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Cancer mortality rates among workers at the Portsmouth Naval Shipyard (SIC-3731) in Kittery, Maine, were surveyed. Vital status was determined as of 1980 for a total of 24,545 workers employed at any time since 1952. The workers were grouped according to radiation exposure. Deaths from all causes were below expected rates, even when latency and duration of employment were considered. No excess death rates from cancer were found. The authors note that the negative results in this study may be due an insufficient latency period between the workers' exposure and the mortality determinations.

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EPIDEMIOLOGIC STUDY OF CIVILIAN EMPLOYEES AT THE PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE

INTRODUCTION

In May 1978, there was reported a five-fold increase in proportional mortality due to leukemia and a two-fold increase due to all cancer among workers employed in the maintenance of nuclear submarines at the Portsmouth Naval Shipyard (PNS) in Kittery, Maine. (Najarian, 1978)

Subsequently, the Subcommittee on Health and the Environment of the United States House of Representatives held a hearing on cancer mortality at PNS. The Subcommittee charged the Department of Health and Human Services (DHHS) (formerly Health, Education, and Welfare) with responsibility for investigating the reported problem. The Centers for Disease Control (CDC) and its occupational safety and health unit, the National Institute for Occupational Safety and Health (NIOSH) were directed to conduct detailed epidemiologic studies. These investigations were intended to evaluate not only radiation risk, but also to identify and study other potential carcinogens (such as asbestos and benzene) and other agents in the shipyard that could have caused chronic health effects. NIOSH chose to conduct the study

in three phases: 1) a retrospective cohort mortality study of all civilian workers at PNS; 2) case-control studies of selected causes of mortality; and 3) if feasible, a cytogenetic study. These studies were to include industrial hygiene and health physics surveys to document exposure levels, work practices, and control procedures.

This report presents results of the retrospective cohort mortality study. The objectives of this study were: 1) to determine if there were any excesses of cause-specific mortality, particularly for those causes previously reported as being present in excess at PNS; 2) to determine if type of work (radiation, non-radiation) was associated with excess cause-specific mortality; and 3) to determine if there was a dose-response relationship between radiation dose and specific mortality from any cause.

The carcinogenic effects of high doses of ionizing radiation have been well documented and recently reviewed (BEIR, 1980). Studies of atomic bomb survivors, (Bizzozero, 1967; Beebe, 1978), of ankylosing spondylitics (Smith, 1978), and of other populations exposed to high doses of ionizing radiation have demonstrated excess risks of malignancies, particularly of leukemia, and of cancers of the lung, thyroid, and breast. The leukemia risk was observable from 2-30 years after exposure; for the atomic bomb survivors, it was greatest at 8

years. For solid tumors the period of expression may not appear clinically until 10 or more years after exposure. The doses at which effects were observed occurred over short time periods (with the exception of radium dial painters and radiologists) and were almost always above 50 rems cumulative. If these observations are extrapolated to the PNS situation where the average cumulative lifetime dose resulting from exposure at the shipyard of 7,615 radiation workers is 2.779 rems, one would not expect to observe any excess risk of solid tumors as 98% of radiation workers were only first exposed less than 20 years ago. However, the minimal period of time necessary for excess mortality due to leukemia to manifest, may well have been met. If one were to assume an incremental risk of two additional leukemia deaths per 10^6 person-year-rems (BEIR, 1972), then we would have expected an additional 0.6 deaths based on the person-year-rems in Table 1, among subcohort I. This would yield a relative risk* of less than 1.1 based on the 8.3 cases expected. Consequently this NIOSH study has almost no statistical power to detect such a risk. On the other hand, recent investigations (Bross, 1979; Kneale, 1978; Mancuso, 1977; Najarian, 1978) of persons exposed

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* relative risk is the ratio of the mortality rate among the studied population to the mortality rate of the comparison population.

to low levels of ionizing radiation suggest that the risk among these populations may be much greater than that extrapolated from the high dose studies. In fact, Najarian's study indicated an excess of leukemia among the PNS radiation workers and requests to confirm the results with better data were a prime motivation for this NIOSH study of the same work force. If a five-fold excess of leukemia does exist for the PNS radiation workers, then this NIOSH study had a very high probability (99%) of detecting it (Beaumont, 1980).

The possibility also exists that leukemogens other than ionizing radiations may be etiologically important at PNS.

DESCRIPTION OF FACILITIES

From 1800, when the Portsmouth Naval Shipyard (PNS) was established, to the present, its responsibilities have included the design, construction, and repair of ships, from sailing vessels to nuclear powered-submarines. The first United States submarine was built at PNS in 1917, and in 1923 PNS was officially designated a submarine yard.

Between 1917 and 1941, 33 diesel submarines were constructed at PNS. Also during that period approximately four to five submarines were under repair or in overhaul at any time. At the beginning of World War II, a large building program was initiated and a contract was

awarded to PNS to build 104 submarines. To meet this commitment, the work force at the shipyard grew to about 20,000. A total of 98 vessels were constructed and 74 repaired or overhauled at PNS from 1939 through 1945.

During the late 1940's and early 1950's, PNS was affected by a de-emphasis of military programs with a subsequent decline in the work force to less than 10,000. Few submarines were built during this period, and the shipyard supplemented its workload with the building of personnel and sounding boats.

The first nuclear submarine was commissioned at the shipyard in 1958, and an additional nine nuclear submarines were built through 1971. However, with subsequent increases in the number of nuclear submarines built at other shipyards, the role of PNS shifted from the construction of nuclear submarines to their overhaul and repair. By 1962, PNS had become the first United States naval shipyard to acquire full capability for overhauling, repairing, and refueling nuclear-powered submarines. Between 1954 and 1977, four non-nuclear and 63 nuclear submarines were either constructed, overhauled, or repaired at PNS. During this period, the work force peaked at approximately 8000 persons in 1968, but subsequently decreased slightly.

WORK ENVIRONMENT

The principal trades at PNS since the 1940's have included forging, machining, painting, welding, and metal fabrication. Employees are assigned to trade-specific occupational groups called shops. Each shop is responsible for specific tasks either in submarine construction/overhaul or in general support of the shipyard. Although an employee is usually assigned to a single shop, individual day-to-day work assignments vary considerably. These changes, in turn, create variability in the types and magnitude of exposures associated with any particular trade. Estimation of specific exposure is further complicated by the fact that much of the work was done in enclosed spaces designed to be air and water tight, and that many occupational trades work side-by-side in such spaces, each contributing to the others' exposures.

PNS is not unusual among United States naval shipyards in the types of work performed, the potential for occupational exposures, or medical programs. PNS, however, is unique among United States naval shipyards in that it has the longest history of nuclear work, and most of the work within the last 30 years has been limited to the construction and overhaul of submarines, both diesel and nuclear-powered.

Since the beginning of the Navy nuclear propulsion program in the 1950's, workers have been selected and trained as needed for work in radiation-controlled areas on the basis of their expertise in a particular trade. Among the radiation workers is a small group of industrial radiographers. These workers are not involved in the nuclear propulsion program but are exposed to ionizing radiation while evaluating the integrity of welds. In addition to possible radiation exposure, each worker, when working in a controlled radiation area, is exposed to airborne contaminants associated with his and other trades. However, workers employed in radiation-controlled areas generally receive lower exposure to non-radiological airborne contaminants than those employed in other work areas. These lower exposures are due, in part, to improved ventilation required for controlling radioactive contaminated airborne particulates and to the fact that fewer workers of various trades worked side-by-side in radiation areas. The average amount of time spent in the radiation-controlled area by any particular occupational group varies depending on the type of overhaul or repair needed, and the number of submarines in dry dock. In general, however, no group spends more than 20 percent of its time in radiation areas.

Many of the non-radiological occupational exposures found currently at PNS are typical of those which have been encountered during the past

30 years. However, improvements in work practices, in personal protective apparel, and in ventilation, have served to reduce the potential for exposure, especially in the last 5-10 years. Likewise, toxic materials such as carbon tetrachloride, tetrachlorethane, and benzene have been eliminated from use or replaced with less known toxic substitutes. The use of other hazardous materials such as asbestos also has been reduced.

Although reconstruction of the exact nature of past non-radiation exposures at PNS is extremely difficult, inferences can be made about average exposures as they relate to shipyard production rates (ship construction and overhaul). Following World War II and until 1958, few diesel submarines were constructed. Because of this decline in activity, average non-radiation exposure intensities were probably somewhat less in those years than during World War II. However, in the late 1950's and through the 1960's, both new construction and overhaul occurred. This activity probably increased the prevalence and intensity of non-radiation exposures.

An important consideration in evaluating the extent of non-radiation exposure is the use of personal protective apparel, particularly respiratory protection. It has been PNS policy since the mid-1950's to require respiratory protection for certain occupational tasks such

as working with lead, asbestos handling, sand blasting, welding, painting, and working in confined spaces. Workers in other tasks are supplied protection only on request. However, discretion in the wearing of respiratory protection is usually left to the worker or to the first-line supervisor, and in most cases protection is used only by those workers exposed to irritating concentrations of materials. Furthermore, no formal training is given for fit-testing or for maintaining respirators. Therefore, except when they are wearing air-supplied respiratory protection, the actual protection afforded workers wearing respirators is questionable.

PERSONNEL RADIATION DOSIMETRY

A program for monitoring personnel for occupational radiation exposure has been well established at PNS since nuclear work was first undertaken in 1958. The program was designed to monitor both internal and external radiation exposure in radiation workers at the shipyard.

Before any shipyard personnel can become eligible to work in radiation-controlled areas, they are given a special medical examination. This examination was repeated every 3 years. Since 1972 (earliest date these records exist), 89 persons have been removed from the nuclear program on the basis of findings in the repeat medical

examination; the number excluded on the basis of the initial examination findings is not known.

Candidates for radiation work also are required to have completed successfully a radiation safety training program. Such workers are deemed "qualified" and are given a personnel radiation dosimeter when access to radiation controlled areas is necessary. All workers in radiation-controlled areas (both on ship and within certain building areas) are required to wear dosimeters.

Internal exposure to radiation results from entry of a radionuclide into the body through inhalation, ingestion, or skin absorption. The radioactive materials of greatest concern for internal exposure have been the activation and corrosion products deposited on various surfaces of reactor plant components. Cobalt 60 has been identified as the radionuclide of primary concern to the Navy. The possibility of internal contamination has been minimized through strict control of airborne radioactivity and surface contamination. Whole-body monitoring of workers for internal radioactivity has been employed: 1) prior to initial radiation work; 2) at termination of radiation work; 3) in periodic radiation physical examinations; 4) following episodes of skin contamination, ingestion, or exposures to airborne radioactivity in concentrations above specified limits; and 5) in

random checks. If internal radioactivity is detected, an employee receives follow-up monitoring until the material can no longer be detected. Although radiation exposure from internal radioactivity has been recorded by the shipyard, the records indicate no instances in which internal radioactivity has resulted in an exposure of greater than 10% of the allowed annual Federal Regulations for radiation exposure. Because NIOSH believes internal radiation exposures were not significant compared to external exposures at PNS, only external exposures were used in this study.

Monitoring of external radiation exposure began in 1950 with the introduction of a film badge program for industrial radiography personnel. The monitoring program was expanded when nuclear work began in 1958 and has continually been refined. These refinements have included the replacement in October 1974, of film badges by calcium fluoride thermoluminescent dosimeters (TLD). Self indicating pocket dosimeters also have been used and have served as a back up monitor while providing a constant surveillance on external radiation exposure during the workday. Film badges were processed every 2 weeks prior to 1960, and monthly thereafter (pocket dosimeter readings above predetermined alert levels required immediate processing of the film badge). TLD badges have been processed daily. Shipyard personnel process all personnel dosimeters except those used to monitor neutron

exposures. Individual doses have been entered monthly into each employee's medical record and into the "DD 1141 file." Recorded cumulative lifetime doses used in this study ranged from 0.001-91.414 rems, with the mean being 2.779 rems and the median 0.545 rems. The shipyard records employee doses to the nearest millirem (0.001 rem). The dose summaries supplied to NIOSH were recorded in this manner. Although NIOSH recognizes the difficulty of achieving this accuracy with personnel dosimeters, the data have been used as supplied without attempting to round off the values.

Various checks have been made by the shipyard to verify the accuracy of the dosimeters and badges and to ascertain the adequacy of the in-house quality control program. The most recent evaluation involved a comparison of the accuracy of PNS analytical methods with those performed by the University of Michigan School of Public Health. These tests were conducted in accordance with the current revision of the draft Health Physics Society/American National Standards Institute (HPS/ANSI) standard on personnel dosimetry performance testing. The results of the Michigan evaluation conclude that the Shipyard has passed the HPS/ANSI Standard regarding personnel dosimetry for ionizing radiation (reference from personal communication, R.A. Bernard, Deputy Director, Radiological Control, PNS to P.J. Bierbaum, Deputy Director, Division of Surveillance, Hazard Evaluations and Field Studies, NIOSH, July 3, 1980).

METHODS

PNS provided NIOSH with a computer printout of each employee's radiation dose compiled from its annual dose reports. To determine the accuracy of this record, a random sample was selected consisting of approximately 200 individuals with over 600 person-years of exposure. The printout for these persons was checked by NIOSH against the employee's "DD 1141 file." Four errors were found: 1) one employee's comptroller (clock) number was incorrect; 2) one name was misspelled; 3) two keypunch errors were found resulting in incorrect dose totals (0.830 vs 0.834 rem in one case, and 7.327 vs 7.321 rem in the other); and 4) one record could not be located, but was later found and verified. Based on this limited sample evaluation, NIOSH determined the PNS dose printout was reasonably correct and was adequate for use in subsequent analysis.

In early 1978, NIOSH received from the Navy a microfilm copy of the personnel records (United States Government Standard Form 7) of all active civilian workers employed at PNS as of August 15, 1977. In April, 1978, NIOSH clerical teams microfilmed the personnel files (approximately 20,000) of former PNS employees. From these files the total identified population that had ever worked at PNS was 27,738

individuals. Shipyard personnel were not certain which years were covered by these records nor how complete they were because there had been no official requirement to maintain the records. However, a comptroller list was located that recorded clock numbers assigned sequentially to all new employees starting with 00001 in 1952. Consequently, a study begin-date of January 1, 1952, was chosen. For all but 298 names (1%) that appeared on the list, a corresponding personnel file existed. It was determined through discussions with shipyard personnel that, most likely, these 298 persons were either very short-term employees (such as temporary, summer help) or persons who were hired but never reported for work. Consequently, these individuals (298) were dropped from the study.

Persons of unknown sex (240) were assumed to be male, and those of unknown race (18,548) were assumed to be white for purposes of this study. This latter assumption was not expected to introduce a serious artifact during analyses since the racial make-up of the PNS population always has been essentially all white. Then 2,793 white females, most of whom were not involved in production work, two black females, and 59 black males were eliminated from the study because of their relatively small numbers. The 329 employees whose entire work histories at the PNS occurred before January 1, 1952, or after August

15, 1977, the date the Navy began microfilming records, also were eliminated. Ten more persons were eliminated from the study due to invalid or missing data.

The final cohort of all civilian white males ever employed at PNS between January 1, 1952, and August 15, 1977, included 24,545 individuals (total cohort). This total cohort was divided into three subcohorts:

1) the first of these (subcohort I, exposed radiation workers) consisted of 7,615 white males who had worked at least 1 day at the shipyard between January 1, 1952, and August 15, 1977, and who had a recorded lifetime cumulative exposure history of at least 0.001 rems;
2) the second group (subcohort II, nonradiation workers) consisted of 15,585 white males who also worked between January 1, 1952, and August 15, 1977, but who had no record of ever having been monitored for radiation. The lack of personnel radiation monitoring data, as indicated by the shipyard, signified that these workers were never assigned to work involving occupational exposure to ionizing radiation;
3) the final group (subcohort III, unexposed radiation workers) consisted of 1,345 individuals who worked at

the shipyard between January 1, 1952, and August 15, 1977, and who were monitored for radiation, but whose total lifetime cumulative dose was equal to 0.000 rems.

This last group was comprised of workers who had been "qualified" for radiation work and issued badges, but who had not actually been assigned to work involving radiation exposure. Also included in this group were workers who had exposure to less than the minimum sensitivity of the monitoring device. For this reason, a large number of individuals had recorded doses of 0.000 rem in their radiation record, and, in fact, a number of these individuals had a recorded cumulative lifetime exposure of 0.000 rem. From 1962 through 1966, radiation histories of 0.000 rem were not made part of the annual dose report which formed the data base for the study. Consequently, subcohort III is not complete. Analyses were run on subcohort III to determine whether the mortality experience of this group differed in any way from that of the non-exposed subcohort II. That analysis was intended to evaluate the possible existence of systematic demographic, biological or other differences between these two unexposed groups -- one of which was "qualified" for radiation work, and the other not.

Follow-up of workers to determine vital status was conducted to the study end-date of August 15, 1977. All workers active on that date were considered to be alive. In addition, all workers lost to

follow-up were considered to be alive as of the study end-date. Thus both of these groups contributed person-years at-risk with the study end-date. Death certificates were obtained for deceased individuals and were coded by a qualified nosologist, who was not familiar with the study, according to the International Classification of Disease adapted (ICDa) revision in effect at the time of death. These codes were then converted to the NIOSH standard cause of death categories shown in Appendix A.

For the total cohort and subcohorts II and III, the NIOSH life-table analysis system was used to generate expected numbers of cause-specific deaths (for each cause of death in Appendix A) based upon the person-years at-risk of dying within 5-year age and 5-year calendar time periods. Expected and observed deaths were accumulated for each of these age and calendar time periods from January 1, 1952, to August 15, 1977. The United States white male death rates, specific for 5-year age and calender time periods were used to generate the expected numbers of deaths. Observed and expected deaths also were stratified by 5-year latency (time since initial employment) and 5-year duration-of-employment categories.

For subcohort I, the same method of generating expected numbers of cause-specific deaths was used, except that duration of employment was replaced by stratification into specific radiation exposure dose categories and specific latency (time since initial exposure of at least 0.001 rem) categories. The dose categories used are as follows: 0.001-0.029 rems, 0.030-0.099, 0.100-0.499, 0.500-0.999, 1.000-4.999, 5.000-14.999, 15.000 and over. The person-years at risk experienced by subcohort I in each of these dose categories are displayed by latency in Table 1. For each year of exposure, an individual's yearly dose was divided into 365 equal dose-days. Because only annual radiation doses were used, each person was assumed to have received that dose at a constant rate throughout the year. As a person accumulated increasing dose, his person-years at risk were distributed over the corresponding dose categories. In the total cohort, and in subcohort II, person-years at risk began on the first date of employment at PNS or on January 1, 1952, whichever was later. In subcohort I, person-years at risk began on January 1, 1952, for persons with radiation exposures prior to that date. Otherwise, in subcohort I, person-years at risk began on the first date of employment in the first year in which the person's annual cumulative radiation dose was greater than or equal to 0.001 rems. This procedure added an average of 6 extra months of observation per person, slightly over estimating person-years at-risk (3%), and thus

expected deaths. The form in which the annual exposure data was supplied to NIOSH necessitated it be handled in this manner. However, this had no meaningful effect on any results. In subcohort III, person-years at risk began on the first date of employment in the first year in which the person's annual cumulative dose was 0.000 rem. In all cohorts, person-years at risk ended on the date of death or August 15, 1977, whichever came first.

When either the observed or expected number of deaths in a cause-specific category was 5 or greater, Standardized Mortality Ratios (SMR--Observed Deaths/Expected Deaths X 100) and their 95% confidence intervals were calculated.* In addition to comparisons based on white male death rates, numbers of expected deaths due to leukemia were generated using the rates in the non-exposed cohort (subcohort II). These numbers were then used to derive internally adjusted standardized mortality ratios for subcohort I. These internally adjusted rates were specific for 10-year age groups

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*Formulae 17 and 18 were used to calculate approximate confidence intervals for SMR's as described on page 29 in Epidemiologic Analysis With a Programmable Calculator, Rothman and Boice, 1979.

and for 13-year calendar periods. Those intervals were chosen in order to create categories with enough person-years to generate reasonably stable rates.

RESULTS

Of the total cohort, 18,771 (76%) were found to be alive, 4,762 (19%) had died, and 1,012 (4%) were lost to follow-up (Table 2). The percent deceased was lower in subcohort I (11%) than in the total cohort, while it was higher for subcohort II (24%). This finding is not surprising because the total cohort and subcohort II include many person-years accumulated since 1952, while most person-years in subcohort I were accumulated after the early 1960's (Tables 3,4,5,6). The percent of death certificates found for the total cohort, and for subcohorts I, II, and III, were 92%, 96%, 92%, and 94%, respectively. Fewer death certificates are outstanding for subcohort I because, in general, deaths from this cohort occurred more recently and, hence, certificates were easier to locate. There were no apparent differences in our ability to determine vital status in the different dose categories in subcohort I (Table 7).

In comparing radiation and non-radiation workers, no significant difference was evident in age at first employment at the shipyard (Table 8); the mean age at time of first employment for subcohorts I and II differed by only 2.3 years. However, the difference between the mean age at entry into the shipyard for subcohort II (31.6 years old) and the mean age at first recorded dosage of greater than or equal to 0.001 rem of subcohort I (38.6) differed by 7 years; this difference indicates a potential selection bias when comparing mortality of the two groups (Table 9). While all three subcohorts had mean ages between 51 and 53.1 years at the-end-of study date (Table 10), the standard deviations varied considerably, reflecting a much wider age distribution for subcohort II. These differences between subcohorts I and II are further demonstrated by comparison of mean overall duration of employment of subcohort I and subcohort II members (18.0 and 10.6 years respectively), because of the large percentage of short term employees in subcohort II (Table 11). Only 14% of subcohort I personnel worked for less than 5 years, while over 52% of subcohort II personnel worked less than 5 years. Accordingly, 43.5% of the person-years at-risk in subcohort II were in the category 0-5 years duration of employment (Table 12). Only 26% of the person-years at-risk for subcohort III (Table 13), but 35% of the person-years at-risk for the entire shipyard cohort, contributed to the less than 5-years duration of employment category (Table 14).

A few personnel in subcohort I experienced their first exposure to radiation as early as 1950, although that early exposure was limited to external doses received from radiographic activities. Widespread exposure to radiation did not begin until after 1958, with the beginning of work on nuclear-powered vessels (Table 15). Only 9% of the exposed workers experienced first exposure in the last 5 years of study. The duration of radiation exposure in subcohort I was heavily skewed towards short periods (Table 16). In fact, 50% of the subcohort I members were exposed to radiation for less than 5 years.

Mortality: Total Cohort (Total Shipyard)

In the total cohort, there were 4,762 deaths observed (Table 17), whereas 5,361.0 were expected (SMR=89). For the 82 individual causes of death examined, most displayed a lower than expected number of deaths. Malignant neoplasms, as a group, did not show the same overall deficits in mortality as did other causes of death.

Statistically significant deficits in mortality occurred for respiratory tuberculosis (SMR=23), stomach cancer (SMR=71), diabetes mellitus (SMR=77), vascular lesions of the central nervous system (SMR=75), circulatory system diseases (SMR=86), diseases of the

respiratory system (SMR=75), diseases of the digestive system (SMR=78), diseases of the genitourinary system (SMR=61), unknown causes of death (SMR=55), and deaths due to accidents (SMR=63) and violence (SMR=60). Comparison of observed and expected deaths for malignant neoplasms of the lymphatic and hematopoietic tissue (NIOSH categories 34-37) revealed no statistically significant excess. All SMR's from each cause of death in this category were less than 100. Deaths from lymphosarcoma and reticulosarcoma (NIOSH category 34) showed a statistically significant deficit (18 observed vs 29.4 expected, SMR=61, p less than 0.05). For leukemia and aleukemia (NIOSH category 36), 39 cases were observed whereas 41.5 were expected (SMR=94).

For most durations of employment and for most latency periods mortality from all causes of death combined was less than expected (Table 18). However, in workers with 15-30 years' latency, excesses were noted in various duration categories. These excesses were not seen in active employees (comprising the top diagonal line in Table 18).

Mortality: Subcohort I (Lifetime Radiation greater than or equal to 0.001 rem)

In subcohort I (Table 19), mortality from all causes combined was well below expected (833 observed deaths vs 1065.3 expected, SMR=78). Mortality experience for each of the 82 causes of death was very similar to that of the total cohort. No cause was significantly elevated. Deaths due to malignant neoplasms of the lymphatic and hematopoietic tissue were lower in subcohort I than for the total shipyard population (15 observed vs 21.1 expected; SMR=71). Seven of these deaths were due to the category leukemia and aleukemia (category 36), while 8.3 were expected (SMR=84). Of these, based on death certificate diagnosis and available medical records, two were lymphatic; two were chronic myelogenous; one was acute leukemia; and two were unspecified as to type.

Mortality: Subcohort II (Non radiated)

In subcohort II, observed mortality was approximately as expected (3,733 observed deaths vs 3801 expected, SMR=98) (Table 20).

Deaths due to malignant neoplasms of the lymphatic and hematopoietic tissue did not differ from expected (67 observed vs 67.7 expected,

SMR=99), and 31 deaths due to leukemia were observed against 29.1 expected (SMR=106). Overall mortality in subcohort I was much lower than in subcohort II over all pre-retirement age groups and for all calendar periods (Tables 21,22). A similar pattern of deficit in mortality existed for nonmalignant respiratory disease and circulatory disease. For cancer, the only exception to this pattern was age group 50-59 and calendar period 1970-1974; and for lung cancer, the age group of 50-59.

Mortality: Subcohort III (Lifetime recorded radiation = 0.000 rem)

As described in the methods section, subcohort III is incomplete. SMR's for subcohort III were generally found to be below 100, but because of small numbers, SMR's were not calculated for most causes (Table 23). No major differences in any cause of death were observed between this subcohort and the other two subcohorts.

Mortality: Lymphatic and Hematopoietic Diseases

No trends by 5-year calendar time periods or by 5-year age groups were observed for any malignant neoplasms of the lymphatic and hematopoietic tissues (NIOSH categories 34-37) in any of the cohorts (Tables 24-29). Also, no excesses or trends were noted for any

diseases of the blood forming organs (NIOSH categories 41-44). Finally, no trends were observed when all of the above specific categories of hematologic diseases were combined and examined together as had been suggested by previous researchers (Colton, 1980).

Examination of any specific category of malignant neoplasms of the lymphatic and hematopoietic tissues by 5-year latency and by duration of employment was equally unrevealing of trends for either the total cohort or for subcohort II (Tables 30A-E and 31A-E). Within subcohort I, no significant increases or trends by radiation dose category were observed for any of the malignant neoplasms of the lymphatic and hematopoietic tissues or for all malignant neoplasms (Table 32A-E). However, slight increases for leukemia were observed in the 10-15 year latency and the 1.000-4.999 rem categories.

In additional analyses, expected deaths from leukemia for subcohort I were compared with observed deaths, based upon the rates of leukemia experienced by subcohort II (Table 33). When expected deaths, derived from subcohort II rates, were applied to person-years in subcohort I, and summed over all ages and time periods, 10.05 deaths due to leukemia would have been expected in the radiation workers. Seven cases of leukemia were observed, (SMR=70, not statistically significant).

DISCUSSION

In this analysis, we observed an overall deficit of mortality among workers at PNS. This deficit is the result of two readily identifiable factors. First, ascertainment of vital status was only 96% complete. While this percentage of follow-up is well within the range generally accepted for studies of this kind, it has the effect of mildly inflating the person-years at risk and hence increasing the expected number of deaths. Second, the phenomenon often referred to as the healthy worker effect had a profound influence on this cohort (Fox, 1976). This effect occurs when a standard population such as all United States white males is used to generate expected numbers of deaths for an employee population. Most populations of workers are healthier than the general population because the latter includes numbers of chronically ill or otherwise unemployable persons. The healthy worker effect is however, not believed substantially to effect deaths due to malignant neoplasms. The PNS radiation workers demonstrated a particularly strong healthy worker effect, most likely due to the special medical screening which they undergo before acceptance into the radiation program.

In addition, failure to obtain death certificates for 8% (361) of the known deceased workers has had the effect of reducing the true SMR's of the 82 individual causes of death. If these death certificates were available, they would be expected to distribute over the death categories examined in the same fashion as the certificates already obtained, thus evenly raising their corresponding SMR's. However, the effect of this increment is expected to be negligible.

The deficit in mortality observed for all causes of death combined was not so clearly evident for deaths due to malignant neoplasms. That finding was not surprising because it is generally believed that the healthy worker phenomenon does not have as much influence on cancer death rates as on other causes of mortality. This difference reflects the fact that cancer is largely a disease of aging and usually occurs late in or after a working career. Procedures such as pre-employment physicals are not likely to detect predisposition to cancer.

Person-years at-risk for individuals in subcohort I prior to their first year radiated were not counted in any of the subcohorts but are included in the total cohort and could have been added into subcohort II. Had those additional person-years (approximately, equivalent to 16% of the person-years in subcohort II) been added to subcohort II, the SMR's for this non-radiation group would have decreased. However,

the reduction in most SMR's would not have been major, because most of these additional person-years are distributed over relatively young age groups where relatively few expected deaths would have occurred. Subsequent analysis will be performed to determine the exact effect on SMR's of including the additional person-years in subcohort II.

The SMR of 70 for leukemia, derived from subcohort II rates and applied to subcohort I, should be interpreted with caution. The probable explanation for this finding is that use of an internal control group accounted for geographic and other demographic variables, but at the same time introduced a new bias caused by the selection of particularly healthy individuals for radiation work. Nevertheless, this analysis was valuable in that it allowed direct comparison of the data from this study with findings of previous investigations (Najarian, 1978; Colton, 1980).

Shipyard workers are generally considered to be at high risk from diseases associated with asbestos exposure. For that reason, particular attention was given in this analysis to deaths resulting from lung cancer, non-malignant respiratory disease, colon cancer, and digestive system cancer. No significant excesses were observed for any of these causes of death and a statistically significant deficit of diseases of the respiratory system was observed (230 observed vs 307.4 expected, SMR=75).

Explanations for not seeing increases in asbestos-related diseases at PNS include the fact that the shipyard was primarily involved in the construction of new submarines prior to the 1950's. During such construction, most asbestos components are prefabricated in one shop and fitted to the vessel, so that little exposure is experienced by workers outside of that fabrication shop. In the 1950's and 1960's, overhaul activities requiring the "rip-out" of asbestos began, undoubtedly resulting in greater exposures than in new construction. It is therefore possible that elevated death rates from asbestos exposure will ultimately be seen, after a longer latency period has elapsed. Case-control studies, presently being conducted by NIOSH, may reveal excess mortality from asbestos-related disease in specific job operations or shops. Three cases of mesothelioma have been observed, but expected numbers of mesothelioma deaths could not be calculated using United States mortality rates as a standard comparison group since there is no ICDA Classification for this cause of death. However, mesothelioma is almost always associated with exposure to asbestos. (IARC, 1977)

Deaths due to accidents were found to be significantly decreased at PNS (204 observed vs 323.1 expected, SMR=63). This finding persisted in spite of a catastrophe in 1963 in which the submarine Thresher was lost during sea trials with 13 civilian shipyard employees on board.

That event made little difference in the overall low mortality from accidents, and was barely visible even when the 5-year category 1960-1965 was examined for the specific category of death "Transportation Accidents" (37 observed vs 31.3, SMR=118). This finding underscores the immense size of the PNS cohort and the ease with which a true excess of deaths among a particular subgroup of individuals can be lost through dilution.

CONCLUSIONS

Excesses of deaths due to malignant neoplasms and due specifically to neoplasms of the blood and blood-forming tissue, were not evident in civilian workers at PNS in this cohort mortality study. This finding is in disagreement with results of a previous study of the PNS population (Najarian, 1978).

This NIOSH study had over a 99% probability of detecting the 5-fold increased risk of death due to leukemia reported by Najarian et al. among radiation exposed employees at PNS if it had existed (Figure 1). Furthermore, had the true relative-risk of death from leukemia been 2.2, the likelihood of detecting such a risk would still have been 80%. However, when observed leukemia deaths at the shipyard were compared with expected deaths, derived from the United States white

male population rates, no excess was found. No relationship between exposure to radiation and mortality from any cause was observed among the PNS population when compared to the United States white male population. Furthermore, no excess in leukemia mortality was observed in the radiation exposed population when compared to the non-radiation exposed employees of PNS.

These findings must be interpreted with caution as they neither vindicate nor imply a relationship between low-level radiation and cancer. A major reason for caution is that an insufficient number of years may have elapsed for the majority of the radiation workers since their initial radiation exposure to permit manifestation of currently latent cancers. In addition, the number of workers with radiation exposure at PNS was relatively small, making the opportunity for observing a slight excess in mortality very unlikely. In fact, if a true relative risk of 1.5 for leukemia exists for the radiation workers in subcohort I, there would have been only a 25% chance of detecting such an increase. Finally, this study utilized mortality only as the endpoint. Effects other than mortality are beyond the scope of the present study, but might include induction of chromosome aberration (Evans, 1979) or of recessive mutations in somatic or germinal cells which might become evident only generations hence. Only time and further studies will allow quantification of such additional hazards of chronic exposure to low doses of ionizing radiation, if they exist.

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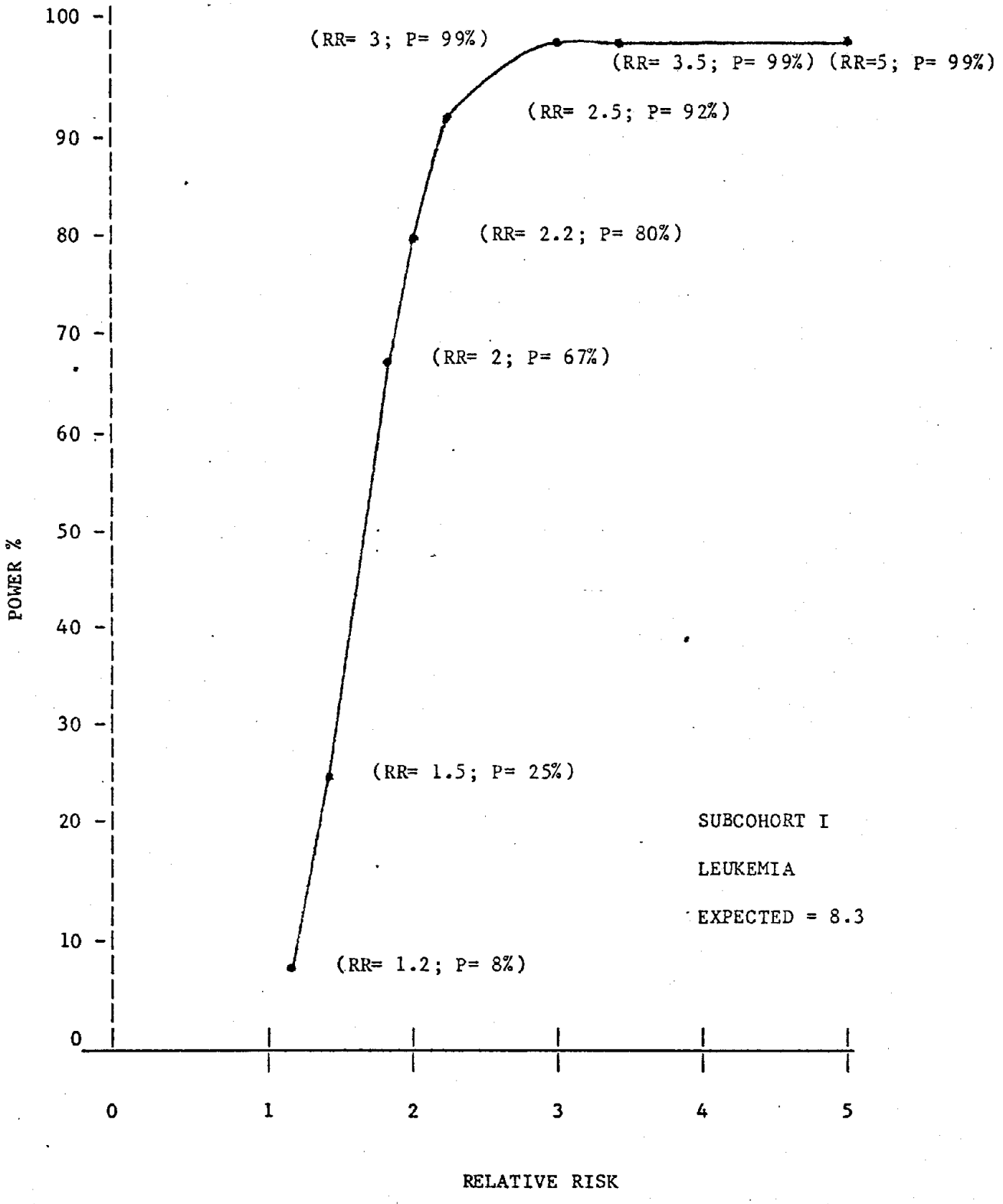
FIGURE 1
Approximate Powers Assuming the Poisson Distribution



(RR= Relative Risk; P= Power)

Table 1

Distribution of Person Years at Risk by Latency and Radiation Dose in rems for 7615 White Males with Recorded Lifetime Cumulative Dose ≥0.001 rem (January 1, 1952 Through August 15, 1977)

	Dose							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.0 & OVER	TOTAL*
1DAY - 1YR	3,372	1,514	1,448	463	486	2	0	7,285
1YR - 3YRS	2,997	3,284	3,754	1,409	2,613	317	0	14,374
3YRS - 5YRS	2,149	2,569	3,641	1,446	3,006	905	25	13,742
5YRS - 10YRS	3,639	5,018	8,167	3,584	7,662	3,190	766	32,028
10YRS - 15YRS	1,802	2,583	5,183	2,562	5,590	2,642	1,268	21,630
15YRS - 20YRS	789	877	1,832	914	2,257	1,215	651	8,535
20YRS - & OVER	62	115	113	39	154	79	67	629
TOTAL*	14,810	15,960	24,138	10,418	21,769	8,350	2,778	98,223

* Person-years for each latency and radiation dose categories are rounded and may not equal totals.

Table 2

Vital Status as of August 15, 1977 for White Males Ever Employed at the Portsmouth Naval Shipyard (January 1, 1952 through August 15, 1977)

	Total Cohort	Subcohort I	Subcohort II	Subcohort III
	Total Shipyard	Lifetime Radiation > 0.001 rem	Non-radiation	Lifetime Radiation = 0.000 rem
Alive	18,771 (76%)	6,658 (87%)	10,999 (71%)	1,114 (83%)
Deceased	4,762 (19%)	833 (11%)	3,733 (24%)	196 (15%)
Death Certificates Obtained	4,401 (92%)	797 (96%)	3,419 (92%)	185 (94%)
Lost to Follow-up	1,012 (4%)	124 (2%)	853 (5.5%)	35 (3%)
Total	24,545	7,615	15,585	1,345

Table 3

Distribution of Person Years at Risk by Age and Calendar Time
for 24,545 White Males, Employed at the Portsmouth Naval Shipyard
from January 1, 1952 Through August 15, 1977

Ages	1952-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total*
15-19	198	290	675	1,585	1,004	220	3,972
20-24	1,344	1,421	2,252	4,460	5,963	2,240	17,680
25-29	4,126	4,492	3,975	4,432	6,969	5,454	29,449
30-34	5,665	8,124	6,583	5,238	5,367	4,231	35,207
35-39	5,818	10,375	10,137	7,415	5,804	3,099	42,648
40-44	5,021	9,766	12,559	10,869	7,935	3,741	49,890
45-49	4,167	8,415	11,381	13,019	11,126	4,942	53,050
50-54	3,752	6,786	9,243	11,463	12,838	6,334	50,416
55-59	3,667	6,116	7,009	8,895	10,976	6,614	43,277
60-64	1,868	5,282	5,882	6,455	8,103	4,908	32,498
65-69	329	2,255	4,629	4,997	5,424	3,565	21,199
70-74	9	348	1,896	3,700	3,924	2,149	12,025
75-79	0	10	291	1,368	2,703	1,507	5,878
80-84	0	0	8	198	912	865	1,983
85+	6	10	9	16	165	272	478
TOTAL*	35,968	63,690	76,529	84,110	89,214	50,139	399,651

* Person-years for each age category and calendar-time period are rounded and may not equal totals.

Table 4

Distribution of Person Years at Risk by Age and Calendar Time
for 7,615 White Males with Recorded Lifetime Cumulative Dose $\geq$ 0.001 rem
(January 1, 1952 Through August 15, 1977)

Ages	1952-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total*
15-19	0	14	48	165	18	2	247
20-24	4	74	469	1,479	1,196	164	3,387
25-29	31	190	1,112	2,037	2,673	1,359	7,401
30-34	55	332	1,612	2,439	2,661	1,706	8,804
35-39	51	573	2,435	2,921	2,779	1,451	10,210
40-44	59	613	3,361	3,963	3,308	1,590	12,894
45-49	46	447	2,948	5,160	4,319	1,848	14,768
50-54	43	371	2,258	4,341	5,486	2,417	14,915
55-59	16	240	1,485	2,908	4,401	2,838	11,887
60-64	1	107	842	1,859	2,788	1,858	7,455
65-69	0	11	289	919	1,672	1,236	4,126
70-74	0	1	26	239	736	645	1,647
75-79	0	0	2	23	168	228	420
80-84	0	0	0	2	16	30	48
85+	0	0	0	3	6	6	15
TOTAL*	305	2,971	16,887	28,457	32,226	17,378	98,223

* Person-years for each age category and calendar-time period are rounded and may not equal totals.

Table 5

Distribution of Person Years at Risk by Age and Calendar Time
for 15,585 White Males with No Recorded History of Radiation
(January 1, 1952 Through August 15, 1977)

Ages	1952-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total*
15-19	141	148	355	1,117	950	217	2,929
20-24	943	810	967	2,168	4,111	1,993	10,993
25-29	2,606	2,741	1,702	1,730	3,404	3,628	15,811
30-34	3,076	4,897	3,462	2,222	2,151	2,158	17,966
35-39	3,095	5,498	5,641	3,817	2,531	1,405	21,986
40-44	3,094	5,342	6,387	5,982	4,095	1,875	26,774
45-49	2,712	5,139	6,062	6,574	6,129	2,823	29,440
50-54	2,851	4,473	5,459	6,086	6,475	3,544	28,889
55-59	3,304	4,744	4,481	5,252	5,819	3,337	26,938
60-64	1,825	4,824	4,447	4,069	4,747	2,708	22,619
65-69	327	2,204	4,167	3,705	3,342	2,080	15,825
70-74	9	346	1,845	3,316	2,877	1,333	9,726
75-79	0	10	289	1,323	2,423	1,158	5,202
80-84	0	0	8	196	878	806	1,888
85+	6	10	9	13	159	264	460
TOTAL*	23,988	41,186	45,282	47,571	50,091	29,329	237,447

* Person-years for each age category and calendar-time period are rounded and may not equal totals.

Table 6

Distribution of Person Years at Risk by Age and Calendar Time for 1345 White Males with Recorded Lifetime Cumulative Dose = 0.000 rem (January 1, 1952 Through August 15, 1977)

Ages	1952-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total*
15-19	4	20	37	100	7	0	168
20-24	39	64	165	333	377	23	1,000
25-29	178	180	288	332	583	312	1,874
30-34	348	392	359	373	423	295	2,190
35-39	372	639	541	403	422	207	2,584
40-44	305	617	797	573	457	247	2,996
45-49	249	511	763	819	613	249	3,205
50-54	269	448	613	752	811	356	3,249
55-59	118	413	519	601	731	433	2,816
60-64	17	151	431	488	560	340	1,988
65-69	0	20	160	370	409	249	1,208
70-74	0	0	23	145	311	171	649
75-79	0	0	0	23	113	121	256
80-84	0	0	0	0	18	29	47
85+	0	0	0	0	0	3	3
TOTAL*	1,899	3,455	4,696	5,311	5,837	3,035	24,232

* Person years for each age category and calendar-time period are rounded and may not equal totals.

Table 7

Vital Status as of August 15, 1977
for 7,615 White Males with Recorded Lifetime
Cumulative Dose Greater Than or Equal to 0.001rem

	Lifetime Cumulative Dose (rems)							
	0.001-0.029	0.030-0.099	0.100-0.499	0.500-0.999	1.00-4.999	5.000-14.999	15.000	Total
Alive	766	894	1508	717	1712	732	329	6658 (87%)
Deceased	113	158	196	86	183	77	20	833 (11%)
Lost to Follow-up	20	23	31	8	34	8	0	124 (2%)
Total	899	1075	1735	811	1929	817	349	7615

TABLE 8

Distribution of Age First Employed for White Males Ever Employed at the Portsmouth Naval Shipyard between (January 1, 1952 through August 15, 1977)

	Total Cohort Total Shipyard		Subcohort I Lifetime Radiation ≥ 0.001 rem		Subcohort II Non-radiation		Subcohort III Lifetime Radiation = 0.000 rem	
Age	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
10-14	28	0.1	3	0.0	22	0.1	3	0.2
15-19	3,334	13.6	939	12.3	2,217	14.2	178	13.2
20-24	5,156	21.0	1,814	23.8	3,042	19.5	300	22.3
25-29	4,675	19.0	1,734	22.8	2,666	17.1	275	20.4
30-34	3,222	13.1	1,160	15.2	1,899	12.2	163	12.1
35-39	2,627	10.7	825	10.8	1,644	10.5	158	11.7
40-44	2,305	9.4	595	7.8	1,594	10.2	116	8.6
45-49	1,643	6.7	312	4.1	1,255	8.1	76	5.7
50-54	911	3.7	156	2.0	714	4.6	41	3.0
55-59	465	1.9	58	0.8	384	2.5	23	1.7
60-64	152	0.6	15	0.2	126	0.8	11	0.8
65-69	14	0.1	1	0.0	12	0.1	1	0.1
OUT OF RANGE	13	0.0	3	0.0	10	0.0	-	-
TOTAL	24,545	100	7,615	100	15,585	100	1,345	100
MEAN	30.9		29.3		31.6		30.4	
MEDIAN	28.4		27.3		29.2		27.7	
Std Dev	10.6		9.0		11.2		10.3	

TABLE 9

Distribution of Age at First Year of Recorded Radiation Greater Than or Equal to 0.001 rem for 7,615 White Males with Recorded Lifetime Cumulative Dose Greater Than or Equal to 0.001 rem.

AGE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)
*15-19	134	1.8
20-24	910	12.0
25-29	1009	13.3
30-34	900	11.8
35-39	1014	13.3
40-44	1181	15.5
45-49	995	13.1
50-54	765	10.0
55-59	460	6.0
60-64	201	2.6
65-69	41	0.5
70-74	2	0.0
OUT OF RANGE	3	0.0
TOTAL	7615	100.0

MEAN: 38.6

MEDIAN: 38.8

Std Dev: 11.4

* All of these workers were 18 years or older.

TABLE 10

Distribution of Age as of August 15, 1977 for
White Males Employed at the Portsmouth Naval Shipyard
between January 1, 1952 and August 15, 1977

	Total Cohort		Subcohort I Lifetime Radiation ≥0.001 rem		Subcohort II Non-radiation		Subcohort III Lifetime Radiation = 0.000 rem	
AGE	Total Shipyard Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
15-19	98	0.4	0	0.0	98	0.6	0	0.0
20-29	2,847	11.6	478	6.3	2,286	14.7	83	6.2
30-39	3,442	14.0	1,340	17.6	1,875	12.0	227	16.8
40-49	3,638	14.8	1,362	17.9	2,073	13.3	203	15.1
50-59	6,009	24.5	2,209	29.0	3,485	22.4	315	23.5
60-69	5,117	20.8	1,645	21.6	3,143	20.2	329	24.5
70-79	2,550	10.3	541	7.1	1,848	12.0	161	12.0
80-89	734	3.0	34	0.4	676	4.4	24	1.7
90-99	24	0.1	0	0.0	24	0.1	0	0.0
Over 99	8	0.0	2	0.0	6	0.0	0	0.0
Out of Range	78	0.3	4	0.1	71	5.0	3	0.2
TOTAL	24,545	100	7,615	100	15,585	100	1,345	100
	MEAN = 51.7		MEAN = 51.0		MEAN = 51.9		MEAN = 53.1	
	MEDIAN = 53.6		MEDIAN = 52.8		MEDIAN = 53.8		MEDIAN = 55.3	
	Std Dev = 16.0		Std Dev = 13.4		Std Dev = 17.2		Std Dev = 14.8	

Table 11

Distribution of Duration of Employment for White Males Employed at the Portsmouth Naval Shipyard between January 1, 1952 and August 15, 1977

Duration of Employment Years	Total Cohort Total Shipyard Frequency	Percent	Subcohort I Lifetime Radiation ≥0.001 rem Frequency	Percent	Subcohort II Non-radiation Frequency	Percent	Subcohort III Lifetime Radiation 0.000 rem Frequency	Percent
5	9,550	38.9	1,068	14.0	8,158	52.3	324	24.1
5-9	2,145	8.7	870	11.4	1,118	7.2	157	11.7
10-14	3,038	12.4	1,224	16.1	1,653	10.6	161	12.0
15-19	2,359	9.6	1,174	15.4	1,047	6.7	138	10.3
20-24	2,072	8.4	813	10.7	1,084	7.0	175	13.0
25-29	1,939	7.9	982	12.9	813	5.2	144	10.7
30-34	1,728	7.0	947	12.4	651	4.2	130	9.7
25-39	1,118	4.6	451	5.9	586	3.8	81	6.0
40-44	344	1.4	33	0.4	293	1.9	18	1.3
45-49	215	0.9	43	0.6	158	1.0	14	1.0
50-54	36	0.1	10	0.1	24	0.2	2	0.1
55-59	1	0.0	0	0.0	0	0.0	1	0.1
Total	24,545	100	7,615	100	15,585	100	1,345	100
Mean	13.1		18.0		10.6		16.6	
Median	10.2		17.3		3.9		16.5	
Std Dev	12.4		11.0		12.3		12.1	

Table 12

Distribution of Person Years at Risk by Latency and Duration of Employment
for 15,585 White Males with No Recorded History of Radiation
(January 1, 1952 Through August 15, 1977)

	Duration of Employment							
LATENCY	UNDER 5 YRS	5 YRS - 10 YRS	10 YRS - 15 YRS	15 YRS - 20 YRS	20 YRS - 25 YRS	25 YRS - 30 YRS	30 YRS & OVER	TOTAL*
UNDER - 5 YRS	40,939	0	0	0	0	0	0	40,939
5 YRS - 10 YRS	23,564	10,746	0	0	0	0	0	34,310
10 YRS - 15 YRS	17,019	3,301	19,211	0	0	0	0	39,531
15 YRS - 20 YRS	11,972	2,649	5,743	16,073	0	0	0	36,437
20 YRS - 25 YRS	8,463	1,919	4,980	3,250	12,123	0	0	30,736
25 YRS - 30 YRS	1,446	1,078	3,949	2,435	3,467	7,346	0	19,720
30 YRS & OVER	0	537	3,612	2,490	3,706	3,938	21,490	35,773
TOTAL*	103,404	20,230	37,495	24,248	19,296	11,283	21,490	237,447

* Person years for each latency and duration of employment category are rounded and may not equal totals.

Table 13

Distribution of Person Years at Risk by Latency and Duration of Employment for 1345 White Males with Recorded Lifetime Cumulative Dose = 0.000 rem (January 1, 1952 Through August 15, 1977)

LATENCY	Duration of Employment: UNDER 5 YRS	5 YRS - 10 YRS	10 YRS - 15 YRS	15 YRS - 20 YRS	20 YRS - 25 YRS	25 YRS - 30 YRS	30 YRS & OVER	TOTAL*
UNDER - 5 YRS	4,003	0	0	0	0	0	0	4,003
5 YRS - 10 YRS	1,337	2,469	0	0	0	0	0	3,806
10 YRS - 15 YRS	671	338	3,074	0	0	0	0	4,083
15 YRS - 20 YRS	298	224	203	2,964	0	0	0	3,689
20 YRS - 25 YRS	11	60	137	248	2,441	0	0	2,896
25 YRS - 30 YRS	1	3	35	176	566	1,521	0	2,301
30 YRS & OVER	0	0	6	134	563	535	2,215	3,453
TOTAL*	6,321	3,093	3,454	3,522	3,570	2,056	2,215	24,232

* Person years for each latency and duration of employment category are rounded and may not equal totals.

Table 14

Distribution of Person Years at Risk by Latency and Duration of Employment for 24,545 White Males Employed at the Portsmouth Naval Shipyard from January 1, 1952 Through August 15, 1977

	Duration of Employment							
LATENCY	UNDER 5 YRS	5 YRS - 10 YRS	10 YRS - 15 YRS	15 YRS - 20 YRS	20 YRS - 25 YRS	25 YRS - 30 YRS	30 YRS & OVER	TOTAL*
UNDER - 5 YRS	68,991	0	0	0	0	0	0	68,991
5 YRS - 10 YRS	27,888	33,776	0	0	0	0	0	61,664
10 YRS - 15 YRS	19,163	5,805	44,927	0	0	0	0	69,895
15 YRS - 20 YRS	12,770	3,940	7,299	37,906	0	0	0	61,915
20 YRS - 25 YRS	8,510	2,082	5,701	4,419	29,112	0	0	49,824
25 YRS - 30 YRS	1,453	1,099	4,121	2,898	5,650	18,747	0	33,968
30 YRS & OVER	0	545	3,646	2,737	5,520	7,221	33,723	53,393
TOTAL*	138,776	47,248	65,694	47,960	40,282	25,968	33,723	399,651

* Person years for each latency and duration of employment category are rounded and may not equal totals.

Table 15

Distribution of Year First Radiated (Greater Than or Equal to 0.001 rem for Subcohort I and = 0.000 rem for Subcohort III)

Year	Subcohort I Lifetime Radiation ≥ 0.001 rem Frequency	Percent	Subcohort III Lifetime Radiation = 0.000 rem Frequency	Percent
1950	16	0.2	0	0.0
1951	70	0.9	0	0.0
1952	10	0.1	1	0.1
1953	9	0.1	2	0.1
1954	8	0.1	5	0.4
1955	23	0.3	4	0.3
1956	18	0.2	0	0.0
1957	11	0.1	0	0.0
1958	234	3.1	3	0.2
1959	1,857	24.4	224	16.7
1960	343	4.5	200	14.9
1961	159	2.1	262	19.5
1962	820	10.8	56	4.2
1963	270	3.5	0	0.0
1964	635	8.3	4	0.3
1965	535	7.0	18	1.3
1966	503	6.6	1	0.1
1967	582	7.6	124	9.2
1968	328	4.3	98	7.3
1969	209	2.7	124	9.2
1970	153	2.0	54	4.0
1971	87	1.1	59	4.4
1972	54	0.7	44	3.3
1973	24	0.3	13	1.0
1974	87	1.1	16	1.2
1975	153	2.0	8	0.6
1976	222	2.9	10	0.7
1977	195	2.6	15	1.1
Total	7,615	100	1,345	100
Mean	1963.9		1964.2	
Median	1963.4		1961.4	
Std Dev.	5.3		5.0	

TABLE 16

Duration of Radiation (years where recorded dose Greater Than or Equal to 0.001 rem) Among 7,615 White Males with a Recorded Cumulative Lifetime Radiation Dose of at least 0.001 rem

Duration (years)	Frequency	Percent
1	1,046	13.7
2	1,092	14.3
3	957	12.6
4	712	9.3
5	639	8.4
6	568	7.5
7	455	6.0
8	345	4.5
9	339	4.5
10	305	4.0
11	282	3.7
12	205	2.7
13	163	2.1
14	142	1.9
15	112	1.5
16	68	0.9
17	55	0.7
18	62	0.8
19	42	0.6
20	20	0.3
21	2	0.0
22	3	0.0
27	1	0.0
TOTAL	7,615	100
Mean 5.7		
Median 4.5		
Std Dev 4.3		

TABLE 17

Observed and Expected Deaths Among the 24,545 White Males Employed at the Portsmouth Naval Shipyard (January 1, 1952 through August 15, 1977)

CAUSE OF DEATH	(NIOSH CATEGORY)*	OBSERVED	EXPECTED	SMR	95% CONFIDENCE INTERVAL
All Causes	(01-17, 23-73, 76-89)	4,762	5,361.00	88.8	86-91
Tuberculosis	(01,02)	8	34.81	22.9	10-45
Respiratory Tuberculosis	(01)	7	32.26	21.6	9-45
Other Tuberculosis	(02)	1	2.55	--	--
All Malignant Neoplasms(MN)	(03-17, 23-37)	977	1,032.79	94.5	89-101
MN of the Buccal Cavity and Pharynx	(03-06)	31	33.74	91.8	62-130
MN of Lip	(03)	0	1.00	--	--
MN of Tongue	(04)	10	8.10	123	59-227
MN of Other Parts of Buccal Cavity	(05)	2	9.14	21.9	02-79
MN of Pharynx	(06)	19	15.50	122	74-191
MN of Digestive System	(07-12)	275	304.59	90.2	80-102
MN of Esophagus	(07)	27	24.49	110	73-160
MN of Stomach	(08)	42	59.30	70.8	51-96
MN of Intestine Except Rectum	(09)	91	95.10	95.7	77-117
MN of Rectum	(10)	37	35.66	103	73-143
MN of Biliary Passages and Liver (Primary and Unspecified)	(11,12)	26	26.79	97.0	63-142
MN of Pancreas	(13)	49	58.79	83.3	62-110
MN of Peritoneum and Unspecified	(14)	3	4.45	--	--
MN of Respiratory System	(15-17)	356	341.80	104	94-116
MN of Larynx	(15)	19	16.19	117	71-183
MN of Trachea, Bronchus and Lung	(16)	333	321.62	103	93-115
MN of Other parts of Respiratory	(17)	4	3.99	--	--
MN of Male Genital Organs	(23,24)	77	75.62	101	80-127
MN of Prostate	(23)	70	69.85	100	78-127
MN of Other Male Genital Organs	(24)	7	5.77	121	49-250
MN of Urinary Organs	(25,26)	51	58.78	86.7	65-114
MN of Kidney	(25)	20	25.59	78.1	48-250
MN of Bladder and Other Urinary Organs	(26)	31	33.19	93.4	63-133
MN of Other and Unspecified Sites (Major)	(27-33)	100	117.53	85.0	69-103
MN of Skin	(27)	12	17.39	69.0	36-121
MN of Eye	(28)	2	1.05	--	--
MN of Brain and Other Parts of Nervous System	(29)	25	29.86	83.7	54-124
MN of Thyroid Gland	(30)	3	2.27	--	--
MN of Bone	(31)	5	5.49	91.0	29-213
MN of Connective Tissue	(32)	3	4.07	--	--
MN of Other and Unspecified Sites (Minor)	(33)	50	57.41	87.0	65-

TABLE 17 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	95%
MN of Lymphatic and Hematopoietic Tissues	(34-37)	84	99.14	84.7	68-105
Lymphosarcoma and Reticulosarcoma	(34)	18	29.44	61.1	36-97
Hodgkin's Disease	(35)	12	12.77	93.9	48-164
Leukemia and Aleukemia	(36)	39	41.53	93.9	67-128
Other Neoplasms of Lymphatic and Hematopoietic Tissues	(37)	15	15.40	97.4	54-161
Neoplasms of the Brain	(38,39)	9	9.08	99.1	45-188
Benign Neoplasms of the Brain	(38)	0	2.58	--	--
Neoplasms of Unspecified Nature of Brain	(39)	9	6.50	138	63-263
Diabetes Mellitus	(40)	59	76.97	76.6	58-99
Diseases of Blood and Blood-forming Organs	(41-44)	12	14.38	83.4	43-146
Pernicious and Hyperchromic Anemias	(41)	1	0.72	--	--
Anemias of Other and Unspecified Type	(42)	9	7.23	124	57-236
Purpura and Other Hemorrhagic Conditions	(43)	2	2.23	--	--
All Other Diseases of Blood-forming Organs	(44)	0	4.21	--	--
Psychoneruotic, Personality Mental Disorders	(45,46)	21	24.31	86.3	53-132
Diseases of the Nervous System	(47,48)	297	397.39	74.7	66-84
Vascular Lesions Affecting Central Nervous System	(47)	295	392.32	75.1	67-84
Multiple Sclerosis	(48)	2	5.07	39.4	04-143
Diseases of the Circulatory System	(49-57)	2,141	2,489.26	86.0	82-90
Rheumatic Fever	(49)	0	1.51	--	--
Chronic Rheumatic Heart Disease	(50)	29	48.82	59.4	40-85
Arteriosclerotic Heart Disease	(51)	1,802	2,045.59	88.1	84-92
Chronic Endocarditis Not Specified as Rheumatic	(52)	15	15.42	97.2	54-160
Other Myocardial Degeneration	(53)	17	45.64	37.2	22-60
Other Diseases of the Heart	(54)	84	93.12	90.2	72-112
Hypertensive Heart Disease	(55)	50	67.97	73.5	55-97
Hypertension Without Heart Disease	(56)	22	18.97	115	73-176
Diseases of the Arteries and Veins	(57)	122	152.2	80.1	67-96
Diseases of the Respiratory System	(58-62)	230	307.44	74.8	65-85
Acute Upper Respiratory Infections	(58)	1	0.59	--	--
Influenza	(59)	6	8.06	74.4	27-162
Pneumonia	(60)	81	119.57	67.7	54-84
Bronchitis	(61)	19	20.66	91.9	55-144
Other Respiratory Diseases	(62)	123	158.56	77.6	64-93

TABLE 17 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	95%
Selected Diseases of the Digestive System	(63-65)	151	192.47	78.4	66-92
Diseases of the Stomach and Duodenum	(63)	39	42.67	91.3	65-125
Hernia and Intestinal Obstruction	(64)	10	20.80	48.0	23-88
Cirrhosis of the Liver	(65)	102	129.00	79.0	--
Selected Diseases of the Genito-Urinary System	(66-73)	36	59.36	60.6	42-84
Acute Nephritis	(66)	1	2.75	--	--
Nephritis with Edema including Nephrosis	(67)	2	2.23	--	--
Chronic and Unspecified Nephritis and Other Renal Sclerosis	(68)	19	26.40	71.9	43-112
Infection of Kidney	(69)	8	14.25	56.1	24-111
Calculi of Urinary System	(70)	2	3.06	--	--
Hyperplasia of Prostate	(71)	3	8.42	35.6	07-104
Other Diseases of Male Genital Organs	(72)	1	2.25	--	--
Diseases of the Breast	(73)	0	0	--	--
Diseases of the Skin	(76,77)	2	4.24	--	--
Diseases of the Bones and Organs of Movement	(78-80)	3	4.79	--	--
Unknown Causes	(81)	31	56.75	55	37-78
Selected Accidents	(82-86)	204	323.12	63.1	55-72
Transportation Accidents	(82)	106	173.44	61.1	50-74
Accidental Poisoning	(83)	6	13.37	44.9	16-98
Accidental Falls	(84)	30	41.60	72.1	49-103
Other Accidents	(85)	59	88.21	66.9	51-86
Medical Complications and Therapeutic Misadventure	(86)	3	6.50	46.2	09-135
Violent Deaths	(87-88)	85	140.95	60.3	48-75
Suicide	(87)	82	111.21	73.7	59-92
Homicide	(88)	3	29.74	10.0	02-29
Other Causes*	(89)	138	194.49	71.0	60-84
Death Certificates Not Obtained		361	--	--	--

Note:

*Residual: calculated by subtraction of the major groupings from all causes.

Three malignant neoplasms are counted in the category "All Malignant Neoplasms" but not in any of the sub categories. One was a breast cancer in a male and two were cervix cancers in persons coded as sex unknown. Due to the "freezing" of the data base the first week of August, the sex code corrections could not be made.

Table 18
ALL CAUSES OF DEATH
LATENCY BY DURATION OF EMPLOYMENT
NIOSH CATEGORIES (01-17, 23-73, 76-89)
TOTAL COHORT

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	235 279.1							235 279.1
5YRS - 10YRS	173 169.3	138 183.8						311 353.1
10YRS - 15YRS	182 187.6	72 63.0	230 332.1					484 582.8
15YRS - 20YRS	189 168.3	63 57.9	137 114.3	256 374.8				645 715.4
20YRS - 25YRS	158 144.3	50 37.9	133 122.4	131 116.3	331 370.1			803 791.1
25YRS - 30YRS	27 30.8	23 20.6	121 114.9	111 115.3	165 174.1	189 280.3		636 736.0
30YRS & OVER		5 10.6	122 136.8	149 167.8	274 273.4	254 270.5	844 1044.2	1648 1903.4
TOTAL	964 979.5	351 374.0	743 820.6	647 774.3	770 817.6	443 550.8	844 1044.2	4762 5361.0

TABLE 19

Observed and Expected Deaths Among the 7,615 White Males with Recorded Lifetime Cumulative Dose ≥ 0.001 rem (January 1, 1952 through August 15, 1977)

CAUSE OF DEATH	(NIOSH CATEGORY)*	OBSERVED	EXPECTED	SMR	95% CONFIDENC INTERVAL
All Causes	(01-17, 23-73, 76-89)	833	1065.33	78.2	73-84
Tuberculosis	(01,02)	0	4.54	--	--
Respiratory Tuberculosis	(01)	0	4.06	--	--
Other Tuberculosis	(02)	0	0.48	--	--
All Malignant Neoplasms(MN)	(03-17, 23-37)	201	218.52	92.0	80-106
MN of the Buccal Cavity and Pharynx	(03-06)	5	7.61	66.0	21-153
MN of Lip	(03)	0	0.16	--	--
MN of Tongue	(04)	2	1.81	--	--
MN of Other Parts of Buccal Cavity	(05)	1	2.01	--	--
MN of Pharynx	(06)	2	3.63	--	--
MN of Digestive System	(07-12)	58	59.08	98.2	75-127
MN of Esophagus	(07)	7	5.31	131	53-272
MN of Stomach	(08)	8	10.09	79.3	34-156
MN of Intestine Except Rectum	(09)	20	18.85	106	65-164
MN of Rectum	(10)	9	6.54	137	63-261
MN of Biliary Passages and Liver (Primary and Unspecified)	(11,12)	3	5.10	59.0	12-172
MN of Pancreas	(13)	10	12.31	81.2	39-149
MN of Peritoneum and Unspecified	(14)	1	0.87	--	--
MN of Respiratory System	(15-17)	83	80.66	102	82-128
MN of Larynx	(15)	1	3.56	--	--
MN of Trachea, Bronchus and Lung	(16)	81	76.23	106	84-132
MN of Other parts of Respiratory	(17)	1	0.86	--	--
MN of Male Genital Organs	(23,24)	8	11.49	70.0	30-137
MN of Prostate	(23)	6	10.19	59.0	22-128
MN of Other Male Genital Organs	(24)	2	1.30	--	--
MN of Urinary Organs	(25,26)	7	11.49	61.0	24-126
MN of Kidney	(25)	1	5.73	17.5	2-97
MN of Bladder and Other Urinary Organs	(26)	6	5.76	104	38-227
MN of Other and Unspecified Sites (Major)	(27-33)	25	26.72	93.6	61-138
MN of Skin	(27)	3	4.11	--	--
MN of Eye	(28)	1	0.20	--	--
MN of Brain and Other Parts of Nervous System	(29)	6	7.47	80.3	29-175
MN of Thyroid Gland	(30)	1	0.45	--	--
MN of Bone	(31)	0	1.07	--	--
MN of Connective Tissue	(32)	0	0.96	--	--
MN of Other and Unspecified Sites (Minor)	(33)	14	12.47	112	61-

TABLE 19 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	95% INTERVAL
MN of Lymphatic and Hematopoietic Tissues	(34-37)	15	21.14	71.0	40-117
Lymphosarcoma and Reticulosarcoma	(34)	3	6.80	44.1	09-129
Hodgkin's Disease	(35)	3	2.88	--	--
Leukemia and Aleukemia	(36)	7	8.29	84.4	34-174
Other Neoplasms of Lymphatic and Hematopoietic Tissues	(37)	2	3.16	--	--
Neoplasms of the Brain	(38,39)	3	2.03	--	--
Benign Neoplasms of the Brain	(38)	0	0.53	--	--
Neoplasms of Unspecified Nature of Brain	(39)	3	1.50	--	--
Diabetes Mellitus	(40)	4	15.08	27.0	7-68
Diseases of Blood and Blood-forming Organs	(41-44)	2	2.83	--	--
Pernicious and Hyperchromic Anemias	(41)	0	0.08	--	--
Anemias of Other and Unspecified Type	(42)	2	1.38	--	--
Purpura and Other Hemorrhagic Conditions	(43)	0	0.51	--	--
All Other Diseases of Blood-forming Organs	(44)	0	0.86	--	--
Psychoneruotic, Personality and Mental Disorders	(45,46)	4	6.45	62.0	17-159
Diseases of the Nervous System	(47,48)	48	61.95	77.5	57-103
Vascular Lesions Affecting Central Nervous System	(47)	48	60.74	79.0	58-105
Multiple Sclerosis	(48)	0	1.22	--	--
Diseases of the Circulatory System	(49-57)	379	477.26	79.0	72-88
Rheumatic Fever	(49)	0	0.22	--	--
Chronic Rheumatic Heart Disease	(50)	6	9.26	65.0	24-141
Arteriosclerotic Heart Disease	(51)	325	402.03	81.0	72-90
Chronic Endocarditis Not Specified as Rheumatic	(52)	3	3.04	--	--
Other Myocardial Degeneration	(53)	0	5.13	--	--
Other Diseases of the Heart	(54)	17	19.68	86.4	50-138
Hypertensive Heart Disease	(55)	1	8.00	13.0	1-70
Hypertension Without Heart Disease	(56)	5	2.72	183	59-429
Diseases of the Arteries and Veins	(57)	22	27.16	81.0	51-123
Diseases of the Respiratory System	(58-62)	31	58.27	53.2	36-76
Acute Upper Respiratory Infections	(58)	0	0.11	--	--
Influenza	(59)	1	1.36	--	--
Pneumonia	(60)	13	20.42	64.0	34-109
Bronchitis	(61)	3	4.04	--	--
Other Respiratory Diseases	(62)	14	32.34	43.3	24-73

TABLE 19 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	95% INTERVAL
Selected Diseases of the Digestive System	(63-65)	31	45.27	68.5	47-97
Diseases of the Stomach and Duodenum	(63)	8	7.40	108	47-213
Hernia and Intestinal Obstruction	(64)	0	3.56	--	--
Cirrhosis of the Liver	(65)	23	34.31	67.0	42-101
Selected Diseases of the Genito-Urinary System	(66-73)	2	8.94	22.4	3-81
Acute Nephritis	(66)	0	0.52	--	--
Nephritis with Edema including Nephrosis	(67)	1	0.40	--	--
Chronic and Unspecified Nephritis and Other Renal Sclerosis	(68)	1	4.38	--	--
Infection of Kidney	(69)	0	2.13	--	--
Calculi of Urinary System	(70)	0	0.45	--	--
Hyperplasia of Prostate	(71)	0	0.74	--	--
Other Diseases of Male Genital Organs	(72)	0	0.33	--	--
Diseases of the Breast	(73)	0	0.00	--	--
Diseases of the Skin	(76,77)	1	0.88	--	--
Diseases of the Bones and Organs of Movement	(78-80)	0	0.98	--	--
Unknown Causes	(81)	6	13.23	45.3	17-99
Selected Accidents	(82-86)	49	74.15	66.1	49-87
Transportation Accidents	(82)	25	40.77	61.3	40-91
Accidental Poisoning	(83)	1	3.45	--	--
Accidental Falls	(84)	6	7.64	79.0	29-171
Other Accidents	(85)	16	20.68	77.4	44-126
Medical Complications and Therapeutic Misadventure	(86)	1	1.59	--	--
Violent Deaths	(87-88)	14	35.70	39.2	21-66
Suicide	(87)	14	27.08	52.0	28-87
Homicide	(88)	0	8.63	--	--
Other Causes*	(89)	22	39.25	56.1	35-85
Death Certificates Not Obtained		36	--	--	--

Note:

* Residual: calculated by subtraction of the major groupings from all causes

TABLE 20

Observed and Expected Deaths Among the 15,585 White Males with No Recorded History of Radiation (January 1, 1952 through August 15, 1977)

CAUSE OF DEATH	(NIOSH CATEGORY)*	OBSERVED	EXPECTED	SMR	95% CONFIDE INTERVAL
ll Causes	(01-17, 23-73, 76-89)	3,733	3,801	98.2	95-101
uberculosis	(01,02)	7	24.97	28.0	11-58
Respiratory Tuberculosis	(01)	6	23.21	25.8	9-56
Other Tuberculosis	(02)	1	1.76	--	--
ll Malignant Neoplasms(MN)	(03-17, 23-37)	726	723.56	100	93-108
N of the Buccal Cavity and Pharynx	(03-06)	25	23.00	108	70-160
MN of Lip	(03)	0	0.75	--	--
MN of Tongue	(04)	8	5.55	144	62-284
MN of Other Parts of Buccal Cavity	(05)	1	6.30	15.8	2-88
MN of Pharynx	(06)	16	10.41	153	88-250
N of Digestive System	(07-12)	205	219.53	93.3	81-107
MN of Esophagus	(07)	20	17.10	116	71-181
MN of Stomach	(08)	33	43.96	75.0	52-105
MN of Intestine Except Rectum	(09)	65	68.48	94.9	73-121
MN of Rectum	(10)	27	26.01	103	68-151
MN of Biliary Passages and Liver (Primary and Unspecified)	(11,12)	21	19.40	108	67-165
MN of Pancreas	(13)	37	41.45	89.2	63-123
MN of Peritoneum and Unspecified	(14)	2	3.15	--	--
N of Respiratory System	(15-17)	253	231.70	109	96-124
MN of Larynx	(15)	15	11.20	133	75-221
MN of Trachea, Bronchus and Lung	(16)	235	217.78	107	95-123
MN of Other parts of Respiratory	(17)	3	2.72	--	--
N of Male Genital Organs	(23,24)	65	59.18	109	85-140
MN of Prostate	(23)	61	55.65	109	84-141
MN of Other Male Genital Organs	(24)	4	3.53	--	--
N of Urinary Organs	(25,26)	41	42.52	96.4	69-131
MN of Kidney	(25)	18	17.49	102	61-163
MN of Bladder and Other Urinary Organs	(26)	23	25.02	91.9	58-138
N of Other and Unspecified Sites (Major)	(27-33)	67	78.80	85.0	66-108
MN of Skin	(27)	8	11.41	70.1	30-138
MN of Eye	(28)	1	0.74	--	--
MN of Brain and Other Parts of Nervous System	(29)	15	18.71	80.1	45-132
MN of Thyroid Gland	(30)	2	1.60	--	--
MN of Bone	(31)	5	3.81	131	42-306
MN of Connective Tissue	(32)	2	2.67	--	--
MN of Other and Unspecified es (Minor)	(33)	34	39.86	85.2	59

pendix A

TABLE 20 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	9 INTERVAL
MN of Lymphatic and Hematopoietic Tissues	(34-37)	67	67.71	98.9	77-126
Lymphosarcoma and Reticulosarcoma	(34)	15	19.73	76.0	43-125
Hodgkin's Disease	(35)	8	8.03	99.6	43-196
Leukemia and Aleukemia	(36)	31	29.11	106	72-151
Other Neoplasms of Lymphatic and Hematopoietic Tissues	(37)	13	10.84	119	64-205
Neoplasms of the Brain	(38,39)	6	5.89	102	37-222
Benign Neoplasms of the Brain	(38)	0	1.68	--	--
Neoplasms of Unspecified Nature of Brain	(39)	6	4.21	142	52-310
Diabetes Mellitus	(40)	54	55.23	97.7	73-128
Diseases of Blood and Blood-forming Organs	(41-49)	10	10.30	97.0	46-179
Pernicious and Hyperchromic Anemias	(41)	1	0.59	--	--
Anemias of Other and Unspecified Type	(42)	7	5.27	132	53-274
Purpura and Other Hemorrhagic Conditions	(43)	2	1.51	--	--
All Other Diseases of Blood-forming Organs	(44)	0	2.93	--	--
Psychoneruotic, Personality and Mental Disorders	(45,46)	16	14.82	107	62-175
Diseases of the Nervous System	(47,48)	240	306.58	78.2	69-89.
Vascular Lesions Affecting Central Nervous System	(47)	238	303.43	78.4	69-89.
Multiple Sclerosis	(48)	2	3.15	--	--
Diseases of the Circulatory System	(49-57)	1,673	1,799.09	93.0	89-98
Rheumatic Fever	(49)	0	0.98	--	--
Chronic Rheumatic Heart Disease	(50)	22	32.24	68.2	43-103
Arteriosclerotic Heart Disease	(51)	1,400	1,470.33	95.2	90-100
Chronic Endocarditis Not Specified as Rheumatic	(52)	11	10.90	100	50-181
Other Myocardial Degeneration	(53)	16	36.65	43.6	25-71
Other Diseases of the Heart	(54)	65	65.45	99.3	77-127
Hypertensive Heart Disease	(55)	47	53.54	87.7	64-117
Hypertension Without Heart Disease	(56)	16	14.44	110	63-180
Diseases of the Arteries and Veins	(57)	96	114.55	83.8	68-102
Diseases of the Respiratory System	(58-62)	184	225.31	81.6	70-94
Acute Upper Respiratory Infections	(58)	1	0.40	--	--
Influenza	(59)	5	6.01	83.1	27-194
Pneumonia	(60)	63	89.36	70.5	54-90
Bronchitis	(61)	15	15.11	99.2	56-164
Other Respiratory Diseases	(62)	100	114.43	87.3	71-106

TABLE 20 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	9 INTERVAL
Selected Diseases of the Digestive System	(63-65)	119	126.59	94	78-112
Diseases of the Stomach and Duodenum	(63)	31	30.66	101	69-144
Hernia and Intestinal Obstruction	(64)	10	15.51	64.4	31-119
Cirrhosis of the Liver	(65)	78	80.43	96.9	77-121
Selected Diseases of the Genito-Urinary System	(66-73)	32	44.16	72.4	50-102
Acute Nephritis	(66)	1	1.91	--	--
Nephritis with Edema including Nephrosis	(67)	1	1.54	--	--
Chronic and Unspecified Nephritis and Other Renal Sclerosis	(68)	17	18.49	91.9	54-147
Infection of Kidney	(69)	8	10.90	73.3	32-145
Calculi of Urinary System	(70)	2	2.28	--	--
Hyperplasia of Prostate	(71)	3	7.25	41.3	08-121
Other Diseases of Male Genital Organs	(72)	0	1.78	--	--
Diseases of the Breast	(73)	0	0.00	--	--
Diseases of the Skin	(76,77)	1	2.93	--	--
Diseases of the Bones and Organs of Movement	(78-80)	3	3.37	--	--
Unknown Causes	(81)	25	37.95	66.0	43-97
Selected Accidents	(82-86)	145	200.89	72.1	61-85
Transportation Accidents	(82)	76	104.71	72.5	57-91
Accidental Poisoning	(83)	5	8.03	62.2	20-145
Accidental Falls	(84)	22	29.54	74.4	47-113
Other Accidents	(85)	40	54.23	73.7	53-100
Medical Complications and Therapeutic Misadventure	(86)	2	4.37	--	--
Violent Deaths	(87-89)	70	85.66	81.7	64-103
Suicide	(87)	67	68.71	97.5	76-124
Homicide	(88)	3	16.95	17.6	04-52
Other Causes*	(89)	111	134.82	82.3	68-99
Death Certificates Not Obtained		314	--	--	--

Note: *Residual: calculated by subtraction of the major groupings from all causes.

Three malignant neoplasms are counted in the category "all Malignant Neoplasms" but not in any o the sub categories. One was a breast cancer in a male and two were cervix cancers in persons co is sex unknown. Due to the "freezing" of the data base the first week of August, the sex code corrections could not be made.

TABLE 21

Observed and Expected Deaths Due to Selected Causes by Age
Among Subcohort I (Lifetime Radiation ≥ 0.001 rem)
and Subcohort II (Non-radiation) between
January 1, 1952 and August 15, 1977

(OBSERVED/EXPECTED, SMR)
Age

	15-29		30-39		40-49		50-59		60-69		70+		Total	
All Causes														
Subcohort I	11/18.44	60	25/141.35	60	105/152.24	69	302/362.62	83	270/352.37	76	120/138.31	87	833/1065.33	78
Subcohort II	54/49.95	108	84/88.95	94	391/313.96	125	836/786.51	106	1231/1223.55	101	1137/1338.38	85	3733/3801.00	98
Circulatory Disease														
Subcohort I	2/.78	--	8/8.05	99	48/60.52	79	146/169.24	86	120/170.77	70	55/67.88	81	379/477.26	79
Subcohort II	3/2.19	--	23/18.93	122	163/127.24	128	410/372.67	110	567/604.61	94	507/674.39	75	1673/1799.09	93
All Cancer														
Subcohort I	1/1.38	--	3/5.12	59	11/25.86	43	87/78.21	111	70/80.31	87	29/27.64	105	201/218.52	92
Subcohort II	4/3.63	--	11/10.93	101	60/51.40	117	163/161.48	101	266/261.26	102	222/235.86	94	726/723.56	100
Lung Cancer														
Subcohort I	0/.04	--	0/.86	--	5/8.49	59	39/29.20	134	29/29.35	99	8/8.30	96	81/76.23	106
Subcohort II	1/.10	--	2/1.65	--	25/15.64	160	46/55.74	83	98/85.31	115	63/58.35	108	235/217.78	108
Non-malignant Respiratory Disease														
Subcohort I	0/.38	--	0/1.15	--	1/5.23	19	9/16.93	53	12/23.21	52	8/11.37	70	31/58.27	53
Subcohort II	1/1.01	--	0/2.56	--	10/10.61	94	23/34.18	67	73/72.24	101	77/104.71	74	184/225.31	82

TABLE 22

Observed and Expected Deaths Due to Selected Causes by Calendar Time Among Subcohort I (Lifetime Radiation ≥ 0.001 rem) and Subcohort II (Non-radiation) between January 1, 1952 and August 15, 1977

(OBSERVED/EXPECTED, SMR)

Calendar Year	1952-1959		1960-1964		1965-1969		1970-1974		1975-1977		Total	
All Causes												
Subcohort I	9/21.80	41	95/132.61	72	207/277.46	75	327/391.79	83	195/241.62	81	833/1065.33	78
Subcohort II	648/683.38	95	673/651.82	103	847/863.81	98	1005/1013.01	99	560/579.75	97	3733/3801.00	98
Circulatory Diseases												
Subcohort I	5/9.39	53	45/59.29	76	89/124.33	72	139/175.97	79	101/108.28	93	379/477.26	79
Subcohort II	317/315.43	100	328/314.36	104	348/414.84	84	458/484.59	95	222/269.87	82	673/799.09	84
All Cancer												
Subcohort I	1/3.72		20/24.15	83	53/53.37	99	85/82.24	103	42/55.05	76	201/218.52	92
Subcohort II	112/121.57	92	123/122.15	101	183/163.50	112	202/198.69	102	106/117.64	90	726/723.56	100
Lung Cancer												
Subcohort I	1/.98		9/7.25	124	19/17.82	107	31/29.82	104	21/20.37	103	81/76.23	106
Subcohort II	30/30.43	99	36/34.74	104	67/49.93	134	76/64.23	118	26/38.45	68	235/217.78	108
Non-malignant Respiratory Disease												
Subcohort I	0/0.78		1/5.69	18	10/14.27	70	13/22.40	58	7/15.12	46	31/58.27	53
Subcohort II	16/25.76	62	29/33.33	87	42/54.09	78	63/69.86	90	34/42.27	80	184/225.31	82

TABLE 23

Observed and Expected Deaths Among the 1,345 White Males with a Recorded Lifetime Cumulative Dose = 0.000 rem (January 1, 1952 through August 15, 1977)

CAUSE OF DEATH	(NIOSH CATEGORY)*	OBSERVED	EXPECTED	SMR	95% CONFIDE INTERVAL
All Causes	(01-17 23-73, 76-89)	196	298.90	65.6	57-75
Tuberculosis	(01,02)	1	1.87	--	--
All Malignant Neoplasms(MN)	(03-17, 23-37)	50	59.49	84.0	62-111
MN of the Buccal Cavity and Pharynx	(03,06)	1	1.98	--	--
MN of Digestive System	(07,14)	12	16.96	70.8	37-124
MN of Respiratory System	(15-17)	20	20.69	96.7	59-149
MN of Male Genital Organs	(23,24)	4	3.80	--	--
MN of Urinary Organs	(25,26)	3	3.29	--	--
MN of Other and Unspecified Sites (Major)	(27-33)	8	6.94	115.3	50-227
MN of Lymphatic and Hematopoietic Tissues	(34-37)	2	5.75	--	--
Lymphosarcoma and Reticulosarcoma	(34)	0	1.75	--	--
Hodgkin's Disease	(35)	1	0.76	--	--
Leukemia and Aleukemia	(36)	1	2.34	--	--
Other Neoplasms of Lymphatic and Hematopoietic Tissue	(37)	0	0.89	--	--
Neoplasms of the Brain	(38,39)	0	0.55	--	--
Diabetes Mellitus	(40)	1	4.27	--	--
Diseases of Blood and Blood-forming Organs	(41-44)	0	0.8	--	--
Pernicious and Hyperchromic Anemias	(41)	0	0.03	--	--
Anemias of Other and Unspecified Type	(42)	0	0.40	--	--
Purpura and Other Hemorrhagic Conditions	(43)	0	0.13	--	--
All Other Diseases of Blood-forming Organs	(44)	0	0.24	--	--
Psychoneruotic, Personality and Mental Disorders	(45,46)	1	1.50	--	--
Diseases of the Nervous System	(47,48)	9	19.87	45.3	21-86
Diseases of the Circulatory System	(49-57)	89	138.88	64.1	51-79
Diseases of the Respiratory System	(58-62)	15	17.02	88.1	49-145
Selected Diseases of the Digestive System	(63-65)	1	11.36	8.8	0.

TABLE 23 (continued)

CAUSE OF DEATH	(NIOSH CATEGORY)	OBSERVED	EXPECTED	SMR	9[illegible] INTERVAL
Selected Diseases of the Genito-Urinary System	(63-73)	2	3.02	--	--
Diseases of the Skin	(76,77)	0	0.24	--	--
Diseases of the Bones and Organs of Movement	(78-80)	0	0.27	--	--
Unknown Causes	(81)	0	3.33	--	--
Selected Accidents	(82-86)	10	19.05	52.5	25-97
Violent Deaths	(87,88)	1	8.54	11.7	0.1-65
Other Causes	(89)	5	10.93	45.7	15-107
Death Certificates Not Obtained		11	--	--	--

Note: NIOSH Categories 18-22 and 74, 75 are not included because they apply only to females.

TABLE 24

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic Tissues Among the 24,545 White Males Employed at the Portsmouth Naval Shipyard from January 1, 1952 Through August 15, 1977

(OBSERVED/EXPECTED)

CAUSE OF DEATH	NIOSH CATEGORY*	1/1952-12/1954	1/1955-12/1959	1/1960-12/1964	1/1965-12/1969	1/1970-12/1974	1/1975 8/1977	Total
MN of Lymphatic & Hematopoietic Tissues	(34-37)	5/5.10	10/11.78	9/16.82	22/22.49	30/26.93	8/16.01	84/99.14
Lymphosarcoma & Reticulosarcoma	(34)	1/1.24	2/3.03	1/4.54	6/6.64	6/8.79	2/5.20	18/29.44
Hodgkin's Disease	(35)	0/1.09	4/2.11	2/2.58	2/2.97	4/2.75	0/1.26	12/12.77
Leukemia and Aleukemia	(36)	3/2.13	3/4.88	4/6.99	10/9.35	13/11.26	6/6.92	39/41.53
Other Neoplasms of Lymphatic & Hematopoietic Tissue	(37)	1/0.65	1/1.77	2/2.71	4/3.52	7/4.13	0/2.63	15/15.40
Diseases of Blood and Blood Forming Organs	(41-44)	1/0.62	0/1.34	0/2.05	2/3.11	5/4.44	4/2.82	12/14.38
Pernicious & Hyper-Chromic Anemias	(41)	0/0.09	0/0.11	0/0.12	0/0.13	1/0.18	0/0.09	1/0.72
Anemias of Other and Unspecified type	(42)	1/0.23	0/0.54	0/0.92	2/1.55	3/2.44	3/1.54	9/7.23
Purpura and Other Hemorrhagic Conditions	(43)	0/0.09	0/0.19	0/0.27	0/0.41	1/0.72	1/0.55	2/2.23
All Other Diseases of Blood-forming Organs	(44)	0/0.20	0/0.50	0/0.73	0/1.01	0/1.11	0/0.65	0/4.21
Total Lymphatic & Hematopoietic Diseases	(34-37, 41-44)	6/5.72	10/13.12	9/18.87	24/25.60	35/31.37	12/18.84	96/113.52

TABLE 25

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic System Among the 7615 White Males with Recorded Lifetime Cumulative Dose ≥0.001rem

(OBSERVED/EXPECTED)

CAUSE OF DEATH	NIOSH CATEGORY*	1/1952-12/1954	1/1955-12/1959	1/1960-12/1964	1/1965-12/1969	1/1970-12/1974	1/1975 8/1977	Total
MN of Lymphatic & Hematopoietic Tissues	(34-37)	0/0.04	0/0.44	2/2.79	1/5.58	11/7.55	1/4.74	15/21.14
Lymphosarcoma & Reticulosarcoma	(34)	0/0.01	0/0.11	0/0.77	0/1.71	3/2.58	0/1.63	3/6.80
Hodgkin's Disease	(35)	0/0.01	0/0.09	0/0.52	0/0.92	3/0.92	0/0.42	3/2.88
Leukemia and Aleukemia	(36)	0/0.01	0/0.17	1/1.09	1/2.15	4/2.94	1/1.92	7/8.29
Other Neoplasms of Lymphatic & Hematopoietic Tissue	(37)	0/0.00	0/0.06	1/0.41	0/0.80	1/1.11	0/0.77	2/3.16
Diseases of Blood and Blood Forming Organs	(41-44)	0/0.00	0/0.04	0/0.30	1/0.67	0/1.08	1/0.73	2/2.83
Pernicious & Hyper-Chromic Anemias	(41)	0/0.00	0/0.00	0/0.01	0/0.02	0/0.03	0/0.02	0/0.08
Anemias of Other and Unspecified type	(42)	0/0.00	0/0.02	0/0.12	1/0.31	0/0.55	1/0.38	2/1.38
Purpura and Other Hemorrhagic Conditions	(43)	0/0.00	0/0.01	0/0.04	0/0.10	0/0.20	0/0.16	0/0.51
All Other Diseases of Blood-forming Organs	(44)	0/0.00	0/0.02	0/0.12	0/0.24	0/0.30	0/0.18	0/0.86
Total Lymphatic & Hematopoietic Diseases	(34-37, 41-44)	0/0.04	0/0.48	2/3.09	2/6.25	11/8.63	2/5.47	17/23.97

* See Appendix A

TABLE 26

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic System Among the 15,585 White Males with No Recorded History of Radiation (January 1, 1952 through August 15, 1977)

(OBSERVED/EXPECTED)

CAUSE OF DEATH	NIOSH CATEGORY*	1/1952-12/1954	1/1955-12/1959	1/1960-12/1964	1/1965-12/1969	1/1970-12/1974	1/1975 8/1977	Total
MN of Lymphatic & Hematopoietic Tissues	(34-37)	5/3.89	10/8.85	6/11.89	20/15.26	19/17.61	7/10.22	67/67.71
Lymphosarcoma & Reticulosarcoma	(34)	1/0.96	2/2.29	1/3.19	6/4.44	3/5.63	2/3.23	15/19.73
Hodgkin's Disease	(35)	0/0.77	4/1.45	1/1.64	2/1.80	1/1.63	0/0.76	8/8.03
Leukemia and Aleukemia	(36)	3/1.63	3/3.71	3/5.06	8/6.54	9/7.59	5/4.56	31/29.11
Other Neoplasms of Lymphatic & Hematopoietic Tissue	(37)	1/0.53	1/1.41	1/2.00	4/2.48	6/2.75	0/1.68	13/10.84
Diseases of Blood and Blood Forming Organs	(41-44)	1/0.50	0/1.04	0/1.53	1/2.24	5/3.09	3/1.91	10/10.30
Pernicious & Hyper Chromic Anemias	(41)	0/0.08	0/0.10	0/0.10	0/0.11	1/0.14	0/0.07	1/0.59
Anemias of Other and Unspecified type	(42)	1/0.19	0/0.42	0/0.71	1/1.15	3/1.74	2/1.06	7/5.27
Purpura and Other Hemorrhagic Conditions	(43)	0/0.07	0/0.14	0/0.19	0/0.29	1/0.47	1/0.36	2/1.51
All Other Diseases of Blood-forming Organs	(44)	0/0.16	0/0.39	0/0.52	0/0.69	0/0.74	0/0.43	0/2.93
Total Lymphatic & Hematopoietic Diseases	(34-37, 41-44)	6/4.39	10/9.89	6/13.41	21/17.50	24/20.69	10/12.13	77/78.02

TABLE 27

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic Tissues Among the 24,545 White Males employed at the Portsmouth Naval Shipyard from January 1, 1952 through August 15, 1977

(OBSERVED/EXPECTED)

CAUSE OF DEATH	NIOSH CATEGORY*	AGE 15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+	Total
MN of Lymphatic & Hematopoietic Tissues		0/0.18	0/0.85	1/1.61	2/2.29	2/3.35	5/5.35	2/7.74	7/10.74	15/13.96	13/15.35	16/14.31	11/11.55	6/7.84	4/4.01	84/99.14
Lymphosarcoma & Reticulosarcoma	(34)	0/0.04	0/0.17	1/0.29	0/0.48	0/0.82	3/1.55	0/2.46	0/3.58	3/4.59	4/4.80	3/4.23	2/3.28	2/2.16	0/0.99	18/29.44
Hodgkin's Disease	(35)	0/0.03	0/0.29	0/0.65	2/0.85	1/1.02	1/1.31	2/1.43	4/1.59	1/1.66	0/1.49	1/1.15	0/0.73	0/0.43	0/0.14	12/12.77
Leukemia and Aleukemia	(36)	0/0.11	0/0.38	0/0.64	0/0.90	1/1.30	1/2.04	0/2.86	2/3.90	10/5.36	7/6.18	8/6.20	6/5.48	2/3.92	2/2.26	39/41.53
Other Neoplasms of Lymphatic and Hematopoietic Tissue	(37)	0/0.00	0/0.01	0/0.03	0/0.07	0/0.20	0/0.45	0/0.98	1/1.66	1/2.36	2/2.88	4/2.73	3/2.06	2/1.34	2/0.63	15/15.40
Diseases of Blood & Blood-forming Organs		0/0.02	0/.9	0/0.13	0/0.19	1/0.29	1/0.48	1/0.77	1/1.22	0/1.78	1/2.20	2/2.28	0/2.10	5/1.67	0/1.16	12/14.38
Pernicious and Hyper-Chromic Anemias	(41)	0/0.00	0/0.00	0/0.00	0/0.00	0/0.01	1/0.01	0/0.02	0/0.05	0/0.08	0/0.11	0/0.13	0/0.12	0/0.09	0/0.10	1/0.72
Anemias of Other & Unspecified Type	(42)	0/0.01	0/0.05	0/0.06	0/0.08	1/0.10	0/0.18	1/0.31	1/0.49	0/0.77	1/1.06	2/1.21	0/1.19	3/1.00	0/0.71	9/7.23
Purpura and Other Hemorrhagic Conditions	(43)	0/0.00	0/0.02	0/0.03	0/0.05	0/0.08	0/0.11	0/0.15	0/0.23	0/0.28	0/0.34	0/0.30	0/0.26	2/0.22	0/0.15	2/2.23
All Other Diseases of Blood-forming Organs	(44)	0/0.01	0/0.02	0/0.04	0/0.06	0/0.10	0/0.18	0/0.29	0/0.45	0/0.64	0/0.69	0/0.65	0/0.52	0/0.35	0/0.21	0/4.21
Total Lymphatic & Hematopoietic Diseases		0/0.20	0/0.94	1/1.75	2/2.48	3/3.64	6/5.83	3/8.51	8/11.96	15/15.74	14/17.55	18/16.59	11/13.65	11/9.51	4/5.17	96/113.52

* See Appendix A

TABLE 28

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic Tissues Among the 7,615 White Males With Recorded Lifetime Cumulative Dose ≥0.001rems (January 1, 1952 through August 15, 1977)

(OBSERVED/EXPECTED)

CAUSE OF DEATH	NIOSH CATEGORY*	AGE 15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+	Total
MN of Lymphatic & Hematopoietic Tissues		0/0.01	0/0.17	0/0.39	0/0.55	1/0.79	0/1.37	1/2.14	2/3.16	4/3.87	3/3.57	3/2.81	1/1.62	0/0.58	0/0.10	15/21.14
Lymphosarcoma & Reticulosarcoma	(34)	0/0.00	0/0.03	0/0.07	0/0.13	0/0.21	0/0.42	0/0.72	0/1.11	1/1.35	1/1.19	0/0.89	1/0.49	0/0.16	0/0.03	3/6.80
Hodgkin's Disease	(35)	0/0.01	0/0.06	0/0.16	0/0.20	0/0.24	0/0.33	1/0.38	1/0.45	1/0.42	0/0.32	0/0.21	0/0.09	0/0.03	0/0.00	3/2.88
Leukemia and Aleukemia	(36)	0/0.01	0/0.07	0/0.15	0/0.21	1/0.30	0/0.51	0/0.78	0/1.12	2/1.47	1/1.39	3/1.18	0/0.75	0/0.29	0/0.06	7/8.29
Other Neoplasms of Lymphatic and Hematopoietic Tissue	(37)	0/0.00	0/0.00	0/0.00	0/0.01	0/0.04	0/0.11	0/0.26	1/0.48	0/0.64	1/0.66	0/0.54	0/0.29	0/0.10	0/0.01	2/3.16
Diseases of Blood and Blood-forming Organs		0/0.00	0/0.02	0/0.03	0/0.05	0/0.06	0/0.13	0/0.21	1/0.37	0/0.50	1/0.53	0/0.47	0/0.30	0/0.12	0/0.03	2/2.83
Pernicious and Hyper-Chromic Anemias	(41)	0/0.00	0/0.00	0/0.00	0/0.00	0/0.00	0/0.00	0/0.00	0/0.01	0/0.01	0/0.01	0/0.02	0/0.01	0/0.01	0/0.00	0/0.08
Anemias of Other and Unspecified type	(42)	0/0.00	0/0.01	0/0.01	0/0.02	0/0.02	0/0.05	0/0.09	0/0.15	0/0.23	1/0.27	0/0.26	0/0.18	0/0.08	0/0.02	2/1.38
Purpura and Other Hemorrhagic Conditions	(43)	0/0.00	0/0.00	0/0.01	0/0.01	0/0.20	0/0.03	0/0.05	0/0.07	0/0.09	0/0.09	0/0.07	0/0.04	0/0.02	0/0.00	0/0.51
All Other Diseases of Blood-forming Organs	(44)	0/0.00	0/0.00	0/0.01	0/0.01	0/0.02	0/0.05	0/0.08	0/0.13	0/0.18	0/0.15	0/0.13	0/0.07	0/0.03	0/0.01	0/0.86
Total Lymphatic & Hematopoietic Diseases		0/0.01	0/0.19	0/0.42	0/0.60	1/0.85	0/1.50	1/2.35	3/3.53	4/4.37	4/4.10	3/3.28	1/1.92	0/0.71	0/0.13	17/23.97

* See Appendix A

TABLE 29

Observed and Expected Deaths Due to Diseases of the Lymphatic and Hematopoietic Tissues Among the 15,585 White Males with no Recorded History of Radiation
(January 1, 1952 through August 15, 1977)

(Observed Expected)

CAUSE OF DEATH	NIOSH CATEGORY*	AGE 15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+	Total
MN of Lymphatic & Hematopoietic Tissues		0/0.13	0/0.52	1/0.86	2/1.18	1/1.73	5/2.87	1/4.29	4/6.15	11/8.66	10/10.64	12/10.65	10/9.29	6/6.91	4/3.83	67/67.71
Lymphosarcoma & Reticulosarcoma	(34)	0/0.03	0/0.11	1/0.15	0/0.24	0/0.42	3/0.83	0/1.36	0/2.02	2/2.79	3/3.25	3/3.09	1/2.60	2/1.89	0/0.95	15/19.73
Hodgkin's Disease	(35)	0/0.02	0/0.18	0/0.35	2/0.44	1/0.53	1/0.70	1/0.80	2/0.92	0/1.06	0/1.06	1/0.88	0/0.60	0/0.38	0/0.13	8/8.03
Leukemia and Aleukemia	(36)	0/0.08	0/0.24	0/0.35	0/0.46	0/0.67	1/1.09	0/1.59	2/2.25	8/3.34	6/4.33	4/4.66	6/4.44	2/3.46	2/2.15	31/29.11
Other Neoplasms of Lymphatic and Hematopoietic Tissue	(37)	0/0.00	0/0.01	0/0.01	0/0.04	0/0.11	0/0.24	0/0.55	0/0.96	1/1.48	1/2.00	4/2.02	3/1.66	2/1.18	2/0.60	13/10.84
Diseases of Blood and Blood-forming Organs		0/0.02	0/0.06	0/0.07	0/0.10	1/0.15	1/0.26	1/0.43	0/0.70	0/1.09	0/1.51	2/1.67	0/1.68	5/1.46	0/1.11	10/10.30
Pernicious and Hyper-Chromic Anemias	(41)	0/0.00	0/0.00	0/0.00	0/0.00	0/0.00	1/0.01	0/0.01	0/0.03	0/0.05	0/0.09	0/0.10	0/0.10	0/0.09	0/0.09	1/0.59
Anemias of Other and Unspecified type	(42)	0/0.01	0/0.03	0/0.03	0/0.04	1/0.05	0/0.10	1/0.17	0/0.28	0/0.47	0/0.71	2/0.88	0/0.95	3/0.88	0/0.68	7/5.27
Purpura and Other Hemorrhagic Conditions	(43)	0/0.00	0/0.01	0/0.02	0/0.02	0/0.04	0/0.06	0/0.08	0/0.13	0/0.17	0/0.22	0/0.21	0/0.21	2/0.19	0/0.14	2/1.51
All Other Diseases of Blood-forming Organs	(44)	0/0.00	0/0.01	0/0.02	0/0.03	0/0.05	0/0.10	0/0.16	0/0.26	0/0.40	0/0.48	0/0.48	0/0.42	0/0.31	0/0.20	0/2.93
Total Lymphatic & Hematopoietic Diseases		0/0.15	0/0.58	1/1.93	2/1.28	2/1.88	6/3.13	2/4.72	4/6.85	11/9.75	10/12.15	14/12.32	10/10.97	11/8.37	4/4.43	77/78.01

* See Appendix A

Table 30A
OBSERVED AND EXPECTED DEATHS FOR LYMPHOSARCOMA AND RETICULOSARCOMA AMONG 24,545 WHITE MALES (TOTAL COHORT) BY DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (34)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 1.7							0 1.7
5YRS 10YRS	0 1.0	1 1.1						1 2.2
10YRS 15YRS	0 1.1	0 0.4	2 1.9					2 3.4
15YRS 20YRS	2 1.0	1 0.3	1 0.6	1 2.1				5 4.1
20YRS 25YRS	1 0.9	0 0.2	0 0.6	0 0.6	3 2.1			4 4.4
25YRS 30YRS	0 0.2	0 0.1	0 0.6	0 0.5	3 0.9	1 1.7		4 4.0
30YRS & OVER		0 0.1	0 0.7	0 0.7	1 1.3	0 1.5	1 5.3	2 9.6
TOTAL	3 6.0	2 2.2	3 4.4	1 3.9	7 4.4	1 3.2	1 5.3	18 29.4

Table 30B
OBSERVED AND EXPECTED DEATHS FOR HODGKIN'S DISEASE
AMONG 24,545 WHITE MALES (TOTAL COHORT) BY DURATION OF EMPLOYMENT
AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (35)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0							0
	1.6							1.6
5YRS	1	0						1
10YRS	0.7	0.9						1.6
10YRS	1	0	0					1
15YRS	0.6	0.2	1.3					2.1
15YRS	1	0	1	2				4
20YRS	0.4	0.1	0.3	1.2				2.0
20YRS	0	0	0	1	2			3
25YRS	0.2	0.1	0.2	0.2	1.0			1.7
25YRS	0	0	0	0	0	3		3
30YRS	0.0	0.0	0.2	0.1	0.3	0.7		1.3
30YRS		0	0	0	0	0	0	0
& OVER		0.0	0.1	0.1	0.3	0.3	1.5	2.4
	3	0	1	3	2	3	0	12
TOTAL	3.6	1.3	2.1	1.7	1.5	1.0	1.5	12.8

Table 30C
OBSERVED AND EXPECTED DEATHS FOR LEUKEMIA AND ALEUKEMIA
AMONG 24,545 WHITE MALES (TOTAL COHORT) BY DURATION OF EMPLOYMENT
AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (36)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 2.6							0 2.6
5YRS - 10YRS	1 1.4	0 1.6						1 3.1
10YRS - 15YRS	4 1.5	2 0.5	2 2.7					8 4.7
15YRS - 20YRS	0 1.3	1 0.4	0 0.9	0 2.9				1 5.6
20YRS - 25YRS	0 1.1	1 0.3	1 0.9	0 0.9	4 2.8			6 6.0
25YRS - 30YRS	1 0.2	0 0.1	2 0.8	0 0.9	1 1.3	2 2.0		6 5.4
30YRS & OVER	 	0 0.1	0 1.0	1 1.2	1 2.1	3 2.0	12 7.7	17 14.2
TOTAL	6 8.2	4 3.1	5 6.3	1 5.9	6 6.2	5 4.1	12 7.7	39 41.5

Table 30D
OBSERVED AND EXPECTED DEATHS FOR OTHER NEOPLASMS OF LYMPHATIC AND HEMATOPOIETIC TISSUES AMONG 24,545 WHITE MALES (TOTAL COHORT) BY DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (37)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0							0
	0.6							0.6
5YRS	0	0						0
10YRS	0.4	0.5						0.9
10YRS	0	0	0					0
15YRS	0.5	0.2	0.9					1.6
15YRS	0	0	1	1				2
20YRS	0.5	0.2	0.3	1.1				2.1
20YRS	0	2	1	0	1			4
25YRS	0.4	0.1	0.4	0.3	1.1			2.4
25YRS	0	0	0	0	0	0		0
30YRS	0.1	0.0	0.3	0.3	0.5	0.9		2.2
30YRS		0	2	0	1	0	6	9
& OVER		0.0	0.4	0.4	0.8	0.8	3.1	5.6
	0	2	4	1	2	0	6	15
TOTAL	2.6	1.0	2.3	2.2	2.5	1.7	3.1	15.4

Table 31A
OBSERVED AND EXPECTED DEATHS FOR LYMPHOSARCOMA AND RETICULOSARCOMA AMONG 15,585 WHITE MALES WITH NO RECORDED HISTORY OF RADIATION (SUBCOHORT II) BY DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (34)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 1.1							0 1.1
5YRS 10YRS	0 0.8	1 0.4						1 1.3
10YRS 15YRS	0 1.0	0 0.2	1 0.9					1 2.1
15YRS 20YRS	2 1.0	1 0.2	1 0.4	1 1.1				5 2.7
20YRS 25YRS	1 0.9	0 0.2	0 0.5	0 0.4	3 1.0			4 3.1
25YRS 30YRS	0 0.2	0 0.1	0 0.5	0 0.4	2 0.6	1 0.7		3 2.6
30YRS & OVER		0 0.1	0 0.7	0 0.7	0 0.9	0 0.8	1 3.6	1 6.8
TOTAL	3 5.0	2 1.2	2 3.1	1 2.6	5 2.5	1 1.5	1 3.6	15 19.7

Table 31B
OBSERVED AND EXPECTED DEATHS FOR HODGKIN'S DISEASE
AMONG 15,585 WHITE MALES WITH NO RECORDED HISTORY OF RADIATION (SUBCOHORT II) BY DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (35)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 0.9							0 0.9
5YRS - 10YRS	1 0.6	0 0.3						1 0.9
10YRS - 15YRS	1 0.5	0 0.1	0 0.6					1 1.2
15YRS - 20YRS	1 0.4	0 0.1	1 0.2	1 0.6				3 1.2
20YRS - 25YRS	0 0.2	0 0.1	0 0.2	1 0.1	1 0.4			2 1.1
25YRS - 30YRS	0 0.0	0 0.0	0 0.2	0 0.1	0 0.2	1 0.3		1 0.8
30YRS & OVER		0 0.0	0 0.1	0 0.1	0 0.2	0 0.2	0 1.0	0 1.7
TOTAL	3 2.7	0 0.6	1 1.3	2 1.0	1 0.8	1 0.5	0 1.0	8 8.0

Table 31C
OBSERVED AND EXPECTED DEATHS FOR LEUKEMIA AND ALEUKEMIA
AMONG 15,585 WHITE MALES WITH NO RECORDED HISTORY OF RADIATION (SUBCOHORT II) BY
DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (36)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 1.7							0 1.7
5YRS 10YRS	1 1.2	0 0.6						1 1.9
10YRS 15YRS	4 1.3	1 0.3	1 1.4					6 3.0
15YRS 20YRS	0 1.2	1 0.3	0 0.7	0 1.6				1 3.8
20YRS 25YRS	0 1.1	1 0.3	1 0.8	0 0.7	3 1.4			5 4.3
25YRS 30YRS	1 0.2	0 0.1	2 0.8	0 0.7	1 0.9	0 0.9		4 3.7
30YRS & OVER		0 0.1	0 1.0	1 1.1	1 1.5	2 1.2	10 5.7	14 10.7
TOTAL	6 6.7	3 1.7	4 4.7	1 4.2	5 3.8	2 2.1	10 5.7	31 29.1

Table 31D
OBSERVED AND EXPECTED DEATHS FOR OTHER NEOPLASMS OF LYMPHATIC AND HEMATOPOIETIC TISSUE AMONG 15,585 WHITE MALES WITH NO RECORDED HISTORY OF RADIATION (SUBCOHORT II) BY DURATION OF EMPLOYMENT AND BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORY (37)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	0 0.4							0 0.4
5YRS - 10YRS	0 0.4	0 0.2						0 0.6
10YRS - 15YRS	0 0.5	0 0.1	0 0.5					0 1.1
15YRS - 20YRS	0 0.4	0 0.1	1 0.3	1 0.6				2 1.5
20YRS - 25YRS	0 0.4	2 0.1	1 0.3	0 0.3	0 0.6			3 1.7
25YRS - 30YRS	0 0.1	0 0.0	0 0.3	0 0.3	0 0.3	0 0.3		0 1.5
30YRS & OVER		0 0.0	2 0.4	0 0.4	1 0.5	0 0.5	5 2.3	8 4.1
TOTAL	0 2.2	2 0.6	4 1.8	1 1.6	1 1.5	0 0.9	5 2.3	13 10.8

Table 31E
OBSERVED AND EXPECTED DEATHS FOR ALL MALIGNANT NEOPLASMS
AMONG 15,585 WHITE MALES WITH NO RECORDED HISTORY OF RADIATION
(SUBCOHORT II) BY DURATION OF EMPLOYMENT AND
BY TIME SINCE INITIAL EMPLOYMENT (LATENCY)
NIOSH CATEGORIES (03-17, 23-37)

OBSERVED
EXPECTED

DURATION OF EMPLOYMENT

LATENCY	UNDER - 5YRS	5YRS - 10YRS	10YRS - 15YRS	15YRS - 20YRS	20YRS - 25YRS	25YRS - 30YRS	30YRS & OVER	TOTAL
UNDER - 5YRS	26 28.9							26 28.9
5YRS - 10YRS	26 25.7	15 13.7						41 39.4
10YRS - 15YRS	31 32.3	9 7.1	39 32.2					79 71.7
15YRS - 20YRS	40 31.6	8 7.6	16 17.1	31 38.9				95 95.3
20YRS - 25YRS	31 30.1	12 6.7	19 20.4	18 18.0	46 37.0			126 112.3
25YRS - 30YRS	4 6.6	2 3.8	23 21.1	13 18.9	25 23.3	17 25.0		84 98.7
30YRS & OVER		0 2.1	24 26.3	21 27.1	41 38.0	41 33.6	148 150.0	275 277.2
TOTAL	158 155.3	46 41.2	121 117.2	83 102.9	112 98.3	58 58.5	148 150.0	726 723.5

Table 32A
OBSERVED AND EXPECTED DEATHS FOR LYMPHOSARCOMA AND RETICULOSARCOMA AMONG 7,615 WHITE MALES WITH RECORDED LIFETIME DOSE ≥0.001 REM (SUBCOHORT I) BY CUMULATIVE DOSE (DOSE) AND BY TIME SINCE INITIAL RADIATION EXPOSURE ≥0.001 REM (LATENCY)
NIOSH CATEGORY (34)

OBSERVED
EXPECTED

	DOSE							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.00 & OVER	TOTAL
1DAY - 1YR	0 0.1	0 0.0	0 0.0	0 0.0	0 0.0			0 0.2
1YR - 3YRS	0 0.1	0 0.1	0 0.1	0 0.0	0 0.1	0 0.0		0 0.6
3YRS - 5YRS	0 0.1	0 0.1	0 0.2	0 0.1	0 0.1	0 0.0	0 0.0	0 0.6
5YRS - 10YRS	0 0.3	0 0.4	0 0.5	0 0.2	1 0.4	0 0.2	0 0.0	1 2.0
10YRS - 15YRS	0 0.2	0 0.3	1 0.5	0 0.2	1 0.5	0 0.2	0 0.1	2 2.1
15YRS - 20YRS	0 0.1	0 0.1	0 0.3	0 0.1	0 0.3	0 0.1	0 0.1	0 1.1
20YRS & OVER	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.1
TOTAL	0 1.0	0 1.1	1 1.7	0 0.7	2 1.4	0 0.6	0 0.2	3 6.8

Table 32B
OBSERVED AND EXPECTED DEATHS FOR HODGKIN'S DISEASE
AMONG 7,615 WHITE MALES WITH RECORDED LIFETIME DOSE ≥0.001 REM
(SUBCOHORT I) BY CUMULATIVE DOSE (DOSE) AND BY TIME SINCE
INITIAL RADIATION EXPOSURE ≥0.001 REM (LATENCY)
NIOSH CATEGORY (35)

OBSERVED
EXPECTED

	DOSE							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.00 & OVER	TOTAL
1DAY - 1YR	0 0.1	0 0.0	0 0.0	0 0.0	0 0.0			0 0.2
1YR - 3YRS	0 0.1	0 0.1	0 0.1	0 0.0	0 0.1	0 0.0		0 0.4
3YRS - 5YRS	0 0.1	0 0.1	0 0.1	0 0.0	0 0.1	0 0.0	0 0.0	0 0.4
5YRS - 10YRS	0 0.1	0 0.1	0 0.2	0 0.1	0 0.2	0 0.1	0 0.0	0 0.9
10YRS - 15YRS	0 0.1	0 0.1	2 0.1	0 0.1	0 0.1	0 0.1	0 0.0	2 0.6
15YRS - 20YRS	0 0.0	0 0.0	0 0.0	0 0.0	1 0.1	0 0.0	0 0.0	1 0.3
20YRS & OVER	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0
TOTAL	0 0.4	0 0.5	2 0.7	0 0.3	1 0.6	0 0.2	0 0.1	3 2.9

Table 32C
OBSERVED AND EXPECTED DEATHS FOR LEUKEMIA AND ALEUKEMIA AMONG 7,615 WHITE MALES WITH RECORDED LIFETIME DOSE ≥0.001 REM (SUBCOHORT I) BY CUMULATIVE DOSE (DOSE) AND BY TIME SINCE INITIAL RADIATION EXPOSURE ≥0.001 REM (LATENCY)
NIOSH CATEGORY (36)

OBSERVED
EXPECTED

	DOSE							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.00 - & OVER	TOTAL
1DAY - 1YR	0 0.2	0 0.1	0 0.1	0 0.0	0 0.0			0 0.3
1YR - 3YRS	0 0.2	0 0.2	0 0.2	0 0.1	0 0.1	0 0.0		0 0.8
3YRS - 5YRS	1 0.1	0 0.2	0 0.2	0 0.1	0 0.1	0 0.0	0 0.0	1 0.8
5YRS - 10YRS	0 0.3	0 0.4	0 0.7	0 0.3	0 0.5	0 0.2	0 0.0	0 2.5
10YRS - 15YRS	0 0.3	0 0.3	1 0.6	0 0.3	3 0.5	0 0.2	1 0.1	5 2.4
15YRS - 20YRS	0 0.2	0 0.2	0 0.3	1 0.1	0 0.3	0 0.1	0 0.0	1 1.3
20YRS & OVER	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0
TOTAL	1 1.3	0 1.4	1 2.1	1 0.9	3 1.6	0 0.7	1 0.2	7 8.3

Table 32D
OBSERVED AND EXPECTED DEATHS FOR OTHER NEOPLASMS OF LYMPHATIC AND HEMATOPOIETIC TISSUES AMONG 7,615 WHITE MALES WITH RECORDED LIFETIME DOSE ≥0.001 REM (SUBCOHORT I) BY CUMULATIVE DOSE (DOSE) AND BY TIME SINCE INITIAL RADIATION EXPOSURE ≥0.001 REM (LATENCY)
NIOSH CATEGORY (37)

OBSERVED
EXPECTED

	DOSE							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.00 - & OVER	TOTAL
1DAY - 1YR	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0			0 0.1
1YR - 3YRS	0 0.1	0 0.1	0 0.1	0 0.0	0 0.0	0 0.0		0 0.2
3YRS - 5YRS	0 0.0	0 0.1	0 0.1	0 0.0	0 0.0	0 0.0	0 0.0	0 0.3
5YRS - 10YRS	1 0.1	0 0.2	0 0.2	0 0.1	0 0.2	0 0.1	0 0.0	1 0.9
10YRS - 15YRS	0 0.1	0 0.1	0 0.2	0 0.1	1 0.2	0 0.1	0 0.0	1 1.0
15YRS - 20YRS	0 0.0	0 0.1	0 0.1	0 0.1	0 0.1	0 0.1	0 0.0	0 0.5
20YRS & OVER	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0
TOTAL	1 0.5	0 0.5	0 0.8	0 0.3	1 0.6	0 0.2	0 0.1	2 3.1

Table 32E
OBSERVED AND EXPECTED DEATHS FOR ALL MALIGNANT NEOPLASMS
AMONG 7,615 WHITE MALES WITH RECORDED LIFETIME DOSE ≥0.001 REM
(SUBCOHORT I) BY CUMULATIVE DOSE (DOSE) AND BY TIME
SINCE INITIAL RADIATION EXPOSURE ≥0.001 REM (LATENCY)
NIOSH CATEGORIES (03-17, 23-37)

OBSERVED
EXPECTED

	DOSE							
LATENCY	0.001 - 0.029	0.030 - 0.099	0.100 - 0.499	0.500 - 0.999	1.00 - 4.99	5.00 - 14.99	15.00 & OVER	TOTAL
1DAY - 1YR	0 3.4	0 1.5	0 1.2	0 0.3	0 0.4	0 0.0		0 6.9
1YR - 3YRS	3 3.9	4 4.2	4 4.3	3 1.4	3 2.2	0 0.3	0 0.0	17 16.3
3YRS - 5YRS	5 3.6	3 4.2	0 5.3	1 1.8	2 3.3	3 1.0	0 0.0	14 19.3
5YRS - 10YRS	10 9.0	12 11.8	19 17.8	4 7.0	10 12.1	5 5.1	0 1.1	60 63.9
10YRS - 15YRS	6 7.9	11 9.9	18 18.1	11 8.4	20 14.9	5 6.8	3 3.2	74.0 69.2
15YRS - 20YRS	5 4.8	2 4.8	5 9.4	7 4.4	9 8.9	4 4.4	3 2.5	35 39.3
20YRS & OVER	0 0.5	0 0.7	0 0.6	0 0.2	1 0.9	0 0.3	0 0.3	1 3.6
TOTAL	29 33.2	32 37.1	46 56.8	26 23.5	45 42.8	17 18.0	6 7.2	201 218.5

TABLE 33

OBSERVED AND EXPECTED LEUKEMIA DEATHS IN SUBCOHORT I
BASED ON RATES FROM SUBCOHORT II

	1 Observed Deaths in Subcohort II	2 Person Years at Risk in Subcohort II	3 (1/2) Death Rate in Subcohort II	4 Person Years at Risk in Subcohort I	5 (4x3) Expected Deaths in Subcohort I
1952-1964					
Age 20-29	0	9,769	0	1,880	0
30-39	0	25,669	0	5,058	0
40-49	0	28,736	0	7,474	0
50-59	4	25,312	0.000158	4,413	0.70
60-69	5	17,795	0.000281	1,250	0.350
70-79	0	2,499	0	29	0
80+	0	33	0	0	0
1965-1977					
Age 20-29	0	17,034	0	8,908	0
30	0	14,284	0	13,957	0
40	1	27,478	0.000036	20,188	0.73
50	6	30,513	0.000197	22,393	4.41
60	5	20,651	0.000242	10,332	2.500
70	8	12,430	0.000644	2,039	1.31
80+	2	2,299	0.000870	63	0.05
TOTAL					10.05

Observed Leukemia Deaths in Subcohort I = 7
SMR = 70

Appendix A

NIOSH CAUSE OF DEATH CATEGORIES

Cause of Death	(NIOSH CATEGORY)	1952 - 1967 6th & 7th Rev.	1968 - 1977 8th Rev.
Tuberculosis			
Respiratory Tuberculosis	(01)	001-008	010-012, 031
Other Tuberculosis	(02)	010-019	013-019
All Malignant Neoplasms(MN)		140-205	140-207
MN of the Buccal Cavity and Pharynx			
MN of Lip	(03)	140	140
MN of Tongue	(04)	141	141
MN of Other Parts of Buccal Cavity	(05)	142-144	142-145
MN of Pharynx	(06)	145-148	146-149
MN of Digestive System			
MN of Esophagus	(07)	150	150
MN of Stomach	(08)	151	151
MN of Intestine Except Rectum	(09)	152,153	152,153
MN of Rectum	(10)	154	154
MN of Biliary Passages and Liver, Primary and Unspecified	(11,12)	155,156A	155,156,197.8
MN of Pancreas	(13)	157	157
MN of Peritoneum and Unspecified	(14)	158,159	158,159
MN of Respiratory System			
MN of Larynx	(15)	161	161
MN of Trachea, Bronchus and Lung	(16)	162,163	162,163.0
MN of Other parts of Respiratory	(17)	160,164	160,163.1,163.9
MN of Male Genital Organs			
MN of Prostate	(23)	177	185
MN of Other Male Genital Organs	(24)	178,179	172.5,173.5,186,187
MN of Urinary Organs			
MN of Kidney	(25)	180	189.0,189.1,189.2
MN of Bladder and Other Urinary Organs	(26)	181	188,189.9

Appendix A (Continued)

Cause of Death	(NIOSH CATEGORY)	1952 - 1967 6th & 7th Rev.	1968 - 1977 8th Rev.
MN of Other and Unspecified Sites (Major)			
MN of Skin	(27)	190,191	172.0-172.4,172.6-172.9,173.0-173.4 173.6-173.9
MN of Eye	(28)	192	190
MN of Brain and Other Parts of Nervous System	(29)	193	191,192
MN of Thyroid Gland	(30)	194	193
MN of Bone	(31)	196	170
MN of Connective Tissue	(32)	197	171
MN of Other and Unspecified Sites (Minor)	(33)	156B,165,195,198 199	194,195,196,197.0 -197.7,197.9,198, 199
MN of Lymphatic and Hematopoietic Tissues			
Lymphosarcoma and Reticulosarcoma	(34)	200	200,202.2
Hodgkin's Disease	(35)	201	201
Leukemia and Aleukemia	(36)	204	204,205,206,207
Other Neoplasms of Lymphatic and Hematopoietic Tissue	(37)	202,203,205	202.0,202.1,202.9, 203
Neoplasms of the Brain			
Benign Neoplasms of the Brain	(38)	223	224,225,743.4
Neoplasms of Unspecified Nature of Brain	(39)	237	238
Diabetes Mellitus	(40)	260	250
Diseases of Blood and Blood-forming Organs			
Pernicious and Hyperchromic Anemias	(41)	290	281.0,281.9
Anemias of Other and Unspecified Type	(42)	291-293	209,280,281.1-281.4 282,283.0,284,285
Purpura and Other Hemorrhagic Conditions	(43)	296	286,287
All Other Diseases of Blood-forming Organs	(44)	294,295,297-299	208,275,283.9,288 289.0,289.9
Psychoneurotic, Personality and Mental Disorders	(45,46)	322,300-326	303,290-305
Diseases of the Nervous System			
Vascular Lesions Affecting Central Nervous System	(47)	330-334	430-438
Multiple Sclerosis	(48)	345	340

Appendix A (Continued)

Cause of Death	(NIOSH CATEGORY)	1952 - 1967 6th & 7th Rev.	1968 - 1977 8th Rev.
Diseases of the Circulatory System			
Rheumatic Fever	(49)	400-402	390-392
Chronic Rheumatic Heart Disease	(50)	410-416	393,394,395.0 396-398
Arteriosclerotic Heart Disease	(51)	420	410,411,412,413
Chronic Endocarditis Not Specified as Rheumatic	(52)	421	395.9, 424
Other Myocardial Degeneration	(53)	422	428
Other Diseases of the Heart	(54)	430-434	420-423,425-427,429
Hypertensive Heart Disease	(55)	440-443	400.1,400.9,402,404
Hypertension Without Heart Disease	(56)	444-447	400.0,400.2,400.3, 401,403,440.1
Diseases of the Arteries and Veins	(57)	450-468	289.1-.3,440.0, 440.2-.9,441.0-444.1,444.3-445.9, 446.0,446.2-.9,447-451,453-458,734.1
Diseases of the Respiratory System			
Acute Upper Respiratory Infections	(58)	470-475	460-465
Influenza	(59)	480-483	470-474
Pneumonia	(60)	490-493	480-486
Bronchitis	(61)	500-502	466,490,491
Other Respiratory Diseases	(62)	510-527	492,500-506 508-519
Selected Diseases of the Digestive System			
Diseases of the Stomach and Duodenum	(63)	540,541,543	531-533,535
Hernia and Intestinal Obstruction	(64)	560,561,570	444.2,550-553,560
Cirrhosis of the Liver	(65)	581	571
Selected Diseases of the Genito Urinary System			
Acute Nephritis	(66)	590	580
Nephritis with Edema including Nephrosis	(67)	591	581,593.1
Chronic and Unspecified Nephritis and Other Renal Sclerosis	(68)	592-594	582-584,593.0
Infection of Kidney	(69)	600	590
Calculi of Urinary System	(70)	602, 604	592,594
Hyperplasia of Prostate	(71)	610	600
Other Diseases of Male Genital Organs	(72)	611-617	601-607
Diseases of the Breast	(73)	620,621	610,611