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EPA-OTS



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Re: 8EHQ-0585-0557

Dear Sir or Madam:

In 1985, Amoco Corporation informed EPA of the results of a Refinery Retrospective Cohort Mortality Study. Additional data on this cohort was submitted in 1990 and 1991. The 1991 Phase II study did not include the Whiting refinery because the records used to identify the Whiting population included research workers as well as refinery employees. A separate study of the Whiting workers has just been completed. Data from other refineries having incomplete personnel records were also analyzed. Results of this fourth study (attached) are being submitted to EPA as supplemental information to the original 8(e) submission.

Whiting Refinery Workers

The overall mortality experience of Whiting refinery employees was favorable when compared to the United States population, with fewer total deaths and cancer deaths than expected. Although the previous Amoco studies indicated an increased risk of death from malignant melanoma among employees at some other Amoco refineries, the current study did not show an increased frequency of death from these cancers among Whiting employees.

The mortality rates for several types of digestive cancer were higher than expected; however, the results were only statistically significant in two categories, esophageal and digestive cancers (both proportional mortality ratios, PMRs). It is unlikely that a workplace exposure is contributing to the observed increase in digestive cancer mortality at the Whiting refinery. Several non-occupational risk factors for digestive cancers have been identified, most of which are related to diet.

Mesothelioma deaths occurred more frequently than expected for those employees who terminated employment in 1960 or anytime thereafter. Exposure to asbestos is strongly associated with increased rates of mesothelioma.

Other Refineries

We did not observe any consistency in increased mortality ratios (PMRs) across the other four refinery populations. Most observed elevations were limited to a single refinery and were based on a very small number of deaths. Moreover, the results of the Phase II study do not support the finding of elevated mortality rates.

There were no deaths attributed to melanoma in these refinery populations.

Whiting Non-Refinery Employees

Most of these employees (73%) worked in research. Similar to employees of the Whiting refinery, elevated mortality rates were found for several digestive cancers, including colon and rectal cancers, and the composite category, *all digestive cancers*. As mentioned above, it is not believed that this increase is occupationally related.

Copies of this study are being submitted to NIOSH, OSHA, OCAW (the Brotherhood of Oil, Chemical, and Atomic Workers) and the American Petroleum Institute. In addition, our employees at our refineries will be informed of the results.

If you have any questions regarding this submission, please contact Dr. Susan L. Schmitt at (312) 856-5792.

Sincerely,

C. J. D'Souza

Enclosure

A Mortality Study
of Whiting Refinery Employees

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Margaret Hornstra
Amoco Corporation
July 1, 1993

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**A Mortality Study
of Whiting Refinery Employees**

93 JUL -3 PM 12:20

**Margaret Hornstra
Amoco Corporation
July 1, 1993**

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A Mortality Study
of Whiting Refinery Employees*

* This report includes an appendix which presents a proportionate mortality analysis for the Baltimore, Salt Lake City, Savannah, and Wood River refineries, and the Whiting non-refinery employees.

July 1, 1993

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INTRODUCTION

For over a decade, Amoco Corporation has conducted epidemiological studies to examine patterns of mortality among refinery employees. Two cohort mortality studies of refinery employees have been completed. The cohort for the first study was defined by the availability of computerized employment records (Phase I); therefore, only employees working between 1970 and 1980 were included. Based on the results of the Phase I study, in particular an elevated skin cancer mortality rate, a second, more expansive study was undertaken (Phase II).

The Phase II study was designed to include refinery employees who worked between 1940 and 1980. The interpretation of company policies governing retention of old work history records varied by refinery. Some refineries maintained records from the start of their operations; others retained only more recent employment records. A thorough review of personnel records revealed that the oldest and largest of the Amoco refineries, located at Whiting, Indiana, did not have complete records prior to 1960, and that subsequent to 1960, non-refinery personnel records were mixed with refinery workers' records. Because of the questionable quality of the Whiting refinery personnel records, this refinery was excluded from the Phase II study.

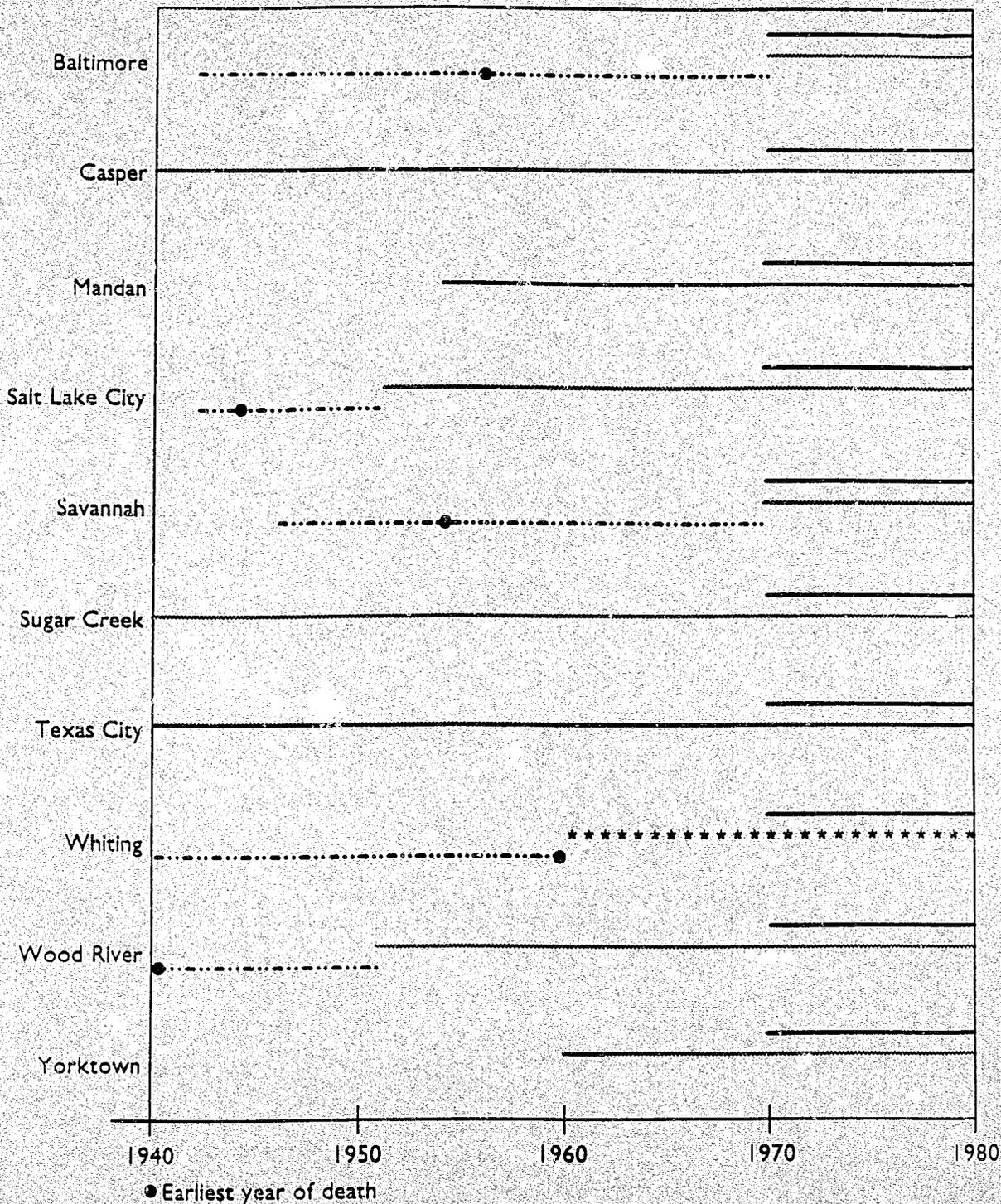
The purpose of this document is to report the mortality experience of Whiting refinery employees, using a study design and analytic technique valid for the study population. Similar to the Whiting refinery practices, four other refineries were found to have incomplete personnel records. The sizes of these refinery populations are quite small relative to Whiting, and the analysis of the mortality experience of these employees will be presented in an appendix to the Whiting report (Appendix A). This appendix also includes a mortality analysis of the Whiting non-refinery personnel whose records were mixed with refinery employee records. Figure 1 presents the employment time frames and populations of the Amoco refinery studies conducted to date.

When examining figure 1, note that, except for the "PMR analysis," the study populations were comprised of employees who worked at the refineries for at least six months during the time frames given on the graphs in figure 1. Because the "PMR analysis" only includes information on deceased employees, the time frames are less easily defined. The beginning of the interval was based on the earliest year of employment termination in the population; the end of the interval coincides with the beginning of the Phase II study. Those included in the PMR analysis were employed at Amoco for at least six months between 1940 and the end of the interval illustrated in figure 1. This report includes results from the PMR analysis and the Whiting SMR analysis.

Figure 1

Employment Time frames and Populations
of Amoco Refinery Mortality Studies

———— Phase I - - - - - PMR Analysis
———— Phase II * * * * * Whiting SMR Analysis



Results of Previous Refinery Mortality Studies

The Amoco refinery studies have generally shown favorable results, with lower overall mortality, and lower cancer and cardiovascular mortality than expected relative to the United States population (1-3). A single cause of death, skin cancer, has consistently been found to occur more frequently than expected among Amoco employees. The mortality rate for skin cancer was highest in employees with the greatest potential exposure to refinery products, suggesting a possible relationship with the workplace. A statistically significant excess of benign neoplasm deaths was reported in the first Amoco study. The benign neoplasm finding was due to an excess rate of mesothelioma deaths. Mesothelioma is a cancer of the membrane surrounding the lungs or the abdominal contents; it is most frequently associated with a history of exposure to asbestos. Most of the mesothelioma deaths in this first study were among employees of the Whiting refinery.

An analysis of mortality at the individual Amoco refineries found stomach cancer deaths to be elevated at both the Salt Lake City and Whiting refineries. A significantly greater than expected number of suicide deaths occurred at the Casper refinery; however, the suicide death rate was as expected when compared to Wyoming rates.

Several other petroleum companies have conducted epidemiology studies examining mortality among their refinery employees (4-17). These studies generally report results similar to those from Amoco, with low overall mortality and fewer lung cancer and cardiovascular deaths than expected. Individual studies have identified elevated mortality rates for several causes including leukemia (13), and cancers of the kidney (14), pancreas (5) and skin (11); however, there is a lack of consistency among the results of these studies. A review article using meta-analysis to summarize the results of refinery cohort mortality studies concluded that refinery employees as a group are not at increased risk for most cancers (18). However, prostatic cancer, leukemia, and kidney cancer may be more common in specific groups of refinery employees than in the general population.

METHODS

Study Population

The study population was comprised of Whiting refinery employees who worked between January 1, 1960 and December 31, 1980, and annuitants who were alive in 1960. Employees who were hired on a temporary or part-time basis and those who worked for less than six months were excluded from the study.

The study cohort was assembled using computer records for those who terminated after 1970 and paper records for those terminating employment before 1970. In addition to identifying the study population, these records provided personal (name and Social Security number), demographic (age, sex, and race), and employment information (hire date, termination date, and pay status—hourly or salary).

To evaluate the completeness of our study population, the cohort was compared to a roster of employees compiled for Social Security purposes (Social Security 941 Report of Wages Taxable) (19). This process attempts to ensure that the cohort is completely enumerated and is therefore unbiased. The comparison found the cohort of Whiting refinery employees who worked between 1960 and 1980 to be reasonably complete (approximately 97 percent).

We were unable to assess the completeness of our Whiting annuitant population; however, we suspect that records of deceased annuitants may have been selectively retained. Approximately 90 percent of the annuitant population is deceased. Appendix B provides a description of the process used to evaluate the completeness of the Whiting refinery records.

The only available indices of potential exposure are pay classification and employment duration. Pay classification is defined as hourly or salaried employment and is based on the final position held at Amoco. Hourly employees are believed to have greater potential for exposure to refinery products. Using the employee's final position for defining pay classification has limitations because it inaccurately assigns exposure status to those who worked in hourly positions for the majority of their careers and were promoted to salaried positions prior to retirement. A better indicator of potential exposure would be whether an employee ever held an hourly position. This information was not available.

Only white males were included in the analysis because the numbers of non-whites and females are small.

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Vital Status Ascertainment

The vital status of each cohort member was assessed as of December 31, 1986. Company records and information supplied by the Social Security Administration identified the vital status of most cohort members through December, 1984. The National Death Index (NDI) identified cohort deaths occurring in 1985 and 1986; individuals known to be alive in 1984 and not identified as deceased by the NDI were assumed to be alive at the close of the study. State motor vehicle bureaus and the Johns Holding Company (credit search) assisted in identifying the vital status of cohort members initially considered lost to follow-up. Cohort members whose vital status could not be identified were classified as lost to follow-up as of employment termination.

For those identified as deceased, death certificates were requested from state vital statistics registries. The underlying cause of death was coded to the Eighth Revision of the International Classification of Diseases (ICD) by contract nosologists having extensive experience working for the National Center for Health Statistics. Although the Eighth Revision of the ICD is not the most current method for coding mortality, we chose this revision because a comparison death rate data set (which spanned a time frame similar to the study) had used this revision of the ICD. In addition, the Eighth ICD and the Ninth ICD are very similar, and there is no important uncertainty introduced by using the Eighth Revision.

Statistical Analysis

Two analytic techniques were used to compare the mortality experience of Whiting employees to that of the U.S. general population. The population of employees working at Whiting between 1960 and 1980 was completely enumerated; therefore, a Standardized Mortality Ratio (SMR) analysis could be conducted. The annuitants included in the study represent a small fraction of the Whiting employees who worked between 1940 and 1960. Because the annuitant population is not complete, a Proportionate Mortality Ratio (PMR) analysis was used in place of the more precise SMR.

The SMR and PMR are both mortality ratios; the SMR is a ratio of rates, and the PMR is a ratio of proportions. Both ratios compare the observed number of deaths in the study population with an expected number of deaths based on mortality statistics of a standard population. The SMR and PMR differ from each other in the method employed to calculate the number of expected deaths. A Proportionate Cancer Mortality Ratio (PCMR) is a type of PMR where only cancer deaths are of interest. Figure 2 provides the formulas for calculating the expected number of deaths for an SMR, a PMR, and a PCMR.

Figure 2

Formulas for Calculating Expected Deaths for an SMR, PMR, and PCMR

A = Study Population
B = Reference Population, e.g., U.S. Population Statistics

Expected Deaths

<u>Statistic</u>	<u>Calculation</u>
SMR*	(No. at risk A) X $\frac{\text{No. Deaths B}}{\text{No. at risk B}}$
PMR** Cause X	(Total Deaths A) X $\frac{\text{No. Deaths (Cause X) B}}{\text{Total Deaths B}}$
PCMR† Cause X	(Total Cancer Deaths A) X $\frac{\text{No. Deaths (Cause X) B}}{\text{Total Cancer Deaths B}}$

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- * Standardized Mortality Ratio
 - ** Proportionate Mortality Ratio
 - † Proportionate Cancer Mortality Ratio

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The comparison population used in most calculations is the U.S. general population. Because mortality rates can vary by geographic region within the United States, Lake county, Indiana mortality rates were used in the analysis where noted. The composition of the population of Lake county is 95 percent urban, with 65 percent of the population residing in highly industrialized townships.

SMRs were calculated for 52 causes of death. PMRs were calculated for seven causes of death including the mortality category *all cancers*, and proportionate cancer mortality ratios (PCMR) were calculated for 29 specific types of cancer. SMRs, PMRs, and PCMRs were calculated using a computer software package and standardized mortality rates (both U.S. and Lake county, Indiana rates) supplied by Marsh (20).

SMRs were calculated for the study group as a whole and separately by length of employment, pay status, date of hire, and latency. Latency is defined as the interval between the first exposure to an exposure of interest and manifestation of some disease (21). In this study, we considered exposure to occur at date of hire and manifestation of disease to occur at date of death.

For the SMR analysis, cohort members identified as deceased for whom death certificates could not be located (n=17, 1% of those deceased) were included in the calculation of the all-cause SMR, but did not contribute to any specific cause of death. Therefore, the SMRs for specific causes of death are slightly underestimated.

SMRs, PMRs, and PCMRs are not included in the tables when the observed number of deaths is less than three and the mortality ratio is less than 1000 because of the instability of the data.

For mortality ratios which were elevated in the entire study population (SMRs or PMRs greater than 125 with at least six observed deaths), additional analyses were conducted to further explore whether the elevation could be related to employment factors. Logistic regression was used for the PMR data, and Cox regression was used for the SMR data (22, 23).

RESULTS

The SMR study population included 5,821 white male Whiting refinery employees. Most cohort members were hired for an hourly position (69%) and worked for at least 20 years (60%). Thirty percent of the cohort members were deceased (n=1773). Less than one percent (n=40) of the SMR study population was lost to follow-up.

The PMR study population was comprised of 976 deceased white males (annuitants). This population differs from the SMR population primarily in the age of the cohort; most (89%) were born before 1900. More than 90 percent of the PMR population worked at least 20 years at the Whiting refinery. Tables 1 through 3 present demographic characteristics of the two study populations.

PMRs and SMRs for the Whiting study populations are presented in tables 4 and 5, respectively. The SMR study shows that the mortality experience of Whiting refinery employees is favorable relative to the U.S. general population for most causes of death, including overall mortality, cancer mortality, lung cancer, and heart disease. In the PMR study, the proportion of deaths attributed to cancer was similar in the Whiting and U.S. populations (PMR=99).

The mortality rates for several types of digestive cancer are higher than expected in both study groups; however, the results are only statistically significant in two categories, esophageal and digestive cancers (both PCMRs). In most cases, the digestive cancer mortality ratios are between 100 and 150, the exception being a PCMR of 267 for esophageal cancer.

The Whiting SMR study population had a four-fold excess of deaths in the mortality category *other respiratory cancers*. This mortality category includes pleural and nasal cancers. Six of the eight deaths in this mortality category resulted from mesothelioma, a cancer almost always associated with a history of asbestos exposure. A non-significantly elevated mortality rate for benign neoplasm deaths was also observed; in the ICD coding convention used, mesothelioma deaths may be categorized as *benign neoplasms*. Of the ten *benign neoplasm* deaths, three were due to mesotheliomas. In addition, seven mesothelioma deaths were identified through a review of study death certificates. These additional mesothelioma deaths were coded as: lung cancers (n=2) and unspecified malignancies (n=5). The PMR study population did not have any deaths attributed to mesothelioma.

The number of deaths from malignant melanoma was lower than expected in both the SMR and PMR study populations. Kidney cancer and leukemias

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both occurred at approximately the rate expected relative to the U.S. population.

Table 6 presents PMRs, PCMRs, and SMRs which were calculated using Lake county, Indiana mortality rates for the comparison population. The substitution of these rates for U.S. mortality rates had little impact on the results. When calculations were made using Lake county mortality rates, the digestive cancer PCMRs and SMRs were slightly lower, whereas lymphatic and hematopoietic cancer PCMRs were slightly higher.

Table 7 presents SMRs, PMRs and PCMRs by phase (Phase I vs. Phase II) and type of study (SMR vs. PMR). The purpose of this table is to examine the data to determine whether the results are consistent between independent populations. Consistency of results is one of the criteria for evaluating whether the relationship between exposure and outcome is causal (24). SMRs listed under the *Phase I* and *additional information* columns represent results for independent populations. The *Phase I* population includes those employed between 1970 and 1980, and the *additional information* population includes those terminating employment between 1960 and 1970. The PMR population is also independent of the SMR study populations.

Two of the three mortality rates for digestive cancers are higher than expected; however, the magnitudes of these elevations are not remarkable. The SMRs for *other respiratory cancers* are consistently high, and the SMRs for *benign neoplasms* are inconsistently high. In contrast, the PMRs for these two mortality categories are low. The SMRs for overall mortality and cancer mortality are consistently low, as are the mortality ratios for brain cancer, and lymphatic and hematopoietic cancers.

Mortality Rates by Pay Status

Standardized mortality ratios were calculated for salaried and hourly employees in the SMR study population; these results are presented in tables 8 and 9. Mortality rates which are higher among hourly employees than salaried employees may be indicative of a workplace effect. However, comparison between categories should be done with reservation because age distributions may not be similar.

The SMRs for *all causes* and *all cancers* were significantly less than expected relative to the U.S. population for both salaried and hourly employees; however, in comparison, SMRs for hourly employees were higher. The SMRs for digestive cancers were slightly elevated for both hourly (SMR=113) and salaried (SMR=111) employees. Deaths attributed to *other respiratory cancers* and *benign neoplasms* occurred significantly more often than expected among hourly employees; this excess was not observed among salaried employees.

SMRs by Employment and Latency

Tables 10 and 11 present SMRs by employment duration and tables 12 and 13 by latency. A finding of increasing SMRs associated with increasing latency or employment duration could be associated with a workplace effect. Again, caution should be used when making comparisons between categories because age distributions are dissimilar.

All cause and *all cancer* SMRs were slightly higher in the cohort with longer latency, yet similar in the two categories of employment duration. Individual digestive cancers were elevated in each category of employment duration and latency. No clear pattern of excess digestive cancer associated with either employment duration or latency was evident.

The SMRs for *other respiratory cancers* were significantly elevated for both categories of employment duration, but only for the latency category of 30 years or greater.

SMRS by Hire Date

Tables 14 and 15 present SMRs for those hired before 1940 and those hired in 1940 or later, respectively. The SMRs for *all cause* and *all cancer* mortality were similar. The mortality rates for most digestive cancers were slightly lower for those hired after 1940, with the exception being rectal cancer, which was similar for both categories of hire date. Deaths attributed to diabetes, cerebrovascular disease, and cirrhosis of the liver also appeared to be slightly more common among employees hired prior to 1940. The SMRs for the lymphatic cancers were somewhat higher in the group hired in 1940 or later.

Regression Analysis

Tables 16 and 17 present the results of the regression analysis. Three causes of death meeting the criterion for inclusion in this analysis ($SMR \geq 125$ and observed deaths ≥ 6) were not analyzed. The purpose of this analysis is to further evaluate whether an elevated mortality ratio is associated with a workplace exposure. The finding of elevated mortality ratios for *other respiratory diseases* and *benign neoplasms* was not unexpected, and is likely associated with workplace exposure to asbestos. This finding was reported and previously discussed in the update of the Phase I study (2). Additional analysis of these outcomes would not yield any new information. Demographic and employment characteristics of the mesothelioma deaths are presented in table 18. The mortality category *other malignant neoplasms* contains several causes of death which are pathologically distinct, such as secondary malignant neoplasms and skin neoplasms. The causes of death comprising

this mortality category and numbers of deaths attributed to each particular cause are presented in table 19.

The regression analysis was limited to digestive cancers. No significant association was observed between the three employment factors and the occurrence of digestive cancer. The results of the regression analysis closely agree with the stratified analysis indicating that the elevated risk of digestive cancers found in the Whiting refinery population does not appear to be associated with refinery exposures.

DISCUSSION

In general, the SMR and PMR components of this study produced similar results, with overall mortality and cancer mortality occurring at comparable or favorable rates relative to the U.S. population. The mortality rates for several types of digestive cancer, including cancers of the esophagus, stomach, and rectum, were elevated in both analyses. For the most part, the magnitude of these elevations was small and not statistically significant. An increased risk of mesothelioma death was found, but this excess was limited to the SMR study population. Because the SMR is the more precise method of analysis, the remainder of the discussion will focus on these results, relating information from the PMR study where relevant.

The SMR study found the mortality experience of the Whiting refinery employees to be favorable relative to the U.S. population, with significantly fewer deaths and cancer deaths than expected. This finding is consistent with other cohort mortality studies of occupational populations which generally report a 10 to 30 percent deficit of mortality relative to the U.S. population (25); this deficit is called the healthy worker effect. Significantly low SMRs were also observed for heart disease and lung cancer. In the PMR analysis, cancer deaths represented the same proportion of deaths in the Whiting refinery population as the U.S. population (PMR=99), demonstrating no excess of overall cancer mortality in this population. The healthy worker effect has a minimal impact on the results of proportionate mortality studies; therefore, the mortality ratio is closer to unity than is typically observed in a SMR analysis (26).

Mesothelioma

The SMR component of this study found a statistically significant excess of mortality due to *other respiratory diseases*, and a near significant excess of *benign neoplasm* deaths. Whiting refinery employees were approximately four times more likely to die from *other respiratory cancers* than other residents of the U.S. or Lake county, Indiana. Mesothelioma accounted for 75 percent of the *other respiratory cancer* deaths and 30 percent of the *benign neoplasm* deaths. In addition, a review of death certificates identified two mesotheliomas coded as lung cancers (ICD 162) and five mesotheliomas coded as *other cancers* (ICD 199). A total of 16 mesothelioma deaths occurred among 5,821 members of the SMR study population. There were no mesothelioma deaths in the PMR component of this study.

Exposure to asbestos is strongly associated with increased rates of mesothelioma, with approximately 80 percent of diffuse mesothelioma cases having a history of workplace exposure to asbestos (27).

The average time period between asbestos exposure and diagnosis of mesothelioma is 32 years (28). The results of the latency analysis support the likelihood of an occupational exposure being responsible for an increased risk of mesothelioma in this population. The excess risk of *other respiratory cancers* was limited to the group of employees with a latency of at least 30 years. In this study, only one case of mesothelioma has a latency which is incompatible with workplace exposure; there were only four years between the date of hire and the date of death.

The occurrence of mesothelioma appears to increase with increasing exposure. The excess risk of mesothelioma was limited to employees receiving an hourly wage, presumably the group with greater potential for asbestos exposure. In addition to mesothelioma, exposure to asbestos is associated with higher than normal mortality rates of lung cancer and pneumoconiosis (asbestosis). Both of these causes of death occurred significantly less frequently than expected in the Whiting population. When the data were reviewed, there were no deaths with asbestosis given as the underlying cause.

A four-fold excess of mesothelioma deaths was observed among members of the Whiting SMR cohort; however, no mesothelioma deaths occurred in the PMR population. There are two explanations for this apparent disparity between the results of the PMR and SMR components of the study. Specifically, 1.) there may not be an increased risk of mesothelioma among members of the PMR study; or 2.) the increased risk may be similar between the two studies, but for some reason was not detected in the PMR study. Given the age of the PMR population, many members could have been either retired or in supervisory positions when asbestos exposure was at its peak.

Another plausible explanation for the differing results may be that identification of disease was less aggressive for members of the PMR study population. The mean age at death for this population is 80 years. Mesothelioma is difficult to distinguish pathologically from metastatic disease when using small tissue samples (29). Physicians may have been reluctant to use more invasive procedures on this older population. Autopsies, which provide more refined diagnosis, are also less common in older persons.

A study by Kaplan (16) was the first to identify an excess of mesothelioma deaths in a large refinery cohort. Kaplan identified nine mesothelioma deaths in a population of 20,169 employees. Cohort studies of several other industries have reported death rates from mesothelioma which are equal to or greater than that observed in this study. High rates of mesothelioma have been reported in the following industries or occupations: sugar refining (30), asbestos manufacturing (31), asbestos mining (27), and asbestos insulating (27).

Digestive Cancers

Mortality ratios for several of the digestive cancers were greater than 100 in both the PMR and SMR studies. These mortality ratios did not change substantially when Lake county, Indiana mortality rates were used for comparison. Mortality ratios did vary slightly with employment factors; however, the regression analysis did not find a statistical association between any of the employment factors and digestive cancer mortality. In most of the stratified analyses, the mortality ratio for at least one type of digestive cancer was greater than expected.

It is unlikely that a workplace exposure is contributing to the observed excess of digestive cancer mortality at the Whiting refinery. Although the consistency of this finding is strong, most other cohort mortality studies do not report elevated SMRs for the digestive cancers (18). In addition, the excess mortality does not appear to be associated with employment factors, such as pay status.

Several non-occupational risk factors for digestive cancers have been identified, most of which are related to diet. Colon cancer has been associated with low fiber/high fat diets (32). Consumption of fresh fruits and vegetables appears to have a strong protective effect against stomach, colon, and rectal cancers (32,33). Doll and Peto estimate that the occurrence of stomach cancer and large bowel cancer can be reduced by as much as 90 percent through dietary modifications (34).

The dietary habits of Whiting refinery employees are not known, although a substantial number of Eastern Europeans and their descendants have been employed at Whiting. Because Eastern Europeans have a higher incidence of stomach cancer, this may in part explain the observed excess of mortality from digestive cancers.

Several studies have examined the association between alcohol consumption and digestive cancers (35). In nearly all studies, cancers of the larynx, pharynx, liver, and esophagus occur more commonly among alcoholics. The evidence is more controversial for cancers of the stomach, colon, and rectum; some studies report an elevated risk associated with alcohol consumption and others do not. The evidence seems to be somewhat more supportive of an association between rectal cancer and heavy consumption of beer.

As part of employee medical examinations, Amoco collects information on smoking and drinking habits of employees. Perhaps because of the sensitive nature of the alcohol consumption questions, most employees at the Whiting refinery (74%) did not respond to this question. We felt that a 26 percent response rate was insufficient for evaluating the potential impact alcohol consumption may have on the digestive cancer mortality rates.

A recent study found an excess of stomach cancer among residents of the north central United States who were German or Scandinavian immigrants or their first generation descendants. The risk was higher among those working in laboring or semi-skilled positions (36). In some respects, the Whiting refinery employees are similar to this study population (European lineage, occupation, and residence in North Central U.S.).

Occupational exposures to dusts have been associated with increased risk of stomach cancer (37). Exposure to asbestos has been associated with colon cancer, although this association is controversial (27,38).

Other Cancers

Previous studies of Amoco refinery employees have reported elevated SMRs for fatal skin cancers, most of which were due to malignant melanoma. These earlier studies found that the increased risk was most pronounced among employees with the greatest potential exposure to refinery products (specifically, employees working in maintenance positions). The number of deaths attributed to malignant melanoma in the Whiting SMR cohort was fewer than expected (SMR=65); no deaths from malignant melanoma occurred in the PMR population. The results of this study do not support an association between refinery exposures and increased risk of malignant melanoma.

Many studies of refinery employees have reported elevated mortality rates for the lymphatic and hematopoietic cancers; however, mortality rates for these cancers have generally been lower than expected in studies of Amoco refinery employees. Both the Whiting PMR and SMR components of this study report mortality ratios for lymphatic and hematopoietic cancers which are within a normal range.

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July 1, 1993

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REFERENCES

1. Nelson NA, Van Peenen PFD, Blanchard AG. Mortality in a recent oil refinery cohort. *J Occup Med* 1987;29:610-2.
2. Hornstra M, Van Peenen PFD. Reanalysis of the phase I cohort mortality study of oil refinery workers (1970-1980): follow-up extended through 1986. Report submitted to Amoco Corporation May 29, 1990 (unpublished).
3. Hornstra M. The phase II cohort mortality study of oil refinery employees (1940-1980): follow-up through 1986. Report submitted to Amoco Corporation May 10, 1991 (unpublished).
4. Dagg TG, Satin KP, Bailey WJ, et al. An updated cause specific mortality study of petroleum refinery employees. *Br J Ind Med* 1992;49:203-12.
5. Hanis NM, Holmes TM, Shallenberger LG, et al. Epidemiologic study of refinery and chemical plant workers. *J Occup Med* 1982;24:203-12.
6. Hanis NM, Stavrazy KM, Fowler JL. Cancer mortality in oil refinery workers. *J Occup Med* 1979;21:167-74.
7. Wen CP, Tsai SP, McClellan WA, et al. Long-term mortality study of oil refinery workers I. Mortality of hourly and salaried workers. *Am J Epidemiology* 1983;118:526-42.
8. Divine BJ, Barron V, Kaplan SD. Texaco mortality study I. Mortality among white male refinery, petrochemical, and research workers. *J Occup Med* 1985;27:445-7.
9. Rushton L, Alderson MR. Epidemiological survey of oil distribution centers in Britain. *Br J Ind Med* 1983;40:333-9.
10. Schottenfeld D, Warshauer ME, Zauber AG, et al. A prospective study of morbidity and mortality in petroleum industry employees in the United States--a preliminary report. In: Peto R, Schneiderman M (eds.). *Quantification of Occupational Cancer*. Cold Spring Harbor NY: Cold Spring Harbor Laboratory, 1981:247-65.
11. Rushton L, Alderson MR. An epidemiological survey of eight oil refineries in Britain. *Br J Ind Med* 1981;38:225-34.

References, Continued

12. Bertazzi PA, Pesatori AC, Zocchetti C, et al. Mortality study of cancer risk among oil refinery workers. *Int Arch Occup Environ Health* 1989;61:261-70.
13. Wongsrichanalai C, Delzell E, Cole P. Mortality from leukemia and other diseases among workers at a petroleum refinery. *J Occup Med* 1989;31:106-11.
14. Shallenberger LG, Acquavella, JF Donaleski DL. An updated mortality study of workers in three major United States refineries and chemical plants. *Br J Ind Med* 1992;49:345-54.
15. Theriault G, Provencher S. Mortality study of oil refinery workers: five-year follow-up. *J Occup Med* 1987;29:357-60.
16. Kaplan SD. Update of a mortality study of workers in petrochemical refineries. *J Occup Med* 1986;28:514-6.
17. Divine BJ, Barron V. Texaco mortality study: III. a cohort study of producing and pipeline workers. *Am J Ind Med* 1987;11:189-202.
18. Wong O, Raabe GK. Critical review of cancer epidemiology in petroleum industry employees with a quantitative meta-analysis by cancer site. *Am J Ind Med* 1989;15:293-310.
19. Marsh GM, Enterline PE. A method for verifying the completeness of cohorts used in occupational mortality studies. *J Occup Med* 1979; 21:665-70.
20. Marsh GM, Preininger M. OCMAP: a user-oriented occupational cohort mortality analysis program. *Am Stat* 1980;34:245-6.
21. Last JM, ed. *A dictionary of epidemiology*. New York: Oxford University Press, 1988.
22. SAS Institute Inc. The LOGISTIC procedure. In: SAS/STAT® user's guide, version 6, fourth edition, volume 2. Cary NC: SAS Institute Inc., 1989.
23. SAS Institute Inc. The PHREG procedure. In: SAS® technical procedures P-229, SAS/STAT® software changes and enhancement, release 607. Cary NC: SAS Institute Inc., 1992.

References, Continued

24. Mausner JS, Kramer S. Epidemiology: an introductory text. Philadelphia: W. B. Saunders Co., 1985:315-16.
25. Choi BCK. Definition, sources, magnitude, effect modifiers, and strategies of reduction of the healthy worker effect. J Occup Med 1992;34:979-988.
26. Park RM, Maizlish NA, Punnett L, et al. A comparison of PMRs and SMRs as estimators of occupational mortality. Epidemiology 1991;2:49-59.
27. Mossman BT, Gee JBL. Asbestos-related diseases. N Eng J Med 1989; 320:1721-30.
28. Lanphear BP, Buncher CR. Latent period for malignant mesothelioma of occupational origin. J Occup Med 1992;34:718-721.
29. Wyngaarden JB, Smith LH (eds.). Respiratory diseases. In: Cecil Textbook of Medicine. Philadelphia: W. B. Saunders Company, 1985:450.
30. Malker HR, Malker BK, Blot WJ. Mesothelioma among sugar refinery workers. (Letter) Lancet 1983;2:858.
31. Selikoff IJ, Lee DHK. Asbestos and disease. New York: Academic Press, Inc., 1978.
32. Freudenheim JL, Graham S. Toward a dietary prevention of cancer. Epidemiol Reviews 1989;11:229-35.
33. Howson CP, Hiyama T, Wynder EL. The decline in gastric cancer: epidemiology of an unplanned triumph. Epidemiol Reviews 1986; 8:1-27.
34. Doll R, Peto R. The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. JNCI; 66:631-42.
35. World Health Organization, International Agency for Research on Cancer Working Group. Alcohol drinking. IARC Monographs on the evaluation of carcinogenic risks to humans, volume 44. Lyon: International Agency for Research on Cancer, 1988.

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References, Continued

36. Kneller RT, McLaughlin JK, Bjelke E, et al. A cohort study of stomach cancer in an high-risk American population. *Cancer* 1991; 68:672-8.
37. Wright WE, Bernstein L, Peters JM, et al. Adenocarcinoma of the stomach and exposure to occupational dust. *Am J Epidemiol* 1988;128:64-73.
38. Frumkin H, Berlin J. Asbestos exposure and gastrointestinal malignancy review and meta-analysis. *Am J Ind Med* 1988;14:79-95.

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Table 1
Demographic Characteristics of
Those Eligible for Inclusion in the
PMR and SMR Studies, Whiting Refinery

Race/Sex	<u>PMR</u>		<u>SMR</u>	
	Total (N)	Dead (N)	Total (N)	Dead (N)
Non-White				
Male	15	13	535	80
Female	0	0	78	2
White				
Male	1,114	976*	5,821*	1,773
Female	40	27	435	38

* Mortality statistics are calculated for these groups and presented in this report.

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Table 2

Study Characteristics of the
Whiting Refinery Employees, White Males

	PMR/PCMR	SMR	
		Total	Deceased
Population Size	976	5,821	1,773
Year of Birth			
1870-1899	868	136	122
1900-1919	103	2,893	1,322
1920-1939	5	1,927	315
1940-1961	0	865	14
Vital Status			
Alive	—	4,008	—
Dead	976	1,773	1,773
Lost to follow-up	—	40	—
Year of Death			
1960-1969	404	326	326
1970-1979	445	732	732
1980-1986	127	715	715
Person-Years of Follow-Up			
< 10	—	904	345
10-19	—	1,190	732
20-26	—	3,727	696

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Table 3
Employment Characteristics of the
Whiting Refinery Employees, White Males

	<u>PMR/PCMR</u>	<u>SMR</u>	
		N	Deceased
Age at Hire			
< 20	91	750	227
20-29	393	3,910	1,029
30-39	339	943	438
40+	153	218	79
Year of Hire			
< 1920	382	43	35
1920-1939	537	1,596	839
1940-1980	57	4,182	899
Length of Employment			
< 5 years	4	258	14
5-9 years	9	523	14
10-19 years	82	1,519	309
20+ years	880	3,521	1,436
Pay Status			
Hourly	841	4,035	1,367
Salary	135	1,776	398
Unknown	—	10	8

Table 4
PMRs/PCMRs for White Males, Whiting Refinery

	PMR** (Obs.)		95%	
			Conf. Limits	
All cancers (140-209)	99	(156)	86	114
Buccal cavity and pharynx (140-149)	137	(5)	58	324
Digestive system and peritoneum (150-159) *	132	(63)	107	161
Esophagus (150) *	267	(8)	136	517
Stomach (151)	142	(13)	84	239
Large intestine (153)	142	(25)	98	205
Rectum (154)	125	(7)	61	258
Biliary passages and liver (155,156)	+	(2)	20	305
Pancreas (157)	81	(7)	40	167
Other digestive organs (152,158,159)	+	(1)	9	438
Respiratory system (160-163) *	71	(28)	52	97
Larynx (161)	---	(0)	---	---
Bronchus, trachea, lung (162)	75	(28)	55	104
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	91	(23)	63	132
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	100	(3)	33	306
Bladder and other urinary (188-189.9)	64	(5)	28	150
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190)	---	(0)	---	---
Central nervous system (191-192)	+	(2)	35	541
Thyroid and other endocrine glands (193-194)	+	(1)	41	1749
Bone (170)	+	(1)	25	1193
Lymphatic and hematopoietic (200-209)	72	(10)	40	130
Lymphosarcoma and reticulosarcoma (200)	+	(2)	21	318
Hodgkins disease (201)	---	(0)	---	---
Leukemia and aleukemia (204-207)	44	(3)	15	130
Other lymphopoietic tissue (202,203,208,209)	127	(5)	54	302
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	139	(15)	86	226
Benign neoplasms (210-239)	+	(1)	9	420
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429) *	91	(406)	85	98
Nonmalignant respiratory disease (460-519) *	74	(61)	58	94
Accidents (E800-E949)	86	(19)	55	134
Motor vehicle accidents (E810-E823)	93	(6)	42	206
Suicides (E950-E959)	58	(3)	19	177

No. of deaths = 976

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000 .

Table 5
SMRs for White Males,
Whiting Refinery

	SMR (Obs.)		95% Conf. Limits	
	SMR	(Obs.)	Lower	Upper
All causes *	86	(1773)	82	90
Tuberculosis (010-019)	58	(3)	12	170
All cancers (140-209) *	85	(414)	77	94
Buccal cavity and pharynx (140-149) *	21	(3)	4	60
Digestive system and peritoneum (150-159)	113	(138)	95	13
Esophagus (150)	136	(16)	78	221
Stomach (151)	138	(26)	90	203
Large intestine (153)	105	(46)	77	140
Rectum (154)	159	(19)	96	249
Biliary passages and liver (155-156)	105	(9)	48	199
Pancreas (157)	70	(18)	41	110
Other digestive (152,158,159)	109	(4)	30	279
Respiratory system (160-163) *	72	(134)	60	85
Larynx (161)	+	(2)	3	100
Bronchus, trachea, lung (162) *	70	(124)	58	83
Other respiratory (160,163) *	406	(8)	175	801
Breast (174)	+	(1)	4	904
Prostate (185)	86	(28)	57	124
Testis and other male genital organs (172.5,173.5,186,187)	+	(1)	2	399
Kidney (189.0,189.1,189.2)	99	(12)	51	173
Bladder and other urinary (188-189.9)	75	(10)	36	138
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	65	(4)	18	166
Eye (190)	---	(0)	0	1045
Central nervous system (191-192)	61	(8)	28	120
Thyroid and other endocrine glands (193,194)	+	(2)	17	497
Bone (170)	---	(0)	0	243
Lymphatic and hematopoietic (200-209)	93	(40)	66	126
Lymphosarcoma and reticulosarcoma (200)	112	(9)	51	213
Hodgkin's disease (201)	+	(1)	1	160
Leukemia and aleukemia (204-207)	89	(15)	50	147
Other lymphatic tissue (202,203,208,209)	102	(15)	57	168
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	93	(33)	64	131
Benign neoplasms (210-239)	191	(10)	92	352
Diabetes mellitus (250)	105	(31)	71	149
Cerebrovascular disease (330-334)	115	(133)	96	136
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429) *	91	(789)	85	97
Rheumatic heart disease (390-398)	83	(13)	44	143
Ischemic heart disease (410-414) *	90	(713)	84	97
Nonmalignant respiratory disease (460-519) *	55	(77)	43	68
Influenza and pneumonia (470-474,480-486) *	54	(24)	34	80
Bronchitis, emphysema, asthma (490-493) *	40	(16)	23	64
Other nonmalignant respiratory (460-466, 500-519) *	64	(37)	45	89
Ulcer of stomach and duodenum (531-533)	71	(7)	29	147
Cirrhosis of liver (571)	96	(52)	72	126
Nephritis and nephrosis (580-584)	80	(7)	32	164
All external causes of death (E800-E999) *	63	(88)	50	77
Accidents (E800-E949) *	70	(62)	53	89
Motor vehicle accidents (E810-E823)	69	(27)	45	100
Other accidents (E800-E809,E824-E949) *	70	(35)	49	98
Suicides (E950-E959) *	56	(20)	34	86
Homicides & other external causes (E960-E978,E980-E999) *	47	(6)	17	103

No. of persons = 5,821
Person-years = 122,102

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

Table 6

PMRs/PCMRs and SMRs for White Males, Whiting Refinery,
Lake County, Indiana Rates Compared to U.S. Rates

	PMR/PCMR†		SMR	
	Indiana	U.S.	Indiana	U.S.
All cancers (140-209)	98	99	81	85
Buccal cavity and pharynx (140-149)	197	137	24	21
Digestive system and peritoneum (150-159)	124*	132*	99	113
Esophagus (150)	249*	267*	126	136
Stomach (151)	120	142	116	138
Large intestine (153)	135	142	91	105
Rectum (154)	106	125	128	159
Biliary passages and liver (155,156)	+	+	90	105
Pancreas (157)	85	81	66	70
Other digestive organs (152,158,159)	+	+	106	109
Respiratory system (160-163)	68	71	68	72
Larynx (161)	---	---	+	+
Bronchus, trachea, lung (162)	69	75	65	70
Other respiratory (160,163)	---	---	364*	406*
Breast (174)	---	---	+	+
Prostate (185)	98	91	89	86
Testes and other male genital organs (172.5,173.5,186,187)	---	---	+	+
Kidney (189.0,189.1,189.2)	118	100	123	99
Bladder and other urinary (188-189.9)	59	64	68	75
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	---	79	65
Eye (190)	---	---	---	---
Central nervous system (191-192)	+	+	55	61
Thyroid and other endocrine glands (193-194)	+	+	+	+
Bone (170)	+	+	---	---
Lymphatic and hematopoietic (200-209)	95	72	97	93
Lymphosarcoma and reticulosarcoma (200)	+	+	118	112
Hodgkins disease (201)	---	---	+	+
Leukemia and aleukemia (204-207)	56	44	88	89
Other lymphopoietic tissue (202,203,208,209)	168	127	109	102
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	133	139	89	93
Benign neoplasms (210-239)	+	+	175	191
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	87	91	82	91
Nonmalignant respiratory disease (460-519)	94	74	63	55
Accidents (E800-E949)	94	86	65	70
Motor vehicle accidents (E810-E823)	113	93	67	69
Suicides (E950-E959)	92	58	75	56

† The values presented in the mortality category, All cancers, and the non-malignant causes are PMRs; all others are PCMRs.

* Significantly elevated at $p \leq .05$.

+ Mortality ratios are not included in the table when the observed is < 3 and the mortality ratio is < 1000 .

Table 7
Mortality among White Males, Whiting Refinery,
By Study Type and Record Source

Cause of Death	SMR (Obs.)		PMR/PCMR* (Obs.)	
	Phase I Study (1970-1980)	Additional Information (1960-1970)	Total SMR (1960-1980)	
All causes	85 (694)	86 (1079)	86 (1773)	— —
All cancers	93 (197)	79 (217)	85 (414)	99 (156)
Digestive	137 (71)	95 (67)	113 (138)	132 (63)
Stomach	190 (14)	105 (12)	138 (26)	142 (13)
Large intestine	142 (27)	77 (19)	105 (46)	142 (25)
Cancer/other respiratory +	473 (4)	364 (4)	406 (8)	— (0)
Malignant melanoma	150 (4)	— (0)	65 (4)	— (0)
Kidney	76 (4)	118 (8)	99 (12)	100 (3)
Brain	54 (3)	66 (5)	60 (8)	37 (2)
Lymphatic & hematopoietic	85 (15)	98 (25)	93 (40)	72 (10)
Leukemia	44 (3)	121 (12)	89 (15)	44 (3)
Benign neoplasms	347 (7)	94 (3)	191 (10)	61 (1)

* The values presented in the mortality categories *All cancers* and *Benign neoplasms* are PMRs; all others in this column are PCMRs.
+ This category includes cancers of the nose, nasal cavities, middle ear, accessory sinuses, pleura, mediastinum, and other unspecified respiratory organs; most deaths in this category resulted from malignant mesothelioma.

Table 8
SMRs for Salaried White Males,
Whiting Refinery

	SMR	(Obs.)	95% Conf. Limits	
All causes *	72	(398)	65	79
Tuberculosis (010-019)	+	(1)	2	413
All cancers (140-209) *	77	(100)	63	94
Buccal cavity and pharynx (140-149) *	---	(0)	0	95
Digestive system and peritoneum (150-159)	111	(36)	78	153
Esophagus (150)	+	(2)	8	230
Stomach (151)	161	(8)	70	318
Large intestine (153)	121	(14)	66	203
Rectum (154)	160	(5)	52	373
Biliary passages and liver (155-156)	174	(4)	48	446
Pancreas (157)	44	(3)	9	128
Other digestive (152,158,159)	---	(0)	0	378
Respiratory system (160-163) *	62	(31)	42	88
Larynx (161)	+	(1)	1	292
Bronchus, trachea, lung (162) *	61	(29)	41	88
Other respiratory (160,163)	+	(1)	5	1047
Breast (174)	---	(0)	0	2241
Prostate (185)	59	(5)	19	138
Testis and other male genital organs (172.5,173.5,186,187)	---	(0)	0	855
Kidney (189.0,189.1,189.2)	92	(3)	19	269
Bladder and other urinary (188-189.9)	+	(2)	7	208
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	+	(1)	1	313
Eye (190)	---	(0)	0	3926
Central nervous system (191-192)	+	(1)	1	152
Thyroid and other endocrine glands (193,194)	---	(0)	0	933
Bone (170)	---	(0)	0	898
Lymphatic and hematopoietic (200-209)	128	(15)	72	211
Lymphosarcoma and reticulosarcoma (200)	186	(4)	51	475
Hodgkin's disease (201)	+	(1)	3	555
Leukemia and aleukemia (204-207)	109	(5)	36	255
Other lymphatic tissue (202,203,208,209)	125	(5)	41	292
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	63	(6)	23	137
Benign neoplasms (210-239)	---	(0)	0	261
Diabetes mellitus (250)	51	(4)	14	130
Cerebrovascular disease (330-334)	106	(32)	72	149
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429) *	83	(191)	72	96
Rheumatic heart disease (390-398)	96	(4)	26	246
Ischemic heart disease (410-414) *	82	(171)	70	95
Nonmalignant respiratory disease (460-519) *	38	(14)	21	63
Influenza and pneumonia (470-474,480-486)	50	(6)	18	109
Bronchitis, emphysema, asthma (490-493) *	29	(3)	6	85
Other nonmalignant respiratory (460-466, 500-519) *	33	(5)	11	77
Ulcer of stomach and duodenum (531-533)	117	(3)	24	342
Cirrhosis of liver (571) *	40	(6)	15	87
Nephritis and nephrosis (580-584)	+	(1)	1	235
All external causes of death (E800-E999) *	26	(11)	13	46
Accidents (E800-E949) *	30	(8)	13	59
Motor vehicle accidents (E810-E823) *	40	(5)	13	94
Other accidents (E800-E809,E824-E949) *	21	(3)	4	60
Suicides (E950-E959) *	28	(3)	6	82
Homicides & other external causes (E960-E978,E980-E999) *	---	(0)	0	89

No. of persons = 1,776
Person-years = 37,854

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

Table 9
SMRs for Hourly White Males,
Whiting Refinery

	SMR (Obs.)		95% Conf. Limits	
	SMR	(Obs.)	Lower	Upper
All causes *	91	(1367)	86	96
Tuberculosis (010-019)	+	(2)	6	190
All cancers (140-209) *	88	(312)	78	98
Buccal cavity and pharynx (140-149) *	28	(3)	6	82
Digestive system and peritoneum (150-159)	113	(102)	93	138
Esophagus (150)	163	(14)	89	273
Stomach (151)	131	(18)	77	206
Large intestine (153)	100	(32)	68	141
Rectum (154)	160	(14)	87	268
Biliary passages and liver (155-156)	80	(5)	26	186
Pancreas (157)	79	(15)	44	131
Other digestive (152, 158, 159)	149	(4)	41	381
Respiratory system (160-163) *	75	(103)	62	91
Larynx (161)	+	(1)	1	106
Bronchus, trachea, lung (162) *	73	(95)	59	89
Other respiratory (160, 163) *	488	(7)	196	1006
Breast (174)	+	(1)	6	1236
Prostate (185)	96	(23)	61	144
Testis and other male genital organs (172.5, 173.5, 186, 187)	+	(1)	3	579
Kidney (189.0, 189.1, 189.2)	102	(9)	47	194
Bladder and other urinary (188-189.9)	71	(7)	29	146
Malignant melanoma of skin (172.0-172.4, 172.6-172.9)	69	(3)	14	200
Eye (190)	---	(0)	0	1428
Central nervous system (191-192)	63	(6)	23	137
Thyroid and other endocrine glands (193, 194)	+	(2)	23	684
Bone (170)	---	(0)	0	333
Lymphatic and hematopoietic (200-209)	80	(25)	52	118
Lymphosarcoma and reticulosarcoma (200)	85	(5)	28	199
Hodgkin's disease (201)	---	(0)	0	149
Leukemia and aleukemia (204-207)	82	(10)	39	150
Other lymphatic tissue (202, 203, 208, 209)	93	(10)	45	171
Other malignant neoplasms (171, 173.0-173.4, 173.6-173.9, 195-199)	105	(27)	69	153
Benign neoplasms (210-239) *	263	(10)	128	484
Diabetes mellitus (250)	125	(27)	82	182
Cerebrovascular disease (330-334)	117	(100)	96	143
All heart disease (390-398, 400.1, 400.9, 402, 404, 410-414, 420-429)	93	(593)	86	101
Rheumatic heart disease (390-398)	79	(9)	36	150
Ischemic heart disease (410-414)	93	(538)	85	101
Nonmalignant respiratory disease (460-519) *	61	(63)	47	78
Influenza and pneumonia (470-474, 480-486) *	55	(18)	33	87
Bronchitis, emphysema, asthma (490-493) *	43	(13)	23	74
Other nonmalignant respiratory (460-466, 500-519)	76	(32)	52	107
Ulcer of stomach and duodenum (531-533)	55	(4)	15	142
Cirrhosis of liver (571)	118	(46)	86	157
Nephritis and nephrosis (580-584)	94	(6)	34	204
All external causes of death (E800-E999) *	79	(77)	62	99
Accidents (E800-E949)	87	(54)	66	114
Motor vehicle accidents (E810-E823)	82	(22)	51	123
Other accidents (E800-E809, E824-E949)	91	(32)	63	129
Suicides (E950-E959)	68	(17)	39	108
Homicides & other external causes (E960-E978, E980-E999)	70	(6)	26	153

No. of persons = 4,035

Person-years = 84,032

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000 .

Table 10.
SMRs for White Males, Whiting Refinery,
Employment Duration Less than 20 Years

	SMR (Obs.)		95% Conf. Limits	
	SMR	(Obs.)	Lower	Upper
All causes *	79	(337)	71	88
Tuberculosis (010-019)	+	(1)	2	498
All cancers (140-209)	84	(82)	67	105
Buccal cavity and pharynx (140-149)	+	(1)	1	182
Digestive system and peritoneum (150-159)	94	(22)	59	143
Esophagus (150)	126	(3)	26	368
Stomach (151)	83	(3)	17	243
Large intestine (153)	99	(8)	43	195
Rectum (154)	136	(3)	28	396
Biliary passages and liver (155-156)	+	(1)	2	343
Pancreas (157)	60	(3)	12	174
Other digestive (152, 158, 159)	+	(1)	3	740
Respiratory system (160-163)	33	(35)	64	129
Larynx (161)	---	(0)	0	258
Bronchus, trachea, lung (162)	89	(32)	61	126
Other respiratory (160, 163) *	693	(3)	143	2025
Breast (174)	---	(0)	0	2908
Prostate (185)	70	(3)	15	205
Testis and other male genital organs (172.5, 173.5, 186, 187)	---	(0)	0	661
Kidney (189.0, 189.1, 189.2)	115	(3)	24	336
Bladder and other urinary (188-189.9)	---	(0)	0	178
Malignant melanoma of skin (172.0-172.4, 172.6-172.9)	+	(1)	1	297
Eye (190)	---	(0)	0	4957
Central nervous system (191-192)	+	(2)	7	206
Thyroid and other endocrine glands (193, 194)	+	(1)	7	1611
Bone (170)	---	(0)	0	1057
Lymphatic and hematopoietic (200-209)	114	(11)	57	204
Lymphosarcoma and reticulosarcoma (200)	+	(2)	13	385
Hodgkin's disease (201)	---	(0)	0	321
Leukemia and aleukemia (204-207)	82	(3)	17	240
Other lymphatic tissue (202, 203, 208, 209)	201	(6)	74	436
Other malignant neoplasms (171, 173.0-173.4, 173.6-173.9, 195-199)	41	(3)	9	120
Benign neoplasms (210-239)	+	(1)	2	474
Diabetes mellitus (250)	85	(5)	28	198
Cerebrovascular disease (330-334)	79	(15)	44	131
All heart disease (390-398, 400.1, 400.9, 402, 404, 410-414, 420-429)	86	(143)	72	101
Pneumatic heart disease (390-398)	+	(2)	7	193
Ischemic heart disease (410-414)	88	(132)	73	104
Nonmalignant respiratory disease (460-519) *	52	(12)	27	90
Influenza and pneumonia (470-474, 480-486)	49	(4)	13	128
Bronchitis, emphysema, asthma (490-493)	+	(2)	4	117
Other nonmalignant respiratory (460-466, 500-519)	65	(6)	24	142
Ulcer of stomach and duodenum (531-533)	+	(1)	1	285
Cirrhosis of liver (571)	60	(9)	27	113
Nephritis and nephrosis (580-584)	+	(1)	1	302
All external causes of death (E800-E999) *	65	(35)	46	91
Accidents (E800-E949)	69	(23)	44	104
Motor vehicle accidents (E810-E823)	66	(11)	33	118
Other accidents (E800-E809, E824-E949)	72	(12)	37	125
Suicides (E950-E959)	61	(8)	27	121
Homicides & other external causes (E960-E978, E980-E999)	67	(4)	18	172

No. of persons = 4,181

Person-years = 50,040

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

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Table 11
SMRs for White Males, Whiting Refinery,
Employment Duration 20 Years or More

	SMR	(Obs.)	95% Conf. Limits	
All causes *	88	(1436)	83	93
Tuberculosis (010-019)	+	(2)	6	179
All cancers (140-209) *	85	(332)	76	95
Buccal cavity and pharynx (140-149) *	+	(2)	2	63
Digestive system and peritoneum (150-159)	117	(116)	97	140
Esophagus (150)	138	(13)	74	237
Stomach (151)	151	(23)	96	227
Large intestine (153)	107	(38)	76	147
Rectum (154)	165	(16)	94	268
Biliary passages and liver (155-156)	115	(8)	50	226
Pancreas (157)	72	(15)	40	119
Other digestive (152,158,159)	103	(3)	21	301
Respiratory system (160-163) *	66	(99)	54	81
Larynx (161)	+	(2)	4	125
Bronchus, trachea, lung (162) *	65	(92)	52	80
Other respiratory (160,163) *	326	(5)	103	760
Breast (174)	+	(1)	5	1138
Prostate (185)	89	(25)	57	131
Testis and other male genital organs (172.5,173.5,186,187)	+	(1)	3	665
Kidney (189.0,189.1,189.2)	95	(9)	43	180
Bladder and other urinary (188-189.9)	89	(10)	43	163
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	70	(3)	14	204
Eye (190)	—	(0)	0	1322
Central nervous system (191-192)	62	(6)	23	135
Thyroid and other endocrine glands (193,194)	+	(1)	2	503
Bone (170)	—	(0)	0	315
Lymphatic and hematopoietic (200-209)	87	(29)	58	125
Lymphosarcoma and reticulosarcoma (200)	114	(7)	46	235
Hodgkin's disease (201)	+	(1)	1	238
Leukemia and aleukemia (204-207)	91	(12)	47	159
Other lymphatic tissue (202,203,208,209)	76	(9)	35	145
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	107	(30)	72	153
Benign neoplasms (210-239) *	222	(9)	102	422
Diabetes mellitus (250)	110	(26)	72	161
Cerebrovascular disease (330-334) *	122	(118)	101	146
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429) *	92	(646)	85	99
Rheumatic heart disease (390-398)	93	(11)	46	166
Ischemic heart disease (410-414)	91	(581)	83	98
Nonmalignant respiratory disease (460-519) *	55	(65)	43	70
Influenza and pneumonia (470-474,480-486) *	54	(20)	33	84
Bronchitis, emphysema, asthma (490-493) *	41	(14)	22	69
Other nonmalignant respiratory (460-466, 500-519) *	64	(31)	44	91
Ulcer of stomach and duodenum (531-533)	76	(6)	28	166
Cirrhosis of liver (571)	110	(43)	80	148
Nephritis and nephrosis (580-584)	86	(6)	32	188
All external causes of death (E800-E999) *	61	(53)	46	80
Accidents (E800-E949) *	70	(39)	50	96
Motor vehicle accidents (E810-E823)	70	(16)	40	114
Other accidents (E800-E809, E824-E949)	70	(23)	44	105
Suicides (E950-E959) *	52	(12)	27	91
Homicides & other external causes (E960-E978, E980-E999)	+	(2)	4	107

No. of persons = 3,521
Person-years = 72,062

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

Table 12
SMRs for White Males, Whiting Refinery,
Latency of Less than 30 Years

	SMR (Obs.)		95% Conf. Limits	
All causes *	73	(374)	66	81
Tuberculosis (010-019)	+	(2)	12	346
All cancers (140-209) *	72	(73)	56	90
Buccal cavity and pharynx (140-149)	+	(1)	1	146
Digestive system and peritoneum (150-159)	103	(26)	67	151
Esophagus (150)	---	(0)	0	153
Stomach (151)	137	(8)	50	298
Large intestine (153)	115	(9)	53	219
Rectum (154)	178	(5)	58	415
Biliary passages and liver (155-156)	+	(2)	18	529
Pancreas (157)	54	(3)	11	156
Other digestive (152,158,159)	+	(1)	3	551
Respiratory system (160-163) *	60	(23)	38	90
Larynx (161)	---	(0)	0	224
Bronchus, trachea, lung (162) *	58	(21)	36	89
Other respiratory (160,163)	+	(2)	47	1416
Breast (174)	---	(0)	0	2384
Prostate (185)	+	(1)	1	212
Testis and other male genital organs (172.5,173.5,186,187)	+	(1)	3	750
Kidney (189.0,189.1,189.2)	+	(2)	8	249
Bladder and other urinary (188-189.9)	---	(0)	0	182
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	+	(2)	12	343
Eye (190)	---	(0)	0	3855
Central nervous system (191-192)	68	(3)	14	198
Thyroid and other endocrine glands (193,194)	+	(1)	6	1226
Bone (170)	---	(0)	0	727
Lymphatic and hematopoietic (200-209)	81	(9)	37	154
Lymphosarcoma and reticulosarcoma (200)	+	(2)	9	256
Hodgkin's disease (201)	+	(1)	1	318
Leukemia and aleukemia (204-207)	148	(6)	54	323
Other lymphatic tissue (202,203,208,209)	---	(0)	0	146
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	56	(4)	15	143
Benign neoplasms (210-239) *	327	(5)	106	763
Diabetes mellitus (250)	73	(5)	24	169
Cerebrovascular disease (330-334) *	54	(12)	28	94
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	87	(178)	74	100
Rheumatic heart disease (390-398)	81	(5)	26	189
Ischemic heart disease (410-414) *	85	(161)	73	99
Nonmalignant respiratory disease (460-519) *	38	(9)	17	71
Influenza and pneumonia (470-474,480-486) *	31	(3)	6	90
Bronchitis, emphysema, asthma (490-493)	45	(4)	12	116
Other nonmalignant respiratory (460-466, 500-519)	+	(2)	4	129
Ulcer of stomach and duodenum (531-533)	+	(1)	1	170
Cirrhosis of liver (571)	65	(14)	36	109
Nephritis and nephrosis (580-584)	+	(2)	10	294
All external causes of death (E800-E999) *	56	(41)	40	76
Accidents (E800-E949) *	59	(27)	39	85
Motor vehicle accidents (E810-E823) *	57	(13)	30	97
Other accidents (E800-E809,E824-E949)	60	(14)	33	101
Suicides (E950-E959)	69	(12)	35	120
Homicides & other external causes (E960-E978,E980-E999) *	+	(2)	3	97

No. of persons = 5,350

Person-years = 65,390

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

Table 13
SMRs for White Males, Whiting Refinery,
Latency of 30 Years or More

	SMR	(Obs.)	95% Conf. Limits	
All causes *	90	(1399)	86	95
Tuberculosis (010-019)	+	(1)	1	181
All cancers (140-209) *	89	(341)	80	99
Buccal cavity and pharynx (140-149) *	+	(2)	2	67
Digestive system and peritoneum (150-159)	115	(112)	95	139
Esophagus (150)	171	(16)	98	278
Stomach (151)	139	(20)	85	214
Large intestine (153)	103	(37)	73	142
Rectum (154)	154	(14)	84	258
Biliary passages and liver (155-156)	97	(7)	39	200
Pancreas (157)	74	(15)	42	122
Other digestive (152,158,159)	113	(3)	23	330
Respiratory system (160-163) *	75	(111)	62	90
Larynx (161)	+	(2)	4	130
Bronchus, trachea, lung (162) *	73	(103)	59	88
Other respiratory (160,163) *	411	(6)	151	895
Breast (174)	+	(1)	5	1207
Prostate (185)	90	(27)	60	131
Testis and other male genital organs (172.5,173.5,186,187)	---	(0)	0	565
Kidney (189.0,189.1,189.2)	109	(10)	52	200
Bladder and other urinary (188-189.9)	88	(10)	42	163
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	+	(2)	6	178
Eye (190)	---	(0)	0	1434
Central nervous system (191-192)	57	(5)	19	133
Thyroid and other endocrine glands (193,194)	+	(1)	3	557
Bone (170)	---	(0)	0	364
Lymphatic and hematopoietic (200-209)	97	(31)	66	138
Lymphosarcoma and reticulosarcoma (200)	135	(7)	54	277
Hodgkin's disease (201)	---	(0)	0	213
Leukemia and aleukemia (204-207)	70	(9)	32	134
Other lymphatic tissue (202,203,208,209)	122	(15)	69	202
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	103	(29)	69	148
Benign neoplasms (210-239)	135	(5)	44	316
Diabetes mellitus (250)	115	(26)	75	168
Cerebrovascular disease (330-334) *	130	(121)	108	155
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	92	(611)	85	100
Rheumatic heart disease (390-398)	85	(8)	37	167
Ischemic heart disease (410-414)	92	(552)	84	100
Nonmalignant respiratory disease (460-519) *	58	(68)	45	74
Influenza and pneumonia (470-474,480-486) *	60	(21)	37	92
Bronchitis, emphysema, asthma (490-493) *	38	(12)	20	66
Other nonmalignant respiratory (460-466, 500-519) *	68	(35)	47	94
Ulcer of stomach and duodenum (531-533)	92	(6)	34	200
Cirrhosis of liver (571)	116	(38)	82	160
Nephritis and nephrosis (580-584)	79	(5)	28	184
All external causes of death (E800-E999) *	70	(47)	51	93
Accidents (E800-E949)	82	(35)	57	114
Motor vehicle accidents (E810-E823)	85	(14)	47	143
Other accidents (E800-E809, E824-E949)	79	(21)	49	121
Suicides (E950-E959) *	43	(8)	19	85
Homicides & other external causes (E960-E978, E980-E999)	76	(4)	21	195

No. of persons = 4,376

Person-years = 56,712

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000 .

Table 14
SMRs for White Males, Whiting Refinery,
Hired before 1940

	SMR (Obs.)		95% Conf. Limits	
	SMR	(Obs.)	Lower	Upper
All causes *	87	(874)	81	93
Tuberculosis (010-019)	+	(1)	1	214
All cancers (140-209) *	81	(186)	70	93
Buccal cavity and pharynx (140-149) *	---	(0)	0	56
Digestive system and peritoneum (150-159)	121	(73)	95	152
Esophagus (150)	169	(9)	77	320
Stomach (151)	170	(16)	97	276
Large intestine (153)	97	(21)	60	148
Rectum (154)	165	(10)	79	303
Biliary passages and liver (155-156)	146	(6)	54	317
Pancreas (157)	72	(9)	33	138
Other digestive (152,158,159)	+	(2)	13	398
Respiratory system (160-163) *	61	(52)	46	80
Larynx (161)	+	(2)	7	216
Bronchus, trachea, lung (162) *	57	(46)	42	76
Other respiratory (160,163) *	450	(4)	123	1151
Breast (174)	---	(0)	0	1266
Prostate (185)	77	(15)	43	127
Testis and other male genital organs (172.5,173.5,186,187)	---	(0)	0	811
Kidney (189.0,189.1,189.2)	92	(5)	30	216
Bladder and other urinary (188-189.9)	54	(4)	15	138
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	+	(1)	1	255
Eye (190)	---	(0)	0	2174
Central nervous system (191-192)	78	(4)	21	200
Thyroid and other endocrine glands (193,194)	---	(0)	0	578
Bone (170)	---	(0)	0	516
Lymphatic and hematopoietic (200-209)	81	(16)	46	131
Lymphosarcoma and reticulosarcoma (200)	109	(4)	30	280
Hodgkin's disease (201)	---	(0)	0	281
Leukemia and aleukemia (204-207)	100	(8)	43	197
Other lymphatic tissue (202,203,208,209)	59	(4)	16	150
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	98	(16)	56	160
Benign neoplasms (210-239)	124	(3)	26	362
Diabetes mellitus (250)	129	(19)	78	201
Cerebrovascular disease (330-334) *	130	(86)	104	160
All heart disease (390-398,400.1, 400.9,402,404,410-414,416-429) *	90	(393)	81	99
Rheumatic heart disease (390-398)	85	(6)	31	186
Ischemic heart disease (410-414) *	89	(354)	80	98
Nonmalignant respiratory disease (460-519) *	44	(34)	30	61
Influenza and pneumonia (470-474,480-486) *	40	(10)	19	74
Bronchitis, emphysema, asthma (490-493) *	39	(9)	18	74
Other nonmalignant respiratory (460-466, 500-519) *	50	(15)	28	82
Ulcer of stomach and duodenum (531-533)	79	(4)	21	201
Cirrhosis of liver (571)	114	(23)	73	172
Nephritis and nephrosis (580-584)	67	(3)	14	197
All external causes of death (E800-E999) *	65	(30)	44	93
Accidents (E800-E949)	73	(22)	46	111
Motor vehicle accidents (E810-E823)	67	(8)	29	132
Other accidents (E800-E809,E824-E949)	77	(14)	42	130
Suicides (E950-E959)	51	(6)	19	110
Homicides & other external causes (E960-E978,E980-E999)	+	(2)	8	236

No. of persons = 1,639
Person-years = 34,737

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000.

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Table 15
SMRs for White Males, Whiting Refinery,
Hired 1940 or After

	SMR (Obs.)		95% Conf. Limits	
	SMR	(Obs.)	Lower	Upper
All causes *	85	(899)	80	91
Tuberculosis (010-019)	+	(2)	10	282
All cancers (140-209)	89	(228)	78	101
Buccal cavity and pharynx (140-149)	38	(3)	8	110
Digestive system and peritoneum (150-159)	104	(65)	80	133
Esophagus (150)	109	(7)	44	224
Stomach (151)	107	(10)	51	196
Large intestine (153)	114	(25)	74	168
Rectum (154)	154	(9)	70	292
Biliary passages and liver (155-156)	67	(3)	14	196
Pancreas (157)	67	(9)	31	127
Other digestive (152,158,159)	+	(2)	13	390
Respiratory system (160-163)	81	(82)	64	100
Larynx (161) *	---	(0)	0	96
Bronchus, trachea, lung (162)	81	(78)	64	101
Other respiratory (160,163) *	371	(4)	101	949
Breast (174)	+	(1)	8	1713
Prostate (185)	100	(13)	53	170
Testis and other male genital organs (172.5,173.5,186,187)	+	(1)	3	592
Kidney (189.0,189.1,189.2)	105	(7)	42	216
Bladder and other urinary (188-189.9)	101	(6)	37	221
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	75	(3)	16	220
Eye (190)	---	(0)	0	2013
Central nervous system (191-192)	50	(4)	14	127
Thyroid and other endocrine glands (193,194)	+	(2)	30	886
Bone (170)	---	(0)	0	458
Lymphatic and hematopoietic (200-209)	103	(24)	66	153
Lymphosarcoma and reticulosarcoma (200)	115	(5)	37	268
Hodgkin's disease (201)	+	(1)	1	256
Leukemia and aleukemia (204-207)	79	(7)	32	163
Other lymphatic tissue (202,203,208,209)	138	(11)	69	248
Other malignant neoplasms (171,173.0-173.4, 173.6-173.9,195-199)	89	(17)	52	143
Benign neoplasms (210-239) *	250	(7)	101	515
Diabetes mellitus (250)	81	(12)	42	142
Cerebrovascular disease (330-334)	96	(47)	70	127
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	92	(396)	83	101
Rheumatic heart disease (390-398)	82	(7)	33	169
Ischemic heart disease (410-414)	92	(359)	82	102
Nonmalignant respiratory disease (460-519) *	67	(43)	49	91
Influenza and pneumonia (470-474,480-486)	70	(14)	38	117
Bronchitis, emphysema, asthma (490-493) *	41	(7)	16	84
Other nonmalignant respiratory (460-466, 500-519)	81	(22)	51	122
Ulcer of stomach and duodenum (531-533)	64	(3)	13	186
Cirrhosis of liver (571)	85	(29)	57	122
Nephritis and nephrosis (580-584)	92	(4)	25	236
All external causes of death (E800-E999) *	61	(58)	47	79
Accidents (E800-E949) *	68	(40)	49	92
Motor vehicle accidents (E810-E823)	69	(19)	42	108
Other accidents (E800-E809, E824-E949)	67	(21)	41	102
Suicides (E950-E959) *	58	(14)	32	97
Homicides & other external causes (E960-E978, E980-E999)	41	(4)	11	106

No. of persons = 4,182

Person-years = 87,365

* Significant at $p \leq 0.05$

+ SMRs are not included in the table when the observed is < 3 and the SMR is < 1000 .

Table 16
 Internal Comparisons Using Logistic Regression,
 Analysis Limited to "Elevated" PMRs
 White Males, Whiting Refinery

Cause of Death (N)	Employment Duration**		Pay Status**		Hire Year**	
	Odds Ratio	p	Odds Ratio	p	Odds Ratio	p
Digestive system cancers (63)+	1.46	0.28	0.86	0.67	1.50	0.22
Esophageal cancer (8)	1.44	0.69	1.21	0.86	1.15	0.87
Stomach cancer (13)	1.12	0.87	2.10	0.49	0.85	0.80
Colon cancer (25)+	1.95	0.25	0.65	0.40	2.04	0.20
Rectal cancer (7)	2.60	0.45	++	—	4.9	0.20

* Elevated PMRs are defined as: PMRs ≥ 125 with at least six observed deaths. The mortality category "other malignant neoplasms" was not analyzed because it is comprised of several unique causes of death.

** Odds ratios for employment duration and hire year are reported for increasing ten-year intervals. Both variables were entered as continuous variables in the logistic regression models. Salary pay status is the reference category; therefore, odds ratios are for hourly employees.

+ Odds ratios did not change appreciably when birth year and death year were controlled for in the regression models.

++ All seven were paid an hourly wage; therefore, odds ratios could not be calculated.

Table 17

Internal Comparisons Using Cox Regression,
 Analysis Limited to "Elevated" SMRs
 White Males, Whiting Refinery

Cause of Death (N)	Employment Duration**		Pay Status**		Hire Year**	
	Odds Ratio	P	Odds Ratio	P	Odds Ratio	P
Esophageal cancer (16)	0.53	0.12	2.60	0.21	1.90	0.32
Stomach cancer (26)	0.69	0.89	0.92	0.84	1.05	0.88
Rectal cancer (19)	0.68	0.25	1.04	0.93	0.86	0.73

* Elevated SMRs are defined as: SMRs ≥ 125 with at least five observed deaths. The mortality categories which include mesothelioma deaths were not analyzed using Cox regression because the risk factors for mesothelioma are well-documented.

** Odds ratios for employment duration and hire year are reported for increasing ten-year intervals. Both variables were entered as continuous variables in the Cox regression models. Salary pay status is the reference category; therefore, odds ratios are for hourly employees.

Table 18
 Characteristics of Whiting Refinery,
 White Male Deaths Attributed to Mesothelioma

	N
ICD-8 Coded As:	
Benign neoplasms (228)	3
Lung cancer (162)	2
Other respiratory cancer (163)	6
Other (199)	5
Year of Hire	
Prior to 1940	8
1940 - 1949	6
1950 and after	2
Employment Duration	
Less than 25 years	3
25 years or more	13
Year of Death	
1960 - 1969	1
1970 - 1979	6
1980 - 1986	9
Job Description	
Insulator	3
Machinist	3
Operator	3
Other *	7

* Other job description includes one each of the following:
 engineer, welder, pipefitter, painter, carpenter, clerk, and
 unknown.

Table 19

White Males, Whiting Refinery,
 Proportionate Cancer Mortality Ratio
Causes of Death in Category of Other Malignant Neoplasms

<u>Category</u>	<u>ICD-8 Code</u>	<u>Number (N)</u>
Malignant neoplasm of connective and other soft tissue	171	1
Other malignant neoplasm of skin, lips	173	1
Malignant neoplasm of ill-defined sites	195	1
Secondary malignant neoplasm of respiratory and digestive systems	197	6
Malignant neoplasm without specification of site	199	6

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A Mortality Study
of Whiting Refinery Employees

APPENDIX A

Proportionate Mortality Analyses,
Whiting Non-Refinery Workers and
Employees at Four Other Amoco Refineries

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**Proportionate Mortality Analyses,
Employees at Four Other Amoco Refineries
and Whiting Non-Refinery Workers**

INTRODUCTION AND METHODS

Study Population

This appendix presents a proportionate mortality analysis for two groups of Amoco employees. These groups are comprised of 1.) employees who worked in Whiting, Indiana in positions not associated with the refinery (primarily research positions); and 2.) some employees from the Baltimore, Salt Lake City, Savannah and Wood River refineries. All records were initially collected to be used in the Phase II cohort mortality study. For reasons explained below, these records were analyzed independently from the Phase II study.

The refinery population for this study was assembled by combining records from refineries which had been evaluated as insufficiently complete for the analytical technique used in the Phase II study, which was the Standardized Mortality Ratio (SMR). The Phase II study assessed cohort completeness over three time intervals; only the time intervals which were determined to be incomplete are included in this study. Employees hired on a part-time or temporary basis and those who worked for less than six months were not included in the study.

The personnel department at the Whiting refinery was responsible for maintaining records for all Amoco employees working in Whiting, including refinery, research, and marine employees. The Whiting refinery cohort was compiled using old personnel records. When the cohort records were reviewed (see Appendix B) we discovered a number of research employees had been included in the refinery cohort. We did not have a completely enumerated cohort of research workers.

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Statistical Analysis

The vital status follow-up of this population is described in the main body of text (page 5).

The analytic technique used in this study to compare the mortality experience of refinery and research employees to the U.S. general population is the Proportionate Mortality Ratio (PMR). The PMR is a ratio of the proportion of deaths attributed to a specific cause in a study population relative to a comparison population. A special type of PMR, a Proportionate Cancer Mortality Ratio (PCMR), was calculated for site-specific cancers. The comparison population used in most calculations is the U.S. general population. Because mortality rates in Utah are considerably different from U.S. rates, state rates were used for the comparison at the Salt Lake City refinery. Utah mortality rates are generally lower for most causes of death, which is attributed to the healthy lifestyle of the Mormon residents.

PMRs and their corresponding 95 confidence intervals were calculated using a computer software package designed by Marsh. U.S. and Utah mortality rates were also supplied by Marsh. The analysis is limited to white males because the number of employees in the other race-sex groups is small.

RESULTS

Refinery Groups

There were 620 deaths in the combined four-refinery population; of these, 94 were attributed to cancer. The combined results are heavily weighted by the Wood River and Salt Lake City refineries, which contributed 54 percent and 32 percent of the total population, respectively. More than 90 percent of the population were born before 1920, and most (84%) were paid an hourly wage. Somewhat unexpectedly, over 40 percent of the population worked for less than five years at Amoco and 75 percent of the Salt Lake City employees were short-term employees. Tables 1 and 2 present demographic and employment characteristics of the employees from these four refineries.

PMRs and PCMRs for the composite refinery population are presented in Table 3. The PMR for all cancer was significantly lower than expected (PMR=74), and the PMR for heart disease was significantly greater than expected (PMR=110). Two site-specific cancers, cancers of the eye and larynx, occurred significantly more often than expected. However, the number of deaths in both of these mortality categories was quite small, with only one (eye cancer) and four deaths (cancer of the larynx). The PCMRs for pancreatic and brain cancer were elevated (175 and 222, respectively) and close to statistically significant.

Tables 4 through 7 present PMRs and PCMRs for each of the individual refineries. Several specific causes of death represented a significantly greater proportion of total deaths than expected. In most cases, the number of deaths is small and therefore the results are somewhat unstable. The following results were statistically significant: pancreatic cancer at the Baltimore refinery; heart disease and cancers of the eye, brain, and larynx at the Salt Lake City refinery; and accidents and leukemia at the Savannah refinery.

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Non-Refinery Group

The Whiting non-refinery group included research employees (73%), marine employees (16%), and employees for whom we could not identify an affiliation (11%). Of the non-refinery employees, 160 were deceased with 40 of these deaths being attributed to cancers. Most of these employees worked for longer than 20 years (60%). Tables 8 and 9 present demographic and employment characteristics of the non-refinery population.

Table 10 presents PMRs and PCMRs for the Whiting non-refinery employees. Cancer deaths represented a slightly greater proportion of the total deaths in this population relative to the U.S. general population (PMR=115). Digestive cancers, including rectal and other digestive cancers, occurred proportionately more often than expected. These differences were statistically significant. Lymphatic and hematopoietic cancers also represented a larger proportion of deaths than expected, although the difference was not statistically significant.

DISCUSSION

Refinery Groups

Among refinery employees, the proportion of deaths attributed to cancer was significantly less than expected with 15 percent of all death certificates listing cancer as the underlying cause. Because of this proportional deficit, it is likely that the PCMRs slightly overestimate cancer mortality.

Several site-specific cancers occurred proportionately more often than expected, including cancers of the eye, brain, pancreas and larynx. The PCMR for eye cancer was the highest observed in the study, but was based on a single death. This result is highly unstable and no inferences can be drawn based on this PCMR.

Deaths from brain cancer represented twice the proportion of expected cancer deaths from this cause. Most (80%) of the brain cancer deaths were among employees of the Salt Lake City refinery. The Phase II study did not find an increased risk of brain cancer at the Salt Lake City refinery (SMR=55, one observed death), nor in the overall refinery population (SMR=104, 33 observed deaths). Mortality studies of refinery employees have produced inconsistent results with some reporting excess mortality due to brain cancer and others reporting no excess. Most of the studies finding an excess have been based on small numbers, and have not shown a dose response with employment duration (1).

The PCMRs for cancer of the esophagus and larynx were higher than expected; however, both results were based on only four observed deaths. Most of the esophageal cancer deaths occurred in the Wood River refinery population (75%), whereas the laryngeal cancers were distributed among three refineries. Smoking cigarettes and consuming alcohol greatly increase the risk of being diagnosed with these cancers (2). Approximately 80 percent of esophageal cancer and 75 percent of laryngeal cancer are attributed to one or both of these risk factors (3,4). A recent article reported an association between occupational exposure to sulfuric acid and increased risk of laryngeal cancer (5).

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Pancreatic cancer deaths occurred proportionately more often than expected. The PCMR for pancreatic cancer was significantly greater than expected at the Baltimore refinery; however, this result was based on only three deaths. Pancreatic cancer is more common among non-whites and the elderly. The following factors have been associated with increased risk of pancreatic cancer: cigarette smoking, diabetes, high-fat diet, and alcohol and coffee consumption (6). The Phase II study did not find an increased risk for pancreatic cancer (SMR=68, 42 observed deaths). In addition, a meta-analysis of 22 mortality studies of refinery employees did not find an excess of pancreatic cancer (1).

Lymphatic and hematopoietic cancers occurred in approximately the proportion expected; however, most of these cancers were among employees of the Salt Lake City refinery. There were no more than two deaths in any single category of hematopoietic cancers at this refinery. The Phase II study did not find an excess of these cancers among Salt Lake City refinery employees (SMR=107, seven observed deaths).

Non-Refinery Group

Among Whiting non-refinery employees, the proportion of deaths attributed to cancer was similar to the U.S. population (PMR=115). Because the PMR was greater than 100, the PCMR may slightly underestimate cancer mortality. Several cancers occurred proportionately more often than expected, including lymphatic and hematopoietic cancers and cancers of the colon and rectum.

Death from lymphatic and hematopoietic cancer represented almost twice the proportion of expected deaths from this cause. A recent study of petrochemical research employees reported a statistically significant two-fold increased risk for lymphatic cancers and leukemia among scientists and engineers (7). Although the results of these studies are similar, undue emphasis should not be placed on the Amoco results because the study population is small and the type of study (PMR) is not the most accurate for evaluating cancer risk.

Digestive cancers, in particular cancers of the colon and rectum, also occurred proportionately more often than expected. Digestive cancers are most frequently associated with dietary risk factors, such as high

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fat/low fiber diets. The results of the refinery mortality studies have consistently found elevated mortality rates for digestive cancers among Whiting refinery employees. We are not certain why digestive cancer mortality rates are higher than expected among employees who worked at Whiting, in both refinery and non-refinery positions. However, among refinery employees, the elevated rates do not appear to be related to employment factors because the digestive cancer mortality rates are consistently high among all categories of employment duration and pay status.

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References

1. Wong O, Raabe GK. Critical review of cancer epidemiology in petroleum industry employees with a quantitative meta-analysis by cancer site. Am J Ind Med 1989;15:293-310.
2. World Health Organization, International Agency for Research on Cancer Working Group. Alcohol drinking. IARC Monographs on the evaluation of carcinogenic risks to humans, volume 44. Lyon: International Agency for Research on Cancer, 1988.
3. Yakshe PN, Fleischer DE. Neoplasms of the esophagus. In: Castell DO (ed.), The esophagus. Boston: Little, Brown and Company, 1992.
4. Blot WJ, McLaughlin JK, Winn DM, et al. Smoking and drinking in relation to oral and pharyngeal cancer. Cancer Res 1988;48:3282-7.
5. Soskolne CL, Jhangri GS, Siemiatycki J, et al. Occupational exposure to sulfuric acid in southern Ontario, Canada, in association with laryngeal cancer. Scand J Work Environ Health 1992;18:225-32.
6. Gordis L, Gold EB. Epidemiology of pancreatic cancer. World J Surg 1984;8:808-21.
7. Arnetz BB, Raymond LW, Nicolich MJ, et al. Mortality among petrochemical science and engineering employees. Arch Environ Health 1991;46:237-48.

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Table 1
Study Characteristics of the
Baltimore, Salt Lake City, Savannah, and Wood River
Refinery Employees, White Males

	<u>Total</u>	<u>Baltimore</u>	<u>Salt Lake City</u>	<u>Savannah</u>	<u>Wood River</u>
Population Size	620	50	197	35	338
Year of Birth					
1870-1899	331	25	81	15	210
1900-1919	235	19	106	20	90
1920-1939	54	6	10	—	38
Year of Death					
1940-1949	80	—	12	—	68
1950-1959	111	3	33	2	73
1960-1969	157	13	48	11	85
1970-1979	161	20	60	15	66
1980-1986	111	14	44	7	46

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Table 2
Employment Characteristics of the
Baltimore, Salt Lake City, Savannah, and Wood River
Refinery Employees

	<u>Total</u>	<u>Baltimore</u>	<u>Salt Lake City</u>	<u>Savannah</u>	<u>Wood River</u>
Age at Hire					
< 20	20	1	—	—	19
20-29	194	17	42	12	123
30-39	257	20	81	14	142
40+	149	12	74	9	54
Year of Hire					
< 1920	163	—	10	1	152
1920-1939	152	29	31	22	70
1940-1960	305	21	158	12	116
Length of Employment					
< 5 years	254	3	149	—	102
5-9 years	36	4	8	2	22
10-19 years	58	14	11	9	24
20+ years	272	29	29	24	190
Pay Status					
Hourly	520	38	170	22	290
Salary	88	12	15	13	48
Unknown	12	—	12	—	—

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Table 3
PMRs/PCMRs for White Males,
Four Refineries Other than Whiting

			95%	
	PMR**	(Obs.)	Conf. Limits	
All cancers (140-209) *	78	(94)	65	94
Buccal cavity and pharynx (140-149)	108	(3)	36	329
Digestive system and peritoneum (150-159)	103	(27)	75	142
Esophagus (150)	193	(4)	75	500
Stomach (151)	106	(5)	45	247
Large intestine (153)	44	(4)	18	109
Rectum (154)	137	(4)	53	359
Biliary passages and liver (155,156)	---	(0)	---	---
Pancreas (157)	175	(9)	94	328
Other digestive organs (152,158,159)	+	(1)	15	746
Respiratory system (160-163)	106	(32)	80	141
Larynx (161) *	310	(4)	123	779
Bronchus, trachea, lung (162)	99	(28)	73	133
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	55	(5)	25	120
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	+	(1)	7	303
Bladder and other urinary (188-189.9)	92	(3)	30	277
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190) *	1220	(1)	265	5623
Central nervous system (191-192)	222	(5)	96	512
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209)	111	(10)	62	199
Lymphosarcoma and reticulosarcoma (200)	+	(2)	27	422
Hodgkins disease (201)	+	(1)	16	709
Leukemia and aleukemia (204-207)	105	(4)	40	273
Other lymphopoietic tissue (202,203,208,209)	126	(3)	41	383
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	106	(7)	52	217
Benign neoplasms (210-239)	---	(0)	---	---
All heart disease (390-398,400.1 400.9,402,404,410-414,420-429) *	110	(295)	101	120
Nonmalignant respiratory disease (460-519)	90	(39)	67	122
Accidents (E800-E949)	88	(27)	63	124
Motor vehicle accidents (E810-E823)	97	(14)	60	156
Suicides (E950-E959)	64	(6)	29	138

No. of deaths = 620

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000 .

Table 4
PMRs/PCMRs for White Males,
Baltimore Refinery

	PMR**	(Obs.)	95%	
			Conf. Limits	
All cancers (140-209)	113	(11)	67	191
Buccal cavity and pharynx (140-149)	---	(0)	---	---
Digestive system and peritoneum (150-159)	170	(5)	81	357
Esophagus (150)	---	(0)	---	---
Stomach (151)	+	(1)	32	1347
Large intestine (153)	+	(1)	15	606
Rectum (154)	---	(0)	---	---
Biliary passages and liver (155,156)	---	(0)	---	---
Pancreas (157) *	513	(3)	191	1376
Other digestive organs (152,158,159)	---	(0)	---	---
Respiratory system (160-163)	105	(4)	48	229
Larynx (161) *	+	(1)	117	3450
Bronchus, trachea, lung (162)	83	(3)	34	207
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	---	(0)	---	---
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	---	(0)	---	---
Bladder and other urinary (188-189.9)	---	(0)	---	---
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190)	---	(0)	---	---
Central nervous system (191-192)	---	(0)	---	---
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209)	---	(0)	---	---
Lymphosarcoma and reticulosarcoma (200)	---	(0)	---	---
Hodgkins disease (201)	---	(0)	---	---
Leukemia and aleukemia (204-207)	---	(0)	---	---
Other lymphopoietic tissue (202,203,208,209)	---	(0)	---	---
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	+	(2)	69	903
Benign neoplasms (210-239)	---	(0)	---	---
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	100	(22)	73	136
Nonmalignant respiratory disease (460-519)	77	(3)	26	228
Accidents (E800-E949)	---	(0)	---	---
Motor vehicle accidents (E810-E823)	---	(0)	---	---
Suicides (E950-E959)	---	(0)	---	---

No. of deaths = 50

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000.

Table 5
PMRs/PCMRs for Salt Lake City Refinery†

	PMR**	(Obs.)	95%	
			Conf. Limits	
All cancers (140-209)	81	(26)	57	115
Buccal cavity and pharynx (140-149)	---	(0)	---	---
Digestive system and peritoneum (150-159)	67	(5)	32	140
Esophagus (150)	+	(1)	30	1314
Stomach (151)	---	(0)	---	---
Large intestine (153)	+	(1)	8	285
Rectum (154)	+	(1)	22	1030
Biliary passages and liver (155,156)	---	(0)	---	---
Pancreas (157)	+	(2)	35	503
Other digestive organs (152,158,159)	---	(0)	---	---
Respiratory system (160-163)	84	(5)	40	177
Larynx (161) *	+	(2)	229	2380
Bronchus, trachea, lung (162)	54	(3)	21	140
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	+	(2)	18	207
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	---	(0)	---	---
Bladder and other urinary (188-189.9)	+	(2)	55	777
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190) *	14035	(1)	6164	31956
Central nervous system (191-192) *	383	(4)	162	904
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209)	193	(6)	93	401
Lymphosarcoma and reticulosarcoma (200)	+	(1)	21	956
Hodgkins disease (201)	+	(1)	34	1428
Leukemia and aleukemia (204-207)	+	(2)	42	597
Other lymphopoietic tissue (202,203,208,209)	+	(2)	79	1072
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	+	(1)	8	317
Benign neoplasms (210-239)	---	(0)	---	---
All heart disease (390-398,400,1, 400.9,402,404,410-414,420-429) *	117	(92)	100	137
Nonmalignant respiratory disease (460-519)	112	(19)	73	172
Accidents (E800-E949)	50	(6)	24	102
Motor vehicle accidents (E810-E823)	+	(2)	11	142
Suicides (E950-E959)	---	(0)	---	---

No. of deaths = 197

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000.

† Reference population is that of the state of Utah.

Table 6
PMRs/PCMRs for White Males,
Savannah Refinery

	PMR** (Obs.)		95% Conf. Limits	
All cancers (140-209) *	+	(2)	9	91
Buccal cavity and pharynx (140-149)	---	(0)	---	---
Digestive system and peritoneum (150-159)	---	(0)	---	---
Esophagus (150)	---	(0)	---	---
Stomach (151)	---	(0)	---	---
Large intestine (153)	---	(0)	---	---
Rectum (154)	---	(0)	---	---
Biliary passages and liver (155,156)	---	(0)	---	---
Pancreas (157)	---	(0)	---	---
Other digestive organs (152,158,159)	---	(0)	---	---
Respiratory system (160-163)	+	(1)	30	683
Larynx (161)	---	(0)	---	---
Bronchus, trachea, lung (162)	+	(1)	30	719
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	---	(0)	---	---
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	---	(0)	---	---
Bladder and other urinary (188-189.9)	---	(0)	---	---
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190)	---	(0)	---	---
Central nervous system (191-192)	---	(0)	---	---
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209) *	+	(1)	113	3060
Lymphosarcoma and reticulosarcoma (200)	---	(0)	---	---
Hodgkins disease (201)	---	(0)	---	---
Leukemia and aleukemia (204-207) *	1372	(1)	318	5950
Other lymphopoietic tissue (202,203,208,209)	---	(0)	---	---
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	---	(0)	---	---
Benign neoplasms (210-239)	---	(0)	---	---
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	128	(20)	93	178
Nonmalignant respiratory disease (460-519)	106	(3)	36	313
Accidents (E800-E949) *	417	(4)	172	1012
Motor vehicle accidents (E810-E823) *	+	(2)	169	1924
Suicides (E950-E959)	+	(1)	48	1945

No. of deaths = 35

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000 .

Table 7
 PMRs/PCMRs for White Males,
 Wood River Refinery

	PMR** (Obs.)		95% Conf. Limits	
	PMR**	(Obs.)	Conf.	Limits
All cancers (140-209)	87	(55)	68	110
Buccal cavity and pharynx (140-149)	189	(3)	63	565
Digestive system and peritoneum (150-159)	110	(17)	74	165
Esophagus (150)	249	(3)	84	733
Stomach (151)	142	(4)	55	366
Large intestine (153)	+	(2)	11	132
Rectum (154)	175	(3)	58	525
Biliary passages and liver (155,156)	---	(0)	---	---
Pancreas (157)	132	(4)	51	341
Other digestive organs (152,158,159)	+	(1)	26	1221
Respiratory system (160-163)	125	(22)	89	174
Larynx (161)	+	(1)	19	930
Bronchus, trachea, lung (162)	126	(21)	89	178
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	55	(3)	20	152
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	+	(1)	11	543
Bladder and other urinary (188-189.9)	+	(1)	8	337
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	---	(0)	---	---
Eye (190)	---	(0)	---	---
Central nervous system (191-192)	+	(1)	12	544
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209)	59	(3)	20	170
Lymphosarcoma and reticulosarcoma (200)	+	(1)	14	660
Hodgkins disease (201)	---	(0)	---	---
Leukemia and aleukemia (204-207)	+	(1)	7	296
Other lymphopoietic tissue (202,203,208,209)	+	(1)	10	484
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	104	(4)	40	267
Benign neoplasms (210-239)	---	(0)	---	---
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	111	(161)	99	125
Nonmalignant respiratory disease (460-519)	63	(14)	38	103
Accidents (E800-E949)	89	(17)	58	135
Motor vehicle accidents (E810-ER23)	105	(10)	60	184
Suicides (E950-E959)	89	(5)	38	210

No. of deaths = 338

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000 .

Table 8
Study Characteristics of the
Whiting Non-Refinery Employees, White Males

	<u>PMR/PCMR</u>
Population Size	130
Year of Birth	
1870-1899	45
1900-1919	78
1920-1939	36
1940-1961	1
Year of Death	
1960-1969	32
1970-1979	64
1980-1986	64

Table 2
Employment Characteristics of the
Whiting Non-Refinery Employees, White Males

	<u>PMR/PCMR</u>
Age at Hire	
< 20	3
20-29	76
30-39	65
40+	16
Year of Hire	
< 1920	9
1920-1939	73
1940-1969	78
Length of Employment	
< 5 years	17
5-9 years	12
10-19 years	35
20+ years	96
Pay Status	
Hourly	10
Salary	29
Unknown	121

Table 10
 PMRs/PCMRs for White Males,
 Whiting Non-Refinery Employees

	PMR** (Obs.)		95% Conf. Limits	
All cancers (140-209)	115	(40)	88	151
Buccal cavity and pharynx (140-149)	+	(2)	47	689
Digestive system and peritoneum (150-159) *	155	(16)	102	235
Esophagus (150)	+	(2)	57	827
Stomach (151)	---	(0)	---	---
Large intestine (153)	158	(6)	75	336
Rectum (154) *	298	(3)	103	862
Biliary passages and liver (155,156)	+	(1)	21	979
Pancreas (157)	+	(2)	25	364
Other digestive organs (152,158,159)	+	(2)	206	2224
Respiratory system (160-163) *	49	(7)	28	87
Larynx (161)	---	(0)	---	---
Bronchus, trachea, lung (162) *	51	(7)	29	92
Other respiratory (160,163)	---	(0)	---	---
Breast (174)	---	(0)	---	---
Prostate (185)	117	(4)	47	290
Testes and other male genital organs (172.5,173.5,186,187)	---	(0)	---	---
Kidney (189.0,189.1,189.2)	+	(1)	15	713
Bladder and other urinary (188-189.9)	---	(0)	---	---
Malignant melanoma of skin (172.0-172.4,172.6-172.9)	+	(1)	28	1288
Eye (190)	---	(0)	---	---
Central nervous system (191-192)	+	(1)	15	695
Thyroid and other endocrine glands (193-194)	---	(0)	---	---
Bone (170)	---	(0)	---	---
Lymphatic and hematopoietic (200-209)	196	(7)	98	392
Lymphosarcoma and reticulosarcoma (200)	+	(2)	90	1199
Hodgkins disease (201)	+	(1)	69	2502
Leukemia and aleukemia (204-207)	+	(1)	10	465
Other lymphopoietic tissue (202,203,208,209)	236	(3)	80	694
Other malignant neoplasms (171,173.0-173.4,173.6-173.9,195-199)	+	(1)	6	207
Benign neoplasms (210-239)	+	(1)	41	1747
All heart disease (390-398,400.1, 400.9,402,404,410-414,420-429)	100	(67)	83	120
Nonmalignant respiratory disease (460-519)	69	(8)	36	133
Accidents (E800-E949)	43	(3)	15	119
Motor vehicle accidents (E810-E823)	+	(2)	17	239
Suicides (E950-E959)	114	(3)	38	345

No. of deaths = 160

* Significant at $p \leq 0.05$

** PCMRs are presented for each site-specific cancer.

+ PMRs/PCMRs are not included in the table when the observed is < 3 and the PMR/PCMR is < 1000 .

A Mortality Study
of Whiting Refinery Employees

APPENDIX B

The Whiting Refinery Cohort

The Whiting Refinery Cohort

BACKGROUND

The Phase II Amoco refinery cohort mortality study included employees who worked for at least six months between 1940 and 1980. The study cohort was assembled using computer records for those who terminated employment after 1970 and paper work history cards for those terminating prior to 1970. The paper work history record used for this study is the 318 Work History card which was kept for payroll purposes.

It is important to verify the completeness of a cohort through an independent data source to make certain that a selection bias is not operating. The most common method of verification, suggested by Marsh et al, is to compare the cohort roster to the listing of names appearing on a Social Security Administration 941 report (SSA 941) of wages taxable. The SSA 941 report is submitted by employers on a quarterly basis and lists all individuals who received compensation, their Social Security Number (SSN), and the amount paid. We used SSA 941's to check the completeness of the Phase II cohort at all refineries except for Whiting. This was not possible for Whiting because the employment rosters submitted to the SSA included not only refinery employees but also research and marine employees.

Incompleteness of Whiting Cohort 1940-1960

In December 1986, we hired a casual employee to computerize old death certificates. Because the Phase II study was in progress, death certificates of refinery employees were computerized first. Refinery employees were identified by either the Amoco life insurance proof of death (POD) form indicating refinery employment or by presence in the refinery cohort. Several PODs identified the decedent as a former Whiting employee yet he/she was not in the Phase II study population. A listing of 19 such decedents was given to Neil Pelley at the Whiting refinery to resolve the discrepancy. Mr. Pelley determined that the individuals were employed at the Whiting refinery, but were not included in the refinery study cohort because the 318 work history records used to assemble the cohort were incomplete prior to 1960 (memo N. Pelley 6/8/87). We attempted unsuccessfully to locate copies of

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these 318 cards by searching in storage and by searching for microfilm records (memo M. Hornstra 1/20/87).

The study protocol set five percent as the maximum rate allowable for cohort incompleteness. We were unable to determine the percentage of the Whiting employees not included in the cohort, but we were aware that it was incomplete; therefore, we decided to omit the 1940 through 1960 records from the study. This segment of the cohort included 1,293 employees of whom 1,042 were deceased. Because proportionate mortality studies use the total number of deaths as the denominator as opposed to person-years at risk used in standardized mortality studies, the 1,042 deaths occurring during this period will be included in a separate proportional mortality analysis (PMR study). By doing this, we will derive at least some information from these records.

Incompleteness of the Whiting Cohort 1960-1970

In December 1989, a preliminary analysis of Phase II data was conducted. Mortality patterns for the Whiting refinery deviated from the expected results in that the cancer standardized mortality ratio (SMR) was substantially less than that observed in the Phase I study. We had expected this SMR to increase since, in general, as the length of follow-up increases the healthy worker effect diminishes.

Because the completeness of the Whiting cohort was not verified prior to 1970 and because of the above unexpected results, we sought the advice of our consultant, Dr. Richard Monson. Dr. Monson recommended that this component of the Whiting refinery cohort (1960-1970) be included in the Phase II study if management would assure that the records were complete. Dr. P. F. D. Van Peenen and Margaret Hornstra met with Whiting management on several occasions to see if we could be given this assurance. Current Whiting management was not sufficiently familiar with these records to determine if they were complete. During these meetings, we discovered that the source used to assemble the Whiting cohort included research and marine employees in addition to refinery employees. A single payroll department was responsible for all three groups and the only separation made was between hourly and salaried employees. Research employee records were kept at the refinery until the research center relocated to Naperville, Illinois in the early 1970's.

An attempt was made to locate the work history records of the Whiting research employees who moved to Naperville. The human resources, payroll, and building maintenance departments, as well as

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research retirees familiar with records (Dick Moore and James Goggan), were contacted for information regarding storage of old payroll records. Unfortunately, it appears that these records were destroyed because of flood damage.

Summary

At this point, we suspected we had a refinery cohort that included a fair number of research personnel. We were also aware that not all of the records for Whiting research employees were included in our cohort; in other words, our cohort was not only impure but also incomplete (for research employees).

During the summer of 1990, M. Hornstra and S. Kane set out to explore the Whiting problem. We had two questions to address: 1) What groups of employees comprise the Whiting refinery cohort? and 2) Does the cohort of employees who terminated employment after 1960 include all those who met the study selection criteria?

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ISSUE #1 COMPOSITION OF THE WHITING COHORT

The first phase of the project, determining the compositions of the Whiting PMR and SMR study cohorts, was accomplished by examining the 318 Work History cards *. The job descriptions and locations listed on the 318 cards were used to identify refinery and research employees. In addition, through the kindness of some Amoco contacts we made in searching for lost records, we were loaned directories of Whiting professional and supervisory staff from the Research and Development department (research employee manuals) for the years 1953, 1958, 1960, 1961; and the 1965 and 1968 seniority listing and annual mailing address (Christmas card) lists. These directories and mailing lists were used to corroborate research employment. A Whiting refinery organizational chart providing job locations and a listing of refinery job titles were also used to verify employment. Susie Kane was responsible for determining whether the employee was a research, refinery, or marine employee.

Cards were first sorted by date of retirement. Those employees who retired prior to 1940 or after 1970 were excluded from review. Those who retired prior to 1940 were excluded because the Social Security Administration cannot trace them to identify their vital status; therefore, they are never considered for inclusion in an epidemiological study. Employees who retired after 1970 were excluded because their records are known to be complete; duplication of previous work was thus avoided.

Next, the work history on each card was examined and eligibility and job classifications were determined. The study cohort included Whiting employees when there was a 318 card available and the work history indicated at least 6 months employment; employees working less than six months were not assigned a job classification.

* The 318 work history cards had been stored in a cabinet at the Whiting refinery main office; drawers from the cabinet were picked up and brought to the Epidemiology section by M. Hornstra and S. Kane in groups of three. Relevant information included on the cards are dates, locations, and job titles for each of the employees working at the Whiting facility dating back to 1909. These cards also contained Social Security numbers and dates of birth; these were used for cross-referencing.

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Each Whiting cohort member was assigned one of four possible job classifications: 1) definite refinery, 2) definite research, 3) probable research, or 4) marine. If a worker occupied a position on the refinery list or organization chart for a period exceeding six months, he was classified as "definite refinery". If, based on examination of a 318 card, an employee appeared to hold a more professional position, such as chemist or engineer, he was listed as "probable research." Included in this classification were support service staff whose job title or location included the work "research". A job classification of "definite research" was made only when verified by the research employee directories or annual mailing address list.

Job titles used to assign job classifications were not necessarily the jobs held the longest time. A card was examined to validate the employee's eligibility, and any job that was performed more than six months was used for job classification. If no single specific job was performed for more than six months, but there were several jobs listed which were defined as refinery, then the job classification was given as "definite refinery" and one of the positions held was chosen at random to be listed as basis for this classification.

There were 4,949 employees included in the SMR and PMR cohorts. Of these, 3913 (79.1%) were listed as definite refinery, 479 (9.7%) were identified as definite research, 474 (9.6%) were probable research, and 37 (0.8%) were marine. The remaining 46 persons were unclassified because there was no 318 card, and they did not appear on any available directory or list. Attachment A lists names, SSNs, and employment dates for these 46 individuals. A larger percentage of research employees was included in the standardized mortality study.

PMR vs. SMR

	SMR	PMR
Definite Refinery	75.8	91.2
Definite Research	11.9	3.6
Probable Research	11.5	4.5
Marine	0.8	0.7

The above dataset was also checked for key entry errors and records not reconciled. Four employees were identified as research via a directory but did not have a 318 card; therefore, we can only presume by their job titles they were never employed at the refinery. A list of these names and job titles is presented in Attachment B.

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ISSUE #2 COMPLETENESS OF THE WHITING COHORT

A list of 5,463 names and Social Security numbers (SSNs) from the 1962 SSA 941 list was computerized to facilitate a comparison of the study cohort to the "gold standard" SSA 941 roster. The 1962 list was chosen because it was the only list available for the 1960 to 1970 time frame. There were 617 individuals who appeared on the 1962 SSA 941 list, but did not appear in the SMR cohort (employees who worked between 1960 and 1980).

These 617 were then matched against the file of Whiting refinery employees included in the PMR study, i.e., those employees terminating employment prior to 1960; 161 of the 617 names were found in this manner. Virtually all of the 161 (n=157) terminated employment prior to 1960, but had received severance in 1962. This group of employees was included on the 1962 SSA 941 form because severance is considered taxable income. Therefore, these employees were appropriately on the SSA 941 list, but did not belong in the cohort. Severance status was confirmed by examination of 318 cards and a severance list provided by the Whiting payroll department. Of the remaining names, two proved to be SSN key entry errors. Another two were casual employees paid in 1962, but who did not work long enough to meet eligibility requirements for inclusion in the cohort.

This left 456 names that appeared on the 1962 SSA 941 form, but not in either the standardized or PMR cohorts. Of these 41 were found to be key entry errors (names matched and Social Security numbers nearly matched); we concluded they were on both lists. One was a casual employee, and one name and SSN appeared twice on the lists. The absence of the remaining 413 individuals from the study cohort represents a 7.8 percent incompleteness rate relative to the SSA 941 rosters. The 318 history cards were located for 56 of these 413 employees. It appears, from examination of these cards, that these 56 were inadvertently omitted because all met the criteria for inclusion in the study population. We will attempt to identify vital status for these 56 employees and include them in subsequent updates of the refinery study. A search of the research center professional employee directories located 279 of the 413 employees. We do not have any explanation of why the remaining 78 names were on the SSA 941 list, but not included in the study population.

Estimated Refinery Cohort Completeness

We used the formula listed below to estimate the completeness of the refinery component of the Whiting SMR cohort:

$$\frac{\text{Total missing*}}{\# \text{ on 1962 SSA 941 list*}} \times \% \text{ of Whiting SMR cohort which is refinery}$$

$$\frac{134}{(5023) \times 75.8\% **} = 2.9\% - 3.5\% \text{ incompleteness}$$

* The 161 employees who received severance in 1962 and the 279 research employees were subtracted from both the numerator and the denominator.

** This percentage varies between 75.8 and 87.3 dependent upon whether you consider all, some, or none of the probable research employees to be refinery employees.

CONCLUSIONS AND RECOMMENDATIONS

The Whiting refinery component of the Phase II study is not a pure refinery cohort. As many as 20 percent of the Whiting cohort were employed in the research or marine divisions. We will therefore separately analyze the research and refinery components of the Whiting cohort.

It does appear that the Whiting study cohort (1960-1970) is reasonably complete for refinery employees. However, a large component of the Whiting study cohort is made up of research employees and at least 25 percent of this cohort was not identified.

It is our conclusion that the Whiting refinery should not be included in the Phase II study, but rather analyzed separately. Although it is possible to separate the research employees from the refinery cohort, we feel that the question of completeness and accuracy of records remains a valid concern. The Whiting refinery cohort is sufficiently large for a meaningful study if analyzed on its own.

Margaret Hornstra

Attachments

October 5, 1990