FINAL REPORT

"HEALTH EFFECTS OF LOW LEVEL IONIZING RADIATION"

CONTRACT NRC-01-78-011

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N O T I C E

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16. Abstract

This paper reports the results of an analysis of a data tape provided by the Nuclear Regulatory Commission purported to contain selected information including mortality, exposure, and work history data for workers employed at the Hanford Atomic Facility who were deceased by the end of 1972.

The intent of the study was to analyze this data for dependencies of death due to cancer on exposure to low level ionizing radiation with proper control for other variables provided. If possible, dose response relationships were to be derived. The analysis methods used included descriptive univariate analysis, discriminant analysis, categorical analysis, and linear logistic regression.

Unfortunately, examination of the data and investigation of background material discovered during the project concerning this data and its sources has lead to the conclusion that the data provided is not a consistent, reliable, and authentic representation of the true facts concerning the exposure experience of Hanford workers. In particular, the data provided has certain characteristics which are not consistent with the data as it is reported to be at its most reliable source. Therefore, while analysis of the data is presented, one should not presume that the results of this analysis accurately reflect relationships which exist in the real world.

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1. INTRODUCTION

In recent years a considerable amount of attention has come to focus on the biological effects of low levels of ionizing radiation as a possible occupational hazard for workers in the atomic industry. Historically, radiation protection criteria have attempted to provide conservative guidelines for avoidance of harm consistent with reasonable practicability in the workplace. In current recommendations permissable levels have been set based in part on data gathered at dose levels and in circumstances quite different from those prevalent in occupational situations (e.g. Japanese atomic bomb victims, radiotherapy patients, and the like). Until recently there have not been extensive and reliable analyses of the effects of chronic, low dose exposures to ionizing radiation in a large human population.

In 1964 a large scale epidemological study of employees in AEC contractor facilities was undertaken in a project funded by AEC and directed by Dr. Thomas F. Mancuso of the University of Pittsburgh. This project, "Study of the Lifetime Health and Mortality Experience of Employees of ERDA (earlier AEC) Contractors" culminated in the publication of a paper by Mancuso, Alice Stewart, and George Kneale in Health Physics (Ref. 1) wherein definite statistical associations were reported between the incidence of various types of cancer and exposure to radiation for workers at the Hanford (Washington) Atomic Facility. The analysis also produced estimates of doubling doses for certain cancers which were much lower than had generally been estimated previously.

Mancuso's findings have resulted in considerable discussion and have motivated further analyses and re-analyses of exposure and mortality data from Hanford. The work presented in this paper is an analysis of certain data provided by the Nuclear Regulatory Commission purported to contain causes of death, exposure records, and other pertinent information for workers once employed at Hanford and now deceased. This data was to be analyzed for the possible dependence of death due to cancer on exposure to ionizing radiation including derivation of dose response relationships where appropriate.

The statistical methodologies selected were descriptive univariate examinations of the data, discriminant analysis, categorical methods using chi-square and analysis of trend tests, and linear logistic regression. Results of these analysis are presented.

Unfortunately the data provided by NRC was very poorly documented and could not be meaningfully analyzed without further information concerning definitions of terms and units of quantities. In the process of investigating these matters and in attempting to answer other questions which were of concern to us we have discovered a number of problems with the data which cast into doubt any conclusions that might be drawn from the statistical analysis.

Consequently, a large part of the material presented in this report has to do with examination of the data with regard to its consistency, authenticity, reliability, and usefulness for purposes of analysis. It is our conclusion based on the information which we currently have in hand that the data presented to us cannot be

regarded as a usable representation of the actual experience of workers at Hanford. In particular, the data does not represent the reported state of the data maintained at its most reliable source. While analysis of the data can be and is presented, one should not and we do not presume that the results of this analysis accurately reflect relationships which exist in the real world.

2.0 THE DATA

In any statistical analysis it is important to understand the background to the data for two reasons: a) to avoid pitfalls such as confounding effects not represented in the variables under consideration; and, b) to develop meaningful interpretations for the results identified. For these reasons we conducted a background review of the data and have presented the results for the reader in sections 2.1 through 2.5 of this report. More specifically, section 2.1 includes a brief summary of primary conclusions; followed by section 2.2, a discussion of the historical origins of the data; section 2.3, a general characterization of the data; section 2.4, issues relating to the dose variables; and finally, section 2.5 includes issues relating to cause of death and other factors not contained in the data subset.

2.1 Summary of Primary Conclusions From the Background Review

Two primary conclusions have been developed from our background review of the data. The first is that neither all of the available data elements (variables) nor all the available cases have been provided to us for a thorough and complete analysis. This conclusion, in and of itself, is obviously of particular concern since the detail and accuracy with which any analyses can be conducted and subsequent interpretations developed is impeded.

The second primary conclusion is that the authenticity and reliability of the data provided to us for analysis has not been adequately established. Clearly, this conclusion presents problems in making statements about the true "state of nature" based on observations obtained from the data.

It cannot be overemphasized that the above conclusions can significantly influence the understanding and interpretation of the analyses presented in the following sections.

2.2 Historical Background

It has become apparent during the project that the exact background details of the data are not fully known by the Nuclear Regulatory Commission (NRC). The written documentation provided to us at the beginning of the project, shown in its entirety in Figure 1, was inadequate for a thorough understanding of the data and would have provided a serious problem in the interpretation of any analyses conducted. As a result, we have made an effort to identify some of the historical and technical aspects of the data. A brief review of the historical aspects of the data will be provided here.

The study was motivated, at least in part, by a series of events. An understanding of the project can be facilitated by a brief chronological presentation of the events preceding it. Our understanding of this sequence of events is presented below.

In 1964 the Atomic Energy Commission initiated and funded a program entitled, "The study of the lifetime health effects and mortality experience of employees of AEC contractors" under the direction of Dr. Thomas Mancuso at the Universtiy of Pittsburgh's School of Public Health. This program AT(30-1)-3394 was continued under contracts CHAT(11-1)-3428 and E(11-1)-3428 when the Energy Research and Development Administration (ERDA) was established incorporating the AEC. The stated purpose of the study is given in the following quote from the abstract of an early progress report:

> "The objective of this study is to follow cohort employee populations of selected AEC Contractor installations, to test the feasibility of using personnel, employment, medical and radiation records in establishing the relationships, if any, between mortality

patterns and levels of radiation exposure. The reason for the study is the absence of empirically tested information pertaining to human populations exposed to recorded low levels of radiation over long periods of time. The procedure devised for the test runs is: to establish a series of cohorts of populations at each facility, those continuously employed as well as those separated, for each year, by tracing these individuals and sibling controls through Social Security records to determine those who have died and their place and date of death; to obtain death certificates to establish age-sex specific death rates; and to analyze causes of death for those with radiation exposure and work-connected health hazards in comparison to appropriate non-exposed controls. The following AEC Contractor facilities have been selected for the test runs: Oak Ridge X10, Oak Ridge Y12, Oak Ridge K25, Hanford and several small feed materials plants. These facilities provide large populations with long intervals of operation. Pilot studies of radiation exposure records of persons exposed in atomic energy facilities will be carried out to determine the average occupational exposure of these populations and appropriate confidence limits in exposure estimates for individuals and various sub-populations."

Format of Tape

Cols.	Content
1-4	age at death (to nearest tenth)
5-6	year of initial employment
7-8	final year of employment
9-11	total years of employment (to nearest tenth)
12-14	cause of death (primary cause) ICD 8th revision
15	race 0 = non-white, 1 = white
16	sex 0 = female, 1 = male
17	exposure code 0 = non-exp, 1 = exp.
18-23	cumulative lifetime dose
24-29	cumulative dose 3 years before death
30-35	" " 5
36-41	" " 10
42-47	" " 15
48-53	" " 20
54-59	" " 25
60-61	year of death

Figure 1. Copy of the documentation provided with the data by NRC.

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One of the facilities considered by the Mancuso study was the Hanford Atomic Facility in Richland, Washington. Around 1974 Dr. Milham of the Department of Public Health for the State of Washington reported (Ref.2) that his analysis showed an increased incidence of cancer in persons who had worked at Hanford and died in Washington, relative to other persons in the State of Washington. This report spurred analysis of the data which was being collected by Mancuso's study group. Eventually Mancuso, et. al., prepared a paper (Ref.1) which reported a relationship between cancer and low level ionizing radiation. At the same time his contract was terminated by ERDA. In the ensuing furor other persons analyzed the same or similar data including S. Marks of the Battelle Northwest Laboratories (Ref.3) and C. Land of the National Cancer Institute (Ref.4). In addition, Congressional hearings were held (Ref.5). Apparently the NRC was not in a position to address the issue at the hearings and this subsequently led to the current program.

In this program NRC decided to use the data employed by Land, rather than study the Hanford data stored at Hanford. Thus, a brief review of the origin of Land's data is in order.

Land had originally requested data from the Oak Ridge Data Processing Facility. Oak Ridge had some version of the data collected in the Mancuso study for the Hanford employees. It is not known to us how or when the data given to Land got from Hanford to Oak Ridge. Land requested, apparently in late 1976, a set of variables for analysis. The rationale for the variables selected is not known to us.

It has been reported to us that the data used by Land is identical with the data used by us. The reported course of events is that a copy of Land's tape was made at Geomet Corporation, a computing services contractor, and was submitted to NRC. NRC then utilized the facilities of Harry Diamond Laboratories to prepare copies of that tape for use by the three contractors on this project. One of those tapes was provided to us. As a consequence of the numerous data handling efforts from Hanford to Hanford Environmental Health Foundation, to Oak Ridge, it is extremely difficult to determine precisely what the available data represents. In an effort to alleviate this problem we requested additional information regarding the data, as well as additional data elements. Our request was not implemented. As an alternative course of action, we took some characteristics of Land's data reported in his study and compared them with the data we received. We did the same with Mancuso's study. The key findings of these comparisons are presented below. A more detailed presentation of these results appears in Section 2.6.

The frequency of each cause of death in our file matches Land's data (Ref. 4), except for two cases in our file which have no cause of death. Our cumulative doses can be shown to be significantly different from Mancuso's reported in Ref. 1. Unfortunately, we were unable to compare cumulative dose frequencies with those in Land's data.

With respect to sample size, we have more cases than Mancuso (Ref. 1), the same number of cases as Land (Ref. 4), and fewer than reported by Mancuso in later reports (Ref. 6 and 7). Perhaps most importantly, we have shown that the

data we have received has doses in time intervals which are not possible in the data collection scheme purported to have been followed in the Hanford study (Ref 8, 9, 10). Specifically there are 138 cases which have reported dose subsequent to the final year of employment. The details and ramifications of this finding are discussed more fully in Section 2.4.3.

It should be noted that our impression, based on among other things, conversations with Howard Fore at Oak Ridge, is that Dr. Mancuso never requested nor was ever sent a data set identical with that used here and by Land. Whether the problems that exist in this data would be present in data used by Mancuso is open to question. In any case, it is certain that the actual data analyzed in the Mancuso paper (Ref. 1) is not the same as that used by Land and by us.

2.3 General Characteristics of the Data

As discussed in section 2.2 the data is an extracted subset, characterised as Hanford employees who have died, of the larger set which includes employees both living and dead. It does not represent a large number of mantenance workers (≈6500) employed by Jones Maintenance Contractors, who are reported to have received higher doses than the average Hanford worker (Ref. 11); nor does it include AEC employees who worked at Hanford.

The data consists of 3992 cases which primarily represent white males as shown in Table 1.

TABLE 1
Number of Deaths by Sex and Race

		SEX	
		Male	Female
RACE	White	3585	379
	Other	25	3

Of the 3585 white male cases, 62.1 percent were characterized as exposed as shown in Table 2.

TABLE 2
Number and Percentage of Cases
Characterized as Being Exposed.

		SEX	
		Male	Female
RACE	White	2226/62.1%	116/30.6%
	Other	12/48.0%	0/0%

It should be noted that the use of the term "exposed" may be somewhat misleading, since those employees who

are classified as non-exposed may be the result of them not being monitored for radiation rather than not being exposed to radiation. This issue is discussed more fully in section 2.5.

Histograms of each variable have been made and are contained in Appendix A to facilitate the readers understanding of at least some of the more general features of the data. The histogram presented for each variable is a frequency distribution over the values taken on by the particular variable.

The "cause of death" frequency distribution is included in Appendix B. However, two data omissions in the file must be noted. First, 5 cases had an invalid initial year of employment and the same 5 cases had invalid total years of employment. Secondly, two cases had no cause of death.

For the purposes of relating cancer to radiation various groupings of ICD (revision 8) codes were used. These are indicated below together with the total number of cases and the number of exposed cases for each group.

TABLE 3

Cancer Groupings Used for the Purpose of Analysis

General Description	ICD CODE	Total Exposed White Male Cases	Total Cases
lip, mouth, pharynx	140-149	14	14
esophagus and stomach	150-151	35	57
small intestine	152	1	2
large intestine and rectum	153-154	66	102
liver and bile	155-156	10	20
pancreas	157	32	53

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TABLE 3 (Cont.)

Cancer Groupings Used for the Purpose of Analysis

General Description	ICD CODE	Total Exposed White Male Cases	Total Cases
	158	1	3
	159	1	1
	160	2	2
lung	161-163	136	213
bone	170	1	1
	171	3	6
skin	172-173	10	16
breast	174	--	31
	180	--	7
	181	--	---
	182-183-184	--	62
prostate	185	21	42
	186	3	4
	187	7	11
	188	--	---
urinary organs	189	15	25
eye, brain nerves	190-192	18	29
thyroid	193	1	2
	194	--	1
	195	2	5
	196	--	1
secondary lung	197	8	13
	198	2	2
unspecified secondary	199	13	30
	200-202,204	30	44
multiple myeloma	203	8	11
	205-206	7	14
	207-209	2	7

2.4 Issues Relating to Radiation Dose

An adequate identification of background information for the dose variables contained in the data extract file was not provided. This lack of information was perhaps due in part to the background of the data discussed in section 2.2. In any case thorough documentation of the dosimetry and data collection practices relevant to the dose variables was not provided during the program. In our own review of the Mancuso Study progress reports, it became clear that there were many potential pitfalls which could exist in the data we had received, depending on when, where and how the data extract file was created. In attempting to answer the questions which arose about what the dose data actually represented, it was the case that we time and time again identified inconsistencies between one information source and another (e.g. various persons and written reports) and between information sources and the actual data extract file. It is the prevalence of this inconsistency which perhaps is most troubling in trying to assess just exactly what the data extract file represents. Consequently, we have been able to establish what the data file at Hanford is supposed to represent; we have not been able to determine whether in fact the data we have is representative of that data.

There are at least three areas of uncertainty with respect to the dose variables in the data extract file and one general area relating to the exclusion of data believed to be relevant to a thorough analysis. These are discussed below.

2.4.1 Penetrating Dose

The dose variable we are supposed to have received is classified by NRC as the "penetrating radiation dose" received by a Hanford employee. Clearly, numerous questions arise as to the definitions and dosimetry used to calculate penetrating dose. These questions are aside from the question of when the dose was received.

It has been reported to us (ref.12) that the penetrating dose variable consists of a summation of various dose sources. Specifically, it is the summation of the gamma, neutron, and Tritium doses plus .35 of the x-ray dose.

It is generally accepted that as a minimum quality factors are necessary in the combination of exposures from various dose sources if such combinations are to be done at all. It has been reported to us that the penetrating dose we have is a simple summation (as described above) of whatever was recorded for each dose source. The next question, then, is what was recorded for each source? To this question we have received two conflicting answers. The first is that quality factors have been applied to the data using 1.0 for gamma rays 10 for fast neutrons, 3 for slow neutrons, 1.0 for x-rays and 1.7 for Tritium, although the value 1.0 may have been used at times for Tritium. To some radio-biologists these quality factors may inadequately reflect the relative efficiencies of each source when interacting with human cells. The other explanation to us was that the data was simply a direct report of various badge readings. It may of course, be the case that both of these reports are correct, but apply to different forms of the Hanford data files. As was stated in section 2.2, which form of the file we have is questionable.

An issue related to quality factors is the combination of the exposure and dose units, namely Roentgens and rads. This concern is applicable to the understanding of what manipulations were applied to data from pocket ionization chambers.

Further, the use of Tritium is particularly puzzling since Tritium becomes involved with the body through inhalation or other means and represents a contribution to the body burden as opposed to a "penetrating dose". At the same time other internal sources have not been included with the penetrating dose. The issue of whether internal burden should be combined with penetrating dose is open to considerable debate.

2.4.2 Dosimetry Aspects

How the reported doses were obtained in the first place is an important issue quite independent of the possible manipulations discussed in the previous section. Most notably the general pattern for the dosimetry is that procedures changed over time, as might be expected. For some procedure changes the consequences may be significant or at best not be clear; in others it is not clear as to whether certain procedures have actually been implemented in the data set we were provided with. Some of the more notable areas of concern are discussed below.

One notable change through time appears to have been improvements in badge quality. These improvements have come both in the expansion of dose sources considered (e.g. neutrons, various X-ray sources, etc.) as well as improvements in the badge sensitivity to low level exposures. In particular there were at least three different badge types used successively prior to 1964 (ref. 8), each representing an improvement to the previous version. In particular, the ability to accurately assess neutron dose may have been totally inadequate prior to 1950. Further, there have been reports that some doses for workers may have been estimated from work area measurements rather than from actual employee badge readings.

Interpretation of any analysis results would require full consideration of the effects induced by changes in both the sensitivity and quality of the dose data if these effects exist in our data extract file.

To further complicate matters, procedures in recording the badge data have changed over time. Two changes are notable here. First, the frequency of badge readings has changed dramatically over the years. In the early years badges were read weekly, followed by a change to bi-weekly readings. Subsequently the badges were read monthly and most recently badge readings were taken yearly. Keep in mind that up until approximately 1963 or 1964, the badge threshold was approximately 30 mr and that the reporting procedure for the data collection process may have been to record zero dose if the threshold was not exceeded. When there was no badge reading threshold a zero may still have been recorded if the dose were below 20 mr.

The consequence of the procedure used to record the doses in the data collection procedure in conjunction with changes in the badge reading frequencies may be severe. One might expect that for monitored workers the average yearly dose recorded would be lower in the early years and higher in later years, since in the early years it would be hard for the dose to accumulate over the threshold due to frequent badge readings. This could be the case even though the true average dose might be approximately constant over time. One further complicating feature when the badge threshold was not exceeded may be that for the very early data the threshold value may have been reported as the dose and then at a later time a zero may have been reported. If this were the case we would see somewhat higher yearly doses in the early years, a subsequent reduction when zeros were reported, and finally an increase as badge readings intervals were increased. In any case, this type of variation may have severe consequences on the interpretation of the analysis results and a full

explanation of the procedures used in the data collection process must be available for responsible conclusions to be produced.

Another aspect of the data collection process of concern is the years for which doses from various sources were incorporated into the data. We have conflicting information with regard to this point which may or may not be related to differing forms of the data file. Hanford personnel indicate that the data for each source is complete, back to the initiation of operations. A report in Mancuso's progress reports, at a time when worker exposure records were reported to have been complete, indicates that data for each source is complete back to varying times, at least for the file at Oak Ridge as shown in Figure 2. A preliminary sample output (Figure 3) contained in the same report shows no radiation records for each source prior to the year in which the relevant data is reported on tape in Figure 2.

Certainly things may have changed subsequent to the time of the report but we were unable to locate any mention of these changes in subsequent progress reports. This does not mean changes did not occur, however, because others working on the project began submitting their own progress reports at about this time. However, if the doses at the Oak Ridge Facility were not updated to include doses received prior to those reported in Figure 2, one might expect to see an increase in the average yearly dose over time. Again the consequences of this would be important in the development of conclusions.

Sources of Exposure Data

Year	Beta-Gamma	X-Ray	Neutron	Tritium	Extremity
1944	Tape				Photometry Records
1945	"				"
1946	"				"
1947	"				"
1948	"				"
1949	"			Bioassay Result Cards	"
1950	"		Hist. File	"	"
1951	"		"	"	"
1952	"		"	"	"
1953	"		"	"	"
1954	"		"	"	"
1955	"		"		"
1956	"		"		"
1957	"	Tape	"		"
1958	"	"	"		"
1959	"	"	Tape		"
1960	"	"	"		"
1961	"	"	"	Front of 1962 Year End Report	"
1962	"	"	"	Tape	Tape
1963	"	"	"	"	"
1964	"	"	"	"	"

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Table 13 - Summary of Sources of Exposure Data at Hanford

Figure 2. Reported Source Summary of Exposure Data at Hanford from Ref. 13.

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44	-	.00	.00	.00	.00	.00	.00	.00	.00	.00

SOCIAL SECURITY NUMBER PAYROLL NUMBERS LAST NAME INITIALS

YEAR	SITE CODE	BETA	GAMMA	X-RAY	NEUTRON	TRITIUM	RINGS	PENETRATING	SKIN	EXTREMITY
44	-	.00	.00	.00	.00	.00	.00	.00	.00	.00
45	-	.00	.94	.00	.00	.00	.00	.94	.94	.94

SOCIAL SECURITY NUMBER PAYROLL NUMBERS LAST NAME INITIALS

YEAR	SITE CODE	BETA	GAMMA	X-RAY	NEUTRON	TRITIUM	RINGS	PENETRATING	SKIN	EXTREMITY
48	-	.12	.03	.00	.00	.00	.00	.03	.15	.15
49	-	.10	.02	.00	.00	.00	.00	.02	.12	.12

SOCIAL SECURITY NUMBER PAYROLL NUMBERS LAST NAME INITIALS

YEAR	SITE CODE	BETA	GAMMA	X-RAY	NEUTRON	TRITIUM	RINGS	PENETRATING	SKIN	EXTREMITY
46	-	.04	.04	.00	.00	.00	.00	.04	.08	.08
47	-	.31	.15	.00	.00	.00	.00	.15	.46	.46
48	-	.03	.00	.00	.00	.00	.00	.00	.03	.03
49	-	.36	.09	.00	.00	.00	.00	.09	.45	.45
50	-	.90	.34	.00	.00	.00	.85	.34	1.24	2.09
52	-	.00	.00	.00	.00	.00	.00	.00	.00	.00
53	-	.27	.36	.00	.00	.00	.00	.36	.63	.63
54	-	1.22	1.15	.00	.00	.00	.00	1.15	2.37	2.37
55	-	1.39	1.11	.00	.00	.00	.00	1.11	2.50	2.50
56	-	.72	.68	.00	.00	.00	.00	.68	1.40	1.40
57	-	.15	.04	.00	.00	.00	.00	.04	.19	.19
58	-	.08	.70	.12	.00	.00	.00	.74	.82	.82
59	-	.00	.24	.10	.00	.00	.00	.28	.34	.34
60	-	.00	.32	.04	.00	.00	.60	.33	.36	.96
61	-	.00	1.14	.35	.00	.00	2.13	1.26	1.49	3.62
62	-	.03	.65	.10	1.86	.00	.10	2.55	2.64	2.74
63	-	.20	.18	.01	.38	.00	2.87	.56	.77	3.64
64	-	.02	.41	.05	.28	.00	1.20	.71	.76	1.96

SOCIAL SECURITY NUMBER PAYROLL NUMBERS LAST NAME INITIALS

YEAR	SITE CODE	BETA	GAMMA	X-RAY	NEUTRON	TRITIUM	RINGS	PENETRATING	SKIN	EXTREMITY

Table 16 - Print out Showing Content of the Occupational Radiation File, Hanford

Figure 3. Reported Preliminary Sample Record From Oak Ridge For Hanford Data as Reported in Ref. 13.

There is yet another conflicting report with regard to the exact nature of the dose data collection procedure. The data for x-rays prior to 1957 may have been combined with the Beta and Gamma doses (Ref.12). The consequences of this effect would depend on exactly how the doses were combined to form the penetrating dose. However, one might suspect that the x-ray data before 1957 (if it's contained in the Beta-Gamma dose) would have a different factor applied (1.0) than the x-ray data after 1957 (.35).

One might expect that the effect of this error if it exists in the data we have, would be to cause a decrease as a function of calendar years in the average yearly doses received by exposed workers while working, assuming a constant true x-ray exposure. The decrease would be caused by an inclusion at full dose in early years up to 1957, but a consideration of only .35 of the full dose after 1957.

In an attempt to resolve the above concerns we attempted within the constraints of the variables presented to assess just what the average yearly dose was for those Hanford deaths who are classified as "exposed" in the data extract file. This plot is shown in Figure 4.

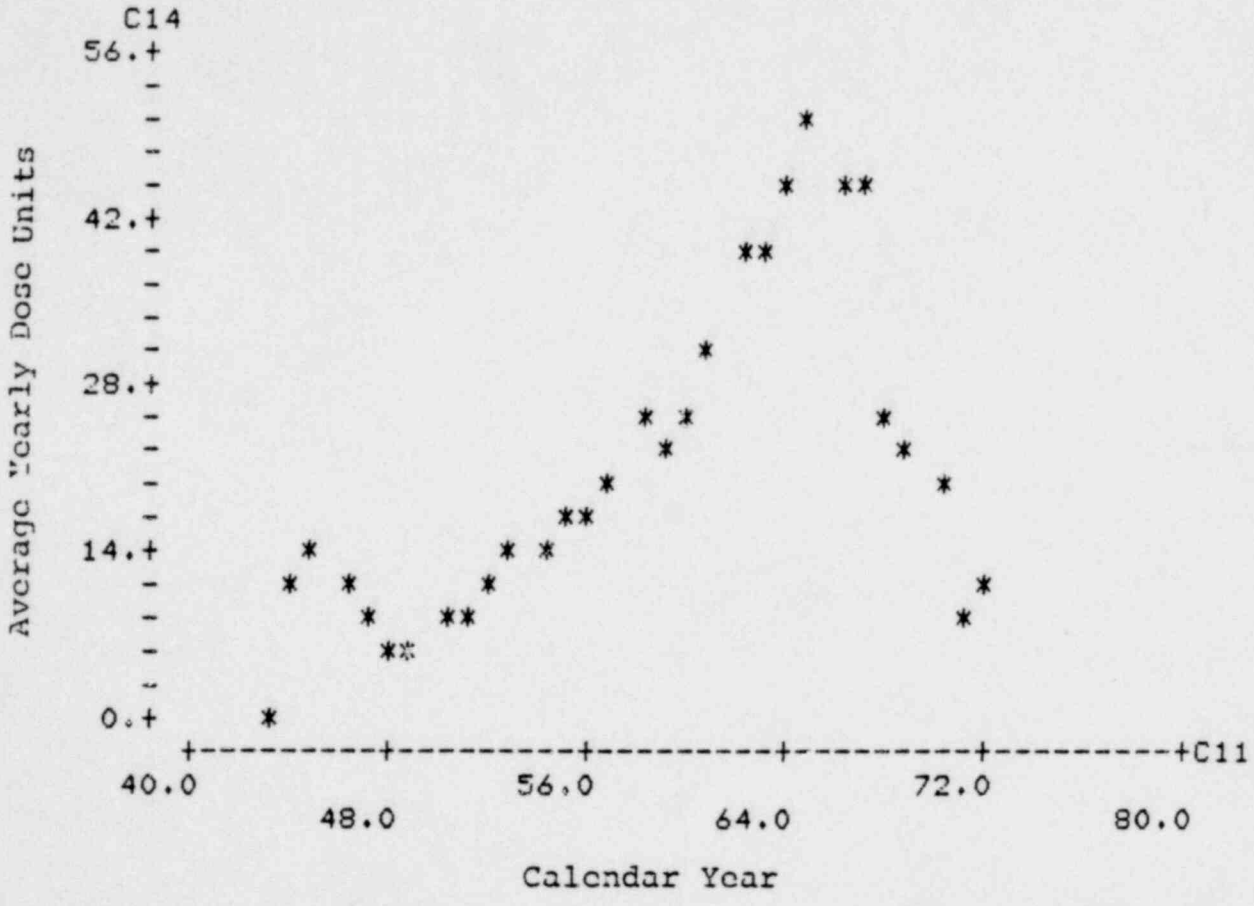

Figure 4. Average Yearly Dose Received by Exposed Workers While Employed Based on Semi-time Averaged Doses.

The exact causes for the shape of the curve (Figure 4) may be related to a combination of one or more of the possible effects which may be present in the data as discussed above or perhaps others which will be discussed in the following section. It should also be

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recalled that the data provided to us in regard to dose-time histories was in reasonably broad time increments and as such the above plot will reflect a semi-time averaged view of the true average yearly dose which would be present if we had more detailed data.

Nevertheless, the implications of the graph are that serious time related effects are present in the data. It emphasizes the need for a detailed description of the exact background for this particular data extract file. Further, the plot suggests that extreme care be used in the interpretation of any analysis results using this data until a full and satisfactory explanation and understanding of this plot is available.

2.4.3 Pre- and Post- Employment Doses

According to several sources (ref. 8, 9, 10), the pre-employment doses for workers at Hanford were obtained by first asking the new employee whether there had been any previous employment where exposure might have been experienced. If the answer was affirmative the health records from previous facilities were requested. When and if they were received, they were apparently installed in an off-site radiation record, although the date assigned to the radiation was apparently the date of the receipt of the material at Hanford rather than the time period over which the dose was received. It is not known to us whether these pre-employment off-site radiation exposures have been included in the data we have, since we have seen conflicting reports with regard to its presence or absence from various data sets. If the data extract file did include this pre-employment exposure recorded on the dates received this might contribute in conjunction with other factors to the explanation of the early peak seen in Figure 4. However, it has been pointed out to us that the safety procedures at Hanford may have been very poor in the early years which in conjunction with the badge reading effects discussed earlier may be sufficient to explain this early peak.

With regard to post-employment exposures, it has been consistently reported that these doses were not collected and cannot be present in the data. This facet of the reported data collection procedure has been the most consistently reported feature of the data. We can definitely show that this feature (i.e. the

non-existence of dose after the final year of employment) is not displayed in the data extract file we have. It is perhaps this contradiction which more strongly than anything else suggests that extreme caution be exercised in any consideration of the analysis results.

We have examined our data file and have found that there are 138 cases for which post-employment doses exist in the dose history. Of these, 130 are white males representing approximately 5.8% of the total 2226 exposed white males in the file. An examination of these cases shows that generally the doses recorded after the final year of employment are likely to be two to three times the total dose recorded during the reported initial and final years of employment at Hanford. The computer program to assess whether post-employment doses exist in the data is contained in Appendix C in conjunction with its output.

The effects of such data problems are, of course, considerable. If the data indicating that doses are received after the end of employment are simply erroneous, then it reflects on the quality of the remaining data. If the data is correct, but was inadvertently included for some cases in the file, then it implies that doses received after employment at Hanford are not negligible, thus affecting quantitative values of possible dose relationships to cancer. Thus, in either case the effect of this finding is to cast serious concern on the reliability of any results based on this data extract file.

We pointed out this significant finding to the CTM and requested new data. The request for new data was denied, although the CTM did request verification of

the findings from other research groups working with this data. We see no reason, however, that these findings would not be substantiated by others.

2.5 Other Concerns

There are many other concerns with regard to data we did not receive, in addition to the concern for the meaning of the data which we did receive. These additional concerns will be discussed briefly below.

2.5.1 Other Exposures

We have not received data which is available with regard to other exposures. Other exposure information which does exist includes internal and accidental depositions. The lack of information with regard to the several hundred accidental depositions known to exist, not to mention the large amount of internal dose information available, is a serious constraint on the development of a responsible analysis.

If the pre-employment exposures are not included in the data they certainly are available and should be considered, although they should be provided as a separate data element.

Medical x-rays were shown in Mancuso's study to be on the average a significant fraction of the radiation received by a worker. Individual records for various procedures show that some workers could easily have received very large exposure from medical x-rays. This data is available for all workers, and the results of the medical x-ray study seem to point out that this is a source not to be neglected if possible.

Other occupational exposures to such things as carcinogenic materials like asbestos through involvement with specific industries at times other than when at Hanford are not included. They may, however, be available since work histories maintained by the Social Security Administration were used in the data collection effort. The inclusion of this information would be a desirable addition.

2.5.2 Cause of Death

The fact that a worker had died was established using the Social Security Administration (SSA) data file in conjunction with the worker's Social Security number, using the information provided by the SSA death certificates were obtained. The causes of death on the death certificate were recoded by a trained nosologist (ref. 8). The accuracy to which these assessments were made, not to mention potential errors on the death certificates which may be present due to lack of recognition of certain types of cancer in earlier years, is unaddressed. It is the case that up to 6 causes of death were recorded in an order reported to be primary, secondary, and tertiary. The consideration of only the primary cause of death raises serious questions in the sense of the actual cause of death (e.g. heart failure) which may have been brought on by stresses induced by cancer or treatment for cancer. The extent to which this phenomena may be present in the data cannot be assessed since only the primary cause of death is provided.

2.5.3 Initial and Final Year of Employment and Total Years of Employment

When considered in conjunction with the other data elements provided to us it s important to at least be aware that these variables do not allow recognition of the situation in which a worker leaves Hanford to work elsewhere and then returns to Hanford after some time interval. A check of all the cases in our data file shows that the variable total years of employment is (to within ±1 year) simply the difference between initial and final years of employment. (The discrepancy

of ±1 year comes about because total years of employment is recorded to one-tenth year while initial and final years are recorded to one year.) Thus we do not know what the true employment time periods were in this data set.

2.5.4 Monitored versus Exposed

Unfortunately the data we have indicates whether a worker was exposed or not exposed at some time during employment at Hanford. An exposed worker is one for which a dose was recorded. There is another variable available which we did not receive indicating whether the subject was monitored for radiation. One can see that if a worker was not monitored there could be no dose recorded. Thus a "non-exposed" worker did not necessarily receive zero dose. Further, the fact that a worker was monitored would not imply that they were monitored continuously at Hanford nor would an "exposed" worker have been monitored for the entire work period at Hanford. These effects might at least have been addressed if the yearly dose readings and the "monitored" variable had been provided to us.

2.6 Comparison to Data of T. Mancuso

Since the data analyzed in this report is from the same source as that analyzed by Mancuso, Stewart, and Kneale in 1977 (Ref. 1) it seems appropriate to compare the data provided to us with that used in the above paper. Table 4 is a comparison of our data to the data appearing in Table 3 of the Mancuso paper while Table 5 is a similar comparison with Table 11 in that same paper. Both tables are for male workers only.

It can be seen that the actual numbers of cases differ slightly between the two data sets. There are more total cases in our data but there are some causes of death where we have fewer cases either totally or for exposed workers only.

There are also differences in the mean doses which in some cases are not insignificant, most notably for lung and brain cancers. It can also be seen from the mean doses for non-cancers, RES neoplasms, and solid tumors that if there is an effect arising from these differences it is in the direction of reducing the doses received by persons dying of cancer and to increase those received by persons dying of causes other than cancer.

It is curious to note in Table 4 that of five diseases (multiple myeloma, pancreas, brain, lung, and kidney) which in our findings might be suspected to show dependencies of cancer incidence on dose received, three (brain, lung, kidney) show significant reductions in the mean dose relative to Mancuso's data while two (multiple myeloma and pancreas) show no significant

change. These last two are the same ones for which other researchers (notably Land) have also found significant relationships to radiation. One of these, pancreas, is a disease whose dose distribution is severely affected by increments of data after the final year of employment (see section 2.4.3). Multiple myeloma is characterized in this data by having only 8 exposed cases of which 3 are at anomalously high dose levels. The additional case (the sixth) in which we found suggestions of dose dependence was unspecified secondaries (ICD 199) which is not represented separately in Table 4.

Table 11 in the Mancuso paper is an examination of the trend in proportions of death by cancer as a function of dose controlled for age at death in 10 year intervals. Table 5 compares the proportions found by Mancuso, et. al., with similar proportions derived from the present data. It will be noticed that again the data is generally similar but that there is a tendency for the proportion of cancers at high doses to be reduced and those at low doses to be increased. In fact, if one ranks the differences in order by algebraic magnitude from most positive to most negative, one arrives at the rankings given in Table 3 to which can be applied a Spearman Rank Correlation Test. The rank correlation coefficients are shown in the last column of Table 3. For 5 pairs significance at the .10 level is reached when ρ exceeds .7 and significance at the .05 level is reached when ρ exceeds .8. In three age categories the coefficient of rank correlation is .7 or more and it is negative in only one of the five categories.

Mancuso, et. al., use a test of the same type to examine their data for a correlation of increase in proportion of death by cancer with increasing dose. They find coefficients of rank correlation of 0.1, 0.0, 0.8, 0.5, and 0.9 respectively for the various age groups. The significance of these correlations is tested by comparing the average value of these coefficients to the mean of 0.0 expected from a set of random rankings. In their case, the average is 0.46, which is different from the test mean of 0.0 by more than two standard deviations. We notice that in our data the results are almost the same except in the age group 60-69 where the rankings are changed and the coefficient is reduced from 0.5 to -0.1 thus reducing the average to 0.34 which is not more than two standard deviations away from the null result of 0.0.

The point of examining the comparison between the present data and the Mancuso data is not to suggest that results derived by Mancuso, et. al., would no longer be substantiated by the new data because the new data is different but rather to see whether or not the two sets of data should be considered to be compatible. While it seems that there are systematic differences between the two sets of data, it is more noteworthy that the differences are in fact quite small in magnitude. It is true that the outcome of one certain test cited in the Mancuso paper is altered, but one should recognize that this is more a consequence of the marginal nature of this test than of drastic changes in the data.

What is more bothersome is to understand why two separate extractions from the same data should produce different information, given that the difference is not

merely the consequence of the accumulations of additional cases as time has gone on.

In a normal sequence of events one would want to investigate the procedures used to prepare both sets of data in order to discover any sources of discrepancy. Since this alternative is not open, one can only note the difference and recognize that there are some uncertainties in the accumulation of the data which may have to be recognized in any evaluation of the results.

TABLE 4

MEAN DOSES BY CAUSE OF DEATH
Column A - Results of Mancuso, et. al.[1]
Column B - Results of Current Analysis

Cause of Death by ICD Codes	Total Cases A	Total Cases B	Cases Exposed A	Cases Exposed B	Mean Dose-Total A	Mean Dose-Total B	Mean Dose-Exposed A	Mean Dose-Exposed B
Non-Cancers								
0-136 Infective	29	32[2]	16	18[2]	43	50	79	90
210-239 Benign Neoplasms	10	10	4	4	15	15	39	39
244-289 Endocr.	54	65	34	40	96	150	153	243
290-389 CNS	36	37	20	21	94	92	169	162
390-458 CVS	1837	1885	1149	1184	105	106	167	168
460-519 Respiratory	194	194	108	107	74	74	133	134
520-577 Digestive	139	140	83	86	114	136	190	221
800-999 Accidents	450	459	271	274	94	98	156	164
580-796 Residue	101	100	57	55	85	43	151	79
RES Neoplasms								
200-202 Lymphomas	34	35	28	28	119	117	145	146
203 Myelomas	11	11	8	8	775	775	1066	1066
204 Lymphatic Leukemia	3	3	2	2	19	9	29	28
205 Myeloid Leukemia	11	12	6	6	122	[illegible]1	223	223
206-209 Residue	5	5	3	3	12	12	19	19
Solid Tumors								
140-149 Mouth & Pharynx	24	23	14	14	89	79	152	129
151 Stomach	38	38	26	26	60	58	86	85
153 Large Intestine	61	63	48	50	135	133	171	167
154 Rectum	19	19	16	16	99	99	118	118
150,152 Other Intestinal	18	20	10	10	32	28	58	57
155-156 Liver, Gall Bladder	18	19	10	10	31	29	56	56
157 Pancreas	49	51	31	32	253	253	399	404
162-163 Lung	192	195	130	129	169	142	249	214
185 Prostate	43	43	21	21	42	42	87	87
189 Kidney	21	23	14	15	187	171	281	263
186-188 Other G.U.	15	15	10	10	82	82	123	122
191 Brain	18	21	11	14	220	194	361	291
Residue	90	92	54	55	81	76	135	127
Totals:								
Non-Cancers	2850	2922	1742	1789	99	102	162	166
RES Neoplasms	64	66	47	47	219	213	299	299
Solid Tumors	606	622	395	402	130	119	199	184
TOTAL	3520	3610	2184	2238	107	107	172	172

[1] Mancuso, T. F., Alice Stewart, and George Kneale, Radiation Exposures of Hanford Workers Dying from Cancer and Other Causes, Health Physics, Vol. 33 (November 1977) p. 376.

[2] Including 2 with no cause of death (1 exposed).

TABLE 5

Proportion of Deaths Due to Cancer by Age and Dose for Male Workers
Comparison Between Results of Mancuso, et. al.[1], and Results of Current Analysis

DOSE

Age	0	1-19	20-99	100-499	500 +	Total	ρ
≤ 39.9	11.5/ 113	13.1/ 61	10.2/ 59	8.0/ 25	20.0/ 10	11.6/ 268	.9
	9.3/ 108	10.9/ 55	8.6/ 58	8.3/ 24	22.2/ 9	9.8/ 254	or
	2.2/1 or 2	2.2/2 or 1	1.6/3	-.3/4	-2.2/5	1.8	1.0
40.0-49.9	11.3/ 203	18.3/ 82	21.9/146	22.8/ 79	9.5/ 21	17.0/ 531	
	13.0/ 185	15.9/ 82	21.9/137	23.0/ 74	11.8/ 17	17.3/ 495	.4
	-1.7/4	2.4/1	.0/2	-.2/3	-2.3/5	-.3	
50.0-59.9	20.9/ 340	14.2/155	23.6/199	20.9/158	26.8/ 56	20.7/ 908	
	19.3/ 331	16.1/137	24.5/200	21.9/155	31.0/ 58	21.2/ 881	.7
	1.6/1	-1.9/4	-.9/2	-1.0/3	-4.2/5	-.5	
60.0-69.9	22.9/ 375	23.2/164	26.2/260	24.1/191	21.7/ 60	23.9/1050	.8
	22.2/ 360	21.6/162	26.6/248	25.0/184	22.6/ 53	23.7/1007	or
	.7/2	1.6/1	-.4/3	-.9/4 or 5	-.9/4 or 5	.2	.9
≥ 70.0	13.5/ 341	10.4/183	18.3/246	18.3/ 71	41.7/ 12	15.0/ 853	
	13.6/ 352	11.6/189	17.5/251	18.9/ 74	29.4/ 17	15.1/ 883	-.5
	-.1/3	-1.2/5	.8/2	-.6/4	12.3/1	-.1	
	17.4/1372	15.8/645	21.8/910	21.4/524	23.3/159	19.1/3610	.9
Total	16.9/1336	15.7/625	21.7/894	22.0/511	25.3/154	19.0/3520	or
	.5/1	.1/2 or 3	.1/2 or 3	-.6/4	-2.0/5	.1	1.0
ρ	.4	.45	.15	.5	-.6	.2	

[1] Mancuso, T.F., Alice Stewart, and George Kneale, Radiation Exposures of Hanford Workers Dying from Cancer and Other Causes, Health Physics, Vol. 33 (November 1977) p. 376.

KEY: % cancer deaths/total cases - Current Results
% cancer deaths/total cases - Mancuso Results
Difference in percents/rank

3.0 DATA ANALYSIS

The general data analysis methodology employed together with a summary of the data survey analyses are contained in Section 3.1. The discussion is, however, limited to a brief overview. A more detailed analysis of respiratory cancers is contained in Section 3.2.

3.1 Methodology and Data Survey Results

The analysis methodology employed was comprehensive in that it applied a number of differing analytical tools to the data. The approach relied, however, not only on the use of differing statistical procedures but also on the consideration of a wide variety of subject groupings.

The data was first reviewed to identify the univariate distributions present in the data. An example of this procedure for the whole data set is contained in Appendix A. Similar distributions were developed for various case subgroups. These subgroups included cases accepted when filtering for various race-sex groupings, followed by subsequent filters on exposure and various causes of death. At the completion of this procedure it was apparent that if race and sex were to be considered as relevant factors, then only the white male group had an adequate number of cases for the analysis approach anticipated. All remaining statistical analyses considered only cases which were white males.

Following the univariate review various bivariate relationships were examined for the white male subgroup. Cumulative dose comparisons with various causes of death were examined for various groups.

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In general, chi-square and t-test analyses were used to evaluate whether notable effects were being observed. An example of such an analysis is shown in Table 6 where the expected and observed dose frequencies for various causes of death are compared using the chi-square method.

EXPECTED FREQUENCIES ARE PRINTED BELOW OBSERVED FREQUENCIES

CAUSE OF DEATH

DOSE VARIABLE	0-139	240-409 412-799	410-411	800-999	157	161-163	200-202 204	140-209*	TOTALS
1	9	418	355	148	14	55	17	123	1139
1-50	8.8	399.5	369.0	138.5	16.5	70.3	15.5	120.9	
2	4	208	208	63	8	48	7	63	609
51-150	4.7	213.6	197.3	74.1	8.8	37.6	8.3	64.7	
[illegible]	2	77	68	26	3	11	2	30	219
151 [illegible]	1.7	76.8	70.9	26.6	3.2	13.5	3.0	23.3	
4	2	70	83	31	7	22	4	18	237
301+	1.8	83.1	76.8	28.8	3.4	14.6	3.2	25.2	
TOTALS	17	773	714	268	32	136	30	234	2204

TOTAL CHI SQUARE =

.01 +	.86 +	.53 +	.65 +	.39 +	3.32 +	.14 +	.04 +
.10 +	.15 +	.58 +	1.65 +	.08 +	2.89 +	.20 +	.04 +
.06 +	.00 +	.12 +	.01 +	.01 +	.47 +	.32 +	1.96 +
.02 +	2.07 +	.50 +	.17 +	3.68 +	3.72 +	.19 +	2.04 +

= 26.97

*Excluding ICD 170, 174, 193, 205, 206, 203, 210-239

Table 6. An example of a Chi-square Analysis of Dose Versus Cause of Death.

In addition, rank tests were used in an attempt to approximate results previously obtained by others. These are reported in section 2.6.

Due to the uncertainty in the validity of cases characterized as unexposed, as discussed in section 2.5.4, it was decided at this point that further survey analysis would consider two general groups. The first group would include both the exposed and unexposed white male (EUWM) workers. The second group would contain simply the exposed white male (EWM) workers.

The varying radio-sensitivity of cancers depending on the particular cells affected was recognized and considered important enough to call for separation of primary causes of death into consistent cancer groups. The ICDA codes used to group various cancers is shown in Table 3 contained in section 2.3. Only those cancer groups which had more than eight cases were considered in subsequent analyses.

In general, subsequent analyses considered the response as the probability of a particular cancer and no-cancer. The cancer group would include those cases which fell within a particular group specified by Table 3. The no-cancer group would contain cases with a primary cause of death which was not considered to be a cancer. However, we could clearly see the effects accidents had on the percent of cases which died of cancer as a function of ages, as shown in Figure 5. We recognized that accidental deaths from external causes are not diseases and may be considered to be a competing risk which might mask the effects of radiation due to the strong dependence of accidental death on age. As a result, our subsequent survey analyses considered two

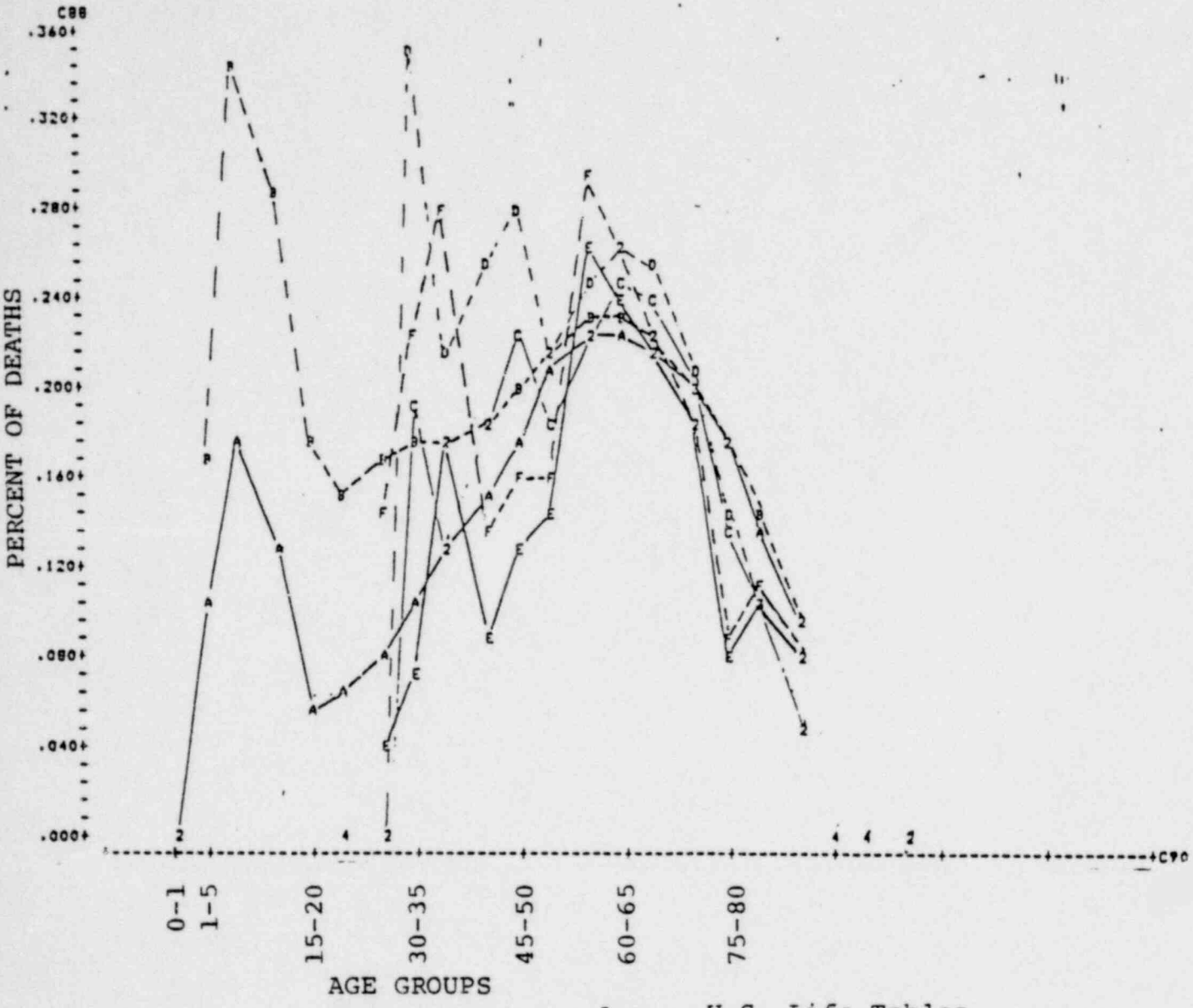

Figure 5. Percent of Deaths Due to Cancer As a Function of Age for White Males in Various Populations

additional subgroups of the EUWM and EWM groups mentioned previously. These additional subgroups where characterized by the non-cancer group containing either all non-cancers or all non-accident non-cancers, and denoted by the letters ALL or NA respectively. Thus, actually four general groups were evaluated for each cancer group of interest. These were 1) The exposed and unexposed white male workers with all non-cancers (EUWM-ALL); 2) The exposed and unexposed white male workers with accidental deaths excluded from the non-cancer group (EUWM-NA); 3) The exposed white males with all non-cancers (EWM-ALL); and 4) The exposed white males with no accidental deaths included in the non-cancer group (EWM-NA). The number of cases available in each group is shown below:

	EUWM-ALL	EUWM-NA	EWM-ALL	EWM-NA
Non-Cancers	2895	2446	1776	1508
All Cancers	684	684	449	449
Total	3579	3130	2225	1957

Table 7 Breakdown of Cases for Various Subgroups Considered in the Analysis.

It should be noted that the data provided in the above table excludes some cases in the data set which contained invalid codes for one or more variables.

3.1.1 Discriminant Analyses

Having identified the general groups of data to be considered it was desired to scan the data on a detailed basis to identify those variables which exhibited a relationship to the incidence of particular cancers for each data group. An automated procedure to select relevant variables was desirable since an additional 15 variables (shown in Appendix D) had been created from the original data elements given to us. Stepwise discriminant analysis was particularly suited to this task, since the response groups could characterize a particular cancer (e.g. pancreas) and no-cancer.

The program used to do the discriminant analyses was BMDP7M. The procedure is based on the assumption of equal population covariances for the groups (as well as multivariate normality of the discriminating variables, but this normality assumption is usually not critical). The sample variances of many of the discriminating variables are different enough between the groups that one could question the assumption of equal population covariances. However, since the goal in using discriminant analysis was simply to pick out those variables which bear a strong relationship to the incidence of cancer, it was felt that the above objection would present no serious problem. The cure for unequal population covariances is to use quadratic discrimination, but it was felt that this procedure would not produce a set of discriminating variables different from that obtained from linear discriminant analysis. Furthermore, quadratic discriminant analysis <u>is</u> sensitive to departures from normality. (See Lachenbruch, pg. 20.) At the conclusion of the analysis it did, however, appear that in some cases the analysis did suffer from lack of homogeneity of variance.

At each step of the discriminant analysis the BMDP program computes an F-statistic for each variable to enter which measures the amount of discriminating power which that variable has. As new variables are entered, the F-statistic for variables previously entered can decrease to the point where the old variable is no longer providing significant discrimination. In such a case, the old variable may be removed at some step. This removal did not occur in our discriminant analyses. For the set of discriminating variables determined at each step of the stepwise procedure, the BMDP program computes the probability of membership for each case in each group and uses this probability to classify each case into the group for which it has the highest probability of membership. The probability is a posterior probability based on a prior probability distribution of group membership specified by the user. In our discriminant runs we always specified equal priors since we were interested solely in the relationship between the incidence of cancer and the variables characterizing the workers history, and we did not want to make use of information about the relative frequency of occurrence of various causes of death. In our runs the probability of overall correct classification varied roughly from 50% to 90%. When using two groups, the probability of correct classification of a particular cancer occasionally dropped below 50%. A more complete description of the computational aspects of discriminant analysis appears in Ref. 14.

Table 8 summarizes the discriminant analysis results obtained for each specific cancer considered. The specific cancer groups considered are shown along the top edge of the table. Under each cancer label are four columns.

VARIABLE	RESPIRATORY 161-163				RECTAL 153-154				ESOPHAGEAL & STOMACH 150-151			
	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA
1 DEATHAGE		3				2		*				
2 INITLYR		*	2	2								
3 FINALYR												
4 TOTALYR					*		*					
5 EXPOSURE	C	C			1	1						
6 CUMDOSE												
7 CDOS 3+									**			
8 CDOS 5+												
9 CDOS 10+												
10 CDOS 15+									*	**		
11 CDOS 20+												
12 CDOS 25+												
13 YRDEATH	2	2								*	1	1
14 DT1	3Δ											
15 DT2								**				
16 DT3												
17 DOS0-3												
18 DOS 4-5												
19 DOS6-10	*		*	*								
20 DOS11-15												
21 DOS16-20	4	**	3	3								
22 DOS21-25												
23 DOS25+												
24 MAXDOS	**		**	**								
25 TMAXDOS												
26 AGE SQ	1	1	1	1	**				1	1	2	*
27 CAUSE												
No. Cancers	202	202	136	136	82	82	66	66	56	56	35	35
No. Non-cancers	2895	2446	1776	1508	2895	2446	1776	1508	2895	2446	1776	1508
% c.c. cancer	67.3	64.9	58.8	71.5	80.5	73.2			73.2		57.1	54.3
% c.c. non-cancer	57.0	54.1	56.3	63.5	38.7	47.8			40.8		60.8	60.7

TABLE 8 Summary of stepwise discriminant analyses, showing the order in which the variables were chosen for inclusion in the model.

VARIABLE	PANCREAS 157				LYMPHOCYTIC LEUKEMIA 200-204, 204				PROSTATE 185			
	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA
1 DEATHAGE					1	1	1	1	1	1	1	1
2 INITLYR												
3 FINALYR	**											
4 TOTALYR								*				
5 EXPOSURE					C	C			C	C		
6 CUMDOSE												
7 CDOS 3+												
8 CDOS 5+												
9 CDOS 10+												
10 CDOS 15+												
11 CDOS 20+												
12 CDOS 25+												
13 YRDEATH												
14 DT1			**			**						
15 DT2							**	**				
16 DT3			*									
17 DOS0-3					*							
18 DOS 4-5	1	1	1	1								
19 DOS6-10						*						
20 DOS11-15												
21 DOS16-20												
22 DOS21-25												
23 DOS25+	*		***	*	**		***					
24 MAXDOS												
25 TMAXDOS					2	2	*		2	2	*	*
26 AGE SQ	2	*										
27 CAUSE												
No. Cancers	51	51	32	32	38	38	30	30	43	43	21	21
No. Non-cancers	2895	2446	1776	1508	2895	2446	1776	1508	2895	2446	1776	1508
% c.c. cancer	21.6	13.7	21.9	21.9	68.4	73.7	63.3	66.7	62.8	62.8	66.7	57.1
% c.c. non-cancer	88.1	91.7	90.4	90.8	63.7	66.9	58.7	61.8	61.6	61.7	57.5	56.2

TABLE 8 Summary of Discriminant Analyses (cont.)

VARIABLE	BRAIN 190-192				KIDNEY 189				MOUTH PHARYNX 140-149			
	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA
1 DEATHAGE	2	1	2	1								*
2 INITLYR												
3 FINALYR												
4 TOTALYR												
5 EXPOSURE												
6 CUMDOSE												
7 CDOS 3+												
8 CDOS 5+												
9 CDOS 10+												
10 CDOS 15+												
11 CDOS 20+												
12 CDOS 25+												
13 YRDEATH					**	2	1					
14 DT1	3	2	3	2								
15 DT2												
16 DT3								1				
17 DOS0-3							*					
18 DOS 4-5	**	*	**		1	1	2					
19 DOS6-10												
20 DOS11-15												
21 DOS16-20			*	**								
22 DOS21-25												
23 DOS25+	1	3	1	*								
24 MAXDOS					*							
25 TMAXDOS												**
26 AGE SQ	*						**		1	1	*	***
27 CAUSE												
No. Cancers	27	27	18	18	22	22	15	15	23	23	14	14
No. Non-cancers	2895	2446	1776	1508	2895	2446	1776	1508	2895	2446	1776	1508
% c.c. cancer	59.3	66.7	72.2	77.8	22.7	45.5	53.3	80.0	78.3	78.3		
% c.c. non-cancer	69.4	69.5	72.4	68.2	91.2	73.2	72.2	61.5	41.6	41.1		

TABLE 8 Summary of Discriminant Analyses (cont.)

VARIABLE	UNSPECIFIED SECONDARY 199				LIVER 155-156				SKIN CANCER 172-173			
	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA
1 DEATHAGE							1	*	*	1	1	1
2 INITLYR												
3 FINALYR				*							**	**
4 TOTALYR			2	***							*	*
5 EXPOSURE	*	**								*		
6 CUMDOSE												
7 CDOS 3+					**							
8 CDOS 5+												
9 CDOS 10+												
10 CDOS 15+												
11 CDOS 20+												
12 CDOS 25+												
13 YRDEATH												
14 DT1									**			
15 DT2				**								
16 DT3												
17 DOS0-3												
18 DOS 4-5												
19 DOS6-10												
20 DOS11-15												
21 DOS16-20					*							
22 DOS21-25												
23 DOS25+	1	*	1	1								
24 MAXDOS	**											
25 TMAXDOS												
26 AGE SQ					1	*		**				***
27 CAUSE												
No. Cancers	27	27	13	13	19	19	10	10	13	13	10	10
No. Non-cancers	2895	2446	1776	1508	2895	2446	1776	1508	2446	2446	1776	1508
% c.c. cancer	11.1		53.8	23.1	73.7		70.0			53.8	60.0	60.0
% c.c. non-cancer	94.2		74.7	91.9	41.6		57.8			62.5	63.7	65.5

TABLE 8 Summary of Discriminant Analyses (cont.)

VARIABLE	SECONDARY LUNG CANCER 197				MULTIPLE MYELOMA 203			
	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA	1 EUWM-ALL	2 EUWM-NA	3 EWM-ALL	4 EWM-NA
1 DEATHAGE								
2 INITLYR			*	*				
3 FINALYR								
4 TOTALYR								
5 EXPOSURE								
6 CUMDOSE								
7 CDOS 3+								
8 CDOS 5+								
9 CDOS 10+								
10 CDOS 15+								
11 CDOS 20+								
12 CDOS 25+								
13 YRDEATH	1	1						
14 DT1								
15 DT2								
16 DT3								
17 DOS0-3								
18 DOS 4-5								
19 DOS6-10							*	*
20 DOS11-15					2	2	2	2
21 DOS16-20					1	1	1	1
22 DOS21-25								
23 DOS25+								
24 MAXDOS					3	3	3	3
25 TMAXDOS							**	**
26 AGE SQ	*	*						
27 CAUSE								
No. Cancers	16	16	8	8	11	11	8	8
No. Non-cancers	2895	2446	1776	1508	2895	2446	1776	1508
% c.c. cancer	43.8	63.8			27.3	27.3	37.5	37.5
% c.c. non-cancer	62.6	65.6			97.3	97.3	97.2	97.9

TABLE 8 Summary of Discriminant Analyses (cont.)

These columns correspond to the four groups which were to be considered as mentioned previously. Specifically, the first column corresponds to the EUWM-ALL group, the second the EUWM-NA group. Column 3 contains the results of the analysis using the EWM-ALL group and column 4 the results of the analysis of the EWM-NA group for the particular cancer group of interest. The rows correspond to the variables considered for selection during the discriminant analysis. The numbers which appear in the columns correspond to the order in which each variable was selected for inclusion in the classification function. Up to five variables were allowed to be selected by the discriminant analysis as long as the F-statistic exceeded 3.0. The maximum number ever selected was 4. At the bottom of each column is presented a number of cases in each of the response groups and the correct classification percentage which resulted from the final classification function. Stars in the table indicate variables which would have been selected after the last variable selected if the F to enter had been set lower.

The letter C by the variable "exposure" indicates that this variable had an F-statistic of more than 2 on the initial step. For the EWM-ALL and EWM-NA "exposure" of course was not considered since all cases in these groups were exposed by definition.

To illustrate the interpretation of the table, consider the respiratory cancer analyses. The first of the four columns under this heading is a summary of the results found when the exposed and unexposed white males were considered. The response groups were, on the one hand, those cases with a cause of death described as respiratory cancer in Table 3, and on the other, those

cases with a non-cancer cause of death including accidental causes of death. We can see at the bottom of the column that there were 2895 non-cancer cases considered which were compared with 202 respiratory cancer cases. The first variable selected was AGESQ, measuring age squared as defined in Appendix D. Note that before any variables had entered the model, the exposure variable was found to be mildly significant as indicated by the C next to exposure. At the second step of the analysis, the variable YRDEATH entered. YRDEATH represents the calendar year of death. The third variable which entered the model was DT1 which is the time interval between the initial year of employment and the year of death. The fourth variable to enter was the dose which was recorded as being received in the time interval 16 to 20 years prior to death. We can also see that other dose variables might have entered the model had the F-to-enter been set low enough, as indicated by the stars. One star means it had the highest F-statistic at that point, two stars the second highest, etc.

We can also see that the correct classification function was 67.3% for the respiratory cancers and 57.0% for the no-cancer group. Thus from this column we have an indication of those variables which are likely to provide the best predicative capability for the incidence of respiratory cancer from those variables considered for the EUWM-ALL group.

A number of features present in Table 8 are perhaps worth noting. As a general rule, AGE or AGESQ appear as important factors in modeling the incidence of cancer

for most cancer groups. Pancreas (157) cancer for the EWM-ALL and EWM-NA groups are notable exceptions, as are kidney cancers (189), unspecified secondary cancers (199), and multiple myeloma (203). Various calendar year effects such as the year of death (YRDEATH), initial year (INITLYR), and various length of time indicators such as total years of employment (TOTALYR), time from maximum dose (TMAXDOS) and DT1, DT2 and DT3 all appear as variables of interest for one cancer group or another. However, their significance may be classified in a general way as very marginal except in a few cases.

A very notable feature in the table is that the cumulative dose (CUMDOSE) was never selected as a variable to enter any model. The fact that the doses received in specific time intervals (e.g. DOS 4-5: dose received in the time interval four to five years prior to death) were selected on numerous occasions, explains the fact that the total cumulative dose was not selected. This fact may simply reflect the concept that there is a latency period between dose and cancer incidence, although the time intervals available to us and the manner in which the time intervals are modeled, are likely to be only a simple minded version of the true relationships. Notable by the inclusion of dose variables in their classification functions are: Respiratory Cancer (161-163), Pancreas (157), Brain (190-192), Kidney (189), Unspecified Secondary cancers (199), and Multiple Myeloma (203). In addition, dose variables were remotely sensitive although not selected in a number of other cancer groups.

The interpretation of the inclusion of the dose variables in the classification functions are of course subject to the concerns identified in section 2.

3.1.2 Logistic Regression Models

In the case of a model with two possible responses, e.g., death from cancer and death from cause other than cancer, the logistic regression model expresses the probability of one response as $p=e^{y}/(1+e^{y})$, or equivalently, as $\log [p/(1-p)] = y$ where $y = \alpha + \Sigma\beta_j x_j$ is a linear combination of the covariates x_j with unknown parameters α and β_j which are to be estimated. The probability of the other response is then 1 - p. The parameters α and β_j are estimated by the method of maximum likelihood. The logistic regression model has several features which make it more appealing than a model in which the data is categorized. First, the logistic regression model can handle continuous covariates as continuous variables. There is no need to categorize these variables; and since the choice of cutpoints is somewhat arbitrary and subjective, one would like to avoid splitting a variable into categories, if possible. Also, in the logistic regression model the probability comes out as a continuous function of a continuous covariate such as dose. There are no jumps in probabilility as one crosses a boundary. A second consideration which favors the logistic regression model over a categorical model is that when one is dealing with a number of categorical variables the number of cells increases rapidly and the number of observations per cell goes down rapidly. The categorical analysis does not behave well with small cell counts. Finally, the logistic regression model usually results in a simpler model since it contains only one parameter for each independent variable in the model. A possible objection to the logistic model is that it postulates a very specific form for the response probability, i. e., that log $[p/(1-p)]$ be a linear function of the independent

variables. However, if this relationship is not linear, one can add square terms, etc. to the model to achieve the desired linearity.

The stepwise discriminant analyses have identified a number of specific cancers in which some dose variable was selected. The next step in our approach at this point is to model the probability of death from cancer as a function of the variables suggested by the discriminant analyses. However, in view of the serious questions raised in section 2 concerning the data, most notably, 1) The marked increase in average dose over the years which the workers received, 2) The failure to distinguish between monitored and not-monitored cases, 3) The failure to distinguish internal depositions, and 4) The occurrence of 138 cases which have relatively large doses recorded after the final year of employment, we feel that no reliable interpretation can be placed on such models. Nevertheless, if one is willing to accept the data at face value, such models may be of interest. We have presented selected models for respiratory cancer, cancer of the pancreas and cancer of the brain in Appendix E. Also, the modeling of respiratory cancer, using exposed workers only, is subjected to a detailed analysis in section 3.2.

In Appendix E for each model the coefficients α and β_j are given, the chi-square value for testing statistical significance of the β_j. (This chi-square value has 1 degree of freedom), the value of $-2 \cdot \log L$, and finally, the decrease in $-2 \cdot \log L$ for the given model relative to the model with a constant alone. The size of $-2 \cdot \log L$ for a given model as compared to that for the constant model may be used as a measure of goodness of fit of the model to the data.

For the logistic modeling four subsets of the file of exposed white males were used, 1) all cases, 2) all cases less accidents, 3) exposed cases only, and 4) exposed cases less accidents. The main features of these models are the following. For respiratory cancer, statistical significance of the dose variables is borderline, at best. There seems to be a definite relation between cancer of the pancreas and dose. However, this conclusion is based on approximately 30 pancreas cases, of which 5 had relatively large post-employment doses (generally twice as large as the dose received during employment) recorded in the data file. Because of the uncertainty of the meaning of these doses, we would be hesitant to draw any conclusions until this question is cleared up. For cancer of the brain, the dose received 25 or more years before death is selected by discriminant analysis as being important. When this variable is put in the logistic model it also tests highly significant. However, when age at death and time from initial employment to death are controlled for, the dose variable becomes totally non-significant. We believe that further modeling work is desirable, but must wait until more basic questions concerning the data are answered.

3.2 Further Detailed Analysis of Respiratory Cancer

This group was chosen for further analysis because it had a large number of cases of cancer and because of the relationship of cancer to dose suggested by the discriminant analysis. Since the argument can be made that workers who have zero cumulative lifetime dose are in essentially different occupations from those who have dose, we have chosen here to work with "exposed" workers only, i.e., those whose cumulative lifetime dose is positive. There were a total of 2225 such cases in the file. When the non-respiratory cancers were removed we were left with 1912 cases, of which 136 or 7.1% were deaths from respiratory cancer. A stepwise discriminant analysis was done on this data using two groups, those dying from respiratory cancer (ICD 161-163) and those dying from causes other than cancer (ICD 1-139, 210-999). Twenty-six variables were used, 13 of the variables appearing in the data set originally sent to us, and 13 variables calculated from those, such variables as time from initial employment to death (DT1), dose received 0-3 years before death, etc. The complete list is described in Appendix D. The means of each of these variables are given in Table 9 and their standard deviations in Table 10 The F-ratios for four steps of the discriminant analysis are given in Tables 11 thru 14. For step 0 (Table 11) it can be seen that the most important variable is AGESQ which is defined as $[(\text{DEATHAGE}-60)/5]^2$. This expression defines AGESQ as a parabola with its vertex at age 60. This particular functional form was suggested by a plot of the percent of cancer deaths vs. categories of age as seen in Figure 6. The data for this plot is in Table 15 below.

MEANS

VARIABLE	GROUP =	RESPCANC	NOCANCER	ALL GPS.
1	DEATHAGE	61.08750	60.05327	60.12683
2	INITLYR	46.97794	46.50507	46.53870
3	FINALYR	56.47059	54.65541	54.78452
4	TOTALYR	9.41616	8.07838	8.17354
5	EXPOSURE	1.00000	1.00000	1.00000
6	CUMDOSE	209.95588	166.43581	169.53138
7	CDOS 3+	190.44853	147.55630	150.60722
8	CDOS 5+	167.57353	128.12331	130.92939
9	CDOS 10+	106.45382	72.17342	74.61036
10	CDOS 15+	53.72059	38.81363	39.87395
11	CDOS 20+	16.56618	15.40428	15.48692
12	CDOS 25+	4.10294	4.22128	4.21287
13	YRDEATH	65.30147	63.97917	64.07322
14	DT1	18.32353	17.47410	17.53452
15	DT2	8.83088	9.32376	9.28870
16	DT3	13.57721	13.39893	13.41161
17	DOS0-3	19.50735	18.87950	18.92416
18	DOS4-5	22.87500	19.43300	19.67782
19	DOS6-10	61.13971	55.94989	56.31904
20	DOS11-15	52.71323	33.35980	34.73640
21	DOS16-20	37.15441	23.45935	24.36703
22	DOS21-25	12.46324	11.18300	11.27406
23	DOS25+	4.10294	4.22128	4.21287
24	MAXDOS	102.31618	89.53209	90.44142
25	TMAXDOS	13.19853	13.53435	13.51046
26	AGE SQ	3.58075	6.94376	6.70455
27	CAUSE	.00000	1.00000	.92887
COUNTS		136.	1776.	1912.

Table 9. Means of variables used in discriminant analysis of respiratory cancers; no cancer group includes all non-cancer deaths.

STANDARD DEVIATIONS

VARIABLE		GROUP = RESPCANC	NOCANCER	ALL GPS.
1	DEATHAGE	9.43349	13.17908	12.94996
2	INITLYR	4.10684	3.88611	3.90212
3	FINALYR	8.55651	7.67790	7.74328
4	TOTALYR	7.79186	7.12960	7.17841
5	EXPOSURE	.00000	.00000	.00000
6	CUMDOSE	491.47090	431.82021	436.30421
7	CDOS 3+	444.26281	390.03605	394.11383
8	CDOS 5+	389.94979	344.84724	348.22697
9	CDOS 10+	244.83652	189.68906	194.10213
10	CDOS 15+	117.93373	89.10683	91.44326
11	CDOS 20+	34.23485	41.18084	40.72881
12	CDOS 25+	15.46143	19.36115	19.11166
13	YRDEATH	5.83136	6.31983	6.28655
14	DT1	6.37690	6.84206	6.81022
15	DT2	8.15003	8.24547	8.23876
16	DT3	6.20271	6.69390	6.66037
17	DOS0-3	63.54560	71.92290	71.36308
18	DOS4-5	67.58867	69.79293	69.63940
19	DOS6-10	163.99697	186.39070	184.89697
20	DOS11-15	148.52942	121.30639	123.42787
21	DOS16-20	100.46173	88.58640	89.52489
22	DOS21-25	29.73684	32.80420	32.59687
23	DOS25+	15.46143	19.36115	19.11166
24	MAXDOS	177.85926	195.58638	194.38833
25	TMAXDOS	7.29441	7.69571	7.66803
26	AGE SQ	4.90601	9.34438	9.10203
27	CAUSE	.00000	.00000	.00000

Table 10. Standard deviation of variables used in discriminant analysis of respiratory cancers; no cancer group includes all non-cancer deaths.

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IABLE	F TO REMOVE	FORCE LEVEL	*	VARIABLE	F TO ENTER	FORCE LEVEL	TOLERANCE
	DF= 1	1911	*	DF=	1	1910	
			*	1 DEATHAGE	.806	1	1.000000
			*	2 INITLYR	1.855	1	1.000000
			*	3 FINALYR	6.942	1	1.000000
			*	4 TOTALYR	4.387	1	1.000000
			*	5 EXPOSURE	.000	1	.000000
			*	6 CUMDOSE	1.257	1	1.000000
			*	7 CDOS 3+	1.496	1	1.000000
			*	8 CDOS 5+	1.621	1	1.000000
			*	9 CDOS 10+	3.936	1	1.000000
			*	10 CDOS 15+	3.357	1	1.000000
			*	11 CDOS 20+	.103	1	1.000000
			*	12 CDOS 25+	.005	1	1.000000
			*	13 YRDEATH	5.589	1	1.000000
			*	14 DT1	1.965	1	1.000000
			*	15 DT2	.452	1	1.000000
			*	16 DT3	.090	1	1.000000
			*	17 DOS0-3	.010	1	1.000000
			*	18 DOS4-5	.309	1	1.000000
			*	19 DOS6-10	.100	1	1.000000
			*	20 DOS11-15	3.106	1	1.000000
			*	21 DOS16-20	4.937	1	1.000000
			*	22 DOS21-25	.195	1	1.000000
			*	23 DOS25+	.005	1	1.000000
			*	24 MAXDOS	.546	1	1.000000
			*	25 TMAXDOS	.242	1	1.000000
			*	26 AGE SQ	17.245	1	1.000000

Table 11. F-ratios at initial step of discriminant analysis on exposed white males using two groups: death from respiratory cancer and death from non-cancer.

VARIABLE ENTERED 26 AGE SQ

VARIABLE	F TO REMOVE	FORCE LEVEL
	DF= 1 1910	
26 AGE SQ	17.245	1

*	VARIABLE	F TO ENTER	FORCE LEVEL	TOLERANCE
		DF= 1 1909		
*	1 DEATHAGE	.008	1	.943687
*	2 INITLYR	4.909	1	.960984
*	3 FINALYR	4.477	1	.983959
*	4 TOTALYR	1.236	1	.940890
*	5 EXPOSURE	.000	1	.000000
*	6 CUMDOSE	.572	1	.992312
*	7 CDOS 5+	.697	1	.991272
*	8 CDOS 5+	.777	1	.991112
*	9 CDOS 10+	2.531	1	.991066
*	10 CDOS 15+	2.269	1	.993940
*	11 CDOS 20+	.019	1	.998037
*	12 CDOS 25+	.025	1	.999529
*	13 YRDEATH	3.556	1	.986319
*	14 DT1	.247	1	.951442
*	15 DT2	.296	1	.999073
*	16 DT3	.068	1	.991196
*	17 DOS0-3	.000	1	.999595
*	18 DOS4-5	.100	1	.996717
*	19 DOS6-10	.000	1	.993665
*	20 DOS11-15	1.915	1	.991724
*	21 DOS16-20	3.614	1	.994156
*	22 DOS21-25	.069	1	.998183
*	23 DOS25+	.025	1	.999529
*	24 MAXDOS	.233	1	.996231
*	25 TMAXDOS	.446	1	.998154

CLASSIFICATION FUNCTIONS

GROUP =	RESPCANC	NOCANCER
VARIABLE 26 AGE SQ	.04322	.08381
CONSTANT	-.77053	-.98414

CLASSIFICATION MATRIX

GROUP	PERCENT CORRECT	NUMBER OF CASES CLASSIFIED INTO GROUP -	
		RESPCANC	NOCANCER
RESPCANC	76.5	104	32
NOCANCER	40.4	1058	718
TOTAL	43.0	1162	750

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Table 12. F-ratios, classification functions and classification matrix at first step of discriminant analysis on exposed white males using two groups: death from respiratory cancer and death from non-cancer.

STEP NUMBER 2
VARIABLE ENTERED 2 INITLYR

VARIABLE	F TO REMOVE	FORCE LEVEL
	DF= 1 1909	
2 INITLYR	4.909	1
26 AGE SQ	20.316	1

* VARIABLE	F TO ENTER	FORCE LEVEL	TOLERANCE
	DF= 1 1908		
* 1 DEATHAGE	.466	1	.840417
* 3 FINALYR	1.627	1	.796628
* 4 TOTALYR	1.576	1	.936767
* 5 EXPOSURE	.000	1	.000000
* 6 CUMDOSE	.202	1	.972815
* 7 CDOS 3+	.321	1	.976362
* 8 CDOS 5+	.435	1	.980935
* 9 CDOS 10+	2.536	1	.991062
* 10 CDOS 15+	3.088	1	.981992
* 11 CDOS 20+	.308	1	.963806
* 12 CDOS 25+	.014	1	.984102
* 13 YRDEATH	2.168	1	.947557
* 14 DT1	2.168	1	.807435
* 15 DT2	.001	1	.933560
* 16 DT3	.551	1	.867066
* 17 DOS0-3	.150	1	.967433
* 18 DOS4-5	.010	1	.961899
* 19 DOS6-10	.197	1	.957014
* 20 DOS11-15	1.469	1	.985835
* 21 DOS16-20	3.912	1	.992906
* 22 DOS21-25	.386	1	.973108
* 23 DOS25+	.014	1	.984102
* 24 MAXDOS	.008	1	.964233
* 25 TMAXDOS	.012	1	.876700

CLASSIFICATION FUNCTIONS

GROUP = VARIABLE	RESPCANC	NOCANCER
2 INITLYR	3.18978	3.13801
26 AGE SQ	-.22689	-.18191
CONSTANT	-75.21168	-73.02815

CLASSIFICATION MATRIX

GROUP	PERCENT CORRECT	NUMBER OF CASES CLASSIFIED INTO GROUP - RESPCANC	NOCANCER
RESPCANC	73.5	100	36
NOCANCER	46.8	949	827
TOTAL	48.5	1049	863

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Table 13. F-ratios, classification functions and classification matrix at second step of discriminant analysis on exposed white males using two groups: death from respiratory cancer and death from non-cancer.

STEP NUMBER 3
VARIABLE ENTERED 21 DOS 16-20

VARIABLE	F TO REMOVE	FORCE LEVEL
DF =	1 1908	
2 INITLYR	5.206	1
21 DOS16-20	3.912	1
26 AGE SQ	18.961	1

*	VARIABLE	F TO ENTER	FORCE LEVEL	TOLERANCE
	DF =	1 1907		
*	1 DEATHAGE	.355	1	.838792
*	3 FINALYR	.766	1	.761025
*	4 TOTALYR	.730	1	.894653
*	5 EXPOSURE	.000	1	.000000
*	6 CUMDOSE	1.473	1	.524902
*	7 CDOS 3+	1.456	1	.478205
*	8 CDOS 5+	1.548	1	.429224
*	9 CDOS 10+	.070	1	.239191
*	10 CDOS 15+	.089	1	.170724
*	11 CDOS 20+	.009	1	.860583
*	12 CDOS 25+	.002	1	.978012
*	13 YRDEATH	1.146	1	.903645
*	14 DT1	1.146	1	.770016
*	15 DT2	.004	1	.933238
*	16 DT3	.311	1	.859359
*	17 DOS0-3	.628	1	.929846
*	18 DOS4-5	.479	1	.883384
*	19 DOS6-10	2.725	1	.718253
*	20 DOS11-15	.060	1	.500792
*	22 DOS21-25	.010	1	.846598
*	23 DOS25+	.002	1	.978612
*	24 MAXDOS	2.110	1	.592837
*	25 TMAXDOS	.004	1	.876199

CLASSIFICATION FUNCTIONS

GROUP =	RESPCANC	NOCANCER
VARIABLE		
2 INITLYR	3.19907	3.14564
21 DOS16-20	.01443	.01187
26 AGE SQ	-.21925	-.17563
CONSTANT	-75.71145	-73.36654

CLASSIFICATION MATRIX

GROUP	PERCENT CORRECT	NUMBER OF CASES CLASSIFIED INTO GROUP	
		RESPCANC	NOCANCER
RESPCANC	58.6	80	56
NOCANCER	56.5	773	1003
TOTAL	56.8	853	1059

1393 139

Table 14. F-ratios, classification functions and classification matrix at third step of discriminant analysis on exposed white males using two groups: death from respiratory cancer and death from non-cancer.

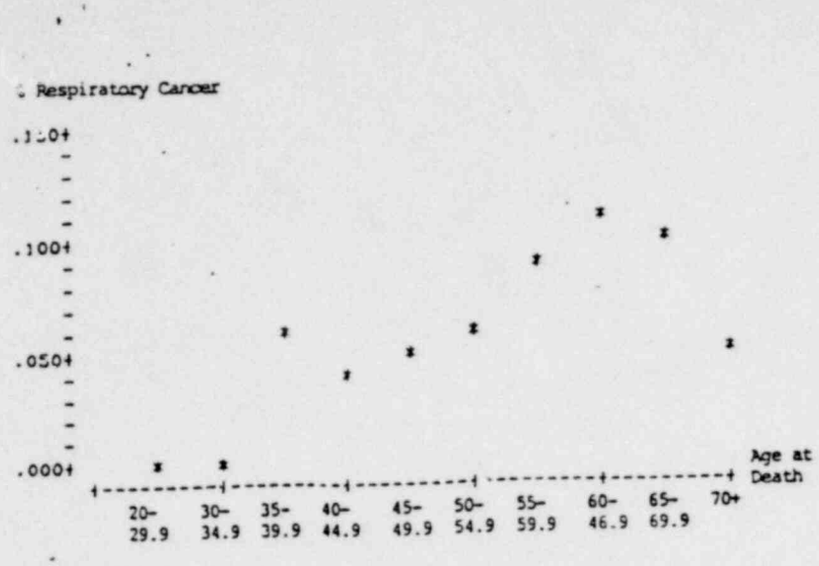

Figure 6 Percent of deaths from respiratory cancer for exposed white males as a function of age at death.

	20-29.9	30-34.9	35-39.9	40-44.9	45-49.9	50-54.9	55-59.9	60-64.9	65-69.9	70+	Total
No. Cancers	0	0	4	5	8	13	24	32	28	22	136
Total	37	29	71	114	156	226	260	289	279	451	1912
% Cancer	0.0	0.0	5.6	4.4	5.1	5.8	9.2	11.1	10.0	4.9	7.1

Table 15 Numbers of and percent of Respiratory Cancers as a function of age for exposed white males.

The left portion of this graph for ages less than 50 departs from a parabolic shape, but this part involves only 407 cases out of a total of 1912 cases. Thus, nearly 80% of the cases are in the age group from 50-70 and the quadratic form which we used ought to provide a good fit. In fitting a logistic model one fits log $[p/(1-p)]$ to the independent variables, where p is the probability of death from cancer. A plot of this expression vs. age is shown in Figure 7, where the percents in Figure 6 were used for p. Again the

parabolic shape stands out in the range 50-70 years where the largest portion of the data is located.

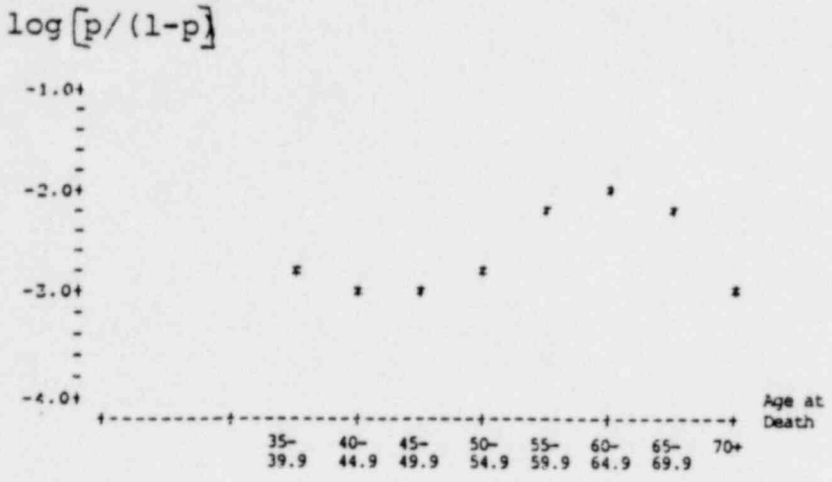

Figure 7 log [p/(1-p)] for exposed white males as a function of age at death, where p is the percent of deaths from respiratory cancer vs. non-cancer.

As seen in Table 11, other important variables at the initial step of the discriminant analysis are final year of employment (FINALYR), year of death (YRDEATH), total years of employment (TOTAL YR), dose received 16 to 20 years before death (DOS16-20) and dose received 11 to 15 years before death (DOS11-15).

After the variable AGESQ is entered in the first step of the discriminant analysis, a curious thing happens. The variable initial year of employment (INITLYR) becomes the next candidate to enter with an F-ratio of 4.9. Other variables that are close are FINALYR, YRDEATH, and DOS16-20. We are at a loss to explain the meaning of this. The coefficients on INITLYR in the classifications functions

are such that the larger the value of INITLYR, the greater the chance of death from respiratory cancer. One might argue that INITLYR is acting as a surrogate for dose, particularly in view of Figure 4 which shows that the average dose which Hanford workers have been receiving has been going up over the years. However, if this is the case, one would expect the dose variables to show up with F-ratios comparable to that of INITLYR, but aside from DOS16-20, they don't. Furthermore, after INITLYR is entered, the F-ratio for DOS16-20 increases a little. If INITLYR were acting as a surrogate for DOS16-20, this F-ratio should decrease considerably. Thus it seems that INITLYR is not acting as a surrogate for any of the dose variables. This question is considered later in more detail and this conclusion is contradicted. One might feel that INITLYR is acting as a surrogate for YRDEATH and that since the incidence of respiratory cancer has been increasing over the years, this produces a positive relation between death from respiratory cancer and INITLYR. Perhaps this is so, but then one would expect the F-ratio for YRDEATH at step 1 of the discriminant analysis to be somewhat higher than that of INITLYR, and this is not the case.

After AGESQ and INITLYR are entered in the stepwise discriminant procedure, DOS16-20 is chosen next with an F-ratio of 3.9 (α = .048). The coefficients on DOS 16-20 in the classification functions are such that higher dose gives higher chance of cancer.

The stepwise discriminant analysis procedure was used to suggest a set of variables to be used in developing a model to give the probability of death from respiratory cancer. The variables chosen were:

AGESQ, INITLYR, YRDEATH, DOS6-10 and DOS16-20.

At all of the steps of the discriminant analysis, correct classification was not impressive, being typically around 50%. One interesting fact which stands out is that cumulative lifetime dose (CUMDOS) does not show up at all (F-ratios all less than 1.5). The stepwise discriminant analysis was also run on the above data set, leaving out accidental deaths, and the results were essentially the same. Finally, the analysis was done including cases with zero cumulative lifetime dose. The biggest difference here was that YRDEATH showed up quite a bit more significant than INITLYR.

A logistic regression model was developed for exposed white males. Two response categories were used: respiratory cancer death (136 cases) and non-cancer deaths (1776 cases). The form of the model is:

$$\log \left[P/(1-p)\right] = \alpha + \sum_{j=1}^{k} \beta_j x_j$$

where p is the probability of respiratory cancer being the cause of death, as opposed to a non-cancer cause of death, x_j is the value of the j-th predictor variable in the model and α and β_j are coefficients to be estimated from the data. Table 16 summarizes the results of 8 different logistic regression models which were fit to the data. First, based on the discriminant analysis results, we would certainly want to include AGESQ in the model. Then discriminant analysis would suggest that INITLYR be included, while the fact that the incidence of respiratory cancer is increasing over time would say that YRDEATH should be in the model. Each of these variables was tried separately (with AGESQ, of course) and together. See models 3, 4 and 5 of Table 16. With both INITLYR and YRDEATH in the model the chi-square values for these variables are about 3.0 (α=.09),

Model	Constant	AGESQ	INITLYR	YRDEATH	DOS16-20	-2·log L
1	-2.57					981.1
2	-2.21	-.291 (16.6)				956.4
3	-4.37	-.301 (18.0)	.047 (4.7)			952.1
4	-4.3[illegible]	-.290 (16.2)		.033 (4.4)		951.7
5	-5.78	-.298 (17.3)	.038 (2.96)	.028 (3.02)		949.0
6	-4.51	-.296 (17.4)	.048 (4.99)		.0018 (3.5)	949.2
7	-4.13	-.286 (15.7)		.029 (3.3)	.0012 (1.6)	950.3
8	-5.64	-.294 (16.9)	.041 (3.4)	.023 (1.9)	.0014 (2.0)	947.2

Table 16. Results of fitting eight logistic regression models using respiratory cancer and no cancer as the two response categories. Only exposed white males are included in the model. Variables which have no entry for a particular model were not used in that model. For each model, the first value under the variable is the coefficient of that variable in the logistic regression model, while the second value (below in parentheses) is the chi-square value for a test of statistical significance of that variable. All chi-square values have one degree of freedom.

but either one alone has a chi-square of 4.7 or 4.4. This suggests that either one, but not both, of these variables belongs in the model. Since YRDEATH has an obvious interpretation while INITLYR does not, it would seem that a reasonable model at this point would consist of AGESQ and YRDEATH. Next, DOS16-20 was added to some of the above models. See models 6, 7 and 8 of Table 16 for the results. When DOS16-20 is added to the model consisting of AGESQ and INITLYR, it has a chi-square value of 3.497 with 1 degree of freedom (α=.06). When DOS16-20 is added to the model consisting of AGESQ and YRDEATH, it has a chi-square value of only 1.6. Also, the chi-square value of YRDEATH drops from 4.4 to 3.3. Finally, when DOS16-20 is added to the model consisting of AGESQ, INITLYR and YRDEATH, both YRDEATH and DOS16-20 drop in significance. This suggests that YRDEATH and DOS16-20 are correlated. This is substantiated further on. This shows that YRDEATH contains information about DOS16-20 and vice-versa; and that we cannot separate the effects of each (except, for example, by having an independent estimate of the effect of YRDEATH on respiratory cancer deaths among Hanford workers). In any case, from the point of view of statistical significance, DOS16-20 is border line at best (α=.06 when we include in DOS16-20 any effect of YRDEATH). The coefficients on AGESQ in all of the models are nearly the same (all between -.301 and -.286) which is reassuring. The coefficients on DOS16-20, on the other hand, vary between .0012 and .0018; which is not a very large magnitude, but percentagewise the change is 33% or 50% depending on one's point of view. This is quite large and can have a considerable effect if one attempts to estimate the effect of dose on the probability of death from respiratory cancer. In view of the relation between YRDEATH and DOS16-20 in the data file, we are reluctant to attempt such an estimate.

Another curious point about the logistic modeling is the fact that when INITLYR is added to the model consisting of AGESQ, YRDEATH and DOS16-20, it is on the border line of testing significant (chi-square = 3.366 with 1 d.f., $\alpha = .07$). As stated before, we are unable to find an interpretation for this.

Based on the above discussion, it is difficult to recommend a single model. Our inability to find an interpretation for INITLYR makes us want to leave it out of the model. On the other hand, the statistical analysis is hinting (mildly, at least) that it belongs in the model. Also, the statistical analysis is hinting that YRDEATH and DOS16-20 belong in the model. However, these variables are correlated, so that when both are put in the model their significance drops, as do the values of their coefficients. Thus it is not possible to estimate the effect of each variable separately on the response.

An attempt to get at the meaning of INITLYR in the model and to see the relation between YRDEATH and dose prompted a more detailed look at the data. Scatterplots were made of three dose variables, DOS6-10, DOS11-15 and DOS16-20 against both INITLYR and YRDEATH. In these plots the extremely low doses were omitted. The plots are shown in Figures 8 thru 13 on the following pages. A number, such as 3, indicates 3 or more points on top of one another on the graph while a plus sign indicates 10 or more points on top of one another. The scatterplots show little or no relationship between INITLYR and the dose variables. However, YRDEATH bears a definite positive relationship with each of the dose variables.

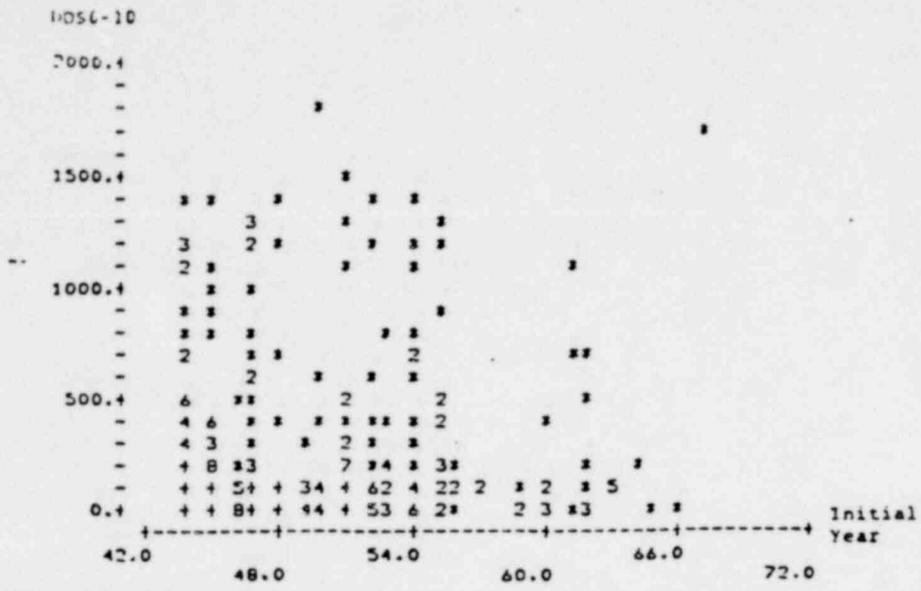

Figure 8. Scatterplot of DOS6-10 vs. Initial Year of Employment for Exposed White Males With Respiratory Cancer or no Cancer as Cause of Death. Cases with DOS 6-10 Less or Equal to 15 have not been plotted.

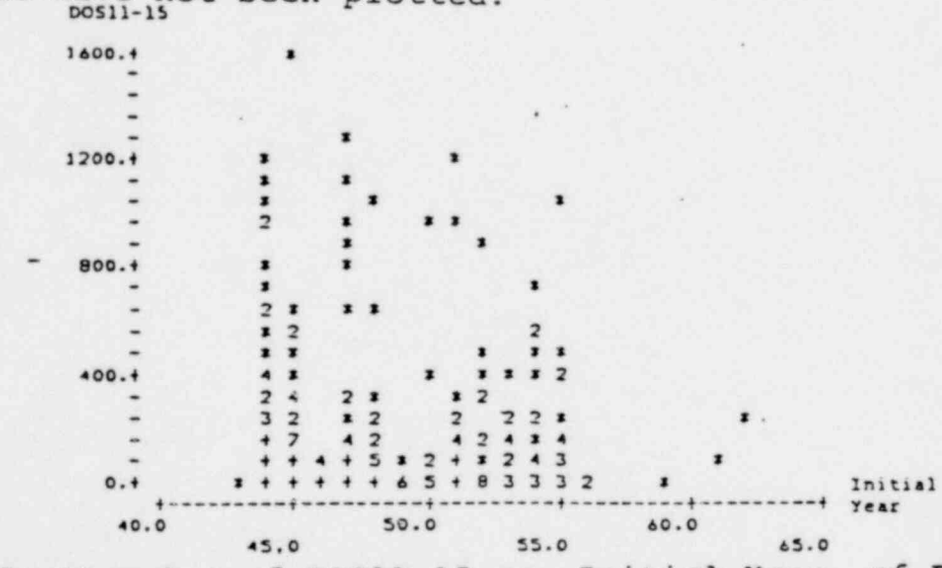

Figure 9. Scatterplot of DOS11-15 vs. Initial Year of Employment for Exposed White Males With Respiratory Cancer or no Cancer as Cause of Death. Cases with Dose Less or Equal to 10 have not been plotted.

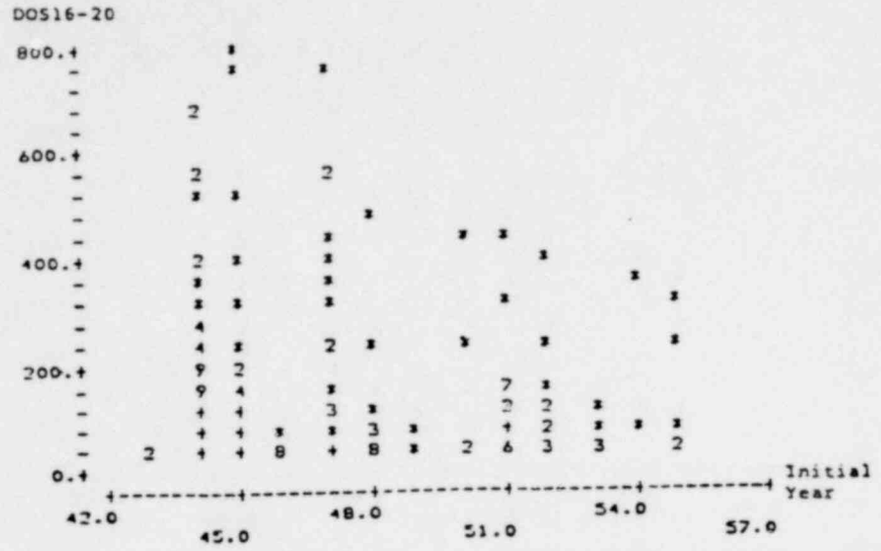

Figure 10. Scatterplot of DOS16-20 vs. Initial Years of Employment for Exposed White Males with Respiratory Cancer or no Cancer as Cause of Death. Cases with Dose Less or Equal to 25 have not been plotted.

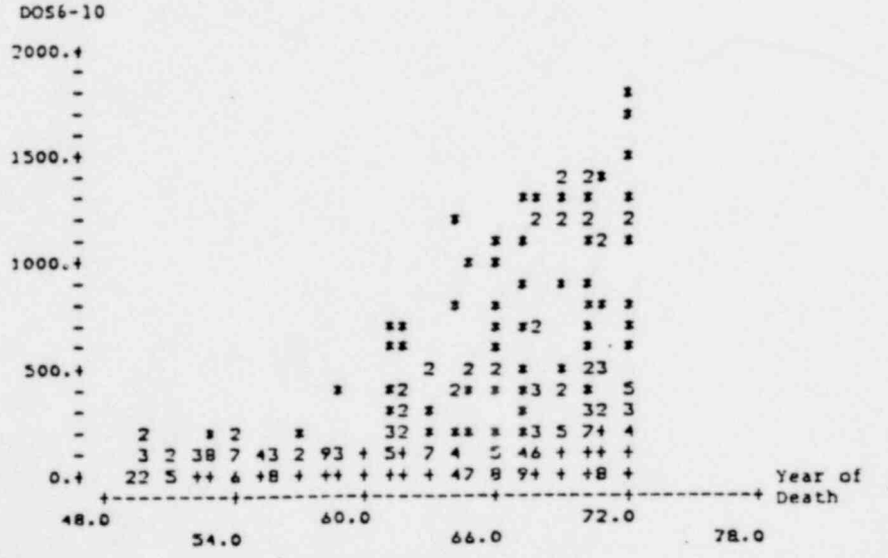

Figure 11. Scatterplot of DOS6-10 vs. Year of Death for Exposed White Males with Respiratory Cancer or no Cancer as Cause of Death. Cases with DOS6-10 Less or Equal to 15 have not been plotted.

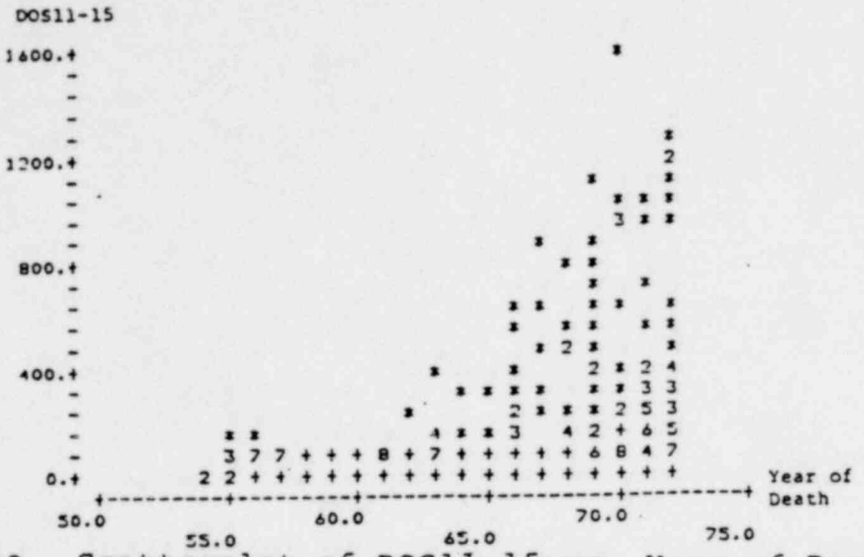

Figure 12. Scatterplot of DOS11-15 vs. Year of Death for Exposed White Males with Respiratory Cancer or no Cancer as Cause of Death. Cases with Dose Less or Equal to 10 have not been plotted.

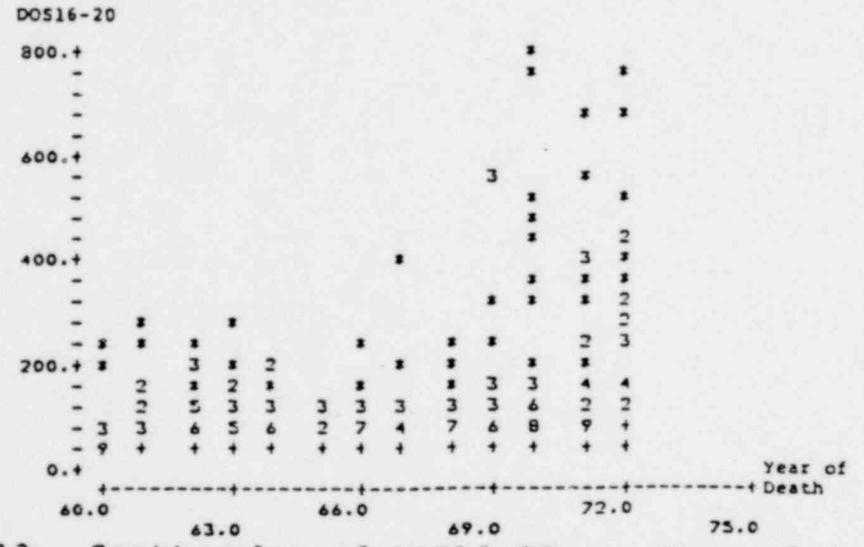

Figure 13. Scatterplot of DOS16-20 vs. Year of Death for Exposed White Males with Respiratory Cancer or no Cancer as Cause of Death. Cases with Dose Less or Equal to 25 have not been plotted.

A close look at the scatterplot of DOS6-10 vs. YRDEATH in Figure 11 shows that the envelope of the dose levels is flat up to about '57 where it begins to rise linearly. The doses plotted for '57 were received 6-10 years earlier, i.e., in '47 to '51. This suggests that the doses (recorded in our file) which Hanford workers received began to rise sometime between 1947 and 1951. Similar considerations for DOS11-15 in Figure 12 would put the beginning of the rise between 1946 and 1950, while consideration of DOS16-20 in Figure 13 would put it between 1945 and 1949. These observations are consistant with Figure 4 which shows that the average dose which Hanford workers received increased over time and that the increase began around 1949. Furthermore, the flat parts of the envelopes of the dose levels in Figures 11, 12, and 13 suggest that the dose which Hanford workers received decrease linearly from 1944 to around 1948 or so; a look at the graph in Figure 4 shows that this is approximately true. Thus, we have established a very definite positive relationship between the dose variables and year of death in our data file.

Next, for each of the dose variables, the average dose was determined for each initial year and each year of death. Plots of these averages appear in Figures 14 thru 19. The plot of average DOS6-10 vs. INITLYR in Figure 14 shows a linear rise up to '55 after which the plot becomes erratic. We don't have an explanation for this erratic behavior. However, the vast majority of cases, 1857 out of 1910 (two cases with initial year of '72 are not included), are on or before '55, so this plot would suggest a positive relationship between DOS6-10 and INITLYR. Such a relationship didn't show up in Figure 8, but a look at the vertical scales of the two graphs shows that the rise detected in Figure 14 is

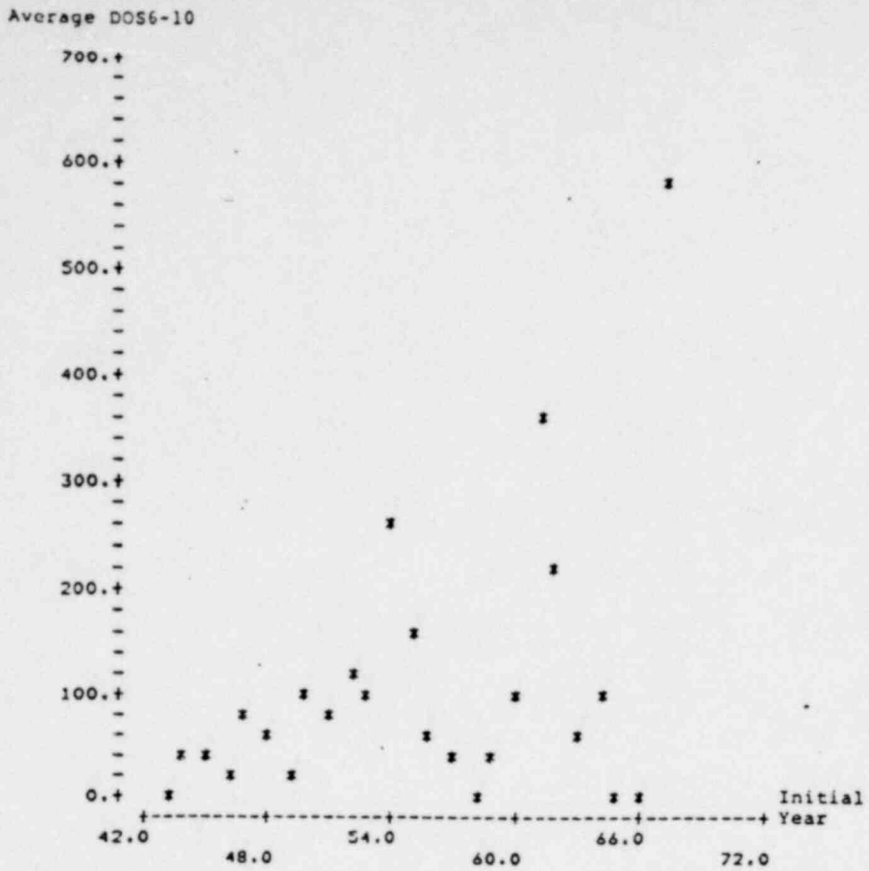

Figure 14. Plot of average DOS6-10 for workers with the specified initial year of employment. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

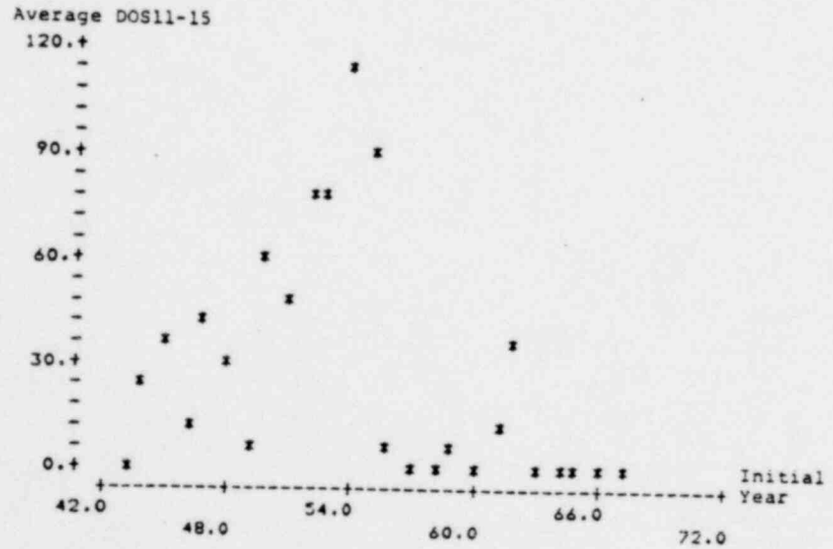

Figure 15. Plot of average DOS11-15 for workers with the specified initial year of employment. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

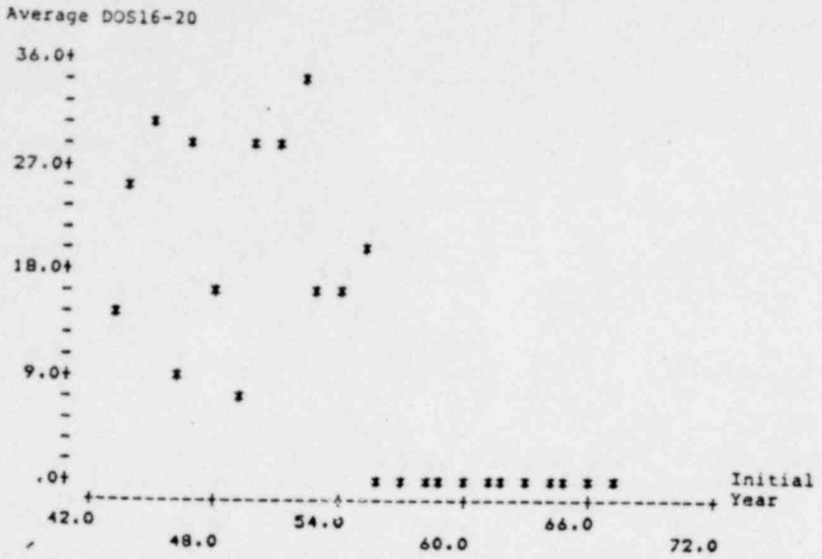

Figure 16. Plot of average DOS16-20 for workers with the specified initial year of employment. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

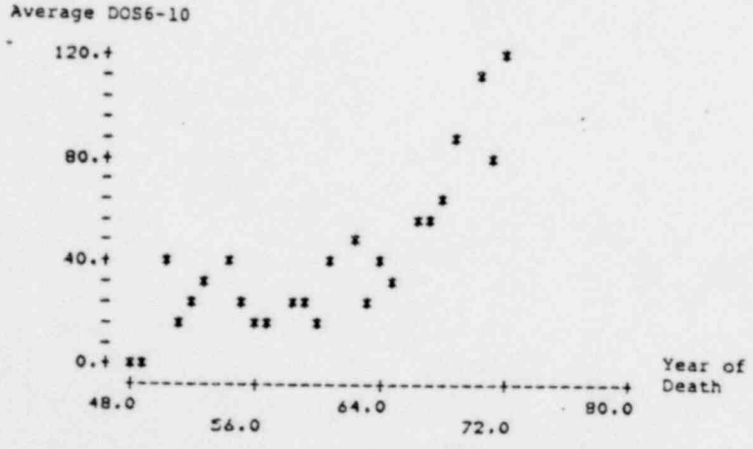

Figure 17. Plot of average DOS6-10 for workers with the specified year of death. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

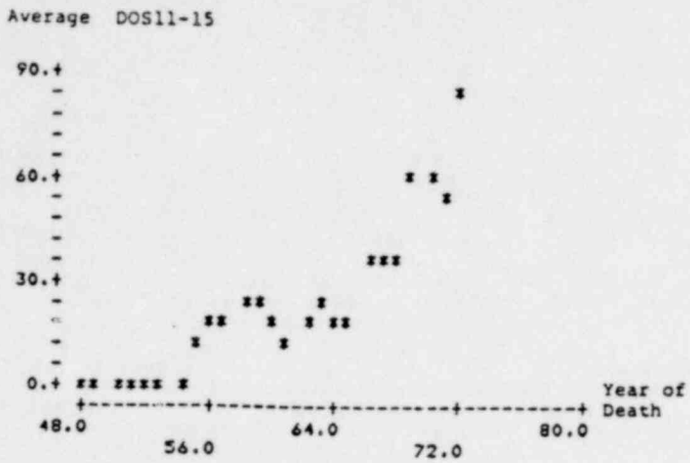

Figure 18. Plot of average DOS11-15 for workers with the specified year of death. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

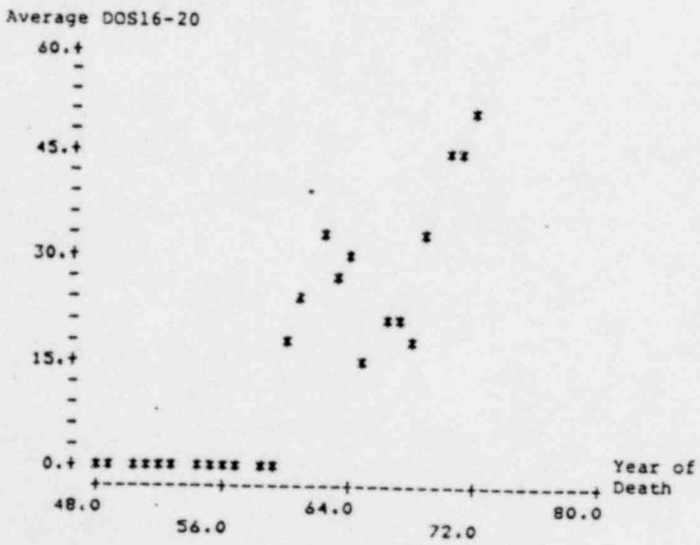

Figure 19. Plot of average DOS16-20 for workers with the specified year of death. Only exposed white males with respiratory cancer or no cancer as cause of death are used.

rather slight compared to the vertical scale of Figure 8 so one would not expect to see that rise in Figure 8 . Similar comments apply to Figure 15. The doses from '63 up must be zero in this figure, since all of the cases are deaths that occurred on or before '72. There is no relation between DOS16-20 and INITLYR other than the logical requirement that average DOS16-20 be zero from '57 up. Thus there is some indication of a positive relationship between dose and initial year of employment. With regard to year of death, Figures 17, 18, and 19 show a very definite positive relationship between the dose variables and year of death, reinforcing that observed in Figures 11, 12, and 13. The implications of these relationships in the logistic modelling have been discussed above.

4.0 PRINCIPAL CONCLUSIONS

A number of conclusions have been reached pertaining to the quality of the data analyzed in this project and the results that can be obtained. These may be listed as follows:

1. We are not convinced that the data is in fact the same data as that collected for Hanford workers and maintained by Battelle Pacific Northwest Laboratories. This concern is due in part to inconsistencies among various sources concerning the data and in part to lack of clear documentation of the chain of events leading to the preparation of the data.

2. The data is not consistent with the purported data collection procedures as evidenced for example by the existence of reported doses after the final year of employment.

3. The data does not correspond with that presented in the Mancuso paper.

4. The data contains a systematic trend of increasing average yearly dose over calendar years, which suggests a possible bias in the data collection procedure applicable to the file from which the current data was extracted.

5. We have not been able to receive or discover an authoritative definition of the meaning of the dose variables, including the units, types of radiation included, and quality factors.

6. The absence of data pertaining to other information that is available but which was not provided was a hindrance to a proper completion of analysis. This includes among other items, data on radiation

(Cont.)6. monitoring, secondary causes of death, internal exposures, accidental deposition, yearly dose records broken down by radiation sources, and inclusion of additional fatalities occurring after 1972.

7. The lack of adequate documentation from NRC forced us to spend considerable time and effort identifying and researching the supporting material required for the preparation of a responsible analysis.

8. In view of the above conclusions concerning the data, it does not seem appropriate to attempt to draw conclusions from the statistical analysis.

9. It is a useful corollary of the evidence presented in this paper that future efforts must carefully consider the reliability of the data studied. This would include careful documentation of the sources of the data and of the procedures used in compiling it.

10. It is our recommendation that this contract should be modified in such a way that the work can be repeated with data which is adequate for the purpose intended.

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APPENDIX A

Univariate Distributions of All Variables Except Race, Sex, and Exposed-Unexposed For All Cases and For Exposed White Males

```
 21.5 TO  22.5-  11***
 22.5 TO  23.5-  5*
 23.5 TO  24.5-  4*
 24.5 TO  25.5-  10***
 25.5 TO  26.5-  11***
 26.5 TO  27.5-  7**
 27.5 TO  28.5-  16******
 28.5 TO  29.5-  9***
 29.5 TO  30.5-  11***
 30.5 TO  31.5-  22*********
 31.5 TO  32.5-  15******
 32.5 TO  33.5-  20********
 33.5 TO  34.5-  16******
 34.5 TO  35.5-  19*******
 35.5 TO  36.5-  23*********
 36.5 TO  37.5-  31*************
 37.5 TO  38.5-  37*****************
 38.5 TO  39.5-  46************************
 39.5 TO  40.5-  32***************
 40.5 TO  41.5-  40******************
 41.5 TO  42.5-  44**********************
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 71.5 TO  72.5-  114***********************************************************
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 80.5 TO  81.5-  41********************
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 82.5 TO  83.5-  33****************
 83.5 TO  84.5-  27************
 84.5 TO  85.5-  21********
 85.5 TO  86.5-  10***
 86.5 TO  87.5-  6**
 87.5 TO  88.5-  5*
 88.5 TO  89.5-  4*
 89.5 TO  90.5-  3
 90.5 TO  91.5-  2
 91.5 TO  92.5-  0
 92.5 TO  93.5-  0
 93.5 TO  94.5-  0
 94.5 TO  95.5-  1
 95.5 TO  96.5-  1
 96.5 TO  97.5-  0
 97.5 TO  98.5-  0
 98.5 TO  99.5-  0
 99.5 TO 100.5-  1
100.5 TO 101.5   1
```

All Cases Age at Death

```
42.5 TO 43.5-   9
43.5 TO 44.5-   1866#####################################################################################################################
44.5 TO 45.5-   574#############################################
45.5 TO 46.5-   107###
46.5 TO 47.5-   441#########################
47.5 TO 48.5-   330################
48.5 TO 49.5-   58#
49.5 TO 50.5-   66##
50.5 TO 51.5-   217##########
51.5 TO 52.5-   75##
52.5 TO 53.5-   44#
53.5 TO 54.5-   43#
54.5 TO 55.5-   62##
55.5 TO 56.5-   16
56.5 TO 57.5-   7
57.5 TO 58.5-   4
58.5 TO 59.5-   7
59.5 TO 60.5-   8
60.5 TO 61.5-   6
61.5 TO 62.5-   8
62.5 TO 63.5-   10
63.5 TO 64.5-   3
64.5 TO 65.5-   2
65.5 TO 66.5-   12
66.5 TO 67.5-   7
67.5 TO 68.5-   0
68.5 TO 69.5-   1
69.5 TO 70.5-   4
THIS HISTOGRAM DOES NOT INCLUDE   5.00   OBS .LT.   40.5   AND   .000   OBS .GE.   79.5
```

All Cases Initial Year of Employment

1393 161

```
43.5 TO 44.5-  364**********
44.5 TO 45.5-  790**********
45.5 TO 46.5-  212**********
46.5 TO 47.5-  116**********
47.5 TO 48.5-  227**********
48.5 TO 49.5-  250**********
49.5 TO 50.5-  136**********
50.5 TO 51.5-  195**********
51.5 TO 52.5-  194**********
52.5 TO 53.5-  136**********
53.5 TO 54.5-  102**********
54.5 TO 55.5-  110**********
55.5 TO 56.5-  104**********
56.5 TO 57.5-  120**********
57.5 TO 58.5-  102**********
58.5 TO 59.5-  107**********
59.5 TO 60.5-  74**********
60.5 TO 61.5-  92**********
61.5 TO 62.5-  83**********
62.5 TO 63.5-  77**********
63.5 TO 64.5-  75**********
64.5 TO 65.5-  88**********
65.5 TO 66.5-  32***
66.5 TO 67.5-  25**
67.5 TO 68.5-  24*
68.5 TO 69.5-  39****
69.5 TO 70.5-  41****
70.5 TO 71.5-  34****
71.5 TO 72.5-  43****
```

All Cases Final Year of Employment

```
 -.5 TO   .5-  1012**********
  .5 TO  1.5-  765**********
 1.5 TO  2.5-  295**********
 2.5 TO  3.5-  172**********
 3.5 TO  4.5-  163**********
 4.5 TO  5.5-  130**********
 5.5 TO  6.5-  140**********
 6.5 TO  7.5-  116**********
 7.5 TO  8.5-  115**********
 8.5 TO  9.5-  110**********
 9.5 TO 10.5-  96**********
10.5 TO 11.5-  98**********
11.5 TO 12.5-  82********
12.5 TO 13.5-  69*******
13.5 TO 14.5-  93*********
14.5 TO 15.5-  77********
15.5 TO 16.5-  59*******
16.5 TO 17.5-  80********
17.5 TO 18.5-  56****
18.5 TO 19.5-  52****
19.5 TO 20.5-  52****
20.5 TO 21.5-  39**
21.5 TO 22.5-  20
22.5 TO 23.5-  12
23.5 TO 24.5-  17
24.5 TO 25.5-  26*
25.5 TO 26.5-  13
26.5 TO 27.5-  14
27.5 TO 28.5-  14
THIS HISTOGRAM DOES NOT INCLUDE   .000   OBS .LT.   -.500   AND   5.00   OBS .GE.   29.5
```

All Cases Total Years Employed

1393 162

8	1
9	4
11	13
23	1
38	2
39	1
40	2
41	1
43	2
46	1
52	1
70	2
93	1
95	1
112	1
136	1
140	1
141	6
142	3
144	2
145	3
146	3
147	1
148	2
149	2
150	18
151	39**
152	2
153	79*******
154	23*
155	9
156	11
157	53****
158	3
159	1
160	2
161	10
162	202**********
163	1
170	1
171	6
172	13
173	3
174	31*
180	7
182	6
183	13
185	43***
186	4
188	11
189	25*
190	1
191	23*
192	5
193	2
194	1
195	5
196	1
197	18
198	2
199	30*
200	22
201	14
202	3
203	11
204	5
205	13
206	1
207	5
208	1
209	1
211	2
218	2
225	1
228	1
231	1
238	5
244	1
250	48***
253	1
255	4
258	1

n.b. Two cases with no cause of death are excluded.

1393 163

All Cases Cause of Death (ICD Codes)

```
269      3
272      4
276      1
277      3
279      3
284      4
289      2
291      2
299      1
303      11
309      3
320      2
322      1
323      2
330      1
331      1
340      2
342      7
345      2
347      3
348      6
355      1
393      1
394      14
395      15
396      9
397      4
398      11
400      8
401      4
402      15
403      7
404      8
410      1109----------
411      19
412      348**************************************
413      1
421      2
422      3
423      1
424      1
425      2
426      3
427      29*
428      15
429      20
430      31*
431      75******
432      8
433      58****
434      1
436      61*****
437      19
```

All Cases Cause of Death

438	6
440	23*
441	55*****
442	3
444	4
445	4
446	3
447	2
450	13
451	2
452	1
453	2
458	2
463	1
466	1
470	5
480	3
481	16
482	2
485	26*
486	19
490	1
491	16
492	81********
493	9
513	1
514	2
515	1
517	9
518	5
519	9
530	2
531	7
532	18
533	8
534	1
535	1
537	1
540	4
551	2
552	1
553	2
560	3
561	1
562	5
563	4
565	1
569	5
570	1
571	75*******
573	5
574	3
575	1
576	3
577	10
581	4
582	16
583	1
584	1
590	12
592	2
593	4
596	1
599	3
600	1

All Cases Cause of Death

601	1
602	3
694	1
695	1
712	1
716	1
717	1
720	1
729	1
733	2
734	4
746	1
747	5
748	1
751	1
753	2
780	1
782	9
786	1
792	1
794	2
795	1
796	25*
805	2
807	1
810	9
812	44***
813	3
814	15
815	1
816	36**
818	6
819	57****
821	1
830	11
832	4
840	3
841	17
853	1
854	4
873	1
874	2
880	5
881	3
882	2
883	1
884	3
885	2
887	13
890	10
891	3
894	1
895	1
898	3
899	2
910	16
911	7
913	2
916	7
918	1
921	1
922	11
923	3
924	3
925	6
926	1
927	3
928	3
929	4
930	6
940	1
942	1
943	1
950	17
952	24*
953	11
954	4
955	80********
958	2
963	1
965	8
968	3
980	3
981	1
982	1
984	3
985	4
986	2
988	2
994	2
995	3

1393 166

All Cases Cause of Death

-.5	TO	49.5-	2851
49.5	TO	99.5-	439
99.5	TO	149.5-	226
149.5	TO	199.5-	120
199.5	TO	249.5-	63
249.5	TO	299.5-	45
299.5	TO	349.5-	30
349.5	TO	399.5-	20
399.5	TO	449.5-	20
449.5	TO	499.5-	13
499.5	TO	549.5-	10
549.5	TO	599.5-	16
599.5	TO	649.5-	19
649.5	TO	699.5-	9
699.5	TO	749.5-	5
749.5	TO	799.5-	7
799.5	TO	849.5-	5
849.5	TO	899.5-	0
899.5	TO	949.5-	8
949.5	TO	999.5-	3
999.5	TO	1049.5-	5
1049.5	TO	1099.5-	1
1099.5	TO	1149.5-	3
1149.5	TO	1199.5-	2
1199.5	TO	1249.5-	3
1249.5	TO	1299.5-	2
1299.5	TO	1349.5-	1
1349.5	TO	1399.5-	2
1399.5	TO	1449.5-	2
1449.5	TO	1499.5-	2
1499.5	TO	1549.5-	4
1549.5	TO	1599.5-	2
1599.5	TO	1649.5-	1
1649.5	TO	1699.5-	6
1699.5	TO	1749.5-	4
1749.5	TO	1799.5-	1
1799.5	TO	1849.5-	1
1849.5	TO	1899.5-	0
1899.5	TO	1949.5-	0
1949.5	TO	1999.5-	2
1999.5	TO	2049.5-	3
2049.5	TO	2099.5-	1
2099.5	TO	2149.5-	1
2149.5	TO	2199.5-	2
2199.5	TO	2249.5-	0
2249.5	TO	2299.5-	0
2299.5	TO	2349.5-	1
2349.5	TO	2399.5-	1
2399.5	TO	2449.5-	0
2449.5	TO	2499.5-	0
2499.5	TO	2549.5-	1
2549.5	TO	2599.5-	5
2599.5	TO	2649.5-	0
2649.5	TO	2699.5-	1
2699.5	TO	2749.5-	2
2749.5	TO	2799.5-	1
2799.5	TO	2849.5-	0
2849.5	TO	2899.5-	2
2899.5	TO	2949.5-	1
2949.5	TO	2999.5-	0
2999.5	TO	3049.5-	0
3049.5	TO	3099.5-	1
3099.5	TO	3149.5-	3
3149.5	TO	3199.5-	1
3199.5	TO	3249.5-	0
3249.5	TO	3299.5-	1
3299.5	TO	3349.5-	0
3349.5	TO	3399.5-	0
3399.5	TO	3449.5-	6
3449.5	TO	3499.5-	0
3499.5	TO	3549.5-	0
3549.5	TO	3599.5-	0
3599.5	TO	3649.5-	1
3649.5	TO	3699.5-	0
3699.5	TO	3749.5-	0
3749.5	TO	3799.5-	0
3799.5	TO	3849.5-	1
3849.5	TO	3899.5-	0
3899.5	TO	3949.5-	0
3949.5	TO	3999.5-	0
3999.5	TO	4049.5-	1
4049.5	TO	4099.5-	0
4099.5	TO	4149.5-	0
4149.5	TO	4199.5-	0
4199.5	TO	4249.5-	0
4249.5	TO	4299.5-	0
4299.5	TO	4349.5-	1
4349.5	TO	4399.5-	0
4399.5	TO	4449.5-	1

1393 167

All Cases Cumulative Lifetime Dose

```
  -.5 TO   49.5-  2922**********************************************************************************************************************
 49.5 TO   99.5-  454**************
 99.5 TO  149.5-  178*****
149.5 TO  199.5-  120*
199.5 TO  249.5-  59
249.5 TO  299.5-  36
299.5 TO  349.5-  29
349.5 TO  399.5-  16
399.5 TO  449.5-  21
449.5 TO  499.5-  11
499.5 TO  549.5-  8
549.5 TO  599.5-  20
599.5 TO  649.5-  12
649.5 TO  699.5-  5
699.5 TO  749.5-  2
749.5 TO  799.5-  9
799.5 TO  849.5-  4
849.5 TO  899.5-  1
899.5 TO  949.5-  7
949.5 TO  999.5-  3
999.5 TO 1049.5-  3
1049.5 TO 1099.5-  3
1099.5 TO 1149.5-  5
1149.5 TO 1199.5-  2
1199.5 TO 1249.5-  2
1249.5 TO 1299.5-  2
1299.5 TO 1349.5-  2
1349.5 TO 1399.5-  2
1399.5 TO 1449.5-  2
1449.5 TO 1499.5-  3
1499.5 TO 1549.5-  5
1549.5 TO 1599.5-  1
1599.5 TO 1649.5-  1
1649.5 TO 1699.5-  3
1699.5 TO 1749.5-  3
1749.5 TO 1799.5-  0
1799.5 TO 1849.5-  0
1849.5 TO 1899.5-  0
1899.5 TO 1949.5-  0
1949.5 TO 1999.5-  1
1999.5 TO 2049.5-  3
2049.5 TO 2099.5-  0
2099.5 TO 2149.5-  4
2149.5 TO 2199.5-  1
2199.5 TO 2249.5-  0
2249.5 TO 2299.5-  1
2299.5 TO 2349.5-  1
2349.5 TO 2399.5-  0
2399.5 TO 2449.5-  1
2449.5 TO 2499.5-  1
2499.5 TO 2549.5-  0
2549.5 TO 2599.5-  3
2599.5 TO 2649.5-  1
2649.5 TO 2699.5-  2
2699.5 TO 2749.5-  2
2749.5 TO 2799.5-  0
2799.5 TO 2849.5-  3
2849.5 TO 2899.5-  0
2899.5 TO 2949.5-  1
2949.5 TO 2999.5-  0
2999.5 TO 3049.5-  0
3049.5 TO 3099.5-  1
3099.5 TO 3149.5-  2
3149.5 TO 3199.5-  1
3199.5 TO 3249.5-  0
3249.5 TO 3299.5-  0
3299.5 TO 3349.5-  0
3349.5 TO 3399.5-  0
3399.5 TO 3449.5-  3
3449.5 TO 3499.5-  0
3499.5 TO 3549.5-  0
3549.5 TO 3599.5-  2
3599.5 TO 3649.5-  0
3649.5 TO 3699.5-  0
3699.5 TO 3749.5-  0
3749.5 TO 3799.5-  0
3799.5 TO 3849.5-  0
3849.5 TO 3899.5-  0
3899.5 TO 3949.5-  1
3949.5 TO 3999.5-  0
3999.5 TO 4049.5-  1
```

1393 168

All Cases Cumulative Dose
3 Years Before Death

```
  -.5 TO   49.5-  3005**********************************************************************************************************************
 49.5 TO   99.5-  433**********
 99.5 TO  149.5-  188****
149.5 TO  199.5-  87*
199.5 TO  249.5-  58
249.5 TO  299.5-  32
299.5 TO  349.5-  21
349.5 TO  399.5-  13
399.5 TO  449.5-  12
449.5 TO  499.5-  16
499.5 TO  549.5-  9
549.5 TO  599.5-  14
599.5 TO  649.5-  9
649.5 TO  699.5-  5
699.5 TO  749.5-  7
749.5 TO  799.5-  8
799.5 TO  849.5-  2
849.5 TO  899.5-  1
899.5 TO  949.5-  8
949.5 TO  999.5-  4
999.5 TO 1049.5-  4
1049.5 TO 1099.5-  1
1099.5 TO 1149.5-  2
1149.5 TO 1199.5-  2
1199.5 TO 1249.5-  3
1249.5 TO 1299.5-  1
1299.5 TO 1349.5-  4
1349.5 TO 1399.5-  1
1399.5 TO 1449.5-  1
1449.5 TO 1499.5-  0
1499.5 TO 1549.5-  2
1549.5 TO 1599.5-  1
1599.5 TO 1649.5-  0
1649.5 TO 1699.5-  2
1699.5 TO 1749.5-  2
1749.5 TO 1799.5-  1
1799.5 TO 1849.5-  1
1849.5 TO 1899.5-  2
1899.5 TO 1949.5-  1
1949.5 TO 1999.5-  2
1999.5 TO 2049.5-  3
2049.5 TO 2099.5-  0
2099.5 TO 2149.5-  0
2149.5 TO 2199.5-  1
2199.5 TO 2249.5-  2
2249.5 TO 2299.5-  2
2299.5 TO 2349.5-  1
2349.5 TO 2399.5-  1
2399.5 TO 2449.5-  1
2449.5 TO 2499.5-  2
2499.5 TO 2549.5-  0
2549.5 TO 2599.5-  2
2599.5 TO 2649.5-  0
2649.5 TO 2699.5-  2
2699.5 TO 2749.5-  2
2749.5 TO 2799.5-  0
2799.5 TO 2849.5-  0
2849.5 TO 2899.5-  0
2899.5 TO 2949.5-  1
2949.5 TO 2999.5-  1
2999.5 TO 3049.5-  1
3049.5 TO 3099.5-  0
3099.5 TO 3149.5-  1
3149.5 TO 3199.5-  0
3199.5 TO 3249.5-  0
3249.5 TO 3299.5-  0
3299.5 TO 3349.5-  0
3349.5 TO 3399.5-  0
3399.5 TO 3449.5-  2
3449.5 TO 3499.5-  1
3499.5 TO 3549.5-  0
3549.5 TO 3599.5-  0
3599.5 TO 3649.5-  0
3649.5 TO 3699.5-  0
3699.5 TO 3749.5-  0
3749.5 TO 3799.5-  0
3799.5 TO 3849.5-  1
```

1393 169

All Cases Cumulative
5 Years Before Dea

```
  -.5 TO   49.5-  3264**********************************************************************************************************
 49.5 TO   99.5-  364*********
 99.5 TO  149.5-  126*
149.5 TO  199.5-  55
199.5 TO  249.5-  44
249.5 TO  299.5-  24
299.5 TO  349.5-  21
349.5 TO  399.5-  6
399.5 TO  449.5-  13
449.5 TO  499.5-  10
499.5 TO  549.5-  6
549.5 TO  599.5-  10
599.5 TO  649.5-  6
649.5 TO  699.5-  4
699.5 TO  749.5-  3
749.5 TO  799.5-  1
799.5 TO  849.5-  3
849.5 TO  899.5-  2
899.5 TO  949.5-  1
949.5 TO  999.5-  0
999.5 TO 1049.5-  1
1049.5 TO 1099.5-  3
1099.5 TO 1149.5-  0
1149.5 TO 1199.5-  0
1199.5 TO 1249.5-  3
1249.5 TO 1299.5-  2
1299.5 TO 1349.5-  3
1349.5 TO 1399.5-  3
1399.5 TO 1449.5-  1
1449.5 TO 1499.5-  2
1499.5 TO 1549.5-  1
1549.5 TO 1599.5-  2
1599.5 TO 1649.5-  2
1649.5 TO 1699.5-  1
1699.5 TO 1749.5-  1
1749.5 TO 1799.5-  0
1799.5 TO 1849.5-  0
1849.5 TO 1899.5-  0
1899.5 TO 1949.5-  0
1949.5 TO 1999.5-  0
1999.5 TO 2049.5-  0
2049.5 TO 2099.5-  0
2099.5 TO 2149.5-  0
2149.5 TO 2199.5-  0
2199.5 TO 2249.5-  0
2249.5 TO 2299.5-  1
2299.5 TO 2349.5-  1
2349.5 TO 2399.5-  0
2399.5 TO 2449.5-  1
2449.5 TO 2499.5-  0
2499.5 TO 2549.5-  1
```

All Cases Cumulative Dose
10 Years Before Death

```
  -.5 TO   49.5-  3506**********************************************************************************************************
 49.5 TO   99.5-  242*****
 99.5 TO  149.5-  99*
149.5 TO  199.5-  42
199.5 TO  249.5-  35
249.5 TO  299.5-  17
299.5 TO  349.5-  16
349.5 TO  399.5-  2
399.5 TO  449.5-  7
449.5 TO  499.5-  5
499.5 TO  549.5-  3
549.5 TO  599.5-  4
599.5 TO  649.5-  4
649.5 TO  699.5-  2
699.5 TO  749.5-  1
749.5 TO  799.5-  1
799.5 TO  849.5-  0
849.5 TO  899.5-  1
899.5 TO  949.5-  2
949.5 TO  999.5-  1
999.5 TO 1049.5-  0
1049.5 TO 1099.5-  0
1099.5 TO 1149.5-  1
1149.5 TO 1199.5-  0
1199.5 TO 1249.5-  1
```

All Cases Cumulative Dose
15 Years Before Death

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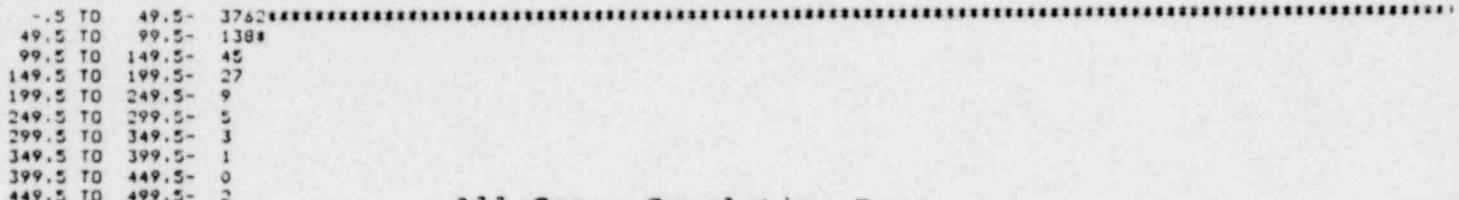
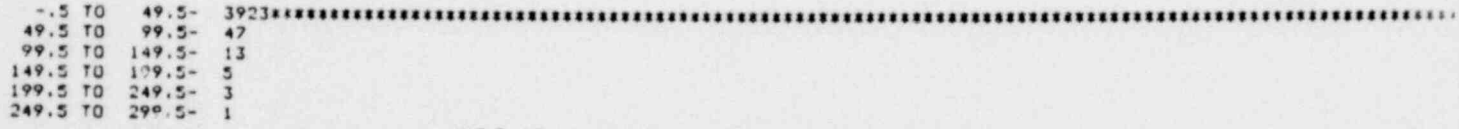
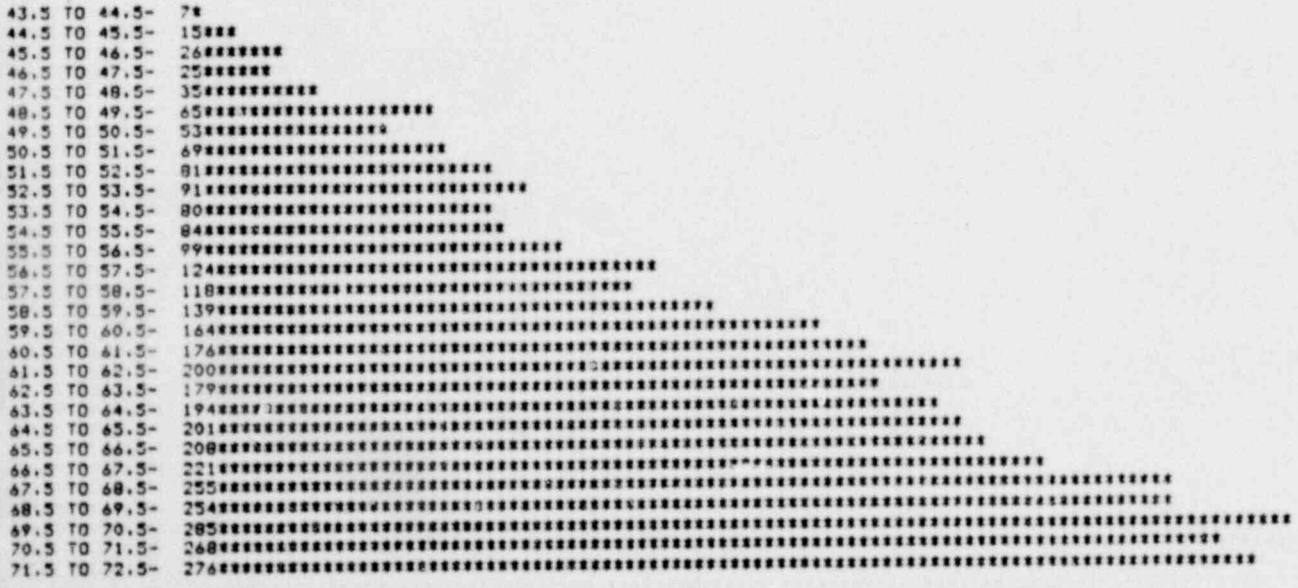


All Cases Cumulative Dose
20 Years Before Death

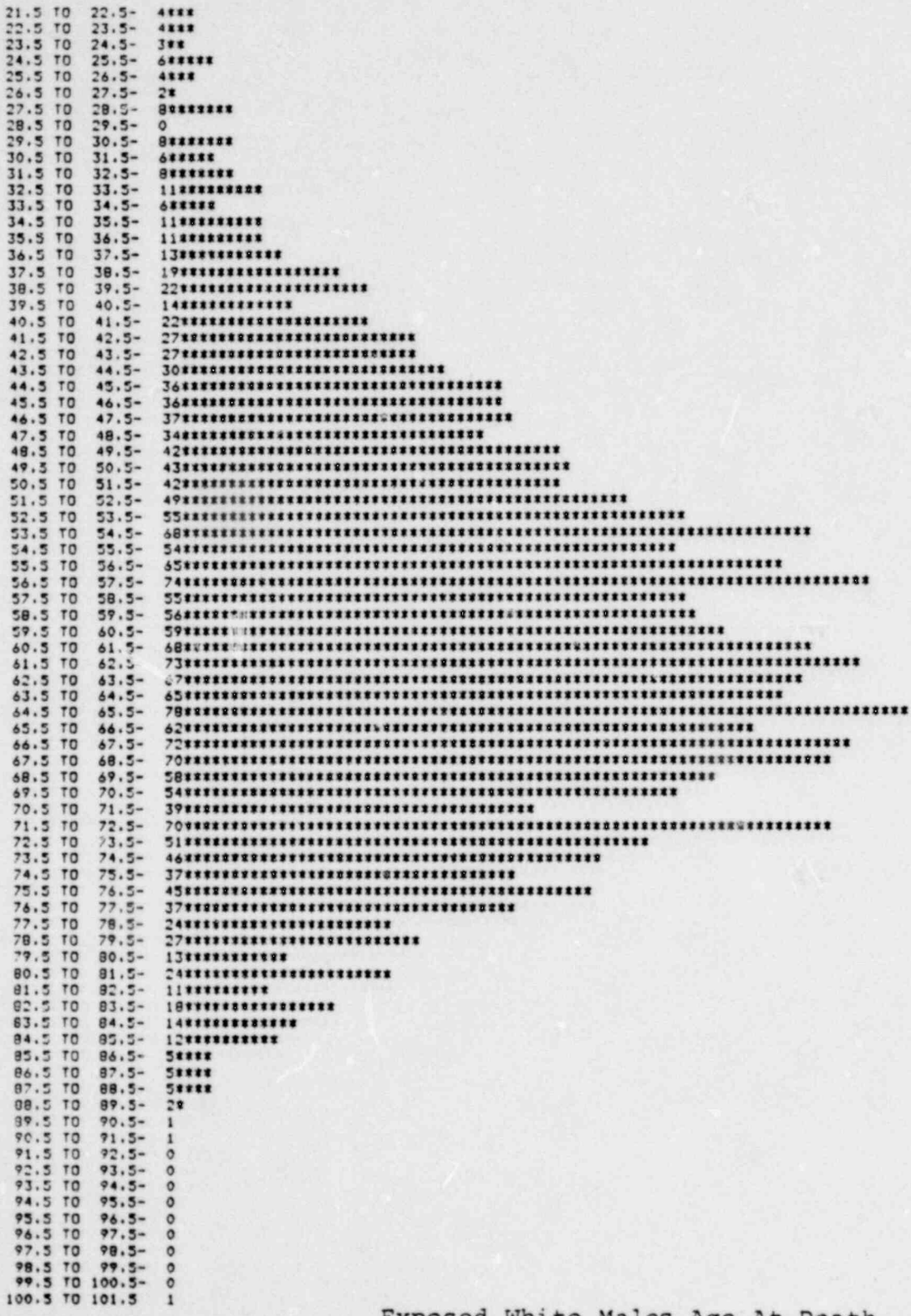


All Cases Cumulative Dose
25 Years Before Death

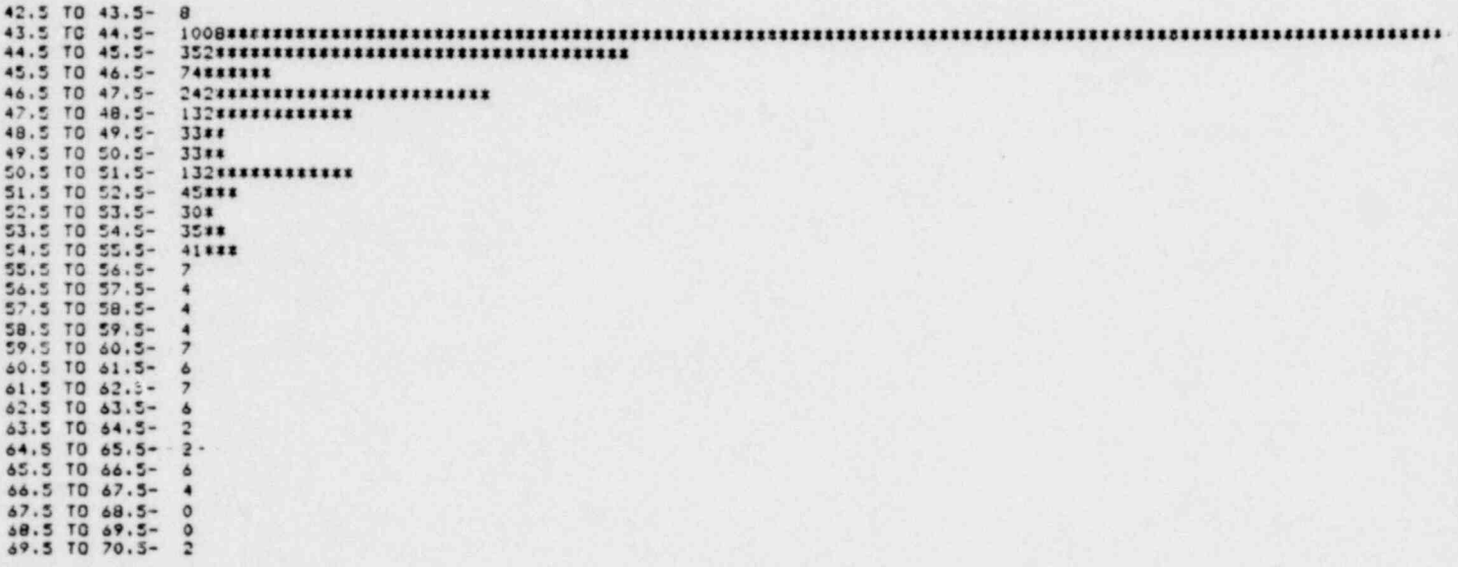


All Cases Year of Death

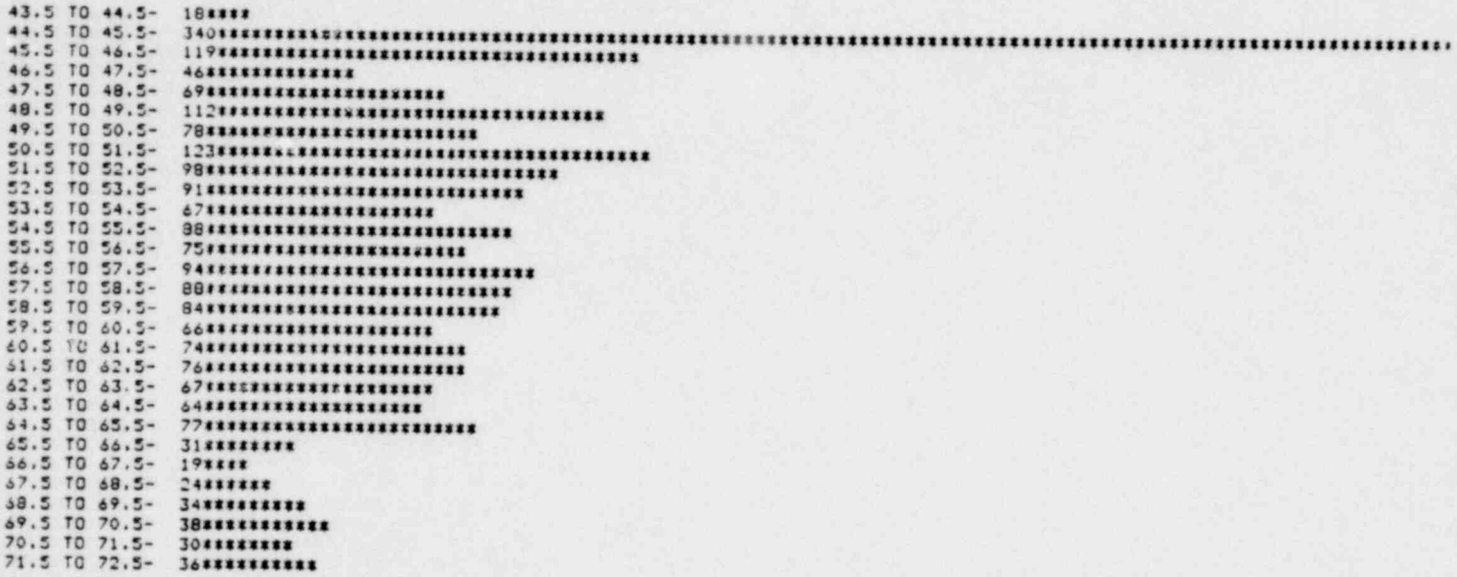
1393 171



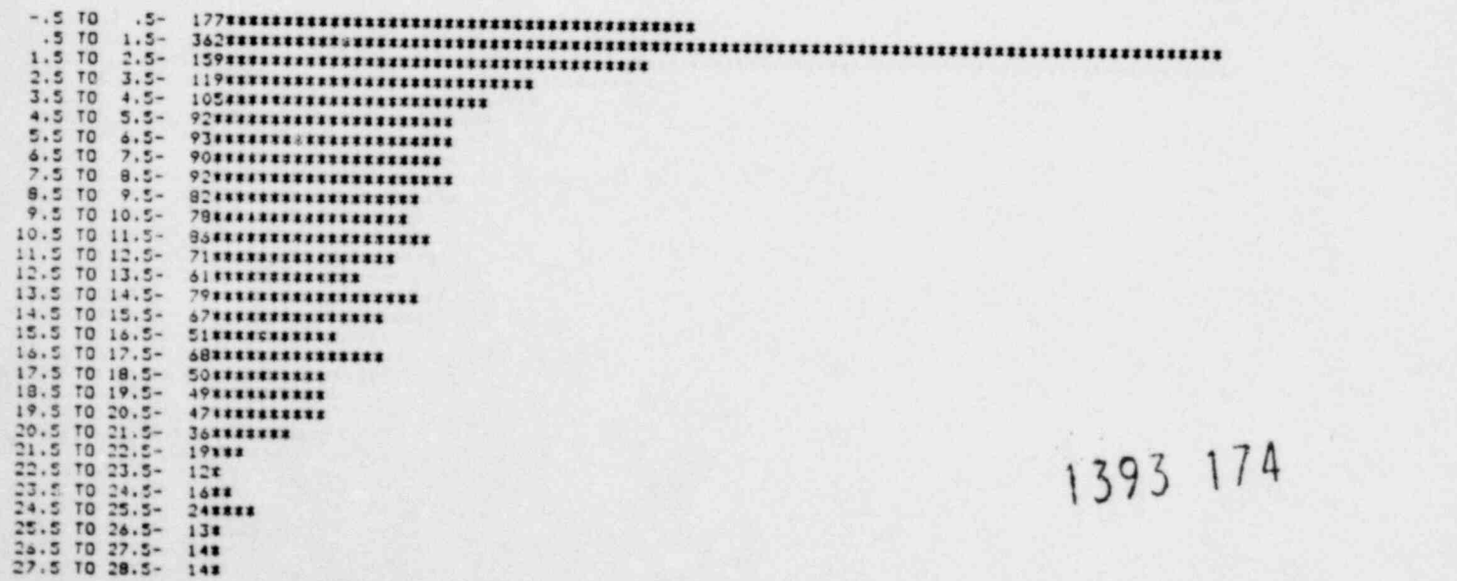
Exposed White Males Age At Death



Exposed White Males Initial Year of Employment



Exposed White Males Final Year of Employment



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Exposed White Male Total Years Employed

```
  9      1
 11      5
 38      1
 40      1
 43      2
 52      1
 70      2
 93      1
 95      1
112      1
136      1
141      3
142      2
144      2
145      3
146      1
147      1
148      1
149      1
150      9
151      26**
152      1
153      50******
154      16*
155      7
156      3
157      32***
158      1
159      1
160      2
161      7
162      128*********.*********
163      1
170      1
171      3
172      9
173      1
185      21*
186      3
188      7
189      15
190      1
191      14
192      3
193      1
195      2
197      8
198      2
199      13
200      16*
201      10
202      2
203      8
204      2
205      6
206      1
207      1
209      1
211      2
225      1
238      1
244      1
250      26**
```

n.b. One case with no cause of death is excluded.

Exposed White Males Cause of Death (ICD codes)

```
255      3
258      1
269      1
272      3
276      1
277      1
279      2
284      1
303      5
309      1
320      2
323      2
340      1
342      2
347      2
348      5
355      1
394      6
395      11
396      3
397      2
398      3
400      7
401      2
402      7
403      4
404      3
410      703**********************************************************************************************************
411      11
412      180****************************
421      1
422      1
425      2
427      18*
428      3
429      11
430      14
431      34****
432      5
433      35****
434      1
436      36****
437      15
438      2
440      13
441      33***
442      2
444      1
445      2
446      2
450      4
451      1
452      1
453      1
458      1
470      2
480      2
481      5
485      9
486      10
490      1
491      11
492      46******
493      5
```

Exposed White Males Cause of Death (ICD codes)

513	1
514	1
517	4
518	3
519	6
530	1
531	4
532	8
533	6
534	1
537	1
540	3
551	2
552	1
560	2
561	1
562	4
569	2
570	1
571	35****
573	3
574	2
575	1
576	2
577	5
581	1
582	8
584	1
590	6
592	1
593	2
599	1
601	1
602	2
695	1
716	1
729	1
733	2
734	2
747	2
748	1
753	2
782	5
786	1
792	1
795	1
796	11
805	1
810	5
812	28***
813	3
814	5
816	16*
818	4
819	29***
830	8
832	2
840	3
841	12
873	1
874	2
880	1
881	2
882	2
884	3
885	2
887	7
890	2
891	1
895	1
898	1
899	1
910	8
911	4
913	1
916	2
918	1
922	10
923	3
924	1
925	4
926	1
927	1
928	2
929	1
930	3
943	1
950	3
952	13
953	6
955	53*******
958	1
980	2
985	2
986	1
988	1
994	1

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Exposed White Males Cause of Death (ICD codes)

-.5	TO	49.5-	1141
49.5	TO	99.5-	406
99.5	TO	149.5-	218
149.5	TO	199.5-	116
199.5	TO	249.5-	60
249.5	TO	299.5-	44
299.5	TO	349.5-	30
349.5	TO	399.5-	19
399.5	TO	449.5-	20
449.5	TO	499.5-	13
499.5	TO	549.5-	9
549.5	TO	599.5-	14
599.5	TO	649.5-	17
649.5	TO	699.5-	9
699.5	TO	749.5-	5
749.5	TO	799.5-	7
799.5	TO	849.5-	5
849.5	TO	899.5-	0
899.5	TO	949.5-	8
949.5	TO	999.5-	3
999.5	TO	1049.5-	5
1049.5	TO	1099.5-	1
1099.5	TO	1149.5-	3
1149.5	TO	1199.5-	2
1199.5	TO	1249.5-	3
1249.5	TO	1299.5-	2
1299.5	TO	1349.5-	1
1349.5	TO	1399.5-	2
1399.5	TO	1449.5-	1
1449.5	TO	1499.5-	2
1499.5	TO	1549.5-	4
1549.5	TO	1599.5-	2
1599.5	TO	1649.5-	1
1649.5	TO	1699.5-	6
1699.5	TO	1749.5-	4
1749.5	TO	1799.5-	1
1799.5	TO	1849.5-	1
1849.5	TO	1899.5-	0
1899.5	TO	1949.5-	0
1949.5	TO	1999.5-	2
1999.5	TO	2049.5-	3
2049.5	TO	2099.5-	1
2099.5	TO	2149.5-	1
2149.5	TO	2199.5-	2
2199.5	TO	2249.5-	0
2249.5	TO	2299.5-	0
2299.5	TO	2349.5-	1
2349.5	TO	2399.5-	1
2399.5	TO	2449.5-	0
2449.5	TO	2499.5-	0
2499.5	TO	2549.5-	1
2549.5	TO	2599.5-	5
2599.5	TO	2649.5-	0
2649.5	TO	2699.5-	1
2699.5	TO	2749.5-	2
2749.5	TO	2799.5-	1
2799.5	TO	2849.5-	0
2849.5	TO	2899.5-	2
2899.5	TO	2949.5-	1
2949.5	TO	2999.5-	0
2999.5	TO	3049.5-	0
3049.5	TO	3099.5-	1
3099.5	TO	3149.5-	3
3149.5	TO	3199.5-	1
3199.5	TO	3249.5-	0
3249.5	TO	3299.5-	1
3299.5	TO	3349.5-	0
3349.5	TO	3399.5-	0
3399.5	TO	3449.5-	6
3449.5	TO	3499.5-	0
3499.5	TO	3549.5-	0
3549.5	TO	3599.5-	0
3599.5	TO	3649.5-	1
3649.5	TO	3699.5-	0
3699.5	TO	3749.5-	0
3749.5	TO	3799.5-	0
3799.5	TO	3849.5-	1
3849.5	TO	3899.5-	0
3899.5	TO	3949.5-	0
3949.5	TO	3999.5-	0
3999.5	TO	4049.5-	1
4049.5	TO	4099.5-	0
4099.5	TO	4149.5-	0
4149.5	TO	4199.5-	0
4199.5	TO	4249.5-	0
4249.5	TO	4299.5-	0
4299.5	TO	4349.5-	1
4349.5	TO	4399.5-	0
4399.5	TO	4449.5-	1

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Exposed White Males Cumulative Lifetime Dose

-.5	TO	49.5-	1206
49.5	TO	99.5-	421
99.5	TO	149.5-	174
149.5	TO	199.5-	117
199.5	TO	249.5-	56
249.5	TO	299.5-	35
299.5	TO	349.5-	29
349.5	TO	399.5-	16
399.5	TO	449.5-	21
449.5	TO	499.5-	10
499.5	TO	549.5-	7
549.5	TO	599.5-	18
599.5	TO	649.5-	11
649.5	TO	699.5-	5
699.5	TO	749.5-	2
749.5	TO	799.5-	9
799.5	TO	849.5-	4
849.5	TO	899.5-	1
899.5	TO	949.5-	7
949.5	TO	999.5-	3
999.5	TO	1049.5-	3
1049.5	TO	1099.5-	3
1099.5	TO	1149.5-	5
1149.5	TO	1199.5-	2
1199.5	TO	1249.5-	2
1249.5	TO	1299.5-	2
1299.5	TO	1349.5-	2
1349.5	TO	1399.5-	2
1399.5	TO	1449.5-	1
1449.5	TO	1499.5-	3
1499.5	TO	1549.5-	5
1549.5	TO	1599.5-	1
1599.5	TO	1649.5-	1
1649.5	TO	1699.5-	3
1699.5	TO	1749.5-	3
1749.5	TO	1799.5-	0
1799.5	TO	1849.5-	0
1849.5	TO	1899.5-	0
1899.5	TO	1949.5-	0
1949.5	TO	1999.5-	1
1999.5	TO	2049.5-	3
2049.5	TO	2099.5-	0
2099.5	TO	2149.5-	4
2149.5	TO	2199.5-	1
2199.5	TO	2249.5-	0
2249.5	TO	2299.5-	1
2299.5	TO	2349.5-	1
2349.5	TO	2399.5-	0
2399.5	TO	2449.5-	1
2449.5	TO	2499.5-	1
2499.5	TO	2549.5-	0
2549.5	TO	2599.5-	3
2599.5	TO	2649.5-	1
2649.5	TO	2699.5-	2
2699.5	TO	2749.5-	2
2749.5	TO	2799.5-	0
2799.5	TO	2849.5-	3
2849.5	TO	2899.5-	0
2899.5	TO	2949.5-	1
2949.5	TO	2999.5-	0
2999.5	TO	3049.5-	0
3049.5	TO	3099.5-	1
3099.5	TO	3149.5-	2
3149.5	TO	3199.5-	1
3199.5	TO	3249.5-	0
3249.5	TO	3299.5-	0
3299.5	TO	3349.5-	0
3349.5	TO	3399.5-	0
3399.5	TO	3449.5-	3
3449.5	TO	3499.5-	0
3499.5	TO	3549.5-	0
3549.5	TO	3599.5-	2
3599.5	TO	3649.5-	0
3649.5	TO	3699.5-	0
3699.5	TO	3749.5-	0
3749.5	TO	3799.5-	0
3799.5	TO	3849.5-	0
3849.5	TO	3899.5-	0
3899.5	TO	3949.5-	1
3949.5	TO	3999.5-	0
3999.5	TO	4049.5-	1

1393 179

Exposed White Males
Cumulative Dose 3 Years Before Death

```
  -.5 TO   49.5-  1281**************************************************************************************************
 49.5 TO   99.5-  407*********************************
 99.5 TO  149.5-  182**************
149.5 TO  199.5-  86******
199.5 TO  249.5-  55****
249.5 TO  299.5-  32*
299.5 TO  349.5-  21
349.5 TO  399.5-  13
399.5 TO  449.5-  10
449.5 TO  499.5-  16
499.5 TO  549.5-  8
549.5 TO  599.5-  13
599.5 TO  649.5-  8
649.5 TO  699.5-  5
699.5 TO  749.5-  7
749.5 TO  799.5-  8
799.5 TO  849.5-  2
849.5 TO  899.5-  1
899.5 TO  949.5-  8
949.5 TO  999.5-  4
999.5 TO 1049.5-  4
1049.5 TO 1099.5-  1
1099.5 TO 1149.5-  2
1149.5 TO 1199.5-  2
1199.5 TO 1249.5-  3
1249.5 TO 1299.5-  1
1299.5 TO 1349.5-  3
1349.5 TO 1399.5-  1
1399.5 TO 1449.5-  1
1449.5 TO 1499.5-  0
1499.5 TO 1549.5-  2
1549.5 TO 1599.5-  1
1599.5 TO 1649.5-  0
1649.5 TO 1699.5-  2
1699.5 TO 1749.5-  2
1749.5 TO 1799.5-  1
1799.5 TO 1849.5-  1
1849.5 TO 1899.5-  2
1899.5 TO 1949.5-  1
1949.5 TO 1999.5-  2
1999.5 TO 2049.5-  3
2049.5 TO 2099.5-  0
2099.5 TO 2149.5-  0
2149.5 TO 2199.5-  1
2199.5 TO 2249.5-  2
2249.5 TO 2299.5-  2
2299.5 TO 2349.5-  1
2349.5 TO 2399.5-  1
2399.5 TO 2449.5-  1
2449.5 TO 2499.5-  2
2499.5 TO 2549.5-  0
2549.5 TO 2599.5-  2
2599.5 TO 2649.5-  0
2649.5 TO 2699.5-  2
2699.5 TO 2749.5-  2
2749.5 TO 2799.5-  0
2799.5 TO 2849.5-  0
2849.5 TO 2899.5-  0
2899.5 TO 2949.5-  1
2949.5 TO 2999.5-  1
2999.5 TO 3049.5-  1
3049.5 TO 3099.5-  0
3099.5 TO 3149.5-  1
3149.5 TO 3199.5-  0
3199.5 TO 3249.5-  0
3249.5 TO 3299.5-  0
3299.5 TO 3349.5-  0
3349.5 TO 3399.5-  0
3399.5 TO 3449.5-  2
3449.5 TO 3499.5-  1
3499.5 TO 3549.5-  0
3549.5 TO 3599.5-  0
3599.5 TO 3649.5-  0
3649.5 TO 3699.5-  0
3699.5 TO 3749.5-  0
3749.5 TO 3799.5-  0
3799.5 TO 3849.5-  1
```

Exposed White Males
Cumulative Dose 5 Years Before Death

1393 180

```
  -.5 TO   49.5-  1526**************************************************************************************************
 49.5 TO   99.5-  345**********************
 99.5 TO  149.5-  125*******
149.5 TO  199.5-  55**
199.5 TO  249.5-  42*
249.5 TO  299.5-  22
299.5 TO  349.5-  19
349.5 TO  399.5-  6
399.5 TO  449.5-  12
449.5 TO  499.5-  10
499.5 TO  549.5-  6
549.5 TO  599.5-  10
599.5 TO  649.5-  5
649.5 TO  699.5-  4
699.5 TO  749.5-  3
749.5 TO  799.5-  1
799.5 TO  849.5-  3
849.5 TO  899.5-  2
899.5 TO  949.5-  1
949.5 TO  999.5-  0
999.5 TO 1049.5-  1
1049.5 TO 1099.5-  3
1099.5 TO 1149.5-  0
1149.5 TO 1199.5-  0
1199.5 TO 1249.5-  3
1249.5 TO 1299.5-  2
1299.5 TO 1349.5-  3
1349.5 TO 1399.5-  3
1399.5 TO 1449.5-  1
1449.5 TO 1499.5-  2
1499.5 TO 1549.5-  1
1549.5 TO 1599.5-  2
1599.5 TO 1649.5-  2
1649.5 TO 1699.5-  1
1699.5 TO 1749.5-  1
1749.5 TO 1799.5-  0
1799.5 TO 1849.5-  0
1849.5 TO 1899.5-  0
1899.5 TO 1949.5-  0
1949.5 TO 1999.5-  0
1999.5 TO 2049.5-  0
2049.5 TO 2099.5-  0
2099.5 TO 2149.5-  0
2149.5 TO 2199.5-  0
2199.5 TO 2249.5-  0
2249.5 TO 2299.5-  1
2299.5 TO 2349.5-  1
2349.5 TO 2399.5-  0
2399.5 TO 2449.5-  1
2449.5 TO 2499.5-  0
2499.5 TO 2549.5-  1
```

Exposed White Males
Cumulative Dose 10 Years Before Death

```
  -.5 TO   49.5-  1758**************************************************************************************************
 49.5 TO   99.5-  228***********
 99.5 TO  149.5-  97****
149.5 TO  199.5-  41*
199.5 TO  249.5-  34
249.5 TO  299.5-  17
299.5 TO  349.5-  16
349.5 TO  399.5-  2
399.5 TO  449.5-  7
449.5 TO  499.5-  5
499.5 TO  549.5-  3
549.5 TO  599.5-  4
599.5 TO  649.5-  4
649.5 TO  699.5-  2
699.5 TO  749.5-  1
749.5 TO  799.5-  1
799.5 TO  849.5-  0
849.5 TO  899.5-  1
899.5 TO  949.5-  2
949.5 TO  999.5-  1
999.5 TO 1049.5-  0
1049.5 TO 1099.5-  0
1099.5 TO 1149.5-  1
1149.5 TO 1199.5-  0
1199.5 TO 1249.5-  1
```

Exposed White Males
Cumulative Dose 15 Years Before Death

```
  -.5 TO   49.5-  2004**************************************************************************************************
 49.5 TO   99.5-  131****
 99.5 TO  149.5-  45
149.5 TO  199.5-  26
199.5 TO  249.5-  9
249.5 TO  299.5-  5
299.5 TO  349.5-  3
349.5 TO  399.5-  1
399.5 TO  449.5-  0
449.5 TO  499.5-  2
```

Exposed White Males
Cumulative Dose 20 Years Before Death

```
  -.5 TO   49.5-  2159**************************************************************************************************
 49.5 TO   99.5-  46
 99.5 TO  149.5-  13
149.5 TO  199.5-  4
199.5 TO  249.5-  3
249.5 TO  299.5-  1
```

Exposed White Males
Cumulative Dose 25 Years Before Death

```
43.5 TO 44.5-  1
44.5 TO 45.5-  5*
45.5 TO 46.5-  7**
46.5 TO 47.5-  8***
47.5 TO 48.5-  6**
48.5 TO 49.5-  23*********
49.5 TO 50.5-  21********
50.5 TO 51.5-  30*************
51.5 TO 52.5-  38******************
52.5 TO 53.5-  47***********************
53.5 TO 54.5-  37*****************
54.5 TO 55.5-  39******************
55.5 TO 56.5-  52************************
56.5 TO 57.5-  59****************************
57.5 TO 58.5-  72***********************************
58.5 TO 59.5-  80***************************************
59.5 TO 60.5-  85*****************************************
60.5 TO 61.5-  96***********************************************
61.5 TO 62.5-  102**************************************************
62.5 TO 63.5-  105***************************************************
63.5 TO 64.5-  111******************************************************
64.5 TO 65.5-  105***************************************************
65.5 TO 66.5-  132****************************************************************
66.5 TO 67.5-  124************************************************************
67.5 TO 68.5-  146*************************************************************************
68.5 TO 69.5-  159*****************************************************************************
69.5 TO 70.5-  183*************************************************************************************
70.5 TO 71.5-  170**********************************************************************************
71.5 TO 72.5-  183*************************************************************************************
```

Exposed White Males Year of Death

APPENDIX B

CAUSE OF DEATH DISTRIBUTION

NO. OF CASES	CODE	DESCRIPTION
1	8	Enteritis due to other specified organism
4	9	Diarrhoeal disease
13	11	Pulmonary tuberculosis
1	23	Brucellosis
2	38	Septicaemia
1	39	Other bacterial diseases
2	40	Acute paralytic poliomyelitis specified as bulbar
1	41	Acute poliomyelitis with other paralysis
2	43	Acute poliomyelitis, unspecified
1	46	Other enterovirus diseases of central nervous system
1	52	Chickenpox
2	70	Infectious hepatitis
1	93	Cardiovascular syphilis
1	95	Other forms of late syphilis, with symptoms
1	112	Moniliasis
1	136	Other and unspecified infective and parasitic diseases
1	140	Malignant neoplasm of lip
6	141	Malignant neoplasm of tongue
3	142	Malignant neoplasm of salivary gland
2	144	Malignant neoplasm of floor of mouth
3	145	Malignant neoplasm of other and unspecified parts of mouth
3	146	Malignant neoplasm of oropharynx
1	147	Malignant neoplasm of nasopharynx

NO. OF CASES	CODE	DESCRIPTION
2	148	Malignant neoplasm of hypopharynx
2	149	Malignant neoplasm of pharynx, unspecified
18	150	Malignant neoplasm of oesophagus
39	151	Malignant neoplasm of stomach
2	152	Malignant neoplasm of small intestine, including duodenum
79	153	Malignant neoplasm of large intestine, except rectum
23*	154	Malignant neoplasm of rectum and rectosigmoid junction
9	155	Malignant neoplasm of liver and intrahepatic bile ducts, specified as primary
11	156	Malignant neoplasm of gallbladder and bile ducts
53	157	Malignant neoplasm of pancreas
3	158	Malignant neoplasm of peritoneum and retroperitoneal tissue
1	159	Malignant neoplasm of unspecified digestive organs
2	160	Malignant neoplasm of nose, nasal cavities, middle ear and accessory sinuses
10	161	Malignant neoplasm of larynx
202	162	Malignant neoplasm of trachea, bronchus and lung
1	163	Malignant neoplasm of other and unspecified respiratory organs
1	170	Malignant neoplasm of bone
6	171	Malignant neoplasm of connective and other soft tissue
13	172	Malignant melanoma of skin
3	173	Other malignant neoplasm of skin

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NO. OF CASES	CODE	DESCRIPTION
31	174	Malignant neoplasm of breast
7	180	Malignant neoplasm of cervix uteri
6	182	Other malignant neoplasm of uterus
13	183	Malignant neoplasm of ovary, fallopian tube and broad ligament
43	185	Malignant neoplasm of prostate
4	186	Malignant neoplasm of testis
11	188	Malignant neoplasm of bladder
25	189	Malignant neoplasm of other and unspecified urinary organs
1	190	Malignant neoplasm of eye
23	191	Malignant neoplasm of brain
5	192	Malignant neoplasm of other parts of nervous system
2	193	Malignant neoplasm of thyroid gland
1	194	Malignant neoplasm of other endocrine glands
5	195	Malignant neoplasm of ill-defined sites
1	196	Secondary and unspecified malignant neoplasm of lymph nodes
18	197	Secondary malignant neoplasm of respiratory and digestive systems
2	198	Other secondary malignant neoplasm
30	199	Malignant neoplasm without specification of site
22	200	Lymphosarcoma and reticulum-cell sarcoma
14	201	Hodgkin's disease
3	202	Other neoplasms of lymphoid tissue
11	203	Multiple myeloma
5	204	Lymphatic leukaemia

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NO. OF CASES	CODE	DESCRIPTION
13	205	Myeloid leukaemia
1	206	Monocytic leukaemia
5	207	Other and unspecified leukaemia
1	208	Polycythaemia vera
1	209	Myelofibrosis
2	211	Benign neoplasm of other parts of digestive system
2	218	Uterine fibroma
1	225	Benign neoplasm of brain and other parts of nervous system
1	228	Benign neoplasm of other and unspecified organs and tissues
1	231	Neoplasm of unspecified nature of respiratory organs
5	238	Neoplasm of unspecified nature of eye, brain and other parts of nervous system
1	244	Myxoedema
48	250	Diabetes mellitus
1	253	Diseases of pituitary gland
4	255	Diseases of adrenal glands
1	258	Polyglandular dysfunction and other diseases of endocrine glands
3	269	Other nutritional deficiency
4	272	Congenital disorders of lipid metabolism
1	276	Amyloidosis
3	277	Obesity not specified as of endocrine origin
3	279	Other and unspecified metabolic diseases
4	284	Aplastic anaemia
2	289	Other diseases of blood and blood-forming organs

NO. OF CASES	CODE	DESCRIPTION
2	291	Alcoholic psychosis
1	299	Unspecified psychosis
11	303	Alcoholism
3	309	Mental disorders not specified as psychotic associated with physical conditions
2	320	Meningitis
1	322	Intracranial and intraspinal abscess
2	323	Encephalitis, myelitis, and encephalomyelitis
1	330	Hereditary neuromuscular disorders
1	331	Hereditary diseases of the striato-pallidal system
2	340	Multiple sclerosis
7	342	Paralysis agitans
2	345	Epilepsy
3	347	Other diseases of brain
6	348	Motor neurone disease
1	355	Other and unspecified forms of neuralgia and neuritis
1	393	Disease of pericardium
14	394	Disease of mitral valve
15	395	Diseases of aortic valve
9	396	Diseases of mitral and aortic valves
4	397	Diseases of other endocardial structures
11	398	Other heart disease, specified as rheumatic
8	400	Malignant hypertension
4	401	Essential benign hypertension
15	402	Hypertensive heart disease

NO. OF CASES	CODE	DESCRIPTION
7	403	Hypertensive renal disease
8	404	Hypertensive heart and renal disease
1109	410	Acute myocardial infarction
19	411	Other acute and subacute forms of ischaemic heart disease
348	412	Chronic ischaemic heart disease
1	413	Angina pectoris
2	421	Acute and sub-acute endocarditis
3	422	Acute myocarditis
1	423	Chronic disease of pericardium, non-rheumatic
1	424	Chronic disease of endocardium
2	425	Cardiomyopathy
3	426	Pulmonary heart disease
29	427	Symptomatic heart disease
15	428	Other myocardial insufficiency
20	429	Ill-defined heart disease
31	430	Subarachnoid haemorrhage
75	431	Cerebral haemorrhage
8	432	Occlusion of pre-cerebral arteries
58	433	Cerebral thrombosis
1	434	Cerebral embolism
61	436	Acute but ill-defined cerebrovascular disease
19	437	Generalized ischaemic cerebrovascular disease
6	438	Other and ill-defined cerebrovascular disease

NO. OF CASES	CODE	DESCRIPTION
23	440	Arteriosclerosis
55	441	Aortic aneurysm (non-syphilitic)
3	442	Other aneurysm
4	444	Arterial embolism and thrombosis
4	445	Gangrene
3	446	Polyarteritis nodosa and allied conditions
2	447	Other diseases of arteries and arterioles
13	450	Pulmonary embolism and infarction
2	451	Phlebitis and thrombophlebitis
1	452	Portal vein thrombosis
2	453	Other venous embolism and thrombosis
2	458	Other diseases of circulatory system
1	463	Acute tonsillitis
1	466	Acute bronchitis and bronchiolitis
5	470	Influenza unqualified
3	480	Viral pneumonia
16	481	Pneumococcal pneumonia
2	482	Other bacterial pneumonia
26	485	Bronchopneumonia, unspecified
19	486	Pneumonia, unspecified
1	490	Bronchitis, unqualified
16	491	Chronic bronchitis
81	492	Emphysema
9	493	Asthma
1	513	Abscess of lung
2	514	Pulmonary congestion and hypostasis

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NO. OF CASES	CODE	DESCRIPTION
1	515	Pneumoconiosis due to silica and silicates
9	517	Other chronic interstritial pneumonia
5	518	Bronchiectasis
9	519	Other diseases of respiratory system
2	530	Diseases of oesophagus
7	531	Ulcer of stomach
18	532	Ulcer of duodenum
8	533	Peptic ulcer, site unspecified
1	534	Gastrojejunal ulcer
1	535	Gastritis and duodenitis
1	537	Other diseases of stomach and duodenum
4	540	Acute appendicitis
2	551	Other hernia of abdominal cavity without mention of obstruction
1	552	Inguinal hernia with obstruction
2	553	Other hernia of abdominal cavity with obstruction
3	560	Intestinal obstruction without mention of hernia
1	561	Gastro-enteritis and colitis, except ulcerative, of non-infectious origin
5	562	Diverticula of intestine
4	563	Chronic enteritis and ulcerative colitis
1	565	Anal fissure and fistula
5	569	Other diseases of intestines and peritoneum
1	570	Acute and subacute necrosis of liver
75	571	Cirrhosis of liver

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NO. OF CASES	CODE	DESCRIPTION
5	573	Other diseases of liver
3	574	Choletithiasis
1	575	Cholecystitis and cholangitis, without mention of calculus
3	576	Other diseases of gallbladder and biliary ducts
10	577	Diseases of pancreas
4	581	Nephrotic syndrome
16	582	Chronic nephritis
1	583	Nephritis unqualified
1	584	Renal sclerosis unqualified
12	590	Infections of kidney
2	592	Calculus of kidney and ureter
4	593	Other diseases of kidney and ureter
1	596	Other diseases of bladder
3	599	Other diseases of urinary tract
1	600	Hyperplasia of prostate
1	601	Prostatitis
3	602	Other diseases of prostate
1	694	Pemphigus
1	695	Erythematous conditions
1	712	Rheumatoid arthritis and allied conditions
1	716	Polymyositis and dermatomyositis
1	717	Other non-articular rheumatism
1	720	Osteomyelitis and periostitis

NO. OF CASES	CODE	DESCRIPTION
1	729	Other diseases of joint
2	733	Other diseases of muscle, tendon, and fascia
4	734	Diffuse diseases of connective tissue
1	746	Congenital anomalies of heart
5	747	Other congenital anomalies of circulatory system
1	748	Congenital anomalies of respiratory system
1	751	Other congenital anomalies of digestive system
2	753	Congenital anomalies of urinary system
1	780	Certain symptoms referable to nervous system and special senses
9	782	Symptoms referable to cardiovascular and lymphatic system
1	786	Symptoms referable to genito-urinary system
1	792	Uraemia
2	794	Senility without mention of psychosis
1	795	Sudden death (cause unknown)
25	796	Other ill-defined and unknown causes of morbidity and mortality
2	E805	Hit by rolling stock
1	E807	Railway accident of unspecified nature
9	E810	Motor vehicle traffic accident involving collision with train
44	E812	Motor vehicle traffic accident involving collision with another motor vehicle
3	E813	Motor vehicle traffic accident involving collision with other vehicle
15	E814	Motor vehicle traffic accident involving collision with pedestrian

NO. OF CASES	CODE	DESCRIPTION
1	E815	Other motor vehicle traffic accident involving collision
36	E816	Non-collision motor vehicle traffic accident due to loss of control
6	E818	Other non-collision motor vehicle traffic accident
57	E819	Motor vehicle traffic accident of unspecified nature
1	E821	Motor vehicle non-traffic accident involving collision with stationary object
11	E830	Accident to watercraft causing submersion
4	E832	Other accidental submersion or drowning in water transport
3	E840	Accident to powered aircraft take-off or landing
17	E841	Accident to powered aircraft, other and unspecified
1	E853	Accidental poisoning by analgesics and antipyretics
4	E854	Accidental poisoning by other sedatives and hypnotics
1	E873	Accidental poisoning by motor vehicle exhaust gas
2	E874	Accidental poisoning by carbon monoxide from incomplete combustion of domestic fuels
5	E880	Fall on or from stairs or steps
3	E881	Fall on or from ladders or scaffolding
2	E882	Fall from or out of building or other structure
1	E883	Fall into hole or other opening in surface
3	E884	Other fall from one level to another
2	E885	Fall on same level from slipping, tripping or stumbling

NO. OF CASES	CODE	DESCRIPTION
13	E887	Other and unspecified fall
10	E890	Accident caused by conflagration in private dwelling
3	E891	Accident caused by conflagration in other building or structure
1	E894	Accident caused by ignition of highly inflammable material
1	E895	Accident caused by controlled fire in private dwelling
3	E898	Accident caused by other specified fires or flames
2	E899	Accident caused by unspecified fire
16	E910	Accidental drowning and submersion
7	E911	Inhalation and ingestion of food causing obstruction or suffocation
2	E913	Accidental mechanical suffocation
7	E916	Struck accidentally by falling object
1	E918	Caught accidentally in or between objects
1	E921	Accident caused by explosion of pressure vessel
11	E922	Accident caused by firearm missiles
3	E923	Accident caused by explosive material
3	E924	Accident caused by hot substance, corrosive liquid, and steam
6	E925	Accident caused by electric current
1	E926	Accident caused by radiation
3	E927	Vehicle accidents not elsewhere classifiable
3	E928	Machinery accidents not elsewhere classifiable
4	E929	Other and unspecified accidents
6	E930	Complications and misadventures in operative therapeutic procedures

NO. OF CASES	CODE	DESCRIPTION
1	E940	Late effect of motor vehicle accident
1	E942	Late effect of accidental poisoning
1	E943	Late effect of accidental fall
17	E950	Suicide and self-inflicted poisoning by solid or liquid substances
24	E952	Suicide and self-inflicted poisoning by other gases
11	E953	Suicide and self-inflicted injury by hanging, strangulation and suffocation
4	E954	Suicide and self-inflicted injury by submersion (drowning)
80	E955	Suicide and self-inflicted injury by firearms and explosives
2	E958	Suicide and self-inflicted injury by other and unspecified means
1	E963	Assault by hanging and strangulation
8	E965	Assault by firearms and explosives
3	E968	Assault by other and unspecified means
3	E980	Poisoning by solid or liquid substances, undetermined whether accidentally or purposely inflicted
1	E981	Poisoning by gases in domestic use, undetermined whether accidentally or purposely inflicted
1	E982	Poisoning by other gases, undetermined whether accidentally or purposely inflicted
3	E984	Submersion (drowning), undetermined whether accidentally or purposely inflicted
4	E985	Injury by firearms and explosives, undetermined whether accidentally or purposely inflicted
2	E986	Injury by cutting and piercing instruments, undetermined whether accidentally or purposely inflicted
2	E988	Injury by other and unspecified means, undetermined whether accidentally or purposely inflicted

NO. OF CASES	CODE	DESCRIPTION
2	E994	Injury due to war operations by destruction of aircraft
3	E995	Injury due to war operations by other and unspecified forms of conventional warfare

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APPENDIX C

Program and Output Which Reviews Dose Time Histories and Generates Average Yearly Dose of Workers

```
FURPUR-MACC 4.14 RLIB36 12/19-09:52:03
2873600908*REGRESS(1).1RUN(3)
      1       @RUN K,13015,2873600908,$50.00,1000
      2       @ASG,AX OUTFILE.
      3       @BRKPT PRINT$/OUTFILE
      4       @PRT,S REGRESS.1RUN
      5       @PRT,S REGRESS.1
      6       @ASG,AX DATA.
      7       @USE 20.,DATA.
      8       @ASG,T TEMP2.
      9       @USE 21.,TEMP2.
     10       @FOR,IXC
     11       @ADD  REGRESS.1
     12       @EOF
     13       @XQT
     14       @COST,A
     15       @BRKPT PRINT$
     16       @FIN
@PRT,S REGRESS.1
2873600908*REGRESS(1).1(1)
      1:        DIMENSION A(16),YC(100),Y1(100),Y1C(100),ITABLE(100),DOS(7)
      2:        DATA ITABLE/481,282,583,584,585,586,7487/
      3:        ICOUNT = 0
      4:        ICNT1 = 0
      5:10      READ(20,100,END=300) (A(I10),I10=1,16)
      6:        ICNT1 = ICNT1 + 1
      7:        I1 = A(16) - A(3) + 1
      8:        I2 = A(16) - A(2) + 1
      9:        ITOP = ITABLE(I1)
     10:        IBOT = ITABLE(I2)
     11:        IFLAG = 0
     12:        DO 700 I = 1,7
     13:        DOS(I) = A(8+I) - A(9+I)
     14:        IF(I.EQ.7) DOS(I) = A(15)
     15:        IF((I.LT.ITOP).OR.(I.GT.IBOT)) GO TO 701
     16:        GO TO 700
     17:701     IF((DOS(I).GT.0.).AND.(IFLAG.EQ.0))WRITE(-,-) (A(I7),I7=1,16)
     18:        IF(DOS(I).EQ.0.) GO TO 700
     19:        IF(IFLAG.EQ.0) ICOUNT = ICOUNT + 1
     20:        IFLAG = 1
     21:700     CONTINUE
     22:100     FORMAT(F4.0,2F2.0,2F3.0,3F1.0,7F6.0,F2.0)
     23:        IX = A(16)
     24:        DO 200 I = 1,35
     25:       IX1 = IX - I + 1
     26:        IF=A(3)
     27:        IF(IX1.GT.IF) GO TO 200
     28:        IN = A(2)
     29:        IF(IX1.LT.IN) GO TO 200
     30:        IF (I.GT.3) GO TO 190
     31:        IFIN = A(3)
     32:        INIT = A(2)
     33:        IU = A(16) - 1. + 1.
     34:        IL = A(16) - 3. + 1.
     35:        IF(IFIN.LT.IU) IU = IFIN
     36:        IF(INIT.GT.IL) IL = INIT
     37:        XINT = IU - IL + 1.
     38:        Y1(IX1) = (A(9) - A(10))/XINT
     39:        Y1C(IX1) = Y1C(IX1) + Y1(IX1)
     40:        YC(IX1) = YC(IX1) + 1.
     41:        GO TO 200
     42:190     IF(I.GT.5) GO TO 192
     43:        IFIN = A(3)
     44:        INIT = A(2)
     45:        IU = A(16) - 4. + 1.
     46:        IL = A(16) - 5. + 1.
     47:        IF(IFIN.LT.IU) IU = IFIN
     48:        IF(INIT.GT.IL) IL = INIT
     49:        XINT = IU - IL + 1.
     50:        Y1(IX1) = (A(10) - A(11))/XINT
```

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```
 51:          Y1C(IX1) = Y1C(IX1) + Y1(IX1)
 52:          YC(IX1) = YC(IX1) + 1.
 53:          GO TO 200
 54:194       IF(I.GT.15) GO TO 196
 55:          IFIN = A(3)
 56:          INIT = A(2)
 57:          IU = A(16) - 6. + 1.
 58:          IL = A(16) - 10. + 1.
 59:          IF(IFIN.LT.IU) IU = IFIN
 60:          IF(INIT.GT.IL) IL = INIT
 61:          XINT = IU - IL + 1.
 62:          Y1(IX1) = (A(11) - A(12))/XINT
 63:          Y1C(IX1) = Y1C(IX1) + Y1(IX1)
 64:          YC(IX1) = YC(IX1) + 1.
 65:          GO TO 200
 66:196       IF(I.GT.20) GO TO 198
 67:          IFIN = A(3)
 68:          INIT = A(2)
 69:          IU = A(16) - 11. + 1.
 70:          IL = A(16) - 15. + 1.
 71:          IF(IFIN.LT.IU) IU = IFIN
 72:          IF(INIT.GT.IL) IL = INIT
 73:          XINT = IU - IL + 1.
 74:          Y1(IX1) = (A(12) - A(13))/XINT
 75:          Y1C(IX1) = Y1C(IX1) + Y1(IX1)
 76:          YC(IX1) = YC(IX1) + 1.
 77:          GO TO 200
 78:198       IF(I.GT.25) GO TO 199
 79:          IFIN = A(3)
 80:          INIT = A(2)
 81:          IU = A(16) - 16. + 1.
 82:          IL = A(16) - 20. + 1.
 83:          IF(IFIN.LT.IU) IU = IFIN
 84:          IF(INIT.GT.IL) IL = INIT
 85:          XINT = IU - IL + 1.
 86:          Y1(IX1) = (A(13) - A(14))/XINT
 87:          Y1C(IX1) = Y1C(IX1) + Y1(IX1)
 88:          YC(IX1) = YC(IX1) + 1.
 89:          GO TO 200
 90:199       IF(I.GT.25) GO TO 199
 91:          IFIN = A(3)
 92:          INIT = A(2)
 93:          IU = A(16) - 21. + 1.
 94:          IL = A(16) - 25  + 1.
 95:          IF(IFIN.LT.IU) IU = IFIN
 96:          IF(INIT.GT.IL) IL = INIT
 97:          XINT = IU - IL + 1.
 98:          Y1(IX1) = (A(14) - A(15))/XINT
 99:          Y1C(IX1) = Y1C(IX1) + Y1(IX1)
100:          YC(IX1) = YC(IX1) + 1.
101:          GO TO 200
102:199       CONTINUE
103:          D = A(16) - A(2)
104:          IF(D.LE.25.) GO TO  200
105:          IFIN = A(3)
106:          INIT = A(2)
107:          IU = A(16) - 26. + 1.
108:          IL = A(16) - 30. + 1.
109:          IF(IFIN.LT.IU) IU = IFIN
110:          IF(INIT.GT.IL) IL = INIT
111:          XINT = IU - IL + 1.
112:          Y1(IX1) = ( A(15))/XINT
```

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```
    113:        Y1C(IX1) = Y1C(IX1) + Y1(IX1)
    114:        YC(IX1) = YC(IX1) + 1.
    115:200     CONTINUE
    116:        GO TO 10
    117:300     CONTINUE
    118:        WRITE(-,-) ICNT1
    119:        WRITE(-,-) ICOUNT
    120:        WRITE(-,201)
    121:201     FORMAT(10X,'YR',10X,'TOTAL DOSE',10X,'COUNTS',10X,'AVERAGE DOSE')
    122:        DO 600 IJK = 1,100
    123:        AS = 0.
    124:        IF (YC(IJK).EQ.0.) GO TO 37
    125:        AS = Y1C(IJK)/YC(IJK)
    126:37      CONTINUE
    127:        WRITE(-,500) IJK,Y1C(IJK),YC(IJK),AS
    128:        WRITE(21,500) IJK,Y1C(IJK),YC(IJK),AS
    129:600     CONTINUE
    130:500     FORMAT(10X,I3,10X,F7.1,10X,F7.1,10X,F7.1)
    131:        STOP
    132:        END
@ASG,AX DATA.
@USE 20.,DATA.
@ASG,T TEMP2.
@USE 21.,TEMP2.
@FOR,IXC
FORTRAN-MACC 1.17S-12/19/78-09:52:09            NAME$
      END OF COMPILATION:        NO  DIAGNOSTICS.
@XQT
MAP28-2 RLIB35 12/19-09:52:15
ADDRESS LIMITS                                                  BDI
                  001000 012622      5011 IBANK WORDS DECIMAL  000004
                  040000 045207      2696 DBANK WORDS DECIMAL  000005
STARTING ADDRESS  011452
          SEGMENT $MAIN$          001000 012622     040000 045207
ERU$
NTAB$/FORIO                                        $(2)    040000 040044
NFTCH$/FORIO              $(1)    001000 001300    $(2)    040045 040102
FORIO$2/FORIO             $(1)    001301 003630    $(2)    040103 042573
NFFTI$/FORIO              $(1)    003631 004674    $(2)    042574 043011
FORIO$3/FORIO             $(1)    004675 005262    $(2)    043012 043020
NOSYM$/FORIO              $(1)    005263 005372    $(2)    043021 043024
NFFTO$/FORIO              $(1)    005373 005763    $(2)    043025 043066
FORIO$4/FORIO             $(1)    005764 006257    $(2)    043067 043111
FORIO$1/FORIO             $(1)    006260 011451    $(2)    043112 044206
NAME$                     $(1)    011452 012622    $(0)    044207 045207
SYS$*RLIB$. LEVEL 41
END MAP
    480.0000        53.0000        55.0000        14.0000       284.0000      1.0000        0.0          1.0000
     17.0000        17.0000        17.0000         0.0            0.0        0.0           0.0         70.0000
    615.0000        44.0000        54.0000       100.0000       162.0000      1.0000        1.0000       1.0000
    222.0000       213.0000       126.0000        88.0000        56.0000     17.0000        0.0         68.0000
    418.0000        63.0000        66.0000        31.0000       162.0000      1.0000        1.0000       1.0000
     97.0000        71.0000        63.0000         0.0            0.0        0.0           0.0         72.0000
    513.0000        48.0000        49.0000         2.0000       250.0000      1.0000        1.0000       1.0000
     74.0000        29.0000         9.0000         4.0000         0.0        0.0           0.0         66.0000
    693.0000        44.0000        62.0000       181.0000       185.0000      1.0000        1.0000       1.0000
    253.0000       253.0000       233.0000       117.0000       100.0000     77.0000       33.0000      72.0000
    637.0000        45.0000        56.0000       115.0000       197.0000      1.0000        1.0000       1.0000
    228.0000       210.0000       162.0000       117.0000       111.0000     49.0000        0.0         69.0000
    631.0000        48.0000        51.0000        34.0000       410.0000      1.0000        1.0000       1.0000
    224.0000       183.0000       100.0000        23.0000        14.0000      8.0000        0.0         72.0000
    514.0000        55.0000        59.0000        43.0000       930.0000      1.0000        1.0000       1.0000
    147.0000        16.0000         0.0            0.0            0.0        0.0           0.0         65.0000
    647.0000        48.0000        48.0000         1.0000       412.0000      1.0000        1.0000       1.0000
      9.0000         9.0000         9.0000         6.0000         0.0        0.0           0.0         58.0000
```

2562.0000	2562.0000	2562.0000	1369.0000	338.0000	0.0	0.0	72.0000
645.0000	48.0000	49.0000	6.0000	410.0000	1.0000	1.0000	1.0000
368.0000	368.0000	356.0000	239.0000	105.0000	39.0000	0.0	72.0000
565.0000	45.0000	56.0000	117.0000	410.0000	1.0000	1.0000	1.0000
353.0000	335.0000	282.0000	171.0000	103.0000	21.0000	0.0	68.0000
619.0000	46.0000	52.0000	56.0000	153.0000	1.0000	1.0000	1.0000
67.0000	16.0000	0.0	0.0	0.0	0.0	0.0	67.0000
656.0000	44.0000	54.0000	100.0000	410.0000	1.0000	1.0000	1.0000
292.0000	292.0000	288.0000	170.0000	145.0000	91.0000	44.0000	71.0000
616.0000	48.0000	48.0000	2.0000	202.0000	1.0000	1.0000	1.0000
7.0000	7.0000	7.0000	7.0000	7.0000	4.0000	0.0	68.0000
584.0000	47.0000	53.0000	58.0000	410.0000	1.0000	1.0000	1.0000
3113.0000	3113.0000	2729.0000	1393.0000	444.0000	22.0000	0.0	72.0000
610.0000	44.0000	46.0000	16.0000	410.0000	1.0000	1.0000	1.0000
646.0000	644.0000	485.0000	321.0000	217.0000	146.0000	28.0000	69.0000
501.0000	47.0000	49.0000	15.0000	562.0000	1.0000	1.0000	1.0000
201.0000	201.0000	133.0000	13.0000	0.0	0.0	0.0	70.0000
537.0000	44.0000	57.0000	129.0000	410.0000	1.0000	1.0000	1.0000
3447.0000	3104.0000	2727.0000	1570.0000	621.0000	100.0000	0.0	70.0000
567.0000	44.0000	45.0000	6.0000	95.0000	1.0000	1.0000	1.0000
173.0000	173.0000	154.0000	0.0	0.0	0.0	0.0	50.0000
633.0000	49.0000	51.0000	15.0000	492.0000	1.0000	1.0000	1.0000
156.0000	156.0000	136.0000	59.0000	43.0000	11.0000	0.0	72.0000
598.0000	46.0000	51.0000	49.0000	429.0000	1.0000	1.0000	1.0000
958.0000	773.0000	651.0000	162.0000	88.0000	69.0000	0.0	69.0000
380.0000	64.0000	65.0000	13.0000	965.0000	0.0	1.0000	1.0000
207.0000	190.0000	144.0000	0.0	0.0	0.0	0.0	71.0000
495.0000	51.0000	51.0000	1.0000	812.0000	1.0000	1.0000	1.0000
134.0000	59.0000	47.0000	47.0000	0.0	0.0	0.0	65.0000
635.0000	45.0000	58.0000	134.0000	410.0000	1.0000	1.0000	1.0000
198.0000	198.0000	198.0000	42.0000	14.0000	14.0000	14.0000	71.0000
587.0000	49.0000	65.0000	159.0000	437.0000	1.0000	1.0000	1.0000
111.0000	72.0000	29.0000	15.0000	9.0000	0.0	0.0	68.0000
555.0000	44.0000	44.0000	1.0000	532.0000	1.0000	1.0000	1.0000
24.0000	24.0000	24.0000	24.0000	23.0000	0.0	0.0	60.0000
624.0000	59.0000	63.0000	38.0000	410.0000	1.0000	1.0000	1.0000
58.0000	58.0000	48.0000	0.0	0.0	0.0	0.0	69.0000
635.0000	45.0000	51.0000	68.0000	571.0000	1.0000	1.0000	1.0000
132.0000	113.0000	83.0000	61.0000	50.0000	29.0000	0.0	69.0000
636.0000	44.0000	50.0000	58.0000	162.0000	1.0000	1.0000	1.0000
17.0000	17.0000	14.0000	0.0	0.0	0.0	0.0	55.0000
666.0000	44.0000	55.0000	108.0000	412.0000	1.0000	1.0000	1.0000
313.0000	313.0000	295.0000	196.0000	176.0000	101.0000	64.0000	72.0000
493.0000	48.0000	55.0000	70.0000	410.0000	1.0000	1.0000	1.0000
161.0000	134.0000	130.0000	12.0000	0.0	0.0	0.0	72.0000
586.0000	44.0000	47.0000	24.0000	410.0000	1.0000	1.0000	1.0000
3183.0000	3066.0000	2913.0000	1747.0000	599.0000	23.0000	0.0	69.0000
448.0000	48.0000	51.0000	23.0000	183.0000	1.0000	0.0	1.0000
96.0000	45.0000	38.0000	38.0000	10.0000	0.0	0.0	65.0000
567.0000	45.0000	48.0000	34.0000	812.0000	1.0000	1.0000	1.0000
1469.0000	1379.0000	1151.0000	382.0000	215.0000	68.0000	0.0	70.0000
510.0000	51.0000	65.0000	135.0000	832.0000	1.0000	0.0	1.0000
169.0000	153.0000	123.0000	39.0000	39.0000	0.0	0.0	70.0000
361.0000	56.0000	56.0000	4.0000	238.0000	1.0000	1.0000	1.0000
101.0000	64.0000	53.0000	5.0000	0.0	0.0	0.0	66.0000
387.0000	52.0000	54.0000	17.0000	433.0000	1.0000	1.0000	1.0000
384.0000	103.0000	78.0000	24.0000	0.0	0.0	0.0	63.0000
572.0000	48.0000	56.0000	83.0000	188.0000	1.0000	1.0000	1.0000
210.0000	194.0000	164.0000	50.0000	354.0000	20.0000	0.0	72.0000
459.0000	44.0000	48.0000	43.0000	428.0000	1.0000	1.0000	1.0000
324.0000	324.0000	324.0000	314.0000	281.0000	0.0	0.0	61.0000
656.0000	51.0000	59.0000	81.0000	532.0000	1.0000	1.0000	1.0000
54.0000	54.0000	54.0000	48.0000	36.0000	0.0	0.0	69.0000
578.0000	44.0000	61.0000	169.0000	174.0000	1.0000	0.0	1.0000
1439.0000	1439.0000	1316.0000	441.0000	218.0000	170.0000	152.0000	71.0000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1781.0000	1566.0000	1253.0000	408.0000	21.0000	0.0	0.0	71.0000
577.0000	56.0000	64.0000	79.0000	348.0000	1.0000	1.0000	1.0000
115.0000	115.0000	97.0000	13.0000	0.0	0.0	0.0	72.0000
609.0000	54.0000	57.0000	32.0000	441.0000	1.0000	1.0000	1.0000
2875.0000	2456.0000	2000.0000	591.0000	14.0000	0.0	0.0	69.0000
689.0000	48.0000	48.0000	8.0000	428.0000	1.0000	1.0000	1.0000
24.0000	24.0000	24.0000	3.0000	0.0	0.0	0.0	59.0000
384.0000	51.0000	57.0000	58.0000	955.0000	1.0000	1.0000	1.0000
385.0000	330.0000	194.0000	65.0000	0.0	0.0	0.0	68.0000
552.0000	45.0000	55.0000	106.0000	395.0000	1.0000	1.0000	1.0000
1691.0000	1152.0000	770.0000	407.0000	71.0000	27.0000	0.0	67.0000
625.0000	45.0000	48.0000	34.0000	446.0000	1.0000	1.0000	1.0000
201.0000	192.0000	175.0000	120.0000	117.0000	95.0000	72.0000	71.0000
570.0000	51.0000	58.0000	65.0000	985.0000	1.0000	1.0000	1.0000
3629.0000	3578.0000	3111.0000	1625.0000	463.0000	8.0000	0.0	72.0000
591.0000	45.0000	50.0000	55.0000	410.0000	1.0000	1.0000	1.0000
328.0000	276.0000	271.0000	268.0000	254.0000	199.0000	0.0	66.0000
631.0000	44.0000	65.0000	206.0000	441.0000	1.0000	1.0000	1.0000
185.0000	164.0000	145.0000	78.0000	73.0000	34.0000	3.0000	70.0000
455.0000	45.0000	45.0000	7.0000	157.0000	1.0000	1.0000	1.0000
149.0000	141.0000	84.0000	59.0000	55.0000	37.0000	0.0	69.0000
670.0000	44.0000	56.0000	120.0000	412.0000	1.0000	1.0000	1.0000
66.0000	66.0000	62.0000	51.0000	32.0000	0.0	0.0	62.0000
532.0000	48.0000	49.0000	10.0000	410.0000	1.0000	1.0000	1.0000
198.0000	172.0000	141.0000	52.0000	32.0000	3.0000	0.0	71.0000
462.0000	54.0000	64.0000	96.0000	410.0000	1.0000	0.0	1.0000
84.0000	84.0000	62.0000	8.0000	0.0	0.0	0.0	69.0000
673.0000	44.0000	47.0000	30.0000	276.0000	1.0000	1.0000	1.0000
3443.0000	3443.0000	3015.0000	1662.0000	713.0000	154.0000	0.0	71.0000
569.0000	55.0000	58.0000	28.0000	410.0000	1.0000	1.0000	1.0000
625.0000	580.0000	556.0000	59.0000	0.0	0.0	0.0	65.0000
500.0000	47.0000	53.0000	59.0000	162.0000	1.0000	1.0000	1.0000
275.0000	275.0000	275.0000	275.0000	247.0000	133.0000	0.0	71.0000
541.0000	52.0000	54.0000	19.0000	412.0000	1.0000	1.0000	1.0000
228.0000	228.0000	226.0000	165.0000	144.0000	30.0000	0.0	72.0000
651.0000	44.0000	46.0000	26.0000	151.0000	1.0000	1.0000	1.0000
23.0000	20.0000	0.0	0.0	0.0	0.0	0.0	49.0000
580.0000	47.0000	56.0000	94.0000	412.0000	1.0000	1.0000	1.0000
241.0000	214.0000	188.0000	120.0000	29.0000	29.0000	8.0000	72.0000
538.0000	48.0000	52.0000	41.0000	410.0000	1.0000	1.0000	1.0000
104.0000	14.0000	8.0000	8.0000	8.0000	0.0	0.0	67.0000
538.0000	45.0000	60.0000	148.0000	191.0000	1.0000	1.0000	1.0000
266.0000	240.0000	183.0000	89.0000	80.0000	28.0000	0.0	70.0000
631.0000	44.0000	56.0000	120.0000	410.0000	1.0000	1.0000	1.0000
166.0000	166.0000	131.0000	71.0000	49.0000	30.0000	10.0000	72.0000
536.0000	44.0000	60.0000	159.0000	395.0000	1.0000	1.0000	1.0000
398.0000	351.0000	320.0000	236.0000	219.0000	150.0000	117.0000	72.0000
504.0000	47.0000	61.0000	138.0000	571.0000	1.0000	1.0000	1.0000
62.0000	25.0000	5.0000	4.0000	0.0	0.0	0.0	65.0000
721.0000	47.0000	49.0000	15.0000	162.0000	1.0000	1.0000	1.0000
754.0000	754.0000	754.0000	664.0000	608.0000	30.0000	0.0	69.0000
491.0000	50.0000	62.0000	116.0000	412.0000	1.0000	1.0000	1.0000
180.0000	167.0000	139.0000	80.0000	68.0000	10.0000	0.0	71.0000
619.0000	44.0000	53.0000	80.0000	185.0000	1.0000	1.0000	1.0000
128.0000	110.0000	70.0000	29.0000	25.0000	19.0000	0.0	69.0000
615.0000	44.0000	52.0000	79.0000	410.0000	1.0000	0.0	1.0000
69.0000	69.0000	67.0000	20.0000	19.0000	0.0	0.0	71.0000
648.0000	52.0000	52.0000	3.0000	792.0000	1.0000	1.0000	1.0000
110.0000	110.0000	48.0000	10.0000	0.0	0.0	0.0	68.0000
652.0000	51.0000	59.0000	76.0000	410.0000	1.0000	1.0000	1.0000
116.0000	96.0000	72.0000	26.0000	20.0000	0.0	0.0	69.0000
651.0000	55.0000	65.0000	100.0000	410.0000	1.0000	1.0000	1.0000
1626.0000	1544.0000	1365.0000	420.0000	0.0	0.0	0.0	70.0000
666.0000	45.0000	58.0000	130.0000	162.0000	1.0000	1.0000	1.0000
696.0000	696.0000	675.0000	477.0000	207.0000	142.0000	122.0000	71.0000

74.0000	69.0000	40.0000	0.0	0.0	0.0	0.0	68.0000
610.0000	44.0000	46.0000	20.0000	412.0000	1.0000	1.0000	1.0000
3.0000	3.0000	3.0000	3.0000	3.0000	0.0	0.0	70.0000
424.0000	50.0000	52.0000	18.0000	812.0000	1.0000	1.0000	1.0000
2176.0000	2113.0000	1955.0000	1398.0000	447.0000	9.0000	0.0	70.0000
681.0000	51.0000	59.0000	76.0000	153.0000	1.0000	1.0000	1.0000
235.0000	235.0000	202.0000	80.0000	55.0000	0.0	0.0	71.0000
410.0000	54.0000	58.0000	33.0000	531.0000	1.0000	1.0000	1.0000
1375.0000	1039.0000	907.0000	243.0000	0.0	0.0	0.0	67.0000
613.0000	45.0000	48.0000	34.0000	410.0000	1.0000	1.0000	1.0000
177.0000	169.0000	143.0000	75.0000	70.0000	11.0000	3.0000	70.0000
535.0000	44.0000	55.0000	104.0000	410.0000	1.0000	1.0000	1.0000
173.0000	157.0000	123.0000	103.0000	89.0000	32.0000	0.0	69.0000
537.0000	44.0000	56.0000	124.0000	157.0000	1.0000	1.0000	1.0000
168.0000	168.0000	124.0000	52.0000	49.0000	45.0000	7.0000	70.0000
535.0000	45.0000	62.0000	171.0000	410.0000	1.0000	1.0000	1.0000
2882.0000	2326.0000	1861.0000	752.0000	175.0000	9.0000	0.0	66.0000
545.0000	44.0000	48.0000	38.0000	154.0000	1.0000	1.0000	1.0000
142.0000	96.0000	77.0000	53.0000	17.0000	6.0000	0.0	67.0000
572.0000	47.0000	55.0000	78.0000	157.0000	1.0000	1.0000	1.0000
2198.0000	1685.0000	1170.0000	282.0000	0.0	0.0	0.0	66.0000
785.0000	44.0000	46.0000	20.0000	410.0000	1.0000	1.0000	1.0000
67.0000	52.0000	52.0000	52.0000	52.0000	52.0000	52.0000	71.0000
483.0000	45.0000	49.0000	39.0000	173.0000	1.0000	1.0000	1.0000
1562.0000	1517.0000	1349.0000	722.0000	293.0000	92.0000	2.0000	70.0000
541.0000	51.0000	54.0000	29.0000	348.0000	1.0000	1.0000	1.0000
141.0000	135.0000	120.0000	23.0000	9.0000	4.0000	0.0	72.0000
552.0000	44.0000	51.0000	64.0000	162.0000	1.0000	1.0000	1.0000
100.0000	97.0000	46.0000	10.0000	7.0000	0.0	0.0	69.0000
695.0000	56.0000	56.0000	2.0000	180.0000	1.0000	1.0000	1.0000
75.0000	75.0000	75.0000	20.0000	0.0	0.0	0.0	72.0000
476.0000	51.0000	54.0000	23.0000	433.0000	1.0000	1.0000	1.0000
1746.0000	1225.0000	781.0000	272.0000	0.0	0.0	0.0	66.0000
436.0000	50.0000	63.0000	127.0000	810.0000	1.0000	1.0000	1.0000
186.0000	139.0000	90.0000	15.0000	15.0000	0.0	0.0	71.0000
599.0000	45.0000	53.0000	83.0000	431.0000	1.0000	1.0000	1.0000
1102.0000	1062.0000	977.0000	577.0000	247.0000	88.0000	43.0000	72.0000
557.0000	54.0000	56.0000	21.0000	410.0000	1.0000	1.0000	1.0000
2374.0000	2122.0000	1659.0000	473.0000	0.0	0.0	0.0	68.0000
538.0000	44.0000	56.0000	120.0000	922.0000	1.0000	1.0000	1.0000
166.0000	166.0000	159.0000	68.0000	57.0000	39.0000	0.0	70.0000
550.0000	46.0000	53.0000	62.0000	432.0000	1.0000	1.0000	1.0000
68.0000	66.0000	23.0000	4.0000	0.0	0.0	0.0	69.0000
511.0000	51.0000	56.0000	55.0000	410.0000	1.0000	1.0000	1.0000
154.0000	154.0000	114.0000	52.0000	37.0000	18.0000	0.0	72.0000
656.0000	53.0000	58.0000	54.0000	410.0000	1.0000	1.0000	1.0000
143.0000	104.0000	79.0000	55.0000	0.0	0.0	0.0	67.0000
384.0000	60.0000	61.0000	2.0000	400.0000	1.0000	1.0000	1.0000
168.0000	154.0000	119.0000	0.0	0.0	0.0	0.0	70.0000
296.0000	60.0000	65.0000	43.0000	450.0000	1.0000	1.0000	1.0000
839.0000	611.0000	368.0000	0.0	0.0	0.0	0.0	68.0000
532.0000	45.0000	46.0000	11.0000	410.0000	1.0000	1.0000	1.0000
222.0000	222.0000	196.0000	143.0000	118.0000	0.0	0.0	67.0000
516.0000	48.0000	49.0000	4.0000	410.0000	1.0000	1.0000	1.0000
46.0000	30.0000	15.0000	7.0000	3.0000	3.0000	0.0	69.0000
639.0000	48.0000	49.0000	7.0000	410.0000	1.0000	1.0000	1.0000
288.0000	96.0000	65.0000	49.0000	18.0000	0.0	0.0	66.0000
322.0000	63.0000	65.0000	16.0000	812.0000	1.0000	1.0000	1.0000
325.0000	302.0000	81.0000	0.0	0.0	0.0	0.0	69.0000
560.0000	51.0000	52.0000	12.0000	425.0000	1.0000	1.0000	1.0000
614.0000	523.0000	448.0000	290.0000	160.0000	3.0000	0.0	71.0000
555.0000	47.0000	59.0000	119.0000	199.0000	1.0000	1.0000	1.0000
218.0000	151.0000	120.0000	99.0000	11.0000	0.0	0.0	67.0000
373.0000	55.0000	55.0000	5.0000	410.0000	1.0000	1.0000	1.0000
59.0000	11.0000	11.0000	11.0000	0.0	0.0	0.0	68.0000

237.0000	237.0000	225.0000	138.0000	127.0000	82.0000	0.0	72.0000
401.0000	51.0000	58.0000	68.0000	205.0000	1.0000	1.0000	1.0000
119.0000	104.0000	72.0000	43.0000	34.0000	0.0	0.0	69.0000
565.0000	45.0000	60.0000	149.0000	200.0000	1.0000	1.0000	1.0000
50.0000	50.0000	38.0000	38.0000	38.0000	38.0000	0.0	67.0000
447.0000	51.0000	57.0000	61.0000	955.0000	1.0000	1.0000	1.0000
520.0000	358.0000	290.0000	179.0000	99.0000	0.0	0.0	67.0000
778.0000	47.0000	49.0000	13.0000	352.0000	1.0000	1.0000	1.0000
26.0000	26.0000	26.0000	26.0000	10.0000	0.0	0.0	69.0000
467.0000	54.0000	65.0000	104.0000	162.0000	1.0000	1.0000	1.0000
142.0000	133.0000	113.0000	26.0000	6.0000	0.0	0.0	72.0000
580.0000	47.0000	52.0000	47.0000	412.0000	1.0000	1.0000	1.0000
3267.0000	2817.0000	2297.0000	1077.0000	260.0000	30.0000	0.0	68.0000
539.0000	54.0000	58.0000	39.0000	410.0000	1.0000	1.0000	1.0000
78.0000	62.0000	18.0000	0.0	0.0	0.0	0.0	69.0000
543.0000	46.0000	54.0000	74.0000	157.0000	1.0000	1.0000	1.0000
177.0000	165.0000	156.0000	76.0000	65.0000	40.0000	2.0000	71.0000
393.0000	53.0000	63.0000	104.0000	410.0000	1.0000	1.0000	1.0000
99.0000	60.0000	27.0000	15.0000	0.0	0.0	0.0	68.0000
387.0000	51.0000	55.0000	31.0000	812.0000	1.0000	1.0000	1.0000
112.0000	82.0000	30.0000	16.0000	6.0000	0.0	0.0	68.0000
526.0000	51.0000	64.0000	132.0000	540.0000	1.0000	1.0000	1.0000
198.0000	181.0000	164.0000	89.0000	79.0000	31.0000	0.0	72.0000
593.0000	44.0000	63.0000	183.0000	410.0000	1.0000	1.0000	1.0000
224.0000	208.0000	176.0000	77.0000	65.0000	33.0000	0.0	70.0000
509.0000	62.0000	65.0000	35.0000	410.0000	1.0000	1.0000	1.0000
636.0000	596.0000	524.0000	0.0	0.0	0.0	0.0	71.0000
392.0000	47.0000	50.0000	29.0000	410.0000	1.0000	1.0000	1.0000
109.0000	39.0000	27.0000	20.0000	2.0000	0.0	0.0	65.0000
515.0000	44.0000	45.0000	13.0000	410.0000	1.0000	1.0000	1.0000
35.0000	35.0000	35.0000	32.0000	8.0000	0.0	0.0	59.0000
595.0000	55.0000	58.0000	24.0000	410.0000	1.0000	1.0000	1.0000
988.0000	969.0000	773.0000	377.0000	0.0	0.0	0.0	69.0000
525.0000	51.0000	52.0000	8.0000	410.0000	1.0000	1.0000	1.0000
16.0000	16.0000	16.0000	16.0000	16.0000	0.0	0.0	72.0000
592.0000	53.0000	54.0000	15.0000	441.0000	1.0000	1.0000	1.0000
12.0000	7.0000	0.0	0.0	0.0	0.0	0.0	70.0000
619.0000	53.0000	58.0000	46.0000	830.0000	1.0000	1.0000	1.0000
637.0000	595.0000	473.0000	227.0000	10.0000	0.0	0.0	71.0000
427.0000	48.0000	58.0000	101.0000	157.0000	1.0000	1.0000	1.0000
458.0000	332.0000	233.0000	205.0000	58.0000	0.0	0.0	65.0000
462.0000	47.0000	48.0000	10.0000	601.0000	1.0000	1.0000	1.0000
149.0000	149.0000	30.0000	0.0	0.0	0.0	0.0	69.0000
383.0000	47.0000	51.0000	40.0000	753.0000	1.0000	1.0000	1.0000
948.0000	948.0000	711.0000	324.0000	21.0000	0.0	0.0	66.0000
519.0000	44.0000	56.0000	118.0000	410.0000	1.0000	1.0000	1.0000
273.0000	100.0000	76.0000	52.0000	20.0000	3.0000	0.0	66.0000
603.0000	44.0000	65.0000	206.0000	436.0000	1.0000	1.0000	1.0000
555.0000	503.0000	358.0000	142.0000	115.0000	44.0000	0.0	69.0000
810.0000	44.0000	49.0000	53.0000	412.0000	1.0000	1.0000	1.0000
33.0000	33.0000	33.0000	33.0000	33.0000	25.0000	12.0000	72.0000
592.0000	47.0000	58.0000	104.0000	162.0000	1.0000	1.0000	1.0000
4421.0000	4036.0000	3472.0000	2253.0000	970.0000	194.0000	3.0000	72.0000
696.0000	47.0000	56.0000	87.0000	151.0000	1.0000	1.0000	1.0000
248.0000	248.0000	248.0000	85.0000	3.0000	0.0	0.0	71.0000
630.0000	45.0000	54.0000	95.0000	450.0000	1.0000	0.0	1.0000
146.0000	60.0000	28.0000	12.0000	0.0	0.0	0.0	67.0000
644.0000	55.0000	58.0000	27.0000	410.0000	1.0000	1.0000	1.0000
2568.0000	2173.0000	1776.0000	491.0000	0.0	0.0	0.0	68.0000

3992
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YR	TOTAL DOSE	COUNTS	AVERAGE DOSE
1	.0	.0	.0
2	.0	.0	.0
3	.0	.0	.0
*	*	*	*

5	.0	.0	.0
6	.0	.0	.0
7	.0	.0	.0
8	.0	.0	.0
9	.0	.0	.0
10	.0	.0	.0
11	.0	.0	.0
12	.0	.0	.0
13	.0	1.0	.0
14	.0	1.0	.0
15	.0	3.0	.0
16	.0	3.0	.0
17	.0	3.0	.0
18	.0	3.0	.0
19	.0	4.0	.0
20	.0	4.0	.0
21	.0	4.0	.0
22	.0	4.0	.0
23	.0	4.0	.0
24	.0	4.0	.0
25	.0	4.0	.0
26	.0	4.0	.0
27	.0	4.0	.0
28	.0	4.0	.0
29	.0	4.0	.0
30	.0	4.0	.0
31	.0	5.0	.0
32	.0	5.0	.0
33	.0	5.0	.0
34	.0	5.0	.0
35	.0	5.0	.0
36	.0	5.0	.0
37	.0	5.0	.0
38	.0	5.0	.0
39	.0	5.0	.0
40	.0	5.0	.0
41	.0	5.0	.0
42	.0	5.0	.0
43	6.8	14.0	.5
44	10865.4	1774.0	6.1
45	19167.9	2044.0	9.4
46	11406.0	1399.0	8.2
47	8935.3	1597.0	5.6
48	9030.2	1850.0	4.9
49	8814.0	1681.0	5.2
50	8647.8	1497.0	5.8
51	10568.3	1578.0	6.7
52	12872.0	1458.0	8.8
53	14945.0	1308.0	11.4
54	14428.7	1215.0	11.9
55	16010.0	1175.0	13.6
56	16225.0	1081.0	15.0
57	16607.3	984.0	16.9
58	19187.3	868.0	22.1
59	15085.0	773.0	19.5
60	14913.2	674.0	22.1
61	17473.8	606.0	28.8
62	18290.2	522.0	35.0
63	16424.5	449.0	36.6
64	15515.7	375.0	41.4
65	14353.9	302.0	47.5
66	9359.6	226.0	41.4
67	8079.9	201.0	40.2
68	4229.5	176.0	24.0
69	3270.8	153.0	21.4
70	1887.2	118.0	16.0

71	632.8	77.0	8.2
72	432.3	43.0	10.1
73	.0	.0	.0
74	.0	.0	.0
75	.0	.0	.0
76	.0	.0	.0
77	.0	.0	.0
78	.0	.0	.0
79	.0	.0	.0
80	.0	.0	.0
81	.0	.0	.0
82	.0	.0	.0
83	.0	.0	.0
84	.0	.0	.0
85	.0	.0	.0
86	.0	.0	.0
87	.0	.0	.0
88	.0	.0	.0
89	.0	.0	.0
90	.0	.0	.0
91	.0	.0	.0
92	.0	.0	.0
93	.0	.0	.0
94	.0	.0	.0
95	.0	.0	.0
96	.0	.0	.0
97	.0	.0	.0
98	.0	.0	.0
99	.0	.0	.0
100	.0	.0	.0

APPENDIX D

DEFINITION OF VARIABLE NAMES

VARIABLE NAME	DEFINITION
DEATHAGE	Age at death to nearest tenth.
INITLYR	Initial year of employment.
FINALYR	Final year of employment
TOTALYR	Total years of employment to nearest tenth.
EXPOSURE	0=zero lifetime dose recorded. 1=positive lifetime dose recorded.
CUMDOSE	Cumulative lifetime dose.
CDOS 3+	Cumulative lifetime dose 3 years before death.
CDOS 5+	Cumulative lifetime dose 5 years before death.
CDOS 10+	Cumulative lifetime dose 10 years before death.
CDOS 15+	Cumulative lifetime dose 15 years before death.
CDOS 20+	Cumulative lifetime dose 20 years before death.
CDOS 25+	Cumulative lifetime dose 25 years before death.
YRDEATH	Year of death.
DT1	Represents the difference between year of death and the initial year of employment.
DT2	Represents the difference between the year of death and the final year of employment.
DT3	Represents the differences between the year of death and the year at the middle of employment.
DOS0-3	Represents the differences between cumulative dose and cumulative dose three years before death.

VARIABLE NAME	DEFINITION
DOS4-5	Represents the difference between cumulative dose 3 years before death and cumulative dose 5 years before death.
DOS6-10	Represents the difference between cumulative dose 5 years before death and 10 years before death.
DOS11-15	Represents the difference between cumulative dose 10 years before death and 15 years before death.
DOS16-20	Represents the difference between cumulative dose 15 years before death and cumulative dose 20 years before death.
DOS21-25	Represents the difference between cumulative dose 20 years prior to death and cumulative dose 25 years prior to death.
DOS25+	Represents the cumulative dose 25 years prior to death.
MAXDOS	Represents the maximum value of DOS0-3, DOS4-5, DOS6-10, DOS11-15, DOS16-30, DOS21-25, and DOS25+
TMAXDOS	Represents the time from the center of the interval in which the maximum dose is found.
AGESQ	Represents the age at death minus 60 all divided by 5 and then squared.

```
F(0),NEWVARFOR/FINAL(0)
      1            DIMENSION XID(100),XTAB(999),DOS(10),DT(10),XDATE(10),XWIDTH(10),
      2           &XINT(50),XREC(10)
      3            DATA XWIDTH/3.,2.,5.,5.,5.,5.,4.,3*0./
      4            DATA XTAB/139*1.,17*13.,5.,3*13.,3*6.,6*13.,7.,
      5           &3*13.,8.,18*13.,9.,6*13.,3*10.,12.,10.,11.,11.,
      6           &3*13.,30*14.,170*2.,2*3.,388*2.,200*4./
      7            DATA XDATE/1.5,4.0,7.5,13.0,18.5,24.0,27.75,3*0./
      8      1     READ(25,50,END=300) (XID(J),J=1,16)
      9      50    FORMAT(F4.1,F2.0,F2.0,F3.1,F3.0,3F1.0,7F6.0,F2.0)
     10      C     FILTER FOR EXPOSED WHITE MALES WITH KNOWN CAUSE OF DEATH
     11      C     IF XID(8).EQ.0.) GO TO 998
     12            IF(XID(7).EQ.0.) GO TO 997
     13            IF(XID(6).EQ.0.) GO TO 996
     14            IF(XID(5).EQ.0.) GO TO 995
     15      C     IF(XID(4).EQ.0.) GO TO 994
     16      C      RECODE CAUSE OF DEATH INTO 14 CATEGORIES
     17      C     1 =  ICDA FROM 1 TO 139
     18      C     2 = ICDA FROM 240 TO 409 AND 412 TO 799
     19      C     3=ICDA 410 AND 411
     20      C     4 = ICDA FROM 800 TO 999
     21      C     5 = ICDA 1157...PANCREAS CANCER
     22      C     6 = ICDA 161 TO 163 ... RESP SYST. CANCER
     23      C     7 = ICDA 170 ... BONE CANCER
     24      C     8 = ICDA 174 ... BREAST CANCER
     25      C     9 = ICDA 193... THYROID CANCER
     26      C     10 = ICDA 200 TO 202 AND 204... LYMPHOID CANCER
     27      C     11 = ICDA 205 AND 206 ... MYELOID LEUK.
     28      C     12 = ICDA 203 ... MULT. MYELOMA
     29      C     13 = ICDA 140 TO 209 EXCLUDING THOSE CODED 5 THROUGH 12 ABOVE
     30      C     14 = ICDA 210 TO 239 OTHER CANCER TYPES (BENIGN OR UNSPECIFIED)
     31            K = XID(5)
     32            XREC(1) = XTAB(K)
     33      C     RECODE CAUSE OF DEATH INTO THREE GROUPS
     34      C     BLOOD CANCER = 0
     35      C     NON CANCER = 1
     36      C     SOLID TUMORS = 2
     37            XREC(2) = 9.
     38            IF((XID(5).LT.140.) .OR.(XID(5).GT.209.)) XREC(2) = 1.
     39            IF((XID(5).GE.140.).AND.(XID(5).LE.199.)) XREC(2) = 2.
     40            IF((XID(5).GE.200.).AND.(XID(5).LE.209.)) XREC(2) = 0
     41      C     GET THE DELTA T FROM VARIOUS POINTS IN EMPLOYMENT AND DEATH
     42      C     DT(1) IS TIME FROM INITAL EMPLOY. TO DEATH
     43      C     DT(2) IS TIME FROM END OF EMPLOYMENT TO DEATH
     44      C     DT(3) IS THE TIME FROM  THE MIDDLE OF EMPLOY. TO DEATH
     45            DT(1) = XID(16) - XID(2)
     46            DT(2) = XID(16) - XID(3)
     47            DT(3) = XID(16) - (((XID(3)-XID(2))/2.)+XID(2))
     48      C     DOSES RECEIVED IN VARIOUS DELTA T INTERVALS
     49      C     DETERMINE THE DOSES AT VARIOUS TIMES TIL DEATH
     50      C     VARIABLE  TIME INTERVAL
     51      C     DOS(1)      0 TO 3
     52      C     DOS(2)       4 TO 5
     53      C     DOS(3)       6 TO 10
     54      C     DOS(4)      11 TO 15
     55      C     DOS(5)     16 TO 20
     56      C     DOS(6)    21 TO 25
     57      C     DOS(7)       MORE THAN 25
     58            DOS(1) = XID(9) - XID(10)
     59            DOS(2) = XID(10) - XID(11)
     60            DOS(3) = XID(11) - XID(12)
     61            DOS(4) = XID(12) - XID(13)
     62            DOS(5) = XID(13) - XID(14)
     63            DOS(6) = XID(14) - XID(15)
     64            DOS(7) = XID(15)
```

Program used to generate variables DT1, DT2, DT3, DOS0-3, DOS4-5, DOS6-10, DOS11-15, DOS16-20, DOS21-25, DOS25+, MAXDOS and TMAXDOS. (Continued on next page)

```
C     FIND THE MAXIMUM DOSE RECIEVED IN ANY GIVEN TIME INTERVAL
C     NOTE THAT THE TIME INTERVALS ARE OF DIFFERENT LENGTH
C     AND THAT THIS PUTS SOME TIME INTERVALS AT A DISADVANTAGE SINCE
C     THEY HAVE FEWER YEARS TO ACCUMULATE DOSE...HOWEVER
C     AT THIS POINT WE'LL SEE WHAT THIS DOES AND IF IF LOOKS AT
C     ALL PROMISING WE CAN TAKE THIS EFFECT INTO ACCOUNT
      XMAXD = AMAX1(DOS(1),DOS(2),DOS(3),DOS(4),DOS(5),DOS(6),DOS(7))
      K = 0
      DO 125  I = 1,7
      IF(XMAXD.EQ.DOS(I)) K = I
      IF(XMAXD.EQ.DOS(I)) GO  TO 126
125   CONTINUE
      IF(K.EQ.0) WRITE(-,-) K,K,K,K,(XID(L5),L5=1,16)
126   CONTINUE
      XDATE(7) = ((XID(16) - XID(2) - 25.)/2.)+25.
      IF((XDATE(7).LT.25.).AND.(K.EQ.7)) WRITE(-,-) (XID(L),L=1,16)
C     FIND THE  TIME FROM THE MAXIMUM DOSE
      DT(4) = XDATE(K)
      XINT(2) = XID(1)**2.
      WRITE(21,70) (XID(L6),L6=1,16),
     &XREC(1),XREC(2),DT(1),DT(2),DT(3),(DOS(I),I=1,7),XMAXD,DT(4),
     &XINT(2)
70    FORMAT(16F8.1,15F8.1)
      GO TO  1
998   ICNT = ICNT + 1
      GO TO 1
997   ICNT1 = ICNT1 + 1
      GO TO 1
996   ICNT2 = ICNT2 + 1
      GO TO 1
995   ICNT3 = ICNT3 + 1
      GO TO 1
994   CONTINUE
      ICNT4 = ICNT4 + 1
      GO TO 1
300   CONTINUE
      WRITE(-,-) ICNT,ICNT1,ICNT2,ICNT3,ICNT4
      STOP
      END
```

Program used to generate variables DT1, DT2, DT3, DOS0-3, DOS4-5, DOS6-10, DOS11-15, DOS16-20, DOS21-25, DOS25+, MAXDOS and TMAXDOS. (Continued from previous page)

APPENDIX E

SUMMARY OF LOGISTIC MODELING

APPENDIX E

KEY

EUWM-ALL	Exposed and Unexposed White Males - All cases included.
EUWM-NA	Exposed and Unexposed White Males - No accident cases included.
EWM-ALL	Exposed White Males - All cases included.
EWM-NA	Exposed White Males - No accident cases included.
-2LOG(L)	Log of the likelihood ratio
Δ	Decrease in -2LOG(L) from the constant model to the specific model.

The tables below contain models which specify

$$\log \left[P/(1-P) \right]$$

where P is the probability that death was due to the specific cancer.

n.b. Definitions of variables are contained in Appendix D. In particular, note the specific form of AGESQ.

RESPIRATORY MODELS*

RESP-ALL
EUWM-ALL

Model	-2LOG(L)	Δ
-2.6625	1493.4	
-2.2484-.3440(AGESQ) 30.1	1445.9	47.7
-5.0539-.3470(AGESQ)+.0439(YRDEATH) 29.8 13.0	1431.9	61.5
-4.9076-.3438(AGESQ)+.0412(YRDEATH)+.0012(DOS16-20) 29.3 11.1 1.5	1430.6	62.8

Model	-2LOG(L)	Δ
-6.18-.346(AGESQ)+.037(YRDEATH)+.033(INITYR)+ 30.2 8.6 2.9 .0013(DOS16-20) 1.8	1427.9	65.5
-6.43-.353(AGESQ)+.041(YRDEATH)+.0337(INITYR) 30.9 10.9 2.92 -.0003(DOS6-10) .44	1428.9	64.5
-6.49-.356(AGESQ)+.0375(YRDEATH)+.0397(INITYR) 31.1 8.7 4.0 +.0026(DOS16-20)-.001(DOS6-10) 4.7 2.6	1424.8	68.6

RESP ALL-ACC
EUWM-NA

Model	-2LOG(L)	Δ
-2.4939	1427.9	
-2.1417-.3139(AGESQ) 23.7	1394.6	33.2
-4.6868-.3240(AGESQ)+.0399(YRDEATH) 24.9 10.4	1383.5	44.3
-4.1035-.3017(AGESQ)+.0464(YRDEATH)-.0167(AGE) 22.0 13.3 4.0	1379.6	48.2

*NOTE: Numbers below the variable names represent chi square values for the variable after all other terms are entered.

EWM-ALL

Model	Constant	AGESQ	INITLYR	YRDEATH	DOS16-20	-2 log·L
1	-2.57					981.1
2	-2.21	-.291 (16.6)				956.4
3	-4.37	-.301 (18.0)	.047 (4.7)			952.1
4	-4.35	-.290 (16.2)		.033 (4.4)		951.7
5	-5.78	-.298 (17.3)	.038 (2.96)	.028 (3.02)		949.0
6	-4.51	-.296 (17.4)	.048 (4.99)		.0018 (3.5)	949.2
7	-4.13	-.286 (15.7)		.029 (3.3)	.0012 (1.6)	950.3
8	-5.64	-.294 (16.9)	.041 (3.4)	.023 (1.9)	.0014 (2.0)	947.2

Results of fitting eight logistic regression models using respiratory cancer and no cancer as the two response categories. Only exposed white males are included in the model. Variables which have no entry for a particular model were not used in that model. For each model, the first value under the variable is the coefficient of that variable in the logistic regression model, while the second value (below in parentheses) is the chi-square value for a test of statistical significance of that variable. All chi-square values have one degree of freedom.

	EWM-NA -2LOG(L)	Δ
-2.406	938.3	
-2.109-.259(AGESQ) 12.4	921.9	16.4
-5.0770-.2563(AGESQ)+.0626(INITYR)+.0017(DOS16-20) 12.3 7.9 3.3	912.5	25.8
-5.4571-.2718(AGESQ)+.0715(INITYR)-.0010(DOS6-10) 13.2 9.9 2.5 +.0030(DOS16-20) 6.3	909.6	28.7

PANCREAS MODELS	PANCREAS EUWM-ALL	
-4.0389	514.9	
-3.7519-.2093(AGESQ) 4.6	508.5	6.4
-3.8432-.1951(AGESQ)+.0033(DOS4-5) 4.1 7.3	503.5	11.4
	EUWM-NA	
-3.8704	497.8	
-3.9494+.0037(DOS4-5) 9.1	491.7	6.1
-3.6534-.1708(AGESQ) 2.8	494.4	3.4
	EWM-ALL	
-4.0164	321.6	
-4.1436+.0036(DOS4-5) 8.5	315.9	5.7
-3.977+.0035(DOS4-5) -.1107(AGESQ) 7.7 1.2	314.5	7.1

	EWM-NA -2LOG(L)	Δ
-3.8528	311.3	
-3.9827+.0038(DOS4-5) 9.0	305.1	6.2
-3.9051+.0037(DOS4-5)-.0550(AGESQ) 8.4 .25	304.8	6.5

BRAIN MODELS

	BRAIN EUWM-ALL	
-4.6749	306.7	
-4.7401+.0121(DOS25+) 5.8	303.2	3.5
-3.2417+.0132(DOS25+)-.0260(AGE) 7.1 3.4	299.9	6.8
-3.2660+.0085(DOS25+)-.0541(AGE)+.0937(DT1) 2.4 8.6 6.6	292.7	14.0
-3.3680+.1054(DT1)-.0551(AGE) 8.7 9.1	294.4	12.3

	EUWM-NA	
-4.506	297.6	
-2.0058-.0424(AGE) 7.6	290.1	7.5
-1.9059-.0453(AGE)+.0125(DOS25+) 8.4 6.4	286.3	11.3
-2.1103-.0713(AGE)+.0993(DT1) 13.9 7.8	281.5	16.1
-1.9985-.0704(AGE)+.0877(DT1)+.0080(DOS25+) 13.4 5.8 2.1	279.97	17.63

	EWM-ALL	
-4.5917	201.5	
-4.6909+.0118(DOS25+) 5.3	198.2	3.3
-3.4725-.0907(AGE)+.2089(DT1) 11.4 14.5	181.1	19.4
-2.9896+.0130(DOS25+)-.0296(AGE) 6.6 2.8	195.5	6.0
-3.3311+.0047(DOS25+)-.0896(AGE)+.1965(DT1) .6 11.1 12.0	180.5	21.0

	EWM-NA -2LOG(L)	Δ
-4.4282	195.6	
-1.8145-.0444(AGE) 5.4	190.3	5.3
-2.3346-.1041(AGE)+.2006(DT1) 14.4 13.2	173.4	22.2
-1.6547-.0490(AGE)+.0124(DOS25+) 6.2 6.0	186.6	9.0
-2.1928-.1031(AGE)+.1887(DT1)+.0042(DOS25+) 14.0 10.8 .46	173.0	22.6

1393 219