGURE 11

EXPOSURE CLASSIFICATION BY PRIOR OCCUPATION IN COAL MINING
OCF WHITE MALES 1970-1981

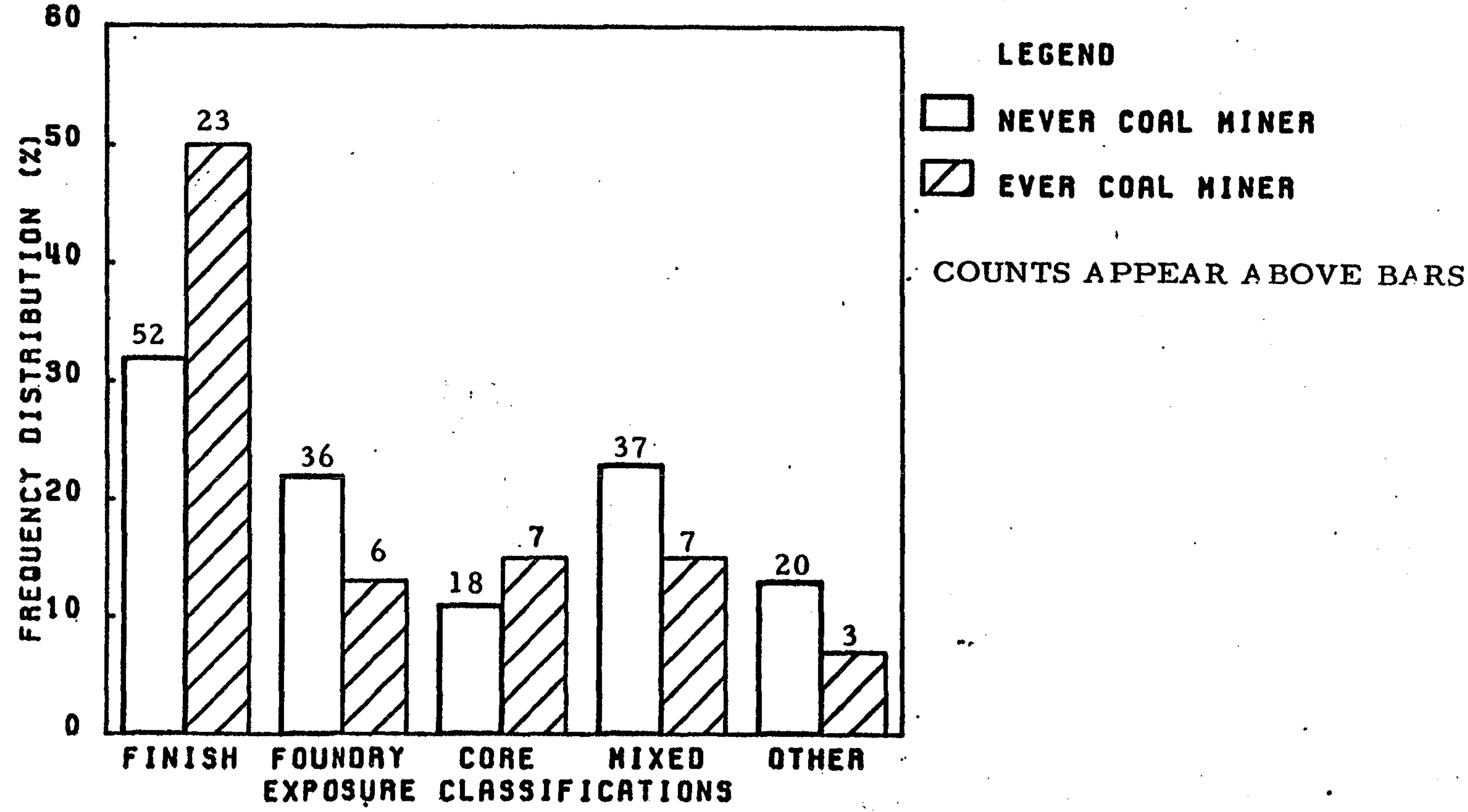


FIGURE 12

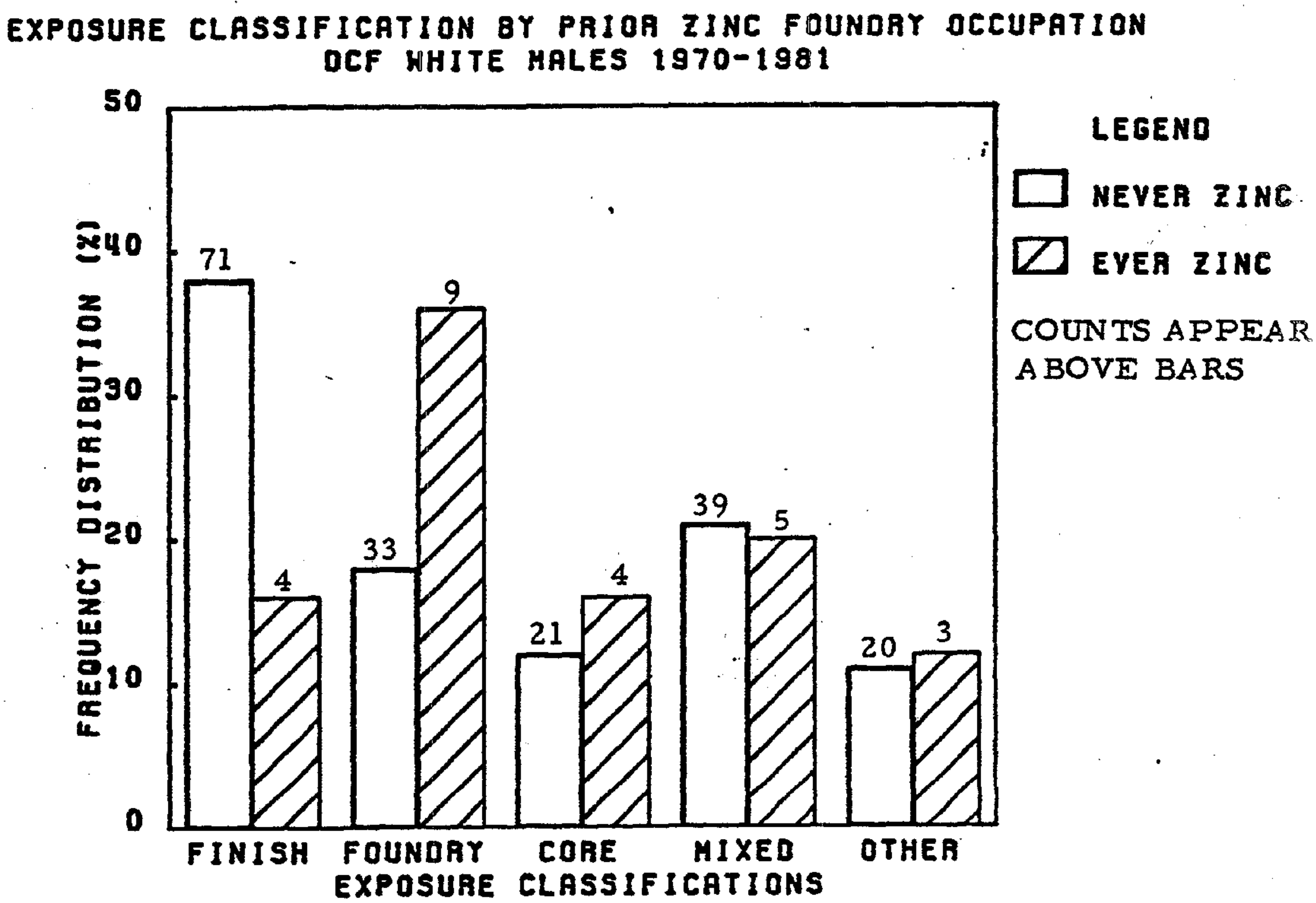

EXPOSURE CLASSIFICATION BY PRIOR ZINC FOUNDRY OCCUPATION
OCF WHITE MALES 1970-1981
FREQUENCY DISTRIBUTION (%)
50
40
30
20
10
0
71
4
33
9
21
4
39
5
20
3
FINISH
FOUNDRY
CORE
MIXED
OTHER
EXPOSURE CLASSIFICATIONS
LEGEND
NEVER ZINC
EVER ZINC
COUNTS APPEAR
ABOVE BARS

FIGURE 13

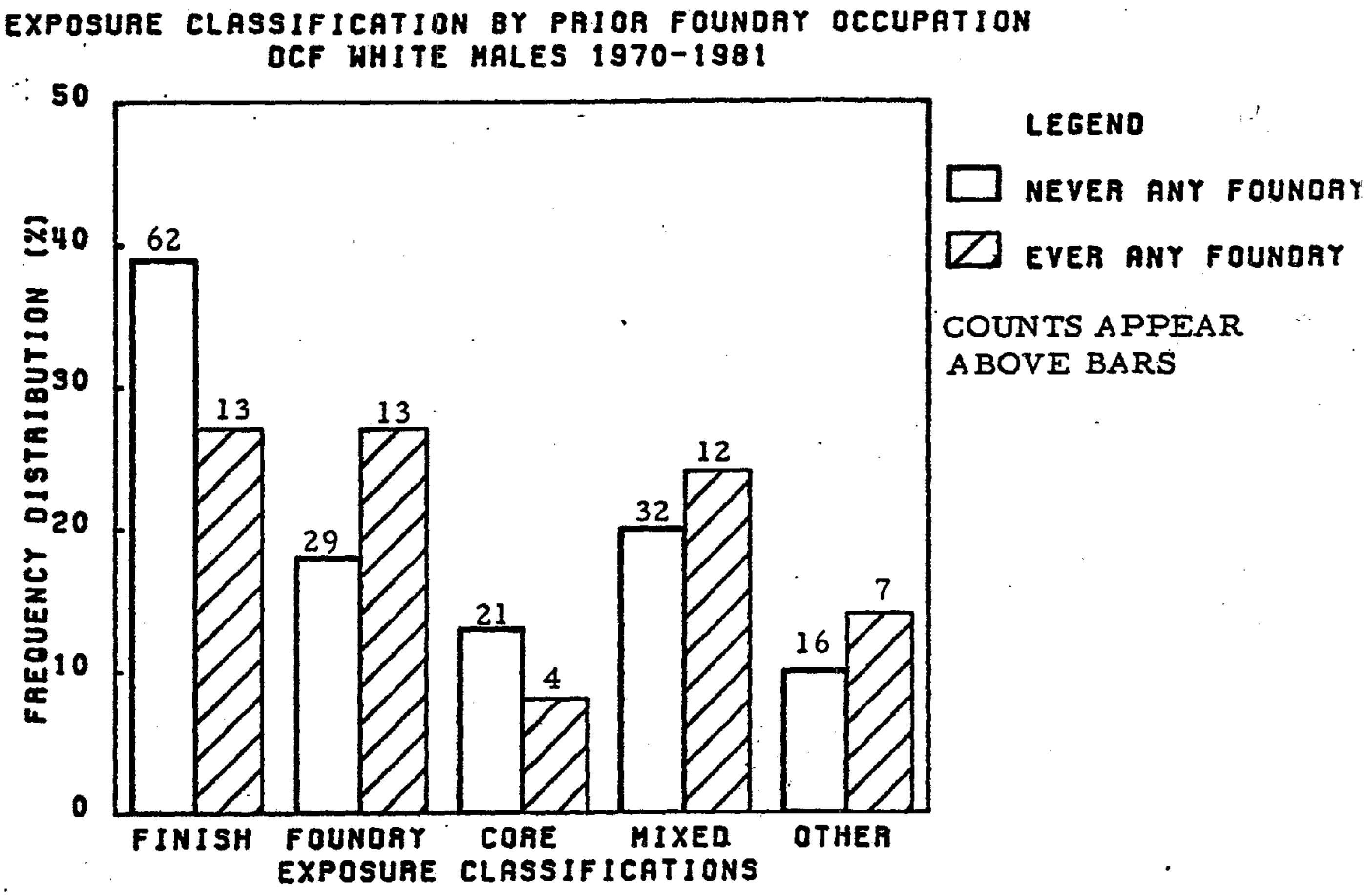
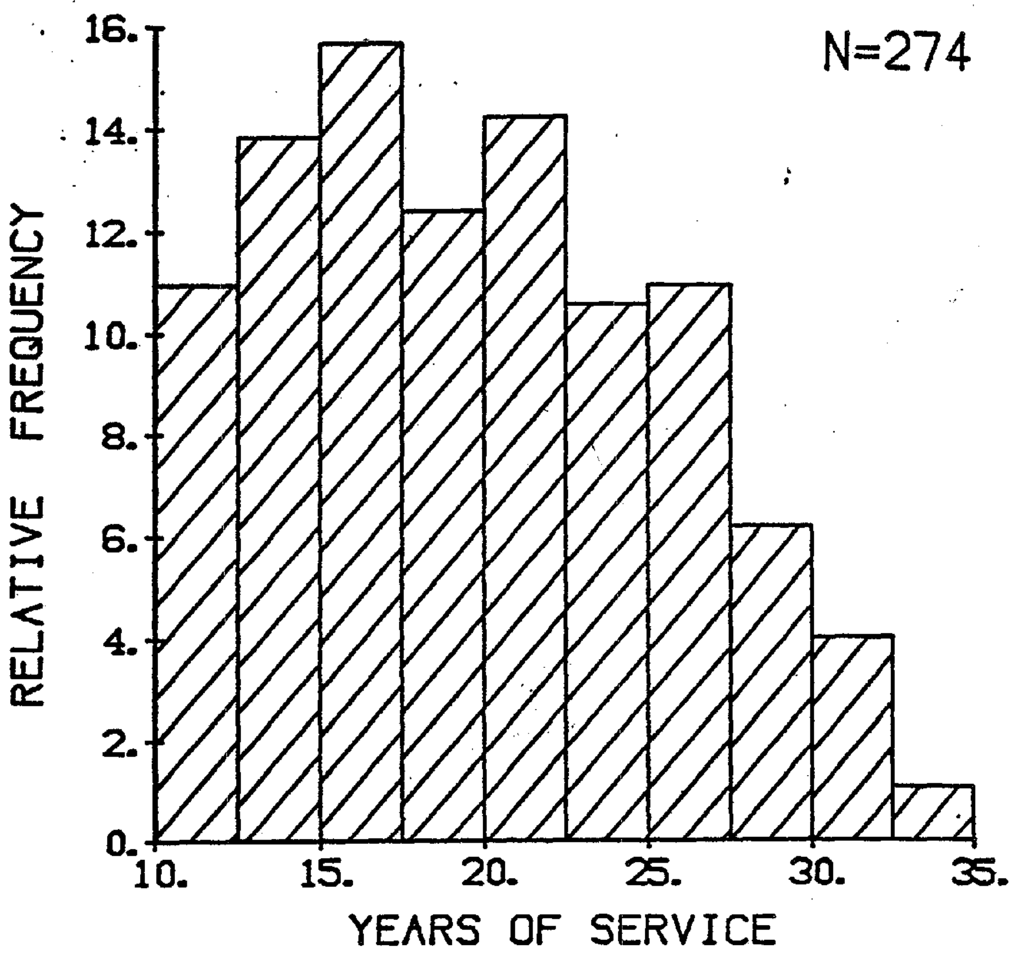

EXPOSURE CLASSIFICATION BY PRIOR FOUNDRY OCCUPATION
OCF WHITE MALES 1970-1981
FREQUENCY DISTRIBUTION (%)
50
40
30
20
10
0
62
13
29
13
21
4
32
12
16
7
FINISH
FOUNDRY
CORE
MIXED
OTHER
EXPOSURE CLASSIFICATIONS
LEGEND
NEVER ANY FOUNDRY
EVER ANY FOUNDRY
COUNTS APPEAR
ABOVE BARS

FIGURE 14

FREQUENCY DISTRIBUTION OF YEARS OF SERVICE

MALES 1970 - 1981



APPENDIX 1

EXPOSURE DATA

APPENDIX 1

Exposure Data

Extensive industrial hygiene information was obtained after the mortality analysis was completed. This information was in the form of periodic survey reports, prepared by the company industrial hygiene department. Seventeen surveys in which air contaminants were measured were conducted between 1947-1976. Dust and carbon monoxide exposure data was not available after 1976.

Methods

Discussions with industrial hygiene personnel involved in the program indicated that the sampling strategy had as its primary goal the detection of exposure which exceeded exposure limits. Measurements were therefore concentrated in job assignments with higher exposures. Samples were not reported as time weighted averages (TWA). Work station breathing zone measurements would tend to overstate TWA exposures because time spent away on breaks was not accounted for, and hygiene personnel would routinely stop collecting samples when the production was stopped. Therefore, the reported dust measurements overstate the time weighted average dust exposures of the population as a whole and its subgroups, and the actual average dust exposures and prevalence at high range fractions was less than the values reported.

Dust exposures were measured plant wide by impinger sampling. Particle counts were reported as millions of particles per cubic foot (mppcf). The majority of samples were said to be "breathing zone." Other samples were termed "general condition" or not differentiated; these results were considered separately in the analysis. Carbon monoxide was measured plantwide. These samples were short term tests. Some were breathing zone tests, others were area samples, collected in high exposure areas which were not work stations.

Air samples for coal tar pitch volatiles and metal fumes (iron oxide, lead, chromium and zinc) were collected in the pouring area. Formaldehyde exposures were measured in coremaking operations.

The assignment of measurements to exposure classifications used in the mortality study was determined by interpretation of the brief narrative which accompanied each sample value. The foundry exposure area was divided into melting and pouring, sand system, and molding through shakeout. Core and finishing areas were as described in the job histories.

For Finishing, Core Room and the major divisions within the Foundry area, the mean and standard deviation for breathing zone and general condition samples was computed for each survey, and were termed the survey mean. For breathing zone samples, the fraction of samples in each survey exceeding 20, 10 and 5 million particles per cubic foot (mppcf), termed the survey range fraction, was also computed. A period mean exposure by area was computed by averaging the survey mean dust counts. Period mean range fractions were computed by averaging the survey range fractions. The following gives results by process areas and on overall population-weighted basis.

Core Making

The average dust exposure was 8.8 ± 5.8 mppcf. The maximum survey mean was 19.7 mppcf in 1963, the minimum 3.3 mppcf in 1976. Relatively few samples were collected in any given survey. For this reason the percentages in excess of given limits might have been unstable. The 20 mppcf level was exceeded by 15.6% of samples; 10 mppcf was exceeded by 21.8% and 5 mppcf was exceeded by 34.2%.

Carbon monoxide was rarely sampled in the core room. The few tests taken were about 10 ppm.

Formaldehyde exposures in core making operations were considered in four surveys. The first samples were collected in 1964 and 1965, and ranged from less than 0.1 to 1.0 ppm, with a mean of 0.6 ppm. Coremaking was next resurveyed in 1971; 7 breathing zone samples ranged from 0.8 to 4.3 ppm, half the samples exceeded 3.0 ppm and the mean value was 2.7 ppm. A recheck in 1972 collected 6 general condition and breathing zone samples; they ranged from 0.2 to 7.1 ppm with a mean of 1.7 ppm. Furfural exposure was measured in 1963: two samples of 1.6 ppm were reported.

Foundry

Exposure data in the foundry area could be attributed to three types of operations: melting and pouring; sand systems; and molding through shakeout.

<u>Melting and Pouring</u>

For melting and pouring, the period mean dust exposure was 14.0 ± 9.9 mppcf. The survey means ranged from a low of 5.7 mppcf in 1973 to a high of 41.9 mppcf in 1965. All survey means exceeding the period mean were between 1963 and 1971.

The mean range fraction of samples greater than 20 mppcf was 12.4%; those exceeding 10 mppcf were 34% of samples in the area, while 53.4% of samples were greater than 5 mppcf. In contrast to the time trend for survey means, high range fraction results in this area persisted to the end of the observation period.

Carbon monoxide was measured frequently in the cupola and pouring areas. Cupola exposures in work area which were not full shift work stations ranged as high as 1000 ppm in early periods, and 200 - 400 ppm in the later periods. During early periods, median exposures were over 100 ppm. By the last available survey, the median exposure was 20 ppm with a maximum of 80 ppm. In the pouring area, short-term exposures in the 400 - 800 ppm range were recorded.

In later years samples ranged from non detectable to 80 ppm, with the median below 50 ppm.

Coal tar pitch volatiles were measured in 1976 in the pouring and adjacent areas in the foundry. Of 9 one-hour, general condition and breathing zone samples, 5 were non-detectable, the others ranged from 70 to 180 ug/m^3. Individual polynuclear aromatic hydrocarbons were not measured.

Iron oxide was measured in the pouring area in 1958 and 1976. Exposures averaged 850 and 970 ug/m^3 on both surveys. Average particle counts in the area on these surveys were 7.5 and 10.1 mppcf.

Chromium oxide was measured in 1976 and ranged from nondetectable to 40 ug/m^3 with a mean value of 4.8 ug/m^3. Four of the thirteen samples were nondetectable.

Lead-in-air exposures were measured in the melt department on 3 occasions. The first samples ranged from nondetectable to 60 ug/m^3, with a mean of 22 ug/m^3. In 1980, 10 short term lead in air samples were collected in the pouring area. These ranged from 28 to 232 ug/m^3 with a mean of 114 ug/m^3. Samples taken in other foundry areas ranged from 7 to 113 ug/m^3 with a mean of 43 ug/m^3.

Bismuth, which was used in the malleable iron process, was detected in the plume of emissions after innoculation of a ladle and in the vicinity of the pouring line at 200 ug/m^3, although 3 of 4 samples were nondetectable.

Sand Systems

The job operations in this group included sand preparation, aerators, sand flights and mullers.

The period mean dust count was 18.8$\pm$ 16.5 mppcf. The survey means ranged from 2.3 mppcf in 1958 to 74.6 mppcf in 1967. The interval with the highest exposures was between 1963 - 1969. The means for six surveys conducted after 1970 all fell below the period mean. The high survey means were the result of outlying results, as shown by very large standard deviations calculated during those years.

The period range fraction of samples greater than 20 mppcf was 19.4%; 43.9% exceeded 10 mppcf and 70.0% exceeded 5 mppcf.

Molding through Shakeout

Work stations in this group included molding, core setting, mold assembly, unclamping after pouring and shakeout. The period mean breathing zone dust count was 9.4 $\pm$ 4.9 mppcf. Survey means ranged from a low of 3.25 mppcf in 1950 to a high of 21.1 mppcf in 1971. The period mean was first exceeded in 1963 and last exceeded in 1974.

The range fraction greater than 20 mppcf for the period was 6.2%; those in excess of 10 mppcf were 24.4% of the tests in the area, while 64.7% exceeded 5 mppcf. Tests in this area seemed to reflect a more even distribution of exposures: in 9 of 16 years where personal exposures were measured there were no samples greater than 20 mppcf.

Carbon monoxide was measured frequently at each of these work stations. In addition, general condition samples were frequently collected in basements or cooling tunnels where workers might go under special conditions. In earlier years, breathing zone samples frequently exceeded 100 ppm, with individual samples at 200 ppm and non-work area samples in the 400 ppm range. The CO source was combustion of organic mold and core binders.

Finishing

The average dust exposure was 9.2 ± 7.2 mppcf. The highest exposures were recorded in 1963 and 1965, when the annual means were 25.7 mppcf. The period mean was also exceeded in 1971, with a survey mean of 18.4 mppcf. The remaining survey means all fell below the period mean.

For the study period, 9.9% of samples collected in finishing areas exceeded 20 mppcf, 23.9% exceeded 10 mppcf, and 44.9% exceeded 5 mppcf. As with the mean dust counts, the range fraction of samples generally peaked in 1963, 1965 and 1971.

Carbon monoxide exposures in finishing varied from nondetectable to 75 ppm, with the majority of samples below 20 ppm. Samples in the vicinity of the annealing furnaces were as high as 400 ppm.

Calculation of Population Average Exposure

A population-weighted average for foundry dust was also calculated. This would be the exposure experienced by individuals if they moved freely from job to job in proportion to the presence of those jobs in the plant population. The populations were approximated by the proportion of decedents in those classifications, assuming that those in the Mixed group were apportioned among the total. The population weighted period mean was 10.3 mppcf. The range fraction greater than 20 mppcf was 10.8%, the range fraction greater than 10 mppcf was 26.0%.

APPENDIX 2

REVISIONS IN WHITE MALE PROPORTIONAL MORTALITIES

1975 - 1981

APPENDIX 2

Revisions in USDR38 (R. Monson, 3/20/79) White

Male Proportional Mortalities

Secular trends in cause specific proportional mortality after 1975 in the U.S. population necessitates an updating of the U.S. standard proportional mortalities for the two 5-year calendar year strata 1975-1979 and 1980-1984. Failure to correct for these trends will result in an under-estimate of expected mortality for causes having a higher post-1975 mortality rate (e.g. lung). Conversely, expected mortality will be over-estimated for causes having a declining post-1975 rate (e.g. stomach).

Since the release of the 38th revision of USDR, three additional years (1976-1978) of U.S. mortality data have been made publicly available on magnetic tape from the National Center for Health Statistics (NCHS). The following materials and methods were used to incorporate the new mortality data into updated proportional mortalities for use in the Monson program.

The source of the number of deaths, ACME-coded ICD causes of death,[2] age, sex, race of U.S. decedents in single years for each year 1975-1978, inclusive, was NCHS magnetic tapes[3]. A FORTRAN program was used to classify age specific deaths in single years according to the 54 male causes of death specified in USDR38.[4]

Proportional mortalities for the 1975-1979 calendar year strata were calculated from:

$$PM_{ijk} = \frac{\sum_{i=1975}^{1978} d_{ijk}}{\sum_{i=1975}^{1978} d_{ij.}}$$

Where d_{ijk} = the number of deaths in the i-th calendar year, j-th 5-year age strata, and k-th cause.

$d_{ij.}$ = the sum of deaths from all causes in the i-th calendar year and j-th age stratum.

Proportional mortalities for the 1980-1984 calendar year strata was computed using mortality data for the single year 1978.

As an independent check for errors in either the source tapes or algorithm, 54 cause specific proportional mortalities were computed for the single year 1975. The proportional mortalities so computed were manually compared and found to be identical (within rounding error at the 6th decimal place) to USDR38 WM proportional mortalities for the 1975-1979 calendar period which are based solely on 1975 NCHS tape data.[5]

It should be pointed out that the procedures and materials used to revise USDR38 proportional mortalities are directly analogous to those reported by R. Monson.[6]

References Cited

1. Monson, R. Analysis of relative survival and proportional mortality. Comp. Biomed. Res. 7: 325-332, 1974.

2. Automated Classification of Medical Entities (ACME) for selection of causes of death. On published paper presented at the annual meeting of the Americal Public Health Association, Houston, TX, October 1970.

3. Vital Statistics Mortality Data, Cause of Death Summary. National Center for Health Statistics DHEW. Magnetic Tape data files: PB80-134133 (1975), PB80-134091 (1976), PB80-126592 (1977), PB81-100257 (1978).

4. Monson R. USDR38 (3/20/79) Documentation. Department of Epidemiology, Harvard School of Public Health. Boston, MA, 9-1-79. page A-7.

5. Ibid, p. 4.

6. Monson R., loc. cit., p. 326.

APPENDIX 3

REVISIONS IN DORN SMOKER PROPORTIONAL MORTALITY

DUE TO LUNG CANCER, 1970 - 1981

APPENDIX 3

Method for Revising and Updating Lung Cancer Proportional Mortality for U.S. Veterans Study Smokers(1)

The Dorn study(1) of US Veterans, initiated in 1954, provided mortality and smoking data on approximately 250,000 male holders of U.S. Government Life Insurance in December 1953. This population was made up of essentially white male skilled or white collar workers (82% of total) and had an overall mortality rate three-fourths that of the U.S. white male population. (Favorable mortality experience in a study population compared to the U.S. standard is frequently encountered in mortality analyses of industrial populations, and is known as the "healthy worker effect").

The U.S. veterans were followed-up over a 16 year period and in 1966, Kahn(2) published extensive data on smoking and cause-specific mortality for the period 1954 to 1962.*

Assuming that after 1962 the rate of change in U.S. veteran smoker lung cancer proportional mortality was the same as that of U.S. white males, it is possible to extrapolate lung cancer proportional mortality during 1970 - 1981. Further assuming the initial (1954 to 1962) absolute difference in lung cancer proportional mortality between the U.S. veteran smokers and U.S. white males was maintained over all successive calendar periods, we obtain the following prediction equation using an additive model:

$$PM'_{ij} = PM_{ij} + (PM'_{io} - PM_{io}) \qquad j \neq o$$

where PM'_{ij} = the proportional mortality due to lung cancer in the U.S. veteran population of smokers for the ith 10-year age strata (35-, 45-, 55-75-) and the jth calendar period j = 0, 1, 2; 1954 - 1962, 1970 - 1974, 1975 - 1981, and

PM_{ij} = the proportional mortality due to lung cancer of U.S. white males.

Kahn's Table A(2) and U.S. vital statistics mortality data(4) were used in the calendar years specified to generate expected lung cancer proportional mortalities of U.S. veteran smokers for 1970 - 1974 and 1975 - 1981. The 1975 - 1981 cell however, was based on U.S. mortality data for the most recent period available, 1975 - 1978. For the purpose of this update, U.S. veteran smokers are defined as U.S. veteran current smokers and ex-smokers who stopped for reasons other than doctors orders. This definition approximates ever-smokers and conforms to the data provided by Kahn. For the period 1954 - 1966 which is coincident with the 7th revision of the International classification of diseases, ICD codes 162 and 163 were used by Kahn and NCHS to signify cancer of lung and bronchus. For the period after 1970, only ICD code 162 was used. It is to be noted that smoking data were gathered only at entry by mail questionnaire in the Dorn Study. Therefore the ever-smoker expected mortality may be affected by the number of nonsmokers at entry who later became smokers. This number is probably quite small and is not likely to cause any appreciable error.

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*Published mortality data for the period after 1962(3) is not in a form in which age-specific proportional mortalities by smoking status can be directly extracted.

References

1. Dorn, H.F. the mortality of smokers and nonsmokers. Proc. Social Stat. Sci. Amer. Stat. Assoc. Papers persented at the annual meeting of American Statistical Association, Chicago, IL, December 27 - 30, 1958. Washington, D.C., American Statistical Association, 1959, pp. 34 - 71.

2. Kahn, H.A. The Dorn study of smoking and mortality among U.S. veterans: report on eight and one-half years of observation. In: Haenszel, W. (Ed.) Epidemiological Approaches to the study of Cancer and other Chronic diseases. NCI monograph No. 19. US DHEW, PHS, NCI, January, 1966, pp. 1 - 125.

3. Rogot, E., Murray, J. Smoking and Causes of Death Among U.S. Veterans: 16 years of observation. Pub. Health Rep. 95 (3):213 - 200, 1980.

4. Vital Statistics of the United States, National Center for Health Statistics, Washington, D.C. 1954 - 1962, 1970 - 1978.

APPENDIX 4

EXCLUSIONS FROM STATISTICAL ANALYSES.

APPENDIX 4

Exclusions from Analyses

1. Distribution of Causes of Death in Workers Excluded from Case-Control Analyses due to Missing Work Records or Unknown Exposure Classifications. Males, 1970-1981.

	White		Black
	Unknown Classification	Missing Records	Unknown Classification
Underlying Cause of Death 8th Revision ICD	N	N	N
Cancer of Larynx (162)	1	—	—
All Circulatory Disease (390-458)	6	3	3
Pneumonia (485)	—	1	—
Cirrhosis of Liver (571)	—	—	1
Genito-urinary Diseases (593)	1	—	—
External Causes (966)	—	—	—
All Causes (1-998)	8	4	5

2. Distribution of Causes of Death and Age at Death, White Females.

Underlying Cause of Death 8th Revision	N	Age at Death
Cancer of Breast (174)	2	60, 67
Myocardial Infarction (410)	1	66,
Motor Vehicle Accident (812)	1	64
All Causes (1-998)	4	—

APPENDIX 5

UNITED STATES AND ILLINOIS PROPORTIONAL MORTALITIES FOR RESPIRATORY CANCER AND EMPHYSEMA BY AGE, WHITE MALES

1970-1974

APPENDIX 5

United States and Illinois Proportional Mortalities[1] for Respiratory Cancer[2] and Emphysema[3] by Age, White Males 1970-1974

	Respiratory Cancer		Emphysema	
Age Group	U.S.	Illinois	U.S.	Illinois
30-	.0122	.0099	.00123	.00165
35-	.0292	.0384	.00236	.00381
40-	.0545	.0515	.00436	.00416
45-	.0739	.0767	.00716	.00661
50-	.0874	.0816	.01117	.00968
55-	.0953	.0916	.01658	.01715
60-	.0958	.0930	.02210	.02075
65-	.0872	.0863	.02668	.02766
70-	.0702	.0653	.02771	.02939
75-	.0486	.0438	.02389	.02402
80-	.0298	.0268	.01734	.01608
85+	.0139	.0122	.00986	.00831

1) Deaths from 69 selected causes. Vital Statistics of the United States, 1970-1974. Mortality Part B. U.S. Government Printing Office, Washington, D.C.

2) ICD 8th Revision Codes 160-163.

3) ICD 8th Revision Code 492.