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An Updated Mortality Study of Workers at a Petroleum Refinery in Beaumont, Texas

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Abstract

The mortality experience of 7,119 workers who were employed at a Beaumont, Texas refinery for at least one year between 1945 and 1987 was investigated. Mortality analyses based on standardized mortality ratios (SMRs) and 95% confidence intervals (95% CI) showed overall mortality was significantly lower than expected compared with the U.S. general population (SMR=82, 95% CI:79-86). Total cancer mortality was also lower than expected (SMR=92, 95% CI:84-100). Significant mortality deficits from several malignant and non-malignant diseases were reported. A significant mortality increase in the broad category of lymphatic and hematopoietic cancers was found (SMR=133, 95% CI:103-170). This increase was attributed to a nonsignificant elevation in leukemia of all cell-types combined (SMR=139, 95% CI:92-201) and a borderline significant increase in other lymphatic tissue cancer (SMR=158, 95% CI:101-235). The elevation in leukemia was confined to workers hired before 1950. Furthermore, the leukemia excess was shown to have peaked during the 1960s, with mortality no longer elevated post-1980. Analyses of cell-type specific leukemias showed a similar temporal pattern for acute myeloid leukemia (AML) which was not significantly elevated (SMR=136, 95% CI:59-268). Mortality from other leukemia cell types was similar to or lower than expected. Mortality from non-Hodgkin's lymphoma (NHL) (SMR=140, 95% CI:88-211) and multiple myeloma (MM) (SMR=121, 95% CI:55-230) were increased, but neither was statistically significant nor likely to be related to refinery employment. No death from asbestosis was reported, and mortality from mesothelioma and pulmonary fibrosis was lower than expected. Lung cancer mortality for the overall cohort was similar to expected. For the overall cohort, analyses by duration of employment and time since first employment showed no evidence of any trends for increasing cause-specific mortality.

Separate analyses of male workers employed in operator jobs showed mortality patterns which were more favorable than those of the total cohort. Maintenance craftworkers showed statistically significant elevations in mortality for prostate cancer (SMR=145, 95% CI: 107-194), leukemia (SMR=179, 95% CI: 111-273), and other lymphatic tissue cancer (SMR=233, 95% CI: 138-368). Detailed analyses indicated that, among maintenance craftworkers mortality was elevated for AML, NHL and MM, but none was significant. Furthermore, no upward trend by duration of maintenance jobs was observed. A small increase of lung cancer was observed among maintenance craftworkers (SMR=120, 95% CI: 99-145), which was borderline significant. No relationship between lung cancer and duration of maintenance employment was found. In contrast, a deficit of pulmonary fibrosis was reported among

maintenance craftworkers (SMR=62, 95% CI: 17-159). These findings were discussed in conjunction with results from other refinery studies, and the limitations of the study were discussed.

INTRODUCTION

The Beaumont refinery has been operating since 1902 and is one of the oldest and largest full service refineries in the U.S. Currently the refinery processes 350,000 barrels of oil a day and produces a variety of petroleum products including gasoline, diesel fuels, fuel oils, jet fuel, kerosene, liquefied petroleum gas, asphalt, lubricating oil and greases, and feedstocks for the petrochemical industry.

Refinery workers in general are potentially exposed to a wide range of petroleum-derived hydrocarbons and chemical substances used in the manufacturing of petroleum fuels and lubricants. Specific substances occurring in the working environment of petroleum refineries and previously evaluated by the International Agency for Research on Cancer (IARC) include: anisidine, arsenic compounds, asbestos, benzene, bitumens, butadiene, carbazole, chlorinated hydrocarbons, chromium and chromium compounds, ethylene dibromide, ethylene dichloride, hydrazine, lead and lead compounds, mineral oils, nickel and nickel compounds, phenylenediamine, polycyclic aromatic compounds, and silica [IARC, 1989].

In 1984, Morgan and Wong completed a retrospective cohort mortality study of workers at the Mobil Beaumont, Texas refinery who worked for at least one year between January 1, 1945 and January 1, 1979 [Morgan and Wong, 1984]. The vital status of these workers was ascertained through December 31, 1978. Based on a comparison to national mortality rates, workers at the Beaumont refinery experienced a 19% deficit in overall mortality and a 4% deficit in total cancer mortality. A statistically significant excess of lymphatic and hematopoietic cancers was observed among white males. The excess was attributed to a statistically significant increase of deaths from leukemia, although nonsignificant elevations were also noted for lymphosarcoma and reticulosarcoma, and for the category of other lymphatic tissue cancer.

To continue surveillance of the mortality experience of the Beaumont refinery workers, enrollment in the study was extended over an additional nine years of employment eligibility (1979-1987). Vital status follow-up was extended to December 31, 1987. The objective of the update was to expand the previous study, and to continue monitoring the mortality patterns of the Beaumont refinery workers. Because of the expanded cohort and the extended observation period, the precision of cause-specific mortality risk estimates would likely be improved, and additional detailed analyses for some causes could be performed.

MATERIALS AND METHODS

The expanded cohort consisted of all Mobil employees who worked a year or more at the Beaumont refinery between January 1, 1945 and December 31, 1987. The cohort members were identified through a combination of personnel records located on-site and computerized payroll files. Information abstracted from these records included social security number, name, sex, race, date of birth, date of employment, employment status at the closing date of the study, vital status at the closing date of the study, and date of retirement, separation, or death when applicable. Employment histories of the cohort members were updated from 1978 to 1987. For each employee, the employment history data consisted of the beginning and ending dates for each job, job titles and departments.

Several sources were used for vital status ascertainment, including the company's personnel database, Pension Benefits Information, Inc., the National Death Index, and the Social Security Administration. Death certificates were obtained from company personnel files or from state vital records offices. A qualified nosologist coded the underlying cause of death according to the Eighth Revision of the International Classification of Diseases (ICD) [World Health Organization, 1967, 1969]. Overall and cause-specific mortality was analyzed with the OCMAP program, a modified life-table computer program that calculates cause-specific standardized mortality ratios (SMRs), the ratio of observed to expected deaths expressed in percentage [Marsh and Preininger, 1980]. Expected deaths were derived from the National Center for Health Statistics NCHS mortality rates for the U.S. population, which are specific for cause, sex, race, and 5-year intervals of age and calendar period [Monson, 1987]. OCMAP also computed cause-specific mortality relative to cumulative duration of employment and time since first employment.

Entry into vital status follow-up was January 1, 1946 for workers with at least one year full-time employment prior to that date or, for all others, one day after completion of one year employment. SMRs for specific death categories were examined relative to time since first employment and by duration of employment. The method discussed by Breslow et al. was used to test for trends in SMRs [Breslow et al., 1983]. To investigate mortality by job category, male employees at the Beaumont refinery were classified into two major job categories: (I) operators (having a minimum of 6 months of employment in operator jobs), and (ii) maintenance craftworkers (having a minimum of 6 months of employment in maintenance craft jobs). This latter subcohort of craftworkers consisted principally of workers involved in a

broad range of labor and maintenance activities in the mechanical and service divisions of the refinery.

In addition, because of the *a priori* interest in lymphatic and hematopoietic cancers, SMRs for major cell-type specific leukemias (acute myeloid, chronic myeloid, acute lymphatic and chronic lymphatic leukemia, or AML, CML, ALL and CLL), non-Hodgkin's lymphoma (NHL) and multiple myeloma (MM), which were not routinely calculated in the OCMAP program, were also performed. U.S. age-specific mortality rates for cell-type specific leukemias based on data from the National Center for Health Statistics (NCHS) [Selvin et al., 1980] and similar rates for NHL and MM compiled by the National Cancer Institute (NCI) [Pickle et al., 1987] were used in computing the expected deaths from these causes. In addition, because of the use of asbestos at the refinery in the past, separate analyses for asbestos-related diseases were also performed. Expected deaths were based on U.S. rates for pulmonary fibrosis obtained from NCHS (unpublished data by special request) and for mesothelioma complied by NCI [Connelly et al., 1987].

RESULTS

Descriptive Statistics

A total of 7,119 workers were eligible for inclusion in the updated study (Table I). This represented an increase of 763 whites (80% male), 216 nonwhites (80% male) and 1 male of unknown race. Consistent with the previous report, those of unknown race (approximately 5% of the total cohort) were treated as white. This resulted in a cohort 91% male and 83% white (including Hispanic). Selected employment and demographic characteristics of the cohort are also provided in Table I. Ninety-two percent were first employed in their thirties or younger, with only 8% hired at age 40 or older. Approximately half (51%) were hired prior to 1950, and 43% were employed for 30 or more years.

The maximum length of potential follow-up was 42 years (January 1, 1946 to December 31, 1987). The average duration of follow-up was 23 years. Fifty-three percent of cohort members had a follow-up of 20 years or more. The increase in person-years from the previous study was 43,072, or 35%, to a total of 166,427. By the end of follow-up (December 31, 1987), 27% of cohort members were still employed, 41% had separated or retired, and 32% were known dead. Information on vital status was 98% complete, with 165 (2%) separated

employees lost to follow-up. Of the 2,294 cohort members identified to have died between 1946 and 1987, death certificates were obtained for 98%.

Overall and Cause-Specific Mortality

The number of observed deaths, SMRs and 95% confidence limits (95% CI) for selected causes for all workers are presented in Table II. The total number of observed deaths was 2,294 compared with 2,782.5 expected (SMR=82, 95% CI: 79-86), indicating a statistically significant deficit of 18% in overall mortality. Mortality from all cancers was slightly lower than expected. The number of observed cancer deaths was 513, versus 559.0 expected (SMR=92, 95% CI: 84-100), and the deficit was borderline significant.

Significant mortality deficits occurred for infective and parasitic diseases, cancer of the buccal cavity and pharynx, cancer of the rectum, liver cancer, circulatory system diseases, nonmalignant respiratory diseases, digestive system diseases, genito-urinary system diseases, and accidents, poisonings and violence.

Significant mortality excesses occurred for the broad category of lymphatic and hematopoietic cancer (SMR=133, 95% CI: 103-170) and senility and ill-defined conditions (SMR=166, 95% CI: 127-212). The elevation for the general category of lymphatic and hematopoietic cancers could be attributed to a borderline significant excess in other lymphatic tissue cancer (SMR=158, 95% CI: 101-235) and a non-significant excess in leukemia (SMR = 139, 95% CI: 92-201).

Results for white males (Table III), comprising 75% of the total cohort, showed mortality patterns generally similar to those in the total cohort. However, unlike the total cohort, the deficit in total cancer mortality was larger and statistically significant. Borderline significant excess mortality was found for the broad category of lymphatic and hematopoietic cancers (SMR=134, 95% CI: 101-175), whereas mortality excess from the category "other lymphatic tissue cancer" was of comparable magnitude but no longer statistically significant. The mortality excess from senility and ill-defined conditions among white males was statistically significant (SMR=255, 95% CI: 192-333).

A total of 52 deaths were observed among female cohort members (not shown). All except 2 deaths occurred among white females. The overall SMR of 95 among white females was not statistically significant. A statistically significant deficit was found for circulatory system diseases (SMR=55, 95% CI: 28-96). Mortality from all cancers was elevated

(SMR=145, 95% CI: 92-217), although the increase was not statistically significant. The only statistically significant mortality excess among white females was found for cancer of the large intestine, based on 5 deaths (SMR=320, 95% CI: 104-748).

A total of 448 deaths (not shown) were observed among 1,136 nonwhite males, compared with 592.1 deaths expected (SMR=76, 95% CI: 69-83). This 24% deficit was statistically significant and could be attributed primarily to a deficit in diseases of the circulatory system. Other statistically significant mortality deficits occurred for infective and parasitic diseases, nonmalignant respiratory diseases, cirrhosis of the liver, and accidents, poisonings and violence. Deaths from senility and ill-defined conditions were significantly lower than expected (SMR=49, 95% CI: 21-97), in contrast to the significant excess found for white males. No statistically significant cause-specific mortality excesses were observed among nonwhite males. Mortality from all cancers was identical to the expected based on U.S. general population rates (SMR=100, 95% CI: 82-121). In contrast to deficits found in white males, there were slight elevations for mortality from cancer of the respiratory system and stomach cancer among nonwhite males.

Mortality by Duration of Employment

Table IV shows cause-specific SMRs by duration of employment (<10, 10-29, 30+ years) among all male employees. No analysis by duration of employment was performed for white or nonwhite female employees, since the number of deaths was small. The results for all males indicated that overall mortality remained the same with increased employment duration, whereas total cancer mortality rose slightly. Results for site-specific cancers did not show any consistent pattern. Although SMRs for prostate and brain cancers appeared to increase with duration of employment (primarily due to deficits in the <10 year group), the results for trend tests for both cancer sites were not statistically significant (X^2=3.17 and 2.03, respectively). There was no upward trend in mortality from either leukemia or other lymphatic tissue cancer (X^2=0.17 and 0.48, respectively).

Mortality analysis by duration of employment for white males is shown in Table V. Results are similar to those reported for all males, except that overall mortality decreased slightly with increased employment duration. Also, there was an elevated leukemia SMR in the longest (30+years) length of employment category which was borderline significant (SMR=186, 95%

101-311). However, there was no upward trend in mortality among white males from leukemia (X^2=0.83).

For nonwhite males (not shown), overall mortality rose with employment duration, particularly for diseases of the circulatory system and the category of accidents, poisonings and violence. In general, for the subcohort of nonwhite males, most cancer SMRs decreased among those with more than 10 years of employment, although some of these SMRs were based on small numbers of deaths. Observed numbers of deaths for kidney cancer, lymphosarcoma and reticulosarcoma, and other lymphatic tissue cancer were small and confined to the longest employment duration category (30+ years). Similarly, nonsignificant mortality excess for lung and prostate cancer occurred among those with 30+ years of employment. The only statistically significant excess occurred for stomach cancer among nonwhite male workers employed for less than 10 years (SMR=640, 95% CI:132-1871). There was a significant inverse trend in stomach cancer mortality with increasing duration of employment (X^2= 5.57).

Mortality by Interval Since First Employment

Mortality analysis for all males by interval since first employment (<20, 20-39, 40+ years) is shown in Table VI. As stated above, the number of deaths among white female workers was too small for any subcohort analysis, and no analysis by interval since first employment was performed for white female employees. Mortality for males from all causes and all cancers was marked by increasing SMRs with increasing interval since first employment. For most site-specific cancers, there was no consistent pattern. Mortality from cancers of the lung, brain & CNS, and lymphosarcoma & reticulosarcoma increased with increased time since first employment. It was interesting to note that prostate, skin, and other lymphatic tissue cancers were each characterized by an inverse trend. No causes of death were significantly elevated for any interval since first employment category.

Mortality analysis by interval since first employment for white males is shown in Table VII. Results are similar to those reported for all males except that mortality from cancers of the lung and brain & CNS are unrelated to time since first employment. Also, mortality from the broad category of lymphatic and hematopoietic cancers among white males in the 20-39 years since hire group was significantly elevated (SMR=154, 95% CI: 102-223). This increase was

attributed to elevated mortality from leukemia (SMR=177, 95% CI: 94-302), although this latter increase was not statistically significant.

For nonwhite males (not shown), mortality in relation to interval since first employment showed a pattern similar to that among white males. Overall mortality and total cancer mortality increased with increasing number of years since hire. Mortality excess from total cancer was statistically significant among nonwhite male workers in the category of 40 or more years since hire (SMR=137, 95% CI: 106-174). This increase could primarily be attributed to a statistically significant excess of respiratory cancer mortality among nonwhite male workers in this interval subgroup (SMR=196, 95% CI: 127-290). Another significant excess was found for stomach cancer among nonwhite male workers in the shortest interval of time since hire (<20 years; SMR=395, 95% CI: 108-1011). Stomach cancer mortality showed a pattern of decreasing mortality with increasing time since first employment.

Mortality from Lymphatic and Hematopoietic Cancers

Observed and expected numbers of deaths and SMRs for leukemia and other lymphatic tissue cancer by age at death (<65, 65+) and decade of death among white and nonwhite males are shown in Table VIII. For leukemia deaths among white males, significant excesses were found in older workers (age 65+) during the 1960s and 1970s only. Table VIII indicates that leukemia mortality appeared to have peaked during the 1960s, when it was significantly elevated among white males (SMR=263). Thereafter, leukemia mortality declined and was no longer elevated post-1980. Mortality from leukemia among nonwhite males was difficult to interpret due to the small number of deaths (N=4). Nevertheless, it appeared that leukemia mortality was highest in the 1970s and decreased thereafter. For other lymphatic tissue cancer among white males, mortality was significantly elevated only among younger workers (< age 65) during the 1970s. Only four other lymphatic tissue cancer deaths were observed among nonwhite males.

Analysis of mortality from lymphatic and hematopoietic cancers by year of first employment has been found to be informative by other studies of petroleum workers. In 1947, the recommended standard for benzene was reduced from 100 ppm to 50 ppm, which was further reduced to 35 ppm in 1948. In general, benzene exposure levels in the petroleum industry after 1948-1950 were much lower than earlier. Table IX shows mortality from lymphatic and hematopoietic cancers by year of first employment (<1950, 1950+).

Considering the two separate employment periods, the only statistically significant increase occurred for all lymphatic and hematopoietic cancers among all male workers hired before 1950 (SMR=135, 95% CI: 102-176). With regard to subcategories, both leukemia and other lymphatic tissue cancer were elevated, but neither was statistically significant. In contrast, mortality from both categories of all lymphatic and hematopoietic cancers and leukemia was similar to the expected among workers hired in or after 1950. There was an increase of other lymphatic tissue cancer in the latter group, but the increase was based on only 5 deaths, and was not statistically significant. Detailed work histories of leukemia and other lymphatic tissue cancer decedents were examined to determine whether there were common work assignments. A review of these records showed no evidence of any clustering of work assignments or locations. The most frequently reported job departments were pipe, cross still and labor. For the total male cohort the most frequently reported job departments were pipe, labor and lube plant.

The subcategories of lymphatic and hematopoietic cancers used in the OCMAP program are based on the statistical classifications compiled by NCHS and do not permit a specific analysis for major cell-type specific leukemias, NHL or MM, which are more appropriate classifications from the biological point of view (Linet, 1985; Heath, 1982; Wintrobe et al., 1981). Therefore, analyses for these specific subcategories of lymphatic and hematopoietic cancers among all male employees were carried out separately. Female cohort members were not included in these analyses since they contributed fewer than one expected death to these subcategories each. Table X shows that there were 8 observed AML deaths, compared to 5.9 expected (SMR=136, 95% CI: 59-268). For CML, the number of observed deaths was similar to expected (SMR=115, 95% CI: 24-336); whereas non-significant deficits were observed for both ALL and CLL. For NHL among all males, the observed mortality was higher than expected (22 observed versus 15.7 expected deaths, SMR=140, 95% CI: 88-211), but the increase was not statistically significant. For MM among all males, SMR was slightly elevated (9 observed versus 7.5 expected deaths, SMR=121, 95% CI: 55-230).

Mortality from Asbestos-related Disease

Because of the use of asbestos at the refinery in the past, mortality from asbestos-related diseases (asbestosis, lung cancer, and mesothelioma) among cohort members was examined. Although the OCMAP program provided an analysis for lung cancer, standard rate sets did not

analyze mortality data specifically for asbestosis or mesothelioma. Analyses for asbestosis (pulmonary fibrosis) and mesothelioma were performed separately. The term asbestosis refers to pulmonary fibrosis caused by exposure to asbestos, or pulmonary fibrosis in persons with a documented asbestos exposure history. The ICD code (8th revision) for asbestosis is 515.2, and is, therefore, part of the broad category "non-malignant respiratory disease" (ICD 460-519). All death certificates within this broad category among Beaumont refinery workers were reviewed, and no asbestosis death was found. However, since certifying physicians might not be aware of the decedents' asbestos exposure (if any), such deaths could have been coded simply as pulmonary fibrosis. Therefore, the category "pulmonary fibrosis" was analyzed. For pulmonary fibrosis (ICD 515-517), there were 4 observed deaths among all male cohort members, compared to 12.0 expected. The corresponding SMR for pulmonary fibrosis was 33 (95% CI: 0-84), which was statistically significant.

As stated above, lung cancer results were provided by the OCMAP program. The results for the overall cohort is presented in Table II and the lung cancer SMR for all males was 92 (95% CI: 78-108). In the 8th revision of ICD, mesothelioma could be coded either as a malignant neoplasm of the peritoneum and retroperitoneal (ICD 158), a respiratory cancer (ICD 162 or 163), a malignant neoplasm of connective and other soft tissue (ICD 171), a malignant neoplasm with unspecified site (ICD 199), or a benign digestive system (ICD 211) or respiratory tumor (ICD 212, 215, or 228). Death certificates with the above ICD codes among Beaumont refinery workers were reviewed to identify all malignant or benign mesotheliomas. One death listed as "mesothelioma" (ICD 163.0) was identified. Based on national mortality rates [Connelly et al., 1987], 3.1 deaths from mesothelioma were expected (SMR=32, 95% CI: 0-179).

Mortality by Job Category

Mortality analyses by job category are presented in Tables XI and XII. A total of 1,240 male employees were classified as operators. The SMR for overall mortality among these operators was 66 (95% CI: 60-72), and that for all cancers was 76 (95% CI: 63-91); both deficits were statistically significant (Table XI). Among operators, no causes of death indicated a significant increase. In contrast, mortality from several malignant and nonmalignant diseases was significantly lower than expected.

Analysis of cause-specific SMRs for the 5,360 maintenance craftworkers is shown in Table XII. The SMR for overall mortality was 91 (95% CI: 87-96), and that for all cancers was 113 (95% CI: 101-125); both were statistically significant. Unlike findings among operators, mortality for maintenance craftworkers was significantly higher than expected for prostate cancer (SMR=145, 95% CI: 107-194), leukemia (SMR=179, 95% CI:111-273) and the heterogeneous category of other lymphatic tissue cancer (SMR=233, 95% CI: 138-368). Lung cancer mortality was slightly elevated (SMR=120, 95% CI: 99-145), with borderline statistical significance. Also, mortality from senility and ill-defined conditions was significantly elevated (SMR=184, 95% CI: 135-246). Further analyses for selected causes of death (Table XIII) showed significant elevations for the above malignant causes were restricted to maintenance craftworkers hired before 1950; the SMR for prostate cancer was 140 (95% CI: 102-189), and that for leukemia was 183 (95% CI: 110-285). For other lymphatic tissue cancer, a higher significant excess occurred among workers hired during or after 1950 (SMR=443, 95% CI: 121-1134), although it was based on only 4 observed deaths.

Table XIV shows the mortality analyses for specific subcategories of hematopoietic cancers among maintenance craftworkers. There were 7 AML deaths, compared to 3.6 expected (SMR=196, 95% CI: 78-408). When the AML data were analyzed by duration of employment in maintenance jobs, no upward trend was detected (X^2 =0.33). There was also a non-significant increase in NHL (16 observed v. 9.5 expected, SMR=168, 95% CI: 96-273). The highest NHL SMR occurred among workers with the shortest duration of maintenance jobs. No upward trend in NHL by duration of maintenance jobs was found (X^2 =0.70). There were 6 MM deaths, slightly more than the 4.4 expected. The corresponding MM SMR of 137 was not significant, and no upward trend by duration of maintenance jobs was observed (X^2 =0.78).

Because maintenance craftworkers were likely to have been exposed to asbestos at the refinery in the past, an analysis of asbestos-related diseases was performed for this subcohort. No death was attributed to asbestosis. For the more general category of pulmonary fibrosis (ICD-8, 515-517), there were 4 observed deaths, compared to 6.43 expected (SMR=63, 95% CI: 17-160). One death was attributed to mesothelioma, whereas 1.84 were expected. For lung cancer, there were 109 deaths among the maintenance craftworker subcohort, compared to 90.8 expected. The corresponding lung cancer SMR of 120 was borderline significant (95% CI: 99-145). A detailed analysis of lung cancer by duration of employment in maintenance jobs

and by first year in a maintenance job is presented in Table XV. A significant increase in lung cancer was observed for workers with 20-29 years of employment in maintenance jobs (46 observed v. 29.8, SMR=154, 95% CI: 113-206). However, there was no upward trend of lung cancer mortality by duration of maintenance jobs (X^2 =1.85). In terms of first year in a maintenance job, only those workers hired between 1940-49 showed a significant increase of lung cancer (43 observed v. 30.5 expected, SMR=141, 95%CI: 102-190). In contrast, there were only 3 lung cancer deaths among those who were hired in or after 1950, compared to 9.3 expected, and the deficit was significant (SMR=32, 95% CI: 7-95).

DISCUSSION

In the discussion below, we will first compare some major results in the updated study to those previously reported for the original Beaumont cohort by Morgan and Wong [1984]. We will then discuss several specific findings in the updated study which are of particular interest in epidemiologic studies of refinery workers.

Extended enrollment and follow-up in this update on Beaumont refinery workers added 980 workers (+16%), 43,072 person-years (+35%) and 712 additional deaths (+45%). In the previous analysis 26% were deceased compared to 36% in this update. Updated results for the total cohort were consistent with the earlier report which demonstrated a favorable overall mortality experience of the Beaumont refinery workers. Based on national rates, the updated SMR of 82 for all causes showed a significant deficit similar to that previously observed (SMR = 81, 95% CI = 77-85). As in the previous study, the favorable overall mortality experience of these refinery workers might be attributed to the "healthy worker effect," whereby working populations exhibit decreased mortality due to initial selection into the workplace and maintenance of this healthier status through benefits derived from employment.

The earlier report showed statistically significant deficits for a variety of non-cancer categories: infective and parasitic diseases, circulatory system diseases, nonmalignant respiratory disease (specifically, pneumonia), diseases of the digestive system, diseases of the genito-urinary system, as well as accidents, poisonings and violence. These significant deficits were also observed in updated study. While the earlier study reported an elevated nonsignificant SMR of 145 (95% CI: 90-222) for senility and ill-defined conditions among white males, the update showed a significant SMR of 255 (95% CI: 192-333). This finding is consistent with

elevations reported for this category in other industrial studies in this region of the U.S. and is explainable by local death certification practices [Bond et al., 1985; Olsen et al., 1994].

The updated SMR of 92 for all cancers for the total cohort was slightly lower than that originally reported (SMR=96, 95% CI: 86-107), and neither was statistically significant. A significant deficit for liver cancer was reported in the update. Mortality from lymphatic and hematopoietic cancers was the only significantly elevated cancer finding in both reports. However, in the earlier report, the elevation was primarily attributed to a significant excess of leukemia (SMR=173, 95% CI: 109-260), whereas the updated results showed a significant excess only in the subcategory of other lymphatic tissue cancer (SMR=158, 95% CI: 101-235). SMRs were lower in the update for the two subcategories of lymphosarcoma and reticulosarcoma and leukemia. In particular, the excess for lymphosarcoma and reticulosarcoma reported in the earlier study was no longer present in the update. Furthermore, mortality from leukemia in the update was no longer significantly elevated.

In comparing the results in the updated study of the Beaumont refinery workers to results from other previous studies of refinery workers, we will concentrate on a number of cancer sites of interest. Some of the previous epidemiologic studies of refinery workers have focused attention on the following cancers: skin, brain or central nervous system, stomach, pancreas, kidney, bone, lung, colon, prostate and lymphopoietic cancers (especially leukemia).

Updated results for Beaumont refinery workers indicated that their mortality from skin, brain, pancreas, kidney, bone, and colon cancers was similar to that in the general population. In addition, there was no relationship or pattern between mortality from these cancers and duration of employment or interval since hire. These findings from the updated Beaumont refinery study were consistent with the conclusion regarding these cancer sites in a comprehensive review conducted by Wong and Raabe [1989].

With regard to prostate cancer, a statistically significant increase was reported among male maintenance craftworkers (SMR=145, 95% CI: 107-194), with SMRs of comparable magnitude reported for white males (SMR=147, 95% CI: 97-209) and nonwhite males (SMR=143, 95% CI: 82-233). However, a formal trend analysis showed no relationship between prostate cancer and employment duration among white males (X^2=1.44) or nonwhite males (X^2=0.57). This finding together with reports of no apparent prostate cancer excess in other refinery studies of maintenance workers [Divine and Barron, 1986; Wong et al., 1986; Tsai et al., 1996] suggests that the excess is not likely related to employment in maintenance

jobs. It should be noted that a number of risk factors for prostate cancer have been suggested by epidemiologic studies including work in the cadmium industry, dietary fat intake, hormones, and sexual habits (Workshop Conference on the Role of Metals in Carcinogenesis, 1981; Heshmat et al. 1985; Kolonel et al. 1988; Mettlin et al. 1989; Hill et al. 1982; Ross et al. 1987; Steele et al. 1971; Krain 1974]. Unfortunately, no information on these potential risk factors was available in the present investigation.

With regard to stomach cancer, a statistically significant increase was reported among nonwhite males who were employed for less than 10 years at the Beaumont refinery. This increase was based on only 3 observed deaths (SMR=640, 95% CI: 132-1871). On the other hand, among nonwhite males with more than 30 years of employment at the refinery, mortality from stomach cancer was less than expected (SMR=78 based on 4 observed deaths). The lack of a relationship between stomach cancer mortality and duration of employment argued against an interpretation that the excess among nonwhite males was related to employment at the refinery. Furthermore, the absence of any increase in mortality from stomach cancer among white males supported our interpretation, which was also consistent with the conclusion regarding stomach cancer in a comprehensive review by Wong and Raabe [1989].

For all males in the updated Beaumont refinery study, a borderline significant mortality increase in lymphatic and hematopoietic cancers was found (SMR=135, 95% CI: 102-176). This excess could be attributed to elevations in leukemia (SMR=143, 95% CI: 95-207) and in other lymphatic tissue cancer (SMR=156, 95% CI: 99-234), which were of borderline significance. This was also the case for male maintenance craftworkers, who experienced a significant increase for lymphatic and hematopoietic cancers (SMR=160, 95% CI: 117-215). This excess was attributed to significant increases in leukemia (SMR=179, 95% CI: 111-273) and the heterogeneous group of other lymphatic tissue cancer (SMR=233, 95% CI: 138-368).

However, the data for all males and the subcohort of craftworkers indicated that the overall leukemia excess peaked during the 1960s and 1970s, and was no longer elevated post-1980. This temporal pattern suggested that the excess observed prior to 1980 was among workers hired in earlier years (prior to 1950), when historical exposures at the refinery might be different from exposures in later years. Substantially lower leukemia mortality was detected among workers hired in or after 1950. A similar observation was made in a comprehensive review of refinery workers [Wong and Raabe, 1989]. Although the present study stops at the end of 1987, this trend of reduced leukemia mortality in the 1980s has been

noted in other studies of workers in the petroleum industry (Honda et al., 1995). With regard to specific job categories at refineries, other studies reported essentially no association between leukemia and maintenance jobs [Divine and Barron, 1986; Wong et al., 1986; Tsai et al., 1996]

Although a borderline significant increase was reported for the heterogeneous category of other lymphatic tissue cancer, the absence of any trend in SMR with increasing duration of employment (X^2=1.68 and 2.63 in white and nonwhite males, respectively) and an apparent inverse relationship with time since hire were inconsistent with the hypothesis that the excess was the result of exposures at the refinery. Furthermore, a review of the work histories of the 23 decedents showed no indication of common job assignments.

Although the excess of other lymphatic tissue cancer was more pronounced and statistically significant among maintenance craftworkers (SMR=233, 95% CI: 138-368), the lack of any trend in SMR with increase in duration of maintenance employment does not support a connection with employment in craft jobs. Also, no other studies of refinery workers have reported excesses for other lymphatic tissue cancer in relation to work in maintenance jobs [Divine and Barron, 1986; Wong et al., 1986; Tsai et al., 1996]. Finally, it is interesting to note that operators had a leukemia mortality experience similar to the general population (SMR=94, 95% CI: 31-220). This suggests that their benzene exposures were controlled below levels at which leukemia risk would be increased.

To further analyze mortality data for lymphatic and hematopoietic cancers, analyses for major cell-type specific leukemias (AML, CML, ALL and CLL), NHL and MM were performed. Mortality from AML was elevated (SMR=136, 95% CI: 59-268, 8 observed deaths versus 5.9 expected), but the increase was not significant. Seven of the 8 AML decedents were hired prior to 1950, including 4 in or prior to the 1930s (7 observed versus 5.0 expected, SMR=140, 95% CI: 56-289). The remaining AML case, who was hired in 1974 and terminated in 1975, died in 1976 at age 23. Based on a consideration of the extremely short latency of two years alone, this AML case could not have been related to employment at the refinery. Indeed, given the average survival of AML, the diagnosis in this short-term employee was most likely made either before or around the time when he was hired at the refinery. The AML data again supported the conclusion that no increase occurred among workers hired in or after 1950. Observed mortality from ALL and CLL was lower than expected, and for CML the observed mortality was similar to expected. Thus, cell-type specific analyses demonstrated that there was no increase in CML, ALL or CLL among workers at the Beaumont refinery.

These results are consistent ... Rinsky & Wong 1996

An increase in mortality was found for NHL among male employees (SMR=140, 95% CI: 88-211), but the increase did not reach statistical significance. Unlike AML, analysis of NHL by hire date did not show any significant difference between those hired prior to 1950 (18 observed versus 13.7 expected, SMR=132, 95% CI: 78-209) and those hired thereafter (4 observed versus 2.1 expected, SMR=193, 95% CI: 23-697). This pattern appeared to indicate that the NHL increase was not related to presumed higher levels of exposure in the earlier employment period (i.e. , <1950). Other studies of refinery workers, which reported NHL as a separate disease category, did not find any association between NHL and refinery employment. A recently completed study of workers at the Mobil Torrance refinery [Milcarek et al., 1994] reported an SMR of 120 (4 observed versus 3.3 expected, 95% CI: 33-307). A study at the Mobil Paulsboro refinery [Collingwood et al., 1996] reported no significant increase of NHL (15 observed vs. 11.4 expected, SMR=132, 95% CI:74-217). Similarly, a recently completed large-scale study of refinery workers in Port Arthur, Texas, reported an SMR for NHL of 71 based on 30 observed NHL deaths [Satin et al., 1996]. Thus, collectively (total observed = 71, total expected = 72.7) these four studies support the interpretation that the nonsignificant increase of NHL among Beaumont refinery workers was not occupationally related. Epidemiologic studies have identified several potential risk factors for NHL, including autoimmune diseases, viruses, chemotherapy and radiation therapy, ionizing radiation, a history of diabetes, tuberculosis or malaria, working or living on a farm, a family history of cancer, and cigarette smoking [Wilson et al., 1991; Franceschi et al., 1989; Cartwright et al., 1988; Vianna and Polan, 1979; Schumacher, 1985; Schumacher and Delzell, 1988; McDonald, 1987; Hoar et al., 1985; Zahm et al., 1989; Woods et al., 1987; Pearce et al., 1987]. Unfortunately, no information on these potential risk factors was available for the NHL cases in this study.

Mortality from MM among male workers at the Beaumont refinery was slightly, but not significantly, elevated (9 observed versus 7.45 expected, SMR=121, 95% CI: 55-230). This small increase was well within expectation based on U.S. rates, and did not indicate any association between the disease and employment at the refinery. Similarly, other studies of refinery workers, in which MM was analyzed as a separate disease category, did not find any association between MM and refinery employment. The SMRs for MM were 128 (95% CI: 15-462) at the Torrance refinery, 74 (95% CI: 20-190) at the Paulsboro refinery, and 98 (95% CI: 59-153) at the Port Arthur refinery [Milcarek et al., 1994; Collingwood et al., 1994; Satin et al.,

1996]. Collectively, these studies do not support a relationship between refinery employment and MM.

Similar to other industrial facilities, asbestos was used at the Beaumont refinery in the past, and detailed analyses of asbestos-related diseases were performed for the overall cohort as well as for the maintenance craftworker subcohort. Although specific exposure measurements were not available, data from the industry as a whole have indicated that asbestos concentrations at refineries were generally extremely low [IARC, 1989]. Among the Beaumont refinery employees, no asbestosis death was reported, and mortality from pulmonary fibrosis was significantly lower than expected. One death was attributed to malignant mesothelioma in the overall cohort , whereas 3.1 deaths were expected.

In the overall cohort, lung cancer mortality was similar to expected. Furthermore, analysis by duration of employment among males did not show any upward trend in lung cancer risk. Thus, the data indicated that there was no relationship between lung cancer mortality and employment at the Beaumont refinery for the overall cohort. A comprehensive review by Wong and Raabe [1989] reached a similar conclusion on lung cancer and employment at refineries.

For male maintenance craftworkers, there was a small increase in lung cancer (SMR=120, 95% CI: 99-145), which was borderline significant. Detailed analysis indicated that the significant lung cancer increase was primarily restricted to maintenance craftworkers hired during 1940-49. Several investigators have suggested that workers hired during the same time period (the "war years") were in general less healthy (Doll 1988, Enterline 1988, Choi 1992). Furthermore, trend analyses showed no relationship with duration of employment in maintenance jobs. A complete evaluation of the lung cancer issue requires information on smoking and employment outside the petroleum industry which might entail potential exposure to asbestos and other carcinogens. Unfortunately, such information is not available in the present study. Nevertheless, it should also be pointed out that other refinery studies showed no association between lung cancer and work in maintenance jobs [Divine and Barron, 1986; Wong et al., 1986; Tsai et al. 1996].

In closing, it should be pointed out that there are some potential limitations in this study. Most are typical of a historical mortality study of industrial populations. First, although both the percentages of individuals with unknown vital status (2%) and the proportion of outstanding death certificates (2%) were low, it was possible that some deaths from causes of interest

might have been missed. We do not believe that such low percentages would have any significant impact on our results.

Second, the health endpoint in our study was mortality, which is a reasonable surrogate for incidence of most cancers. However, being a mortality study, the investigation inherited the problems associated with death certificates (diagnostic accuracy, for example). No detailed clinical information was available on the deaths in our study. However, it must be pointed out that although detailed information derived from medical records or pathology reports may be more accurate than that based on death certificates, it would be inappropriate to use such information in a historical cohort mortality study. In our study we compared diagnoses based on death certificates to national statistics which were derived from death certificates as well. Furthermore, our analysis was adjusted for calendar time, thus at least partially controlling for changes in survival and diagnostic practices.

As in most historical cohort mortality studies, little quantitative exposure data were available during the early part of the study, and analyses by quantitative exposure indices were not possible. In the present study, we relied on duration of employment, period of first exposure as well as the broad classification of jobs (operators and maintenance craftworkers). Such exposure surrogates might lack both sensitivity and specificity.

Although several additional detailed analyses were performed for both white and non-white male employees, the number of deaths among white female employees remained small and it was not meaningful to perform similar detailed statistical analyses for the latter in this update. Furthermore, also due to small numbers, no statistical analyses were performed for nonwhite females. Hopefully, by periodically updating and expanding the cohort, the number will be adequate for detailed statistical analyses among female employees in the future.

Finally, information on lifestyle as well as on employment elsewhere was not available, although such information would be extremely helpful in interpreting some of the findings in the present study. For example, information on smoking as well as employment elsewhere with potential exposure to asbestos and other carcinogens would be needed in a complete evaluation of the lung cancer issue.

CONCLUSION

This updated study has confirmed earlier findings of an overall favorable mortality experience of employees at the Beaumont, Texas refinery compared to the U.S. general

population. In addition, significant mortality deficits were found for several causes of death. No significant increase was detected in any cause-specific mortality, except for the heterogeneous category of other lymphatic tissue cancer. A non-significant increase in leukemia was also observed. However, detailed analyses indicated that the excess was restricted to workers hired prior to 1950, and that the excess appeared to have peaked in the 1960s. Detailed analyses by specific leukemia cell-types indicated a similar pattern for acute myeloid leukemia, but no increase was detected for other leukemia cell-types. No cause-specific mortality was found to be associated with duration of employment at the refinery, including several causes which have been reported to be elevated in some previous studies.

Subcohort analyses by job category showed mortality patterns in operators which were generally more favorable than the total cohort. On the other hand, statistically significant increases in mortality occurred among maintenance craftworkers for prostate cancer, leukemia, and the heterogeneous category other lymphatic tissue cancer. Also, a small increase in lung cancer was seen. Analyses of the temporal patterns of these SMRs along with findings from other studies of similar cohorts provided evidence that the excesses were most likely to be unrelated to work in maintenance craftsman jobs.

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Table I. Characteristics of the Beaumont, Texas Cohort

	N	%Total
Total Employees	7,119	100.0
Total Person-years	166,427	100.0
Race		
White	5,544	77.9
Nonwhite	1,204	16.9
Unknown	371	5.2
Sex		
Male	6,482	91.1
Female	637	8.9
Year of hire		
Before 1950	3,647	51.2
1950+	3,472	48.8
Duration of employment (yr)		
<10	2,409	33.8
10-29	2,569	36.1
30+	2,141	30.1
Age at hire		
<20	959	13.5
20-39	5,613	78.8
40+	547	7.7
Age at death		
<50	205	8.9
50-59	342	14.9
60-69	677	29.5
70+	1,070	46.6
Total Deaths	2,294	100.0

Table II. Observed and Expected Deaths by Cause for the Beaumont Refinery Cohort

Number of Persons: 7,119 — Person Years: 166,427

Cause of Death (8th ICDA)	Observed Deaths	Expected Deaths	SMR		Confidence Limits Lower	Upper
All Causes (001-999)	2,294	2,782.5	82	**	79	86
Infective & Parasitic Diseases (001-139)	18	51.5	35	**	21	55
All Cancers (140-209)	513	559.0	92		84	100
Cancer of Buccal Cavity and Pharynx (140-149)	4	15.8	25	**	7	65
Cancer of Digestive System (150-159)	129	163.7	79	**	66	94
Cancer of Esophagus (150)	10	15.8	63		30	116
Cancer of Stomach (151)	32	33.8	95		65	134
Cancer of Large Intestine (153)	40	50.9	79		56	107
Cancer of Rectum (154)	5	16.2	31	**	10	72
Cancer of Liver (155-156)	5	13.3	38	*	12	88
Cancer of Pancreas (157)	31	29.7	105		71	148
Cancer of Respiratory System (160-163)	158	175.3	90		77	105
Cancer of Larynx (161)	3	7.9	38		8	111
Cancer of Lung (162-163)	155	165.7	94		79	110
Cancer of Bone (170)	0	2.2	0		---	---
Cancer of Skin (172-173)	9	8.1	111		51	211
Cancer of Breast (174)	7	3.8	185		74	382
Cancer of Prostate (185)	53	54.6	97		73	127
Cancer of Testis (186-187)	1	2.3	44		1	247
Cancer of Bladder (188)	11	17.2	64		32	115
Cancer of Kidney (189)	8	12.1	66		29	130
Cancer of Brain and CNS (191-192)	12	12.0	100		52	175
Lymphatic & Hematopoietic Cancer (200-209)	65	48.7	133	*	103	170
Lymphosarcoma and Reticulosarcoma (200)	9	8.6	105		48	199
Hodgkin's Disease (201)	3	4.5	66		14	194
Leukemia & Aleukemia (204-207)	28	20.1	139		92	201
Other Lymphatic Tissue Cancer (202, 203, 208)	24	15.2	158	*	101	235
Benign Neoplasms (210-239)	5	7.1	70		23	164
Diabetes Mellitus (250)	32	41.4	77		53	109
Diseases of Blood (280-289)	4	7.0	57		16	146
Diseases of Nervous System (320-389)	23	24.9	93		59	139
Diseases of Circulatory System (390-458)	1,246	1,454.9	86	**	81	91
Chronic Rheumatic Heart Disease (393-398)	12	20.7	58		30	101
Arteriosclerotic Heart Disease (410-413)	815	926.1	88	**	82	94
Vascular Lesions of CNS (430-438)	191	228.3	84	*	72	96
Nonmalignant Respiratory Disease (460-519)	101	184.8	55	**	45	66
Pneumonia (480-486)	35	74.4	47	**	33	65
Emphysema (492)	37	33.5	111		78	152
Diseases of Digestive System (520-577)	70	112.1	62	**	49	79
Cirrhosis of Liver (571)	20	50.8	39	**	24	61
Diseases of Genito-Urinary System (580-629)	25	54.5	46	**	30	68
Senility & Ill-Defined Conditions (780-799)	63	38.0	166	**	127	212
Accidents, Poisonings, & Violence (800-998)	123	206.1	60	**	50	71
Accidents (800-949)	82	135.8	60	**	48	75
Motor Vehicle Accidents (810-827)	32	58.6	55	**	37	77
Suicide (950-959)	28	41.3	68	*	45	98

* Statistically significant at 0.05 level

** Statistically significant at 0.01 level

Table III. Observed and Expected Deaths by Cause for White Male Employees in the Beaumont Refinery Cohort

Number of Persons: 5,346 — Person Years: 129,793

Cause of Death (8th ICDA)	Observed Deaths	Expected Deaths	SMR		95% Confidence Limits Lower	Upper
All Causes (001-999)	1,794	2,135.4	84	**	80	88
Infective & Parasitic Diseases (001-139)	13	29.8	44	**	23	75
All Cancers (140-209)	381	433.7	88	*	79	97
Cancer of Buccal Cavity and Pharynx (140-149)	3	12.4	24	*	5	71
Cancer of Digestive System (150-159)	93	124.1	75	**	61	92
Cancer of Esophagus (150)	9	10.1	89		41	170
Cancer of Stomach (151)	19	23.3	82		49	128
Cancer of Large Intestine (153)	30	41.5	72		49	103
Cancer of Rectum (154)	3	13.3	23	**	5	66
Cancer of Liver (155-156)	3	9.7	31	*	6	90
Cancer of Pancreas (157)	24	23.1	104		67	154
Cancer of Respiratory System (160-163)	120	142.5	84		70	101
Cancer of Larynx (161)	3	6.1	49		10	143
Cancer of Lung (162-163)	117	134.9	87		72	104
Cancer of Bone (170)	0	1.8	0		---	---
Cancer of Skin (172-173)	8	7.3	110		48	217
Cancer of Prostate (185)	37	37.6	98		69	136
Cancer of Testis (186-187)	0	1.8	0		---	---
Cancer of Bladder (188)	9	14.4	63		29	119
Cancer of Kidney (189)	7	10.3	68		27	140
Cancer of Brain and CNS (191-192)	10	10.6	95		45	174
Lymphatic & Hematopoietic Cancer (200-209)	54	40.2	134	*	101	175
Lymphosarcoma and Reticulosarcoma (200)	7	7.4	95		38	196
Hodgkin's Disease (201)	3	3.8	79		16	230
Leukemia & Aleukemia (204-207)	24	16.9	142		91	211
Other Lymphatic Tissue Cancer (202, 203, 208)	19	11.9	160		96	249
Benign Neoplasms (210-239)	4	5.4	74		20	188
Diabetes Mellitus (250)	22	30.6	72		45	109
Diseases of Blood (280-289)	3	5.3	56		12	165
Diseases of Nervous System (320-389)	19	19.3	99		59	154
Diseases of Circulatory System (390-458)	999	1,140.2	88	**	82	93
Chronic Rheumatic Heart Disease (393-398)	9	16.5	55		25	104
Arteriosclerotic Heart Disease (410-413)	677	774.6	87	**	81	94
Vascular Lesions of CNS (430-438)	142	158.3	90		76	106
Nonmalignant Respiratory Disease (460-519)	80	146.1	55	**	43	68
Pneumonia (480-486)	26	53.8	48	**	32	71
Emphysema (492)	31	29.7	104		71	148
Diseases of Digestive System (520-577)	55	88.3	62	**	47	81
Cirrhosis of Liver (571)	18	41.0	44	**	26	69
Diseases of Genito-Urinary System (580-629)	13	33.6	39	**	21	66
Senility & Ill-Defined Conditions (780-799)	54	21.2	255	**	192	333
Accidents, Poisonings, & Violence (800-998)	100	153.1	65	**	53	79
Accidents (800-949)	68	103.8	66	**	51	83
Motor Vehicle Accidents (810-827)	25	45.8	55	**	35	81
Suicide (950-959)	26	37.2	70		46	103

* Statistically significant at 0.05 level

** Statistically significant at 0.01 level

Table IV. Observed Deaths, SMRs and 95% CI for Selected Causes of Death Among All Male Employees in the Beaumont Refinery Cohort by Length of Employment

	Length of Employment (Years)								
	< 10			10-29			30+		
Cause of Death (8th ICDA)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)
All Causes	300	83 **	(74-93)	886	81 **	(75-86)	1056	84 **	(79-89)
All Cancers (140-209)	60	89	(68-115)	185	87	(75-100)	245	93	(82-106)
Cancer of Digestive System (150-159)	20	113	(69-175)	37	58 **	(41-80)	66	85	(65-108)
Cancer of Esophagus (150)	1	61	(2-175)	4	62	(17-160)	5	66	(21-153)
Cancer of Stomach (151)	6	181	(67-395)	11	78	(39-139)	15	94	(53-156)
Cancer of Large Intestine (153)	4	70	(19-180)	8	42 **	(18-84)	23	93	(59-139)
Cancer of Rectum (154)	1	57	(1-317)	3	46	(10-135)	1	13 **	(0-73)
Cancer of Liver (155-156)	1	69	(2-382)	1	19	(1-106)	2	32	(4-115)
Cancer of Pancreas (157)	6	181	(66-393)	9	79	(36-149)	16	113	(64-183)
Cancer of Respiratory System (160-163)	18	80	(47-126)	64	95	(73-122)	72	87	(68-109)
Cancer of Lung (162-163)	18	84	(50-133)	63	100	(77-127)	70	88	(69-112)
Cancer of Skin (172-173)	3	190	(39-554)	4	126	(34-324)	2	65	(8-235)
Cancer of Prostate (185)	1	28	(1-153)	16	82	(47-133)	36	115	(80-159)
Cancer of Bladder (188)	0	0	—	7	108	(43-222)	4	45	(12-114)
Cancer of Kidney (189)	1	60	(2-333)	3	63	(13-184)	4	74	(20-190)
Cancer of Brain and CNS (191-192)	0	0	—	6	121	(44-262)	5	123	(40-287)
Lymphatic and Hematopoietic Cancer (200-209)	9	119	(55-227)	25	134	(87-198)	29	137	(92-197)
Lymphosarcoma and Reticulosarcoma (200)	0	0	—	5	142	(46-332)	3	85	(18-249)
Hodgkin's Disease (201)	0	0	—	2	104	(13-376)	1	80	(2-446)
Leukemia& Aleukemia (204-207)	5	165	(54-385)	8	105	(45-207)	15	168	(94-277)
Other Lymphatic Tissue Cancer (202, 203, 208)	4	204	(56-521)	9	165	(75-313)	10	137	(66-251)
Benign Neoplasms (210-239)	0	0	—	3	105	(22-306)	2	71	(9-258)
Diseases of Blood (280-289)	2	196	(24-708)	1	36	(1-202)	1	33	(1-185)
Diseases of Circulatory System (390-458)	133	89	(74-105)	470	82 **	(75-90)	630	89 **	(82-96)
Arteriosclerotic Heart Disease (410-413)	89	89	(72-110)	320	88 *	(79-99)	401	89 *	(80-98)
Nonmalignant Respiratory Disease (460-519)	9	46 *	(21-88)	46	66 **	(48-88)	45	49 **	(35-65)
Pneumonia (480-486)	3	40	(8-116)	12	42 **	(21-73)	19	52 **	(31-81)
Emphysema (492)	2	66	(8-238)	21	167 *	(104-256)	14	80	(44-134)
Diseases of Digestive System (520-577)	9	51 *	(23-96)	37	76	(54-105)	23	53 **	(34-80)
Cirrhosis of Liver (551)	7	72	(29-148)	7	31 **	(12-63)	6	36 **	(13-78)
Accidents, Poisonings, & Violence (E800-E998)	34	49 **	(34-69)	55	65 **	(49-85)	33	67 *	(46-94)
Accidents (800-949)	24	55 **	(35-82)	36	65 **	(46-90)	22	63 *	(40-96)
Motor Vehicle Accidents (810-827)	11	50 *	(25-89)	11	48 **	(24-86)	10	81	(39-150)
Suicide (950-959)	7	55	(22-113)	11	64	(32-114)	9	87	(40-165)
Number of Persons at Risk	5,054			4,444			2,104		
Number of Person-Years	57,887			64,849			32,356		

* Statistically significant at 0.05 level
** Statistically significant at 0.01 level

Table V. Observed Deaths, SMRs and 95% CI for Selected Causes of Death Among White Male Employees in the Beaumont Refinery Cohort by Length of Employment

	Length of Employment (Years)								
	< 10			10-29			30+		
Cause of Death (8th ICDA)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)
All Causes	273	87 *	(77-98)	703	84 **	(78-90)	818	83 **	(78-89)
All Cancers (140-209)	53	84	(63-110)	149	89	(75-104)	179	88	(76-102)
Cancer of Digestive System (150-159)	15	93	(52-153)	27	55 **	(36-80)	51	86	(64-114)
Cancer of Esophagus (150)	0	0	---	4	101	(28-259)	5	107	(35-249)
Cancer of Stomach (151)	3	106	(22-309)	5	52	(17-121)	11	102	(51-182)
Cancer of Large Intestine (153)	4	74	(20-190)	7	44 *	(18-91)	19	94	(56-146)
Cancer of Rectum (154)	1	61	(2-341)	2	37	(5-134)	0	0 **	---
Cancer of Liver (155-156)	1	79	(2-438)	1	26	(1-145)	1	22	(1-121)
Cancer of Pancreas (157)	5	160	(52-374)	8	88	(38-174)	11	101	(50-180)
Cancer of Respiratory System (160-163)	17	79	(46-127)	54	98	(74-128)	49	74 *	(55-98)
Cancer of Lung (162-163)	17	83	(48-133)	53	102	(76-133)	47	75	(55-100)
Cancer of Skin (172-173)	3	195	(40-569)	3	103	(21-301)	2	71	(9-257)
Cancer of Prostate (185)	1	30	(1-169)	13	98	(52-168)	23	109	(69-164)
Cancer of Bladder (188)	0	0	---	5	93	(30-216)	4	53	(15-136)
Cancer of Kidney (189)	1	63	(2-350)	3	73	(15-213)	3	66	(14-191)
Cancer of Brain and CNS (191-192)	0	0	---	5	111	(36-258)	5	137	(45-320)
Lymphatic and Hematopoietic Cancer (200-209)	8	114	(49-224)	23	147	(93-220)	23	132	(84-198)
Lymphosarcoma and Reticulosarcoma (200)	0	0	---	5	163	(53-381)	2	66	(8-237)
Hodgkin's Disease (201)	0	0	---	2	122	(15-442)	1	95	(2-527)
Leukemia& Aleukemia (204-207)	4	142	(39-365)	6	92	(34-200)	14	186 *	(101-311)
Other Lymphatic Tissue Cancer (202, 203, 208)	4	216	(59-553)	9	206	(94-392)	6	106	(39-230)
Benign Neoplasms (210-239)	0	0	---	2	89	(11-323)	2	92	(11-331)
Diseases of Blood (280-289)	2	247	(30-892)	0	0	---	1	42	(1-234)
Diseases of Circulatory System (390-458)	123	90	(75-107)	374	84 **	(76-93)	502	90 *	(82-98)
Arteriosclerotic Heart Disease (410-413)	84	88	(71-109)	266	88 *	(77-99)	327	87 *	(78-97)
Nonmalignant Respiratory Disease (460-519)	8	47 *	(20-93)	37	68 *	(48-94)	35	47 **	(33-65)
Pneumonia (480-486)	2	33	(4-118)	10	50 *	(24-92)	14	51 **	(28-85)
Emphysema (492)	2	68	(8-245)	18	162	(96-225)	11	71	(35-126)
Diseases of Digestive System (520-577)	9	58	(27-110)	29	76	(51-109)	17	49 **	(29-79)
Cirrhosis of Liver (551)	7	82	(33-168)	6	32 **	(12-70)	5	36 *	(12-84)
Accidents, Poisonings, & Violence (E800-E998)	30	56 **	(38-80)	44	71 *	(52-95)	26	69	(45-101)
Accidents (800-949)	22	61 *	(38-92)	30	73	(49-104)	16	62 *	(35-100)
Motor Vehicle Accidents (810-827)	11	58	(29-104)	9	51 *	(24-98)	5	54	(18-126)
Suicide (950-959)	7	60	(24-124)	11	69	(35-124)	8	83	(36-164)
Number of Persons at Risk	4,207			3,569			1,691		
Number of Person-Years	50,631			53,254			25,908		

* Statistically significant at 0.05 level
** Statistically significant at 0.01 level

Table VI. Observed Deaths, SMRs and 95% CI for Selected Causes of Death Among All Male Employees In the Beaumont Refinery Cohort by Time Since First Employment

	Time Since First Employment (Years)								
	< 20			20-39			40+		
Cause of Death (8th ICDA)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)
All Causes	231	62 **	(54-71)	949	78 **	(73-83)	1062	94 *	(88-100)
All Cancers (140-209)	40	71 *	(51-96)	218	84 **	(73-96)	232	103	(90-117)
Cancer of Digestive System (150-159)	14	85	(47-143)	50	65 **	(48-85)	59	89	(68-115)
Cancer of Esophagus (150)	1	65	(2-362)	4	47	(13-121)	5	88	(29-205)
Cancer of Stomach (151)	6	153	(56-333)	12	71	(37-125)	14	111	(61-186)
Cancer of Large Intestine (153)	2	46	(6-166)	9	41 **	(19-77)	24	105	(68-157)
Cancer of Rectum (154)	1	55	(1-308)	2	26 *	(3-94)	2	32	(4-114)
Cancer of Liver (155-156)	1	67	(2-373)	2	31	(4-113)	1	20	(1-110)
Cancer of Pancreas (157)	2	71	(9-258)	16	113	(65-184)	13	108	(57-185)
Cancer of Respiratory System (160-163)	9	56	(25-106)	75	84	(66-105)	70	104	(81-131)
Cancer of Lung (162-163)	9	60	(27-113)	74	88	(69-110)	68	106	(82-134)
Cancer of Skin (172-173)	3	195	(40-568)	5	133	(43-311)	1	40	(1-220)
Cancer of Prostate (185)	2	106	(13-384)	20	105	(64-162)	31	92	(63-131)
Cancer of Bladder (188)	0	0	---	6	83	(30-180)	5	58	(19-136)
Cancer of Kidney (189)	0	0	---	4	66	(18-169)	4	91	(25-234)
Cancer of Brain and CNS (191-192)	2	75	(9-270)	6	98	(36-213)	3	109	(23-319)
Lymphatic and Hematopoietic Cancer (200-209)	8	108	(47-213)	29	136	(91-196)	26	140	(91-205)
Lymphosarcoma and Reticulosarcoma (200)	1	67	(2-373)	3	73	(15-214)	4	145	(40-372)
Hodgkin's Disease (201)	1	62	(2-347)	2	103	(13-374)	0	0	---
Leukemia& Aleukemia (204-207)	2	67	(8-242)	14	165	(90-276)	12	148	(77-259)
Other Lymphatic Tissue Cancer (202, 203, 208)	4	302	(82-773)	9	135	(62-257)	10	148	(71-272)
Benign Neoplasms (210-239)	0	0	---	2	63	(8-228)	3	129	(27-376)
Diseases of Blood (280-289)	0	0	---	3	105	(22-307)	1	36	(1-199)
Diseases of Circulatory System (390-458)	92	64 **	(52-79)	514	81 **	(74-88)	627	96	(89-104)
Arteriosclerotic Heart Disease (410-413)	66	74 *	(57-95)	351	85 **	(77-95)	393	95	(86-105)
Nonmalignant Respiratory Disease (460-519)	3	18 **	(4-54)	42	58 **	(42-78)	55	59 **	(45-77)
Pneumonia (480-486)	2	26 *	(3-94)	9	33 **	(15-62)	23	60 *	(38-90)
Emphysema (492)	0	0	---	17	120	(70-192)	20	120	(73-185)
Diseases of Digestive System (520-577)	10	48 *	(23-89)	35	62 **	(43-87)	24	73	(47-109)
Cirrhosis of Liver (551)	5	46	(15-107)	10	35 **	(17-65)	5	49	(16-113)
Accidents, Poisonings, & Violence (E800-E998)	55	63 **	(48-82)	43	54 **	(39-72)	24	69	(44-103)
Accidents (800-949)	37	67 *	(47-93)	30	57 **	(38-81)	15	59 *	(33-97)
Motor Vehicle Accidents (810-827)	14	50 **	(27-84)	9	42 **	(19-81)	9	111	(51-211)
Suicide (950-959)	12	76	(39-133)	7	39 **	(16-81)	8	119	(51-234)
Number of Persons at Risk	5,601			4,078			2,279		
Number of Person-Years	73,429			62,124			19,539		

* Statistically significant at 0.05 level
** Statistically significant at 0.01 level

Table VII. Observed Deaths, SMRs and 95% CI for Selected Causes of Death Among White Male Employees in the Beaumont Refinery Cohort by Time Since First Employment

	Time Since First Employment (Years)								
	< 20			20-39			40+		
Cause of Death (8th ICDA)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)
All Causes	188	66 **	(57-76)	797	84 **	(78-90)	809	90 *	(84-97)
All Cancers (140-209)	33	69 *	(48-97)	183	88	(76-101)	165	93	(79-108)
Cancer of Digestive System (150-159)	8	61	(26-120)	38	64 **	(45-87)	47	92	(68-123)
Cancer of Esophagus (150)	0	0	---	4	75	(21-193)	5	134	(43-312)
Cancer of Stomach (151)	2	69	(8-249)	6	51	(19-112)	11	127	(63-227)
Cancer of Large Intestine (153)	2	52	(6-189)	8	42 *	(18-84)	20	106	(65-164)
Cancer of Rectum (154)	1	64	(2-355)	1	15 *	(0-86)	1	19	(1-106)
Cancer of Liver (155-156)	1	91	(2-506)	2	42	(5-152)	0	0 *	---
Cancer of Pancreas (157)	2	84	(10-305)	12	106	(55-185)	10	106	(51-195)
Cancer of Respiratory System (160-163)	9	65	(30-123)	66	90	(69-114)	45	82	(60-110)
Cancer of Lung (162-163)	9	69	(32-131)	65	93	(72-119)	43	82	(60-111)
Cancer of Skin (172-173)	3	206	(42-601)	4	115	(31-295)	1	43	(1-239)
Cancer of Prostate (185)	2	139	(17-503)	15	114	(64-188)	20	87	(53-134)
Cancer of Bladder (188)	0	0	---	4	66	(18-169)	5	69	(22-160)
Cancer of Kidney (189)	0	0	---	4	75	(21-193)	3	80	(17-234)
Cancer of Brain and CNS (191-192)	2	81	(10-293)	6	107	(39-233)	2	80	(10-290)
Lymphatic and Hematopoietic Cancer (200-209)	7	108	(43-222)	28	154 *	(102-223)	19	123	(74-191)
Lymphosarcoma and Reticulosarcoma (200)	1	75	(2-416)	3	83	(17-243)	3	125	(26-365)
Hodgkin's Disease (201)	1	70	(2-390)	2	120	(15-435)	0	0	---
Leukemia& Aleukemia (204-207)	1	38	(1-214)	13	177	(94-302)	10	145	(69-266)
Other Lymphatic Tissue Cancer (202, 203, 208)	4	363	(99-929)	9	165	(76-314)	6	112	(41-244)
Benign Neoplasms (210-239)	0	0	---	1	40	(1-222)	3	162	(33-474)
Diseases of Blood (280-289)	0	0	---	2	89	(11-320)	1	44	(1-247)
Diseases of Circulatory System (390-458)	77	67 **	(53-83)	430	85 **	(77-94)	492	95	(86-103)
Arteriosclerotic Heart Disease (410-413)	56	71 **	(54-92)	304	87 *	(77-97)	317	92	(82-103)
Nonmalignant Respiratory Disease (460-519)	1	8 **	(0-47)	36	63 **	(44-87)	43	56 **	(40-75)
Pneumonia (480-486)	1	20	(1-112)	7	37 **	(15-76)	18	61 *	(36-96)
Emphysema (492)	0	0	---	16	126	(72-205)	15	101	(56-166)
Diseases of Digestive System (520-577)	10	62	(30-114)	28	62 **	(41-89)	17	64	(37-102)
Cirrhosis of Liver (551)	5	58	(19-135)	9	38 **	(17-72)	4	46	(13-118)
Accidents, Poisonings, & Violence (E800-E998)	45	70 *	(51-93)	37	60 **	(42-83)	18	67	(40-106)
Accidents (800-949)	31	70 *	(48-100)	27	67 *	(44-98)	10	51 *	(25-94)
Motor Vehicle Accidents (810-827)	12	52 *	(27-91)	8	48 *	(21-95)	5	81	(26-188)
Suicide (950-959)	12	85	(44-148)	7	42 *	(17-86)	7	112	(45-231)
Number of Persons at Risk	4,656			3,443			1,825		
Number of Person-Years	62,035			52,135			15,623		

* Statistically significant at 0.05 level

** Statistically significant at 0.01 level

Table VIII. Observed and Expected Deaths and SMRs by Decade of and Age at Death for White and Nonwhite Males

Leukemia

Decade of Death	Age at Death		White Males O	White Males E	White Males SMR		NonWhite Males O	NonWhite Males E	NonWhite Males SMR
1950s	< 65		3	1.71	175		0	0.32	0
	65+		0	0.56	0		0	0.10	0
		Total	3	2.27	132		0	0.42	0
1960s	<65		3	1.94	155		1	0.30	333
	65+		7	1.87	374	**	0	0.33	0
		Total	10	3.81	263	*	1	0.63	159
1970s	<65		2	1.80	111		1	0.28	357
	65+		8	3.44	233	*	1	0.56	179
		Total	10	5.24	191		2	0.84	238
1980s	<65		0	1.46	0		0	0.20	0
	65+		1	3.62	28		1	0.52	192
		Total	1	5.08	20		1	0.72	139
		TOTAL	24	16.89	142		4	2.70	148

"Other Lymphatic Tissue" Cancer

Decade of Death	Age at Death		White Males O	White Males E	White Males SMR		NonWhite Males O	NonWhite Males E	NonWhite Males SMR	
1950s	< 65		1	0.73	137		0	0.26	0	
	65+		0	0.15	0		1	0.02	5000	*
		Total	1	0.88	114		1	0.28	357	
1960s	<65		0	0.83	0		0	0.29	0	
	65+		3	0.82	366		1	0.26	385	
		Total	3	1.65	182		1	0.55	182	
1970s	<65		5	1.46	343	*	0	0.30	0	
	65+		1	2.42	41		1	0.66	152	
		Total	6	3.88	155		1	0.96	104	
1980s	<65		4	1.65	242		0	0.28	0	
	65+		5	3.82	131		1	0.77	130	
		Total	9	5.47	165		1	1.05	95	
		TOTAL	19	11.90	160		4	2.85	140	

* Statistically significant at 0.05 level
** Statistically significant at 0.01 level

Table IX. Observed and Expected Deaths from Lymphatic and Hematopoietic Cancers Among All Males by Year of First Employment (<1950, 1950+)

	Year of First Employment								
	< 1950			1950+			Total		
Cause of Death (8th ICDA) (95%)	Obs	Expected	SMR (95% CI)	Obs	Expected	SMR (95% CI)	Obs	Expected	SMR (95% CI)
All Lymphopoietic Cancer	55	40.8	135* (102-176)	8	6.6	122 (53-241)	63	47.3	133* (102-170)
Lymphosarcoma & Reticulosarcoma	8	7.3	110 (48-217)	0	0	---	8	8.3	96 (41-189)
Hodgkin's Disease	3	3.5	85 (18-249)	0	0	---	3	4.4	68 (14-200)
Leukemia	25	17.0	147 (95-217)	3	2.6	117 (24-343)	28	19.6	143 (95-207)
Other Lymphatic Tissue	18	12.7	141 (84-224)	5	2.0	248 (80-578)	23	14.8	156 (99-234)

* Statistically significant at 0.05 level

Table X. Observed and Expected Deaths, SMRs and 95% CI for Leukemia Cell Types,Non-Hodgkin's Lymphoma, and Multiple Myeloma Among Male Employees

	Deaths		
Cause of Death (ICD-8)	Observed	Expected	SMR (95% CI)
ALL (204.0)	0	1.1	0 ---
CLL (204.1)	1	4.0	25 (1-139)
AML (205.0)	8	5.9	136 (59-268)
CML (205.1)	3	2.6	115 (24-336)
NHL (200, 202)	22	15.7	140 (88-211)
MM (203)	9	7.5	121 (55-230)

Table XI. Observed and Expected Deaths, SMRs and 95% CI by Cause for Male Beaumont Refinery Workers with ≥ 6 Months Employment in Operator Jobs

Number of Persons: 1,240 — Person-Years: 34,739

Cause of Death (8th ICDA)	Observed Deaths	Expected Deaths	SMR		95% Confidence Limits Lower	Upper
All Causes of Death	501	761.3	66	**	60	72
All Malignant Neoplasms	113	148.7	76	**	63	91
All Infective and Parasitic Disease	3	14.1	21	**	4	62
Cancer of Buccal Cavity and Pharynx	1	4.1	24		1	135
Cancer of Digestive Organs and Peritoneum	23	44.6	52	**	33	77
Cancer of Esophagus	1	4.4	23		1	126
Cancer of Stomach	4	9.4	42		12	109
Cancer of Large Intestine	10	13.7	73		35	134
Cancer of Rectum	1	4.4	23		1	127
All Cancer of Liver	1	3.6	28		1	154
Cancer of Pancreas	5	8.0	62		20	146
Cancer of Respiratory System	36	45.9	78		55	109
Cancer of Larynx	0	2.1	0		---	---
All Cancer of Lung - Primary and Secondary	36	43.3	83		58	115
Cancer of Bone	0	0.6	0		---	---
Cancer of Skin	3	1.9	156		32	456
Cancer of Prostate (Males Only)	17	16.8	101		59	162
Cancer of Testis (Males Only)	0	0.6	0		---	---
Cancer of Bladder	1	5.0	20		1	113
Cancer of Kidney	3	3.1	97		20	282
Cancer of Brain and Other Central Nervous System	4	2.7	146		40	374
All Lymphopoietic Cancer	12	12.7	95		49	166
Lymphosarcoma and Reticulosarcoma	2	2.2	91		11	330
Hodgkin's Disease	0	1.1	0		---	---
Leukemia and Aleukemia	5	5.3	94		31	220
Cancer of Other Lymphatic Tissue	5	4.0	125		40	291
Benign Neoplasms	2	1.8	109		13	393
Diabetes Mellitus	6	11.4	53		19	115
All Diseases of Blood and Blood-Forming Organs	2	1.9	105		13	378
All Diseases of Nervous System and Sense Organs	3	6.4	47		10	137
All Diseases of Circulatory System	301	409.5	74	**	65	82
Chronic Rheumatic Heart Disease	2	5.1	39		5	142
Arteriosclerotic Heart Disease, Including CHD	204	258.1	79	**	69	91
All Vascular Lesions of CNS	39	67.3	58	**	41	79
All Respiratory Diseases	33	53.1	62	**	43	87
All Pneumonia	11	22.1	50	*	25	89
Emphysema	13	9.6	135		72	231
All Diseases of Digestive System	8	28.7	28	**	12	55
Cirrhosis of Liver	1	11.9	8	**	0	47
All Diseases of Genito-Urinary System	5	15.5	32	**	11	75
Symptoms, Senility & Ill Defined Conditions	9	10.6	85		39	161
All External Causes of Death	12	48.9	25	**	13	43
All Accidents	8	32.7	25	**	11	48
Motor Vehicle Accidents	2	13.4	15	**	2	54
Suicide	3	9.2	33	*	7	95
Unknown Causes (In All Causes Category Only)	1					

* Statistically Significant at 0.05 Level
** Statistically Significant at 0.01 Level

Table XII. Observed and Expected Deaths, SMRs and 95% CI by Cause for Male Beaumont Refinery Workers with ≥ 6 Months Employment In Maintenance Craft Jobs

Number of Persons: 5,360 *Person-Years: 105,370*

Cause of Death (8th ICDA)	Observed Deaths	Expected Deaths	SMR		Confidence Limits Lower	Upper
All Causes of Death	1559	1706.4	91	**	87	96
All Malignant Neoplasms	358	317.7	113	*	101	125
All Infective and Parasitic Disease	9	35.6	25	**	12	48
Cancer of Buccal Cavity and Pharynx	4	9.7	41		11	106
Cancer of Digestive Organs and Peritoneum	86	97.5	88		71	109
Cancer of Esophagus	7	9.8	72		29	148
Cancer of Stomach	18	21.9	82		49	130
Cancer of Large Intestine	28	28.3	99		66	143
Cancer of Rectum	4	10.1	40		11	102
All Cancer of Liver	2	7.9	25	*	3	92
Cancer of Pancreas	21	17.4	121		75	185
Cancer of Respiratory System	111	96.7	115		95	138
Cancer of Larynx	2	4.8	42		5	151
All Cancer of Lung - Primary and Secondary	109	90.8	120		99	145
Cancer of Bone	0	1.5	0		---	---
Cancer of Skin	5	4.6	110		36	256
Cancer of Prostate	46	31.6	145	*	107	194
Cancer of Testis	1	1.6	65		2	359
Cancer of Bladder	8	10.2	78		34	155
Cancer of Kidney	6	6.9	87		32	190
Cancer of Brain and Other Central Nervous System	7	6.9	101		41	208
All Lymphopoietic Cancer	45	28.1	160	**	117	215
Lymphosarcoma and Reticulosarcoma	4	5.4	74		20	189
Hodgkin's Disease	1	3.0	33		1	186
Leukemia and Aleukemia	21	11.7	179	*	111	273
Cancer of Other Lymphatic Tissue	18	7.7	233	**	138	368
Benign Neoplasms	4	4.2	95		26	242
Diabetes Mellitus	27	24.8	109		72	158
All Diseases of Blood and Blood-Forming Organs	2	4.3	47		16	170
All Diseases of Nervous System and Sense Organs	17	14.0	121		71	194
All Diseases of Circulatory System	873	902.3	97		90	103
Chronic Rheumatic Heart Disease	9	13.9	65		30	123
Arteriosclerotic Heart Disease, Including CHD	568	565.6	100		92	109
All Vascular Lesions of CNS	141	148.2	95		80	112
All Respiratory Diseases	80	107.5	74	**	59	93
All Pneumonia	31	46.2	67	*	46	95
Emphysema	26	20.9	125		81	183
All Diseases of Digestive System	44	71.3	62	**	45	83
Cirrhosis of Liver	10	31.7	32	**	15	58
All Diseases of Genito-Urinary System	11	35.0	31	**	16	56
Symptoms, Senility & Ill Defined Conditions	46	25.0	184	**	135	246
All External Causes of Death	74	141.2	52	**	41	66
All Accidents	51	93.0	55	**	41	72
Motor Vehicle Accidents	19	40.5	47	**	28	73
Suicide	17	26.6	64		37	103
Unknown Causes (In All Causes Category Only)	7					

* Statistically Significant at 0.05 Level
** Statistically Significant at 0.01 Level

Table XIII. Selected Cause-Specific Mortality Among Beaumont Males Employed ≥ 6 Months in Maintenance Craft Jobs by Hire Period

	< 1950				1950+			
	Obs	Exp	SMR	(95%CI)	Obs	Exp	SMR	(95% CI)
All Causes	1428	1554.0	92**	(87-97)	131	152.4	86	(72-102)
All Cancer	334	89.8	115*	(103-128)	24	27.9	86	(55-128)
Digestive Cancer	81	90.7	89	(71-111)	5	6.8	74	(24-173)
Lung Cancer	106	81.6	130*	(106-157)	3	9.3	32*	(7-95)
Skin Cancer	3	3.7	81	(17-236)	2	0.8	237	(29-856)
Prostate Cancer	43	30.7	140*	(102-189)	3	1.0	305	(63-891)
Kidney Cancer	5	6.2	81	(26-190)	1	0.7	138	(3-767)
Brain & CNS Cancer	6	5.7	105	(38-228)	1	1.2	84	(2-465)
Leukemia	19	10.4	183*	(110-285)	2	1.3	149	(18-539)
Other Lymphatic Tissue	14	6.8	205*	(112-344)	4	0.9	443*	(121-1134)
Blood Diseases	2	3.9	52	(6-187)	0	0.4	0	-----
Non-malignant Respiratory Diseases	76	100.7	76*	(60-94)	4	6.8	59	(16-150)

* Statistically significant at 0.05 level.
** Statistically significant at 0.01 level.

Table XIV. Observed and Expected Deaths, SMRs and 95% CI for Hematopoietic Cancers Among Male Maintenance Craftworkers by Duration of Employment

Cause of Death (ICD-8)		Duration of Employment (Years) <10	10-29	30+	Total
ALL (204.0)	OBS	0	0	0	0
	EXP	0.2	0.3	0.2	0.7
	SMR (95%CI)	0	0	0	0
CLL (204.1)	OBS	0	1	0	1
	EXP	0.2	1.2	0.9	2.3
	SMR (95%CI)	0	83 (1-460)	0	43 (1-242)
AML (205.0)	OBS	1	3	3	7
	EXP	0.6	1.9	1.1	3.6
	SMR (95%CI)	167 (2-976)	158 (32-459)	273 (55-797)	194 (78-401)
					Chi-square trend = 0.33
CML (205.1)	OBS	0	1	1	2
	EXP	0.3	0.9	0.5	1.6
	SMR (95%CI)	0	115 (2-640)	213 (3-1184)	124 (14-449)
NHL (200,202)	OBS	3	9	4	16
	EXP	1.2	5.2	3.1	9.5
	SMR (95%CI)	244 (49-713)	174 (79-330)	129 (35-329)	168 (96-273)
					Chi-square trend = 0.70
MM (203)	OBS	1	1	4	6
	EXP	0.4	2.3	1.6	4.4
	SMR (95%CI)	238 (3-1325)	43 (1-238)	247 (67-637)	137(50-299)
					Chi-square trend = 0.78

Table XV. Lung Cancer Mortality Among Male Maintenance Craftworkers by Duration of Employment and Year of First Employment in Craft Jobs

Duration of Employment (years)	Observed	SMR (95% CI)
<10	4	48 (13-122)
10-19	20	109 (67-168)
20-29	46	154** (113-206)
30-39	30	102 (69-146)
40+	9	180 (83-343)

Chi-square trend = 1.85

Calendar Year of Hire	Observed	SMR (95% CI)
<1920	19	141 (85-220)
1920-1929	33	108 (75-152)
1930-1939	11	154 (77-275)
1940-1949	43	141* (102-190)
1950+	3	32* (7-95)

* $p<0.05$
** $p<0.01$