age at risk to consider latency (lag). In no case is there a suggestion of increasing odds ratios with increasing numbers of x-rays. As noted above, this variable is highly associated with length of employment.

Case-control differences in estimates of exposures to various chemical and physical hazards on the job are shown in Table 4.24. For this analysis, workers with an unexposed rating of medium or high confidence are considered as the referent group. Workers with an exposed rating of medium or high confidence are considered to be exposed, and workers classified with a low level of certainty are considered separately as uncertain. Each hazard is considered in a separate set of analyses using Model 1 and Model 2. Model 1 odds ratios reflect only the matching. Model 2 odds ratios include adjustment for race, gender, and longest facility worked. Considering the small numbers in these analyses, there are no strong associations of MM with any of the hazards in Table 4.24. The largest odds ratios among the exposed are observed for aromatic hydrocarbons (panel A), uranium (panel I), and welding fumes (panel J), however these are smaller following adjustments in Model 2. In the case of welding fumes, odds ratios are as large or larger for the group with uncertain exposure as for the group classified as exposed.

Monitoring for internal contamination by selected radionuclides is considered in Table 4.25 using Models 1 and 2. None of the odds ratios for selected radionuclides or for the category of any internal monitoring, which includes workers who were monitored by whole body counting, is very different from the null value. Odds ratios with additional adjustment for Model 2 factors were generally similar to those for Model 1. The largest effect of adjustment occurs for strontium, for which there were only five exposed cases: the Model 1 odds ratio is 1.25 and the Model 2 ratio is 0.76.

Analyses of external penetrating ionizing radiation are presented using a "full model" to control for all other factors considered above that are of interest due to the design of the study and the evaluation of the other occupational exposures. This model includes all the Model 2 variables used above (race, gender, birth cohort and facility) as well as two additional factors, hire during the W.W.II era, and monitoring for internal radionuclide contamination. Results for cumulative external radiation doses over all ages are given in Table 4.26. Separate models were estimated for doses cumulated under 5, 10 and 20 year lags; internal monitoring is considered in each model with a lag equal to the lag for external dose. The odds ratio is the estimate of the relative risk for 10 mSv increase in cumulative external radiation. Odds ratios for 5 and 10 year lags are very close to the null value, 1.0, which represents no association. The odds ratio for a 20 year lag is below 1.0, suggesting a negative association, but the confidence interval is wider, reflecting the smaller numbers of workers with higher doses under the longer lag assumption.

External radiation dose was also considered according to age at exposure. In this model, doses are counted as a separate variable depending on whether they occurred before age 45, or at ages 45 and above. Results for younger and older age doses are estimated from a single model that includes race, gender, birth cohort, facility, W.W.II hire, and internal monitoring. This means that the association of doses in each age range with MM is adjusted for the effects of doses in the other age range. A model was fit only for a 5 year lag due to the small numbers of workers with higher age-specific doses under longer lag assumptions. Table 4.27 shows that doses below age 45 have negative (odds ratio less than 1.0) but imprecisely estimated association with MM. In contrast, the odds ratio for doses at ages 45 and above shows a positive association (odds ratio=1.07), and it is estimated with higher level of precision that is conventionally interpreted as a positive result (95% CI=1.01-1.13, p=0.02). In this model, the odds ratio for black race is 8.19 (95% CI=2.0-33.09), the odds ratio for male gender is 2.3 (1.14-4.77), the odds ratio for W.W.II hire is 1.9 (1.10-3.28), and the odds ratio for internal monitoring is 0.58 (0.32-1.03). The odds ratios for birth cohort and facility are close to 1.0 and similar to the values presented earlier without adjustment for occupational factors.

Doses accumulated at ages 45 and older were also considered using indicator variables to compute odds ratios for doses of 10 to 50 mSv and 50 mSv and above to doses below 10 mSv as the referent. These odds ratios were adjusted for the other variables noted above. Odds ratios were 0.76 (0.26-2.21) for the 10-50 mSv group and 4.34 (1.46-12.90) for the 50+ mSv group.

V. DISCUSSION

As researchers outside DOE's Epidemiology program and under contract to NIOSH, we have conducted a study of DOE workers across multiple facilities, attempting to collect and compare detailed exposure information from worker records for a selected group of cases and a randomly chosen comparison group. This work was accomplished during the period of time shortly following transfer of responsibility for epidemiological studies of DOE workers from DOE to NIOSH. The facilities in this study had little experience cooperating with researchers outside the DOE system. We therefore encountered numerous legal and bureaucratic problems related to facility access, cooperation of professional staff, and access to records with personal identifiers. For example, data access at LANL was not possible until a confidentiality agreement had been reached that involved interactions of researchers, administrators and attorneys for UNC, NIOSH, DOE and the University of California. These conditions affected the completeness and quality of data that were collected, and delayed our progress.

This study included workers from two scientific laboratories and two production facilities. General historical information about these facilities indicated that each facility had unique industrial characteristics and activities with the potential for particular exposure situations that could influence the occurrence of MM. However, because the facilities have been involved in activities that are classified as secret, specific information about some processes was not available. This is important for general descriptions of facilities and also affected assessment of specific physical and chemical hazards; for example, at SRS, codes indicating building locations were redacted from the information on physical and chemical hazards present in certain work areas. This study was not primarily designed to assess differences in MM occurrence between the study facilities, however, because we chose not to match cases and controls by facility, we could compare differences in facilities of employment between cases and controls to observe whether MM rates were higher at any specific facility. Results of these comparisons, which included the additional MM cases identified at LANL through review of death certificates for MM as a contributory cause of death, were in general agreement with the cohort comparison analyses conducted for NIOSH following the feasibility report for this project: there were small differences in the occurrence of MM between facilities. The role of differential completeness of death certificate ascertainment of MM between facilities cannot be assessed in our study, although previous studies in New Mexico and Oak Ridge suggest this possibility (Becker et al., 1990; Cragle and Fetcher, 1992). However, given the sample size of the study, MM rate differences between facilities on the order of 50 to 100 percent could not be estimated with much precision (see Tables 18-20).

It is not surprising that some data were not suitable for analytical purposes. These include information from job applications and medical records that had not been used previously for epidemiological studies. We had hoped that monitoring from industrial hygiene programs would have been of sufficient quality across facilities to allow development of a quantitative exposure measure for at least some agents. However, only a qualitative score could be developed considering the quality of the original records, the obstacles to data access, and the resources available. This problem is evident from the proportions of workers who received chemical and physical hazard ratings of only low or moderate certainty for a categorization of ever vs. never exposed (Table 4.8). The lack of strong associations of any of the physical and chemical hazard variables with MM must be considered in light of the incompleteness of monitoring and the small size of this study. Modest-sized associations of public health importance may easily go undetected in such situations.

Our inability to collect better data on exposures to ionizing radiation was a disappointment. In the case of internal radionuclide contamination, it was recognized that calculation of quantitative bone marrow dose estimates would be difficult. However, collection of data on internal radiation was incomplete due to our inability to collect original bioassay records from LANL.

The prevalence of exposure to external penetrating ionizing radiation above 50 mSv was low in this study compared to other studies of populations from the same facilities (e.g., Gilbert et al., 1993a; Wing et al., 1991). This occurred because women, non-Whites, and short-term employees were part of the study in addition to men and workers with longer durations of employment who have been studied in the past. This not only resulted in a more inclusive study in terms of groups such as women and African Americans who have been excluded from past research, but increased the number of cases of MM available for analysis. Thus, although the number of cases was increased, in particular by including short term employees and women, this did not help increase the sample size at higher exposure levels, which would have been more important to increasing the statistical power of the study.

In the case of external penetrating radiation, we had hoped to uniformly collect detailed dose records for all workers. These are the records from which annual doses were calculated by the facilities and which have been available through CEDR. However, Battelle-Pacific Northwest Laboratory, which was responsible for historical dosimetry at the Hanford site, did not agree to provide detailed radiation records for Hanford workers. Additionally, at ORNL and Hanford, all dose records for workers who had only worked in the early years under Du Pont had been removed from the sites. We therefore had to depend on the annual CEDR records for those workers. Had detailed external dose records been routinely available, we could have made data-based estimates of errors in doses that could have been used to adjust for some measurement problems. However, because no such data were available for a substantial proportion of workers in the study, this was not done.

Although the percentage of African American workers in these cohorts was small, the odds ratio for African Americans compared to other racial groups was large. Other studies have shown higher MM rates for Blacks, however, the magnitude of the association in this population, although based on only five Black cases, is very large. Adjustment for other factors including radiation does not statistically account for any of this association; rather, the odds ratio for Blacks vs. others is larger with adjustments for internal and external radiation (8.19) than with adjustments only for gender, birth cohort and facility (5.76). If the excess of MM among African Americans is associated with radiation exposures, the exposure measurements in this study were not accurate enough to detect the relationship.

Hire during the WW II era was associated with MM even after adjustment for other variables, including birth year, facility of longest employment, race, gender, monitoring for radionuclide contamination, and external dose. The meaning of this excess is unclear. It is possible that workers hired during these years experienced higher exposures to radiation or other occupational agents that increase the occurrence of MM, but that adjustment for those exposures does not account for the excess due to poor measurements during that period. Another possibility is that other unmeasured exposures both before and after employment in the study facilities may have differed between workers hired in the WW II era and other workers. For example, some workers came to study facilities with prior experience on the Manhattan Project to develop nuclear weapons.

Occurrence of MM was estimated to be lower among workers who had been monitored for internal radionuclide contamination than among workers who had not been so monitored. The odds ratio for internal monitoring was 0.58 with adjustment for age-specific external radiation doses and other factors. One problem with this variable is an unknown degree of misclassification due to lack of data from LANL for both LANL and Zia workers. Another issue of interpretation is that the monitoring does not mean that workers were actually contaminated, only that they had worked at a time and place where there were concerns about possible contamination. Therefore, monitoring is not only a measure of exposure potential, but is also a marker of work in certain jobs that may have involved more health-related selection than other jobs, which could have contributed to the observed negative association.

Total cumulative radiation dose was not associated with MM. However, those exposures above age 45 were positively associated with MM. The odds ratio, considering a five-year lag and adjustment for other factors including radiation exposure at younger ages, indicates about a 7% increase per 10 mSv of cumulative radiation dose. Workers with total cumulative doses at ages 45 and above of 50 mSv or greater (the current annual occupational limit) were estimated to have had a MM rate over 4 times higher than workers whose older-age cumulative dose was less than 10 mSv. The finding of higher sensitivity to radiation at older ages is consistent with other studies of workers that have examined age differences in carcinogenicity of ionizing radiation (Stewart and Kneale, 1996; Dupree et al., 1995; Polednak and Frome, 1981; Hornung and Meinhardt, 1987).

VI. SUMMARY AND CONCLUSIONS

We were able to collect a large amount of data from facilities that had not previously opened their records to organizations external to the DOE system. Many but not all of the records sought for the study were collected. Overall, there was little indication of any association between specific suspected occupational carcinogens and MM. The exception to this observation was external penetrating radiation doses received at ages 45 and above.

The study was limited by both measurement quality and sample size. Only workers who died with MM as an underlying or contributory cause of death were counted as cases. Because MM has a poor prognosis, this would not result in as much of an undercount of cases as would occur with a disease that has a high survival rate, but it no doubt plays a role in reducing the power of the study. Only 98 cases of MM were identified among over 115,000 workers in the five DOE cohorts included in this study.

Multiple myeloma is a rare hematological malignancy that has been associated with exposure to external penetrating ionizing radiation in certain populations, including some worker groups. Because ionizing radiation has been established as a causal agent for induction of MM, the primary scientific rationale for this case control study was *not* to provide evidence on whether external ionizing radiation is a risk factor for MM. Rather, the scientific questions concerned the magnitude of the excess risk for protracted low doses of ionizing radiation, and the potential confounding or synergistic influences of other exposures. These two issues, the magnitude of low dose effects and the combined influences of multiple exposures, reflect the historical development of epidemiological research beyond the identification of a disease agent to more complex questions about the form of exposure-disease relationships and the roles of multiple interacting exposures. Recognition of the stages of development of research questions in the normal conduct of risk factor epidemiology is critical to planning and justifying the present research. Because the status of ionizing radiation as a risk factor is well accepted, studies should be designed to focus on these other outstanding scientific questions.

The rareness of MM raises strategic questions about the choices of diseases to study in occupational health studies in general, and radiation epidemiology in particular. Ionizing radiation is perhaps the best known mutagen and has been associated with all or almost all types of malignancies. Because recorded radiation doses at most DOE facilities are fairly low, large numbers of cases are needed to detect statistical associations between measured doses and disease. Large sample sizes are also required for studies of synergistic relationships between multiple exposures, such as internal and external radiation, or radiation and chemicals. Separate study of specific diseases, especially rare ones like MM, limits the statistical power to detect associations at low doses and to identify synergistic effects. Study of rare diseases also reduces the public health implications of the work by focusing on conditions of importance to smaller numbers of workers rather than on more broadly defined diseases that affect more people. We recommend that future studies of DOE workers include broader groups of diseases, and that questions about variations in dose response relationships for specific disease sub-types be addressed conducting sub-group analyses within the context of larger studies.

VII. DISSEMINATION OF DATA

Copies of all information collected for this study have been provided to the Health-Related Energy Research Branch at the National Institute for Occupational Safety and Health. The documents in our reference collection have been scanned by NIOSH and available at their Cincinnati offices. Information about individual workers that was used in data analyses has been entered into electronic files and copies given to NIOSH. The original paper copies of our records on individual workers will be forwarded to NIOSH for archiving after a paper has been completed and accepted for publication. At that time, the electronic files used for data analyses will also be made available for public use through the Department of Energy's Comprehensive Epidemiologic Data Resource (CEDR). The latter files have been stripped of unique identifiers and other personal information in order to protect the identity and privacy of individual DOE workers.

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Table 3.1 (cont): Characteristics of Five Worker Cohorts

Attribute	ORNL #	ORNL %	SRP #	SRP %	Hanford #	Hanford %	LANL #	LANL %	ZIA #	ZIA %	Total #	Total %
Gender												
Male	15,877	75.5	13,126	84.1	30,966	71.0	15,135	70.3	9,240	69.0	84,344	73.3
Female	5,142	24.5	2,483	15.9	12,624	29.0	6,292	29.2	871	6.5	27,412	23.8
Unknown	2	0.0	2	0.0	-	-	97	0.5	3,286	24.5	3,387	2.9
TOTAL	21,021	100.0	15,611	100.0	43,590	100.0	21,524	100.0	13,397	100.0	T 115,143	T 100.0
Decade of Hire												
1940-1949	5,980	28.4	--	--	16,474	37.8	6,682	31.1	8,503	63.5	37,639	32.7
1950-1959	5,584	26.6	11,206	71.8	9,316	21.4	5,388	25.0	1,552	11.6	33,046	28.7
1960-1969	4,993	23,8	1,741	11.1	6,173	14.1	4,356	20.2	1,573	11.7	18,836	16.4
1970-1978	4,464	21.2	2,664	17.1	11,627	26.7	5,098	23.7	1,769	13.2	25,622	22.2
TOTAL	21,021	100.0	15,611	100.0	43,590	100.0	21,524	100.0	13,397	100.0	T 115,143	T 100.0
Age at Death												
15 - <30	76	1.8	60	2.3	126	1.3	70	1.9	69	1.5	401	1,6
30 - <50	606	14.1	550	21.3	1,179	12.4	538	14.3	528	11.4	3401	13.8
50 - <60	891	20.8	736	28.6	1,858	19.6	746	19.9	774	16.7	5005	20.2
60 - <70	1,347	31.4	793	30.8	2,808	29.6	1,094	29.2	1,318	28.5	7360	29.8
70 - <80	992	23.1	362	14.1	2,433	25.6	894	23.8	1,233	26.6	5914	23.9
80+	378	8.8	76	2.9	1,087	11.5	407	10.9	710	15.3	2658	10.7
TOTAL	4,290	100.0	2,577	100.0	9,491	100.0	3,749	100.0	4,632	100.0	T 24,739	T 100.0

1 Subjects are counted only once and according to the facility of first hire.
2 Date of last observation is not available. All persons not deceased were assumed to be alive at the end of follow-up (12-31-86).
3 Estimated dates of death were not available for persons with death indications but without a verified death certificate. These cases were considered unknown at the end of the study and were withdrawn as of the date last known alive.

Source of Data: Program: MMB0001 Data Files: MMB0206A.S.CHXS
MB0301A.S.CHL2
MMB0401A.S.CH

Table 3.2: Number and Percent of Personnel, Occupational Health, and Radiation Records Retrieved by Facility[1]

Record Type	ORNL # (%)	SRS # (%)	Hanford # (%)	LANL # (%)	Zia # (%)	TOTAL[2] # (%)
Personnel	50 (65.8)	33 (63.5)	131 (74.9)	110 (97.3)	19 (20.4)	343 (67.4)
Occupation Health	62 (81.5)	52 (100.0)	170 (97.1)	94 (83.2)	42 (45.2)	420 (82.5)
Invivo	13 (17.1)	32 (61.5)	50 (28.6)	12 (10.6)	2 (2.1)	109 (21.4)
Bioassay	20 (26.3)	40 (76.9)	95 (54.3)	---	---	155 (30.5)
External Radiation	58 (76.3)	46 (88.5)	119 (68.0)	54 (47.8)	24 (25.8)	301 (59.1)
Total Ever Worked	76	52	175	113	93	509

[1] Includes only records retrieved onsite.
[2] Workers are counted at each facility employed, except for two workers at Hanford selected for 2 different cases.

Table 3.3: Number and Percent of Personnel and Occupational Records Retrieved for Cases and Controls

Record Type	Case Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
Personnel	67	(68.4)	276	(70.6)	343	(70.1)
Occupational Health	79	(80.6)	326	(83.3)	405	(82.8)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Table 4.1: Distribution of Age at Risk for Cases and Controls

Age Group	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
<55	11	(11.2)	44	(11.2)	55	(11.2)
55 - 64	34	(34.7)	136	(34.8)	170	(34.8)
65 - 74	32	(32.7)	127	(32.5)	159	(32.5)
75+	21	(21.4)	84	(21.5)	105	(21.5)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Source: mmian11 (9/17/96)

Table 4.2: Distribution of Race for Cases and Controls

Race	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
White	90	(91.8)	360	(92.1)	450	(92.0)
African-American	5	(5.1)	5	(1.3)	10	(2.0)
Other	1	(1.0)	2	(0.5)	3	(0.7)
Unknown	2	(2.0)	24	(6.1)	26	(5.3)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Source: mmian20 (10/17/96)

Table 4.3: Distribution of Year of Hire at Index Facility for Cases and Controls

Year of Hire	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
< 1948	60	(61.2)	190	(48.6)	250	(51.1)
1948 - 54	23	(23.5)	137	(35.0)	160	(32.7)
1955+	15	(15.3)	64	(16.4)	79	(16.2)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Source: mmian11

Table 4.4: Number and Percent of Workers by Years Worked at All Facilities for Cases and Controls

Length of Employment	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
< 1 Years	24	(24.5)	103	(26.3)	127	(26.0)
1 - <5 Years	29	(29.6)	96	(24.6)	125	(25.6)
5 - <15 Years	20	(20.4)	79	(20.2)	99	(20.2)
15+ Years	25	(25.5)	113	(28.9)	138	(28.2)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Source: mmifq15 (11/22/96)

Table 4.5: Distribution of Highest Educational Level Attained for Cases and Controls

Attained Educational Level	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
< 9 Years	8	(8.2)	33	(8.4)	41	(8.4)
9 - 11 Years	12	(12.2)	29	(7.4)	41	(8.4)
HS Grad	12	(12.2)	45	(11.5)	57	(11.6)
Some College	8	(8.2)	56	(14.3)	64	(13.1)
2 Year College	1	(1.0)	14	(3.6)	15	(3.1)
BS/BA	5	(5.1)	43	(11.0)	48	(9.8)
MS/PhD	16	(16.3)	35	(9.0)	51	(10.4)
Unknown	36	(36.8)	136	(34.8)	172	(35.2)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Table 4.6: Distribution of Smoking Habits Noted During Employment for Cases and Controls

Smoking	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
Yes	22	(22.4)	112	(28.7)	134	(27.4)
No	12	(12.3)	45	(11.5)	57	(11.7)
Unknown	64	(65.3)	234	(59.8)	298	(60.9)
Total	98	(100.0)	391	(100.0)	489	(100.0)

Source: ccbase10.db

Table 4.7: Number and Percent of Occupationally Related Chest Xrays[1] Received During Employment at DOE Study Facilities for Cases and Controls

Number of Xrays	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
0 - 1[2]	37	(37.8)	149	(38.1)	186	(38.0)
2 - 9	39	(39.8)	148	(37.9)	187	(38.2)
10+	22	(22.4)	94	(24.0)	116	(23.7)
Total	98	(100.0)	391	(100.0)	489	(100.0)

[1] Xrays counted with a 5 year lag.
[2] Workers without medical records were counted in the 0-1 Xray group because as a group they worked less than 2 years, and the number of chest Xrays was higly correlated with the number of years worked.
Source: mmian28 (10/30/96)

Table 4.8: Rating of Exposure to Chemicals and Non-Ionizing Radiation by Confidence Level for All Cases and Controls

Chemical/Physical Agent	Level of Confidence: Low #	(Row %)	Medium #	(Row %)	High #	(Row %)	Total #	(Column%)
A. Aromatic Hydrocarbons								
Exposed	113	(53.5)	22	(10.4)	76	(36.0)	211	(43.1)
Unexposed	55	(19.9)	170	(61.0)	53	(19.1)	278	(56.9)
TOTAL	168	(34.4)	192	(39.3)	129	(26.4)	489	(100.0)
B. Halogenated Hydrocarbons								
Exposed	96	(41.0)	17	(7.3)	121	(51.7)	234	(47.9)
Unexposed	45	(17.6)	156	(61.2)	54	(21.2)	255	(52.1)
TOTAL	141	(28.8)	173	(35.4)	175	(35.8)	489	(100.0)
C. Any Metal								
Exposed	66	(29.9)	22	(9.9)	133	(60.2)	221	(45.2)
Unexposed	44	(16.4)	165	(61.6)	59	(22.0)	268	(54.8)
TOTAL	110	(22.5)	187	(38.2)	192	(39.3)	489	(100.0)
D. Beryllium								
Exposed	81	(56.2)	4	(2.8)	59	(41.0)	144	(29.4)
Unexposed	80	(23.2)	205	(59.4)	60	(17.4)	345	(70.6)
TOTAL	161	(32.9)	209	(42.7)	119	(24.4)	489	(100.0)
E. Cadmium								
Exposed	112	(70.0)	6	(3.7)	42	(26.3)	160	(32.7)
Unexposed	77	(23.4)	192	(58.4)	60	(18.2)	329	(67.3)
TOTAL	189	(38.6)	198	(40.5)	102	(20.9)	489	(100.0)

Source: mmfih02 (10/7/96)

Table 4.8 (cont): Rating of Exposure to Chemicals and Non-Ionizing Radiation by Confidence Level for All Cases and Controls

Chemical/Physical Agent	Level of Confidence						Total	
	Low		Medium		High			
	#	(Row %)	#	(Row %)	#	(Row %)	#	(Column%)
F. Lead								
Exposed	88	(46.1)	18	(9.4)	85	(44.5)	191	(39.1)
Unexposed	68	(22.8)	171	(57.4)	59	(19.8)	298	(60.9)
TOTAL	156	(31.9)	189	(38.7)	144	(29.4)	489	(100.0)
G. Mercury								
Exposed	80	(53.7)	14	(9.4)	55	(36.9)	149	(30.5)
Unexposed	77	(22.6)	203	(59.7)	60	(17.7)	340	(69.5)
TOTAL	157	(32.1)	217	(44.4)	115	(23.5)	489	(100.0)
H. Nickel								
Exposed	90	(75.6)	6	(5.1)	23	(19.3)	119	(24.3)
Unexposed	83	(22.4)	227	(61.4)	60	(16.2)	370	(75.7)
TOTAL	173	(35.4)	233	(47.6)	83	(17.0)	489	(100.0)
I. Uranium								
Exposed	53	(41.1)	8	(6.2)	68	(52.7)	129	(26.4)
Unexposed	89	(24.7)	212	(58.9)	59	(16.4)	360	(73.6)
TOTAL	142	(29.0)	220	(45.0)	127	(26.0)	489	(100.0)
J. Welding Fumes								
Exposed	64	(52.5)	12	(9.8)	46	(37.7)	122	(24.9)
Unexposed	62	(16.9)	245	(66.8)	60	(16.3)	367	(75.1)
TOTAL	126	(25.8)	257	(52.5)	106	(21.7)	489	(100.0)

Source: mmfih02 (10/7/96)

Table 4.8 (cont): Rating of Exposure to Chemicals and Non-Ionizing Radiation by Confidence Level for All Cases and Controls

Chemical/Physical Agent	Level of Confidence						Total	
	Low		Medium		High			
	#	(Row %)	#	(Row %)	#	(Row %)	#	(Column%)
K. Other Metals								
Exposed	66	(42.0)	11	(7.0)	80	(51.0)	157	(32.1)
Unexposed	93	(28.0)	180	(54.2)	59	(17.8)	332	(67.9)
TOTAL	159	(32.5)	191	(39.1)	139	(28.4)	489	(100.0)
L. Radiofrequency/ Microwave Radiation								
Exposed	78	(78.8)	7	(7.1)	14	(14.1)	99	(20.2)
Unexposed	32	(8.2)	306	(78.5)	52	(13.3)	390	(79.8)
TOTAL	110	(22.5)	313	(64.0)	66	(13.5)	489	(100.0)
M. ELF EMF								
Exposed	56	(38.4)	56	(38.4)	34	(23.2)	146	(29.9)
Unexposed	27	(7.9)	264	(77.0)	52	(15.1)	343	(70.1)
TOTAL	83	(17.0)	320	(65.4)	86	(17.5)	489	(100.0)
N. Static Magnetic Fields								
Exposed	58	(58.0)	23	(23.0)	19	(19.0)	100	(20.4)
Unexposed	30	(7.7)	307	(78.9)	52	(13.4)	389	(79.6)
TOTAL	88	(18.0)	330	(67.5)	71	(14.5)	489	(100.0)
O. Asbestos								
Exposed	88	(39.6)	55	(24.8)	79	(35.6)	222	(45.4)
Unexposed	35	(13.1)	168	(62.9)	64	(24.0)	267	(54.6)
TOTAL	123	(25.2)	223	(45.6)	143	(29.2)	489	(100.0)

Source: mmfih02 (10/7/96)

Table 4.9: Number and Percent of All Workers Monitored for Internal Contamination by Select Radionuclides at Each Facility[1]

Radionuclide	Facility[1]											
	ORNL		SRS		Hanford		LANL		ZIA		TOTAL	
	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)
A. Plutonium[2]												
Monitored	14	(18.4)	36	(69.2)	97	(54.8)	25	(22.1)	20	(21.5)	192	(37.6)
Not Monitored	62	(81.6)	16	(30.8)	80	(45.2)	88	(77.9)	73	(78.5)	319	(62.4)
TOTAL	76	(100.0)	52	(100.0)	177	(100.0)	113	(100.0)	93	(100.0)	511	(100.0)
B. Uranium												
Monitored	16	(21.1)	21	(40.4)	8	(4.4)	6	(5.3)	1	(1.0)	52	(10.2)
Not Monitored	60	(78.9)	31	(59.6)	169	(95.6)	107	(94.7)	92	(99.0)	459	(89.8)
TOTAL	76	(100.0)	52	(100.0)	177	(100.0)	113	(100.0)	93	(100.0)	511	(100.0)
C. Strontium												
Monitored	18	(23.7)	0	(0.0)	6	(3.4)	1	(0.9)	0	(0.0)	25	(4.9)
Not Monitored	58	(76.3)	52	(100.0)	171	(96.6)	112	(99.1)	93	(100.0)	486	(95.1)
TOTAL	76	(100.0)	52	(100.0)	177	(100.0)	113	(100.0)	93	(100.0)	511	(100.0)
D. Other												
Monitored	19	(25.0)	27	(51.9)	56	(31.6)	4	(3.5)	1	(1.0)	107	(20.9)
Not Monitored	57	(75.0)	25	(48.1)	121	(68.4)	109	(96.5)	92	(99.0)	404	(79.1)
TOTAL	76	(100.0)	52	(100.0)	177	(100.0)	113	(100.0	93	(100.0)	511	(100.0)

[1] Workers are counted in every facility of employment.
[2] Plutonium includes bioassay and nose swipes.
Source: mmifq12

Table 4.10: Number and Percent of All Workers Monitored for Contamination by Whole Body Counts at Each Facility[1]

Radionuclide	Facility[1]											
	ORNL		SRS		Hanford		LANL		ZIA		TOTAL	
	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)
Whole Body Counts												
Monitored	13	(17.1)	32	(61.5)	50	(28.2)	12	(10.6)	2	(2.2)	109	(21.3)
Not Monitored	63	(82.9)	20	(38.5)	127	(71.8)	101	(89.4)	91	(97.8)	402	(78.7)
TOTAL	76	(100.0)	52	(100.0)	177	(100.0)	113	(100.0)	93	(100.0)	511	(100.0)

[1] Workers are counted in every facility of employment.
Source: mmifq12 (11/1/96)

Table 4.11: Number and Percent of Workers Monitored for External Whole Body Radiation[1], and Neutrons for Cases and Controls

Radiation Dose Type	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
A. Whole Body Dose2[1]						
Monitored	67	(68.4)	257	(65.7)	324	(66.3)
Not-Monitored	31	(31.6)	134	(34.3)	165	(33.7)
TOTAL	98	(100.0)	391	(33.7)	489	(100.0)
B. Neutron						
Monitored	13	(13.3)	66	(16.9)	79	(16.2)
Not-Monitored	85	(86.7)	325	(83.1)	410	(83.8)
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)

[1] Includes gamma, xray, high energy betas, neutrons, and tritium.
Source: mmifq09 (10/15/96)

Table 4.12: Percent of Work Years with External Radiation[1] Monitoring Data by Facility[2], for Cases and Controls

Facility[2]	Cases #	Cases (%)	Controls #	Controls (%)	Total #	Total (%)
ORNL						
None	2	(11.1)	5	(8.9)	7	(9.5)
1 - 49%	1	(5.5)	2	(3.6)	3	(4.0)
50 - 74%	1	(5.5)	3	(5.3)	4	(5.4)
75+%	14	(77.8)	46	(82.1)	60	(81.1)
TOTAL	18	(100.0)	56	(100.0)	74	(100.0)
SRS						
None	1	(11.1)	3	(7.0)	4	(7.7)
1 - 49%		--	7	(16.3)	7	(13.5)
50 - 74%		--	8	(18.6)	8	(15.4)
75+%	8	(88.9)	25	(58.1)	33	(63.4)
TOTAL	9	(100.0)	43	(100.0)	52	(100.0)
Hanford						
None	7	(20.0)	29	(20.4)	36	(20.3)
1 - 49%	6	(17.1)	8	(56.3)	14	(7.9)
50 - 74%		--	15	(10.6)	15	(8.5)
75+%	22	(62.9)	90	(63.4)	112	(63.3)
TOTAL	35	(100.0)	142	(100.0)	177	(100.0)
LANL/ZIA						
None	22	(59.5)	99	(62.3)	121	(61.7)
1 - 49%	9	(24.3)	22	(13.8)	31	(15.8)
50 - 74%	3	(8.1)	18	(11.3)	21	(10.7)
75+%	3	(8.1)	20	(12.6)	23	(11.8)
TOTAL	37	(100.0)	159	(100.0)	196	(100.0)
All Facilities						
None	32	(32.3)	136	(34.0)	168	(33.7)
1 - 49%	16	(16.2)	39	(9.8)	55	(11.0)
50 - 74%	4	(4.0)	44	(11.0)	48	(9.6)
75+%	47	(47.5)	181	(45.2)	228	(45.7)
TOTAL	99	(100.0)	400	(100.0)	499	(100.0)

[1] Includes gamma, xray, high energy betas, neutrons, and tritium.
[2] Workers counted in all facilities of employment.
Source: mmifq09 (10/15/96)

Table 4.13: Number and Percent of Workers in External Radiation Dose Equivalent[1] Categories for Cases and Controls

External Radiation Dose Equivalent (mSv)	Case-Control Status					
	Cases		Controls		Total	
	#	(%)	#	(%)	#	(%)
0[2]	47	(47.9)	187	(47.8)	234	(47.8)
>0 - <10	30	(30.6)	118	(30.2)	148	(30.3)
10 - <50	9	(9.2)	56	(14.3)	65	(13.3)
50 - <100	4	(4.1)	10	(2.6)	14	(2.9)
100 - <200	5	(5.1)	9	(2.3)	14	(2.9)
200 - <400	3	(3.1)	9	(2.3)	12	(2.4)
400+	0	(0.0)	2	(0.5)	2	(0.4)
Total	98	(100.0)	391	(100.0)	489	(100.0)

[1] All external radiation dose equivalents are calculated with a 5-year lag and include gamma, x-ray, high energy betas, neutron, and tritium doses.
[2] Not monitored workers are included.
Source: mmifq07 (10/14/96)

Table 4.14: Number and Percent of Workers in Age-Specific, External Radiation Dose Equivalent[1] Categories for Cases and Controls

External Radiation Dose Equivalent (mSv)	Under Age 45			Age 45+		
	Cases	Controls	Total	Cases	Controls	Total
0[2]	64 (65.3)	248 (63.4)	312 (63.8)	65 (66.3)	253 (64.7)	318 (65.0)
>0 - <10	21 (21.4)	89 (22.8)	110 (22.5)	18 (18.4)	88 (22.5)	106 (21.7)
10 - <50	10 (10.2)	40 (10.2)	50 (10.2)	5 (5.1)	31 (7.9)	36 (7.4)
50 - <100	2 (2.1)	5 (1.3)	7 (1.5)	3 (3.0)	7 (1.8)	10 (2.0)
>100 - <200	0 (0.0)	5 (1.3)	5 (1.0)	5 (5.1)	7 (1.8)	12 (2.4)
200 - <400	1 (1.0)	3 (0.8)	4 (0.8)	2 (2.1)	5 (1.3)	7 (1.5)
>400	0 (0.0)	1 (0.2)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)
TOTAL	98 (100.0)	391 (100.0)	489 (100.0)	98 (100.0)	391 (100.0)	489 (100.0)

[1] All radiation dose equivalents are calculated with a 5-year lag and include gamma, xray, high energy betas, neutron, and tritium doses.
[2] Not monitored workers are included.
Source: mmifq14 (11/12/96)

Table 4.15: Model 1[1] and Model 2[2] Odds Ratios for Race

Race	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
African-American	5	(5.1)	5	(1.3)	10	(2.0)	4.00 1.16 - 13.82 (0.03)	5.76 1.46 - 22.69 (0.01)
Other	93	(94.9)	386	(98.7)	479	(98.0)	1.00	1.00
Total	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, longest facility worked, and gender.
Source: mmian26 (11/26/96)

Table 4.16: Model 1[1] and Model 2[2] Odds Ratios for Male vs. Female

Gender	Case-Control Status			Model 1[1]	Model 2[2]
	Cases	Controls	Total	Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	# (%)	# (%)	# (%)		
Male	87 (88.8)	313 (80.05)	400 (81.8)	1.99 1.01 - 3.94 (0.05)	2.20 1.09 - 4.44 (0.03)
Female	11 (11.2)	78 (19.95)	89 (18.2)	1.00	1.00
Total	98 (100.0)	391 (100.0)	489 (100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, longest facility worked, and race.
Source: mmian26 (11/26/96)

Table 4.17: Model 1[1] and Model 2[2] Odds Ratios for Birth cohorts <1905 and 1905-1914 vs. Birth Cohort 1915 and after

Birth Cohort	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
< 1905	27	(27.5)	96	(24.6)	123	(25.1)	1.10 0.57 - 2.13 (0.78)	1.02 0.51 - 2.04 (0.96)
1905-14	28	(28.6)	126	(32.2)	154	(31.5)	0.86 0.46 - 1.60 (0.64)	0.76 0.40 - 1.44 (0.40)
1915+	43	(43.9)	169	(43.2)	212	(43.4)	1.00	1.00
Total	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for race, longest facility worked, and gender.
Source: mmian27 (11/26/96)

Table 4.18: Model 1[1] and Model 2[2] Odds Ratios for Ever Employed at Five Study Cohorts[3]

Facility	Ever Employed	Cases #	Cases (%)	Controls #	Controls (%)	Total #	Total (%)	Model 1[1] Odds Ratio 95% CI (p-value)	Model 2[2] Odds Ratio 95% CI (p-value)
A. ORNL	Yes	18	(18.4)	58	(14.8)	76	(15.5)	1.29 0.72 - 2.29 (0.39)	1.23 0.68 - 2.23 (0.49)
	No	80	(81.6)	333	(85.2)	413	(84.5)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
B. SRS	Yes	9	(9.2)	43	(11.0)	52	(10.6)	0.81 0.38 - 1.74 (0.59)	0.52 0.22 - 1.22 (0.13)
	No	89	(90.8)	348	(89.0)	437	(89.4)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
C. Hanford	Yes	35	(35.7)	142	(36.3)	177	(36.2)	0.97 0.61 - 1.56 (0.91)	1.04 0.65 - 1.69 (0.86)
	No	63	(64.3)	249	(63.7)	312	(63.8)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
D. LANL	Yes	21	(21.4)	92	(23.5)	113	(23.1)	0.89 0.53 - 1.51 (0.67)	1.03 0.60 - 1.77 (0.91)
	No	77	(78.6)	299	(76.5)	376	(76.9)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
E. ZIA	Yes	18	(18.4)	75	(19.2)	93	(19.0)	0.94 0.53 - 1.68 (0.84)	0.95 0.52 - 1.72 (0.86)
	No	80	(81.6)	316	(80.8)	396	(81.0)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, and gender.
[3] Separate odds ratios for ever employed at each facility compared to never employed at that facility.
Source: mmian27 (10/31/96)

Table 4.19: Model 1[1] and Model 2[2] Odds Ratios for Work at Each Study Facility (or Multiple Facilities) vs. Work Only at Hanford

Facility	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
Multiple Study Facilities	3	(3.1)	17	(4.3)	20	(4.1)	0.71 0.20 - 2.55 (0.60)	0.67 0.18 - 2.46 (0.55)
Only ORNL	18	(18.4)	50	(13.0)	68	(13.9)	1.43 0.74 - 2.76 (0.29)	1.27 0.64 - 2.53 (0.49)
Only SRS	8	(8.2)	41	(10.5)	49	(10.0)	0.80 0.34 - 1.87 (0.61)	0.48 0.18 - 1.27 (0.14)
Only LANL	19	(19.4)	79	(20.2)	98	(20.0)	0.97 0.51 - 1.83 (0.92)	1.03 0.54 - 1.98 (0.93)
Only ZIA	16	(16.3)	67	(17.1)	83	(17.0)	0.95 0.48 - 1.87 (0.88)	0.91 0.46 - 1.81 (0.79)
Only Hanford	34	(34.7)	137	(35.0)	171	(35.0)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian26 (11/26/96)

Table 4.20: Model 1[1] and Model 2[2] Odds Ratios for Facility of Longest Employment

Facility	Case-Control Status		Total	Model 1[1]	Model 2[2]
	Cases # (%)	Controls # (%)		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
ORNL	18 (18.4)	52 (13.3)	70 (14.3)	1.38 0.72 - 2.66 (0.33)	1.25 0.64 - 2.47 (0.51)
SRS	9 (9.2)	43 (11.0)	52 (10.6)	0.86 0.38 - 1.95 (0.71)	0.54 0.22 - 1.37 (0.19)
LANL	20 (20.9)	88 (22.5)	108 (22.1)	0.93 0.50 - 1.73 (0.81)	0.97 0.51 - 1.84 (0.93)
ZIA	17 (17.3)	70 (17.9)	87 (17.8)	0.97 0.51 - 1.88 (0.94)	0.94 0.48 - 1.84 (0.86)
Hanford	34 (34.7)	138 (35.3)	172 (35.2)	1.00	1.00
Total	98 (100.0)	391 (100.0)	489 (100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in the same model.
[2] Adjusted for race, birth cohort, and gender.
Source: mmian2c (11/26/96)

Table 4.21: Model 1[1] and Model 2[2] Odds Ratios for Hire Before 1948 at Index Facility

Year of Hire	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
< 1948	60	(61.2)	190	(48.6)	250	(51.1)	1.68 1.07 - 2.66 (0.03)	1.89 1.11 - 3.21 (0.02)
1948+	38	(38.8)	201	(51.4)	239	(48.9)	1.00	1.00
Total	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian26 (11/26/96)

Table 4.22: Model 1[1] and Model 2[2] Odds Ratios for Work Experience Prior to Employment at Any Study Facility for Cases and Controls

Prior Work History	Cases #	Cases (%)	Controls #	Controls (%)	Total #	Total (%)	Model 1[1] Odds Ratio 95% CI (p-value)	Model 2[2] Odds Ratio 95% CI (p-value)
A. Farm								
Yes	11	(11.2)	58	(14.8)	69	(14.1)	0.72 0.34 - 1.49 (0.37)	0.65 0.30 - 1.41 (0.28)
Unknown	49	(50.0)	189	(48.4)	238	(48.7)	0.97 0.60 - 1.59 (0.92)	1.03 0.59 - 1.77 (0.93)
No	38	(38.8)	144	(36.8)	182	(37.2)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
B. Military Service								
Yes	34	(34.7)	121	(31.0)	155	(31.7)	1.13 0.65 - 1.95 (0.66)	0.97 0.53 - 1.78 (0.94)
Unknown	31	(31.6)	140	(35.8)	171	(35.0)	0.86 0.49 - 1.49 (0.59)	0.77 0.40 - 1.49 (0.44)
No	33	(33.7)	130	(33.2)	163	(33.3)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
C. DOE Nuclear Industry								
Yes	9	(9.2)	26	(6.7)	35	(7.2)	1.51 0.67 - 3.40 (0.32)	1.34 0.56 - 3.22 (0.51)
Unknown	42	(42.8)	158	(40.4)	200	(40.9)	1.17 0.73 - 1.86 (0.51)	1.30 0.76 - 2.22 (0.34)
No	47	(48.0)	207	(52.9)	254	(51.9)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, gender, and longest facility worked.
Source: 1) ccbase10.db 2) mmian22 (10/6/96) 3) mmian26 (11/26/96)

Table 4.22 (cont): Model 1[1] and Model 2[2] Odds Ratios for Work Experience Prior to Employment at Any Study Facility for Cases and Controls

Prior Work History		Case-Control Status						Model 1[1]	Model 2[2]
		Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
		#	(%)	#	(%)	#	(%)		
D. Non-Doe Nuclear Work	Yes	6	(6.1)	23	(5.9)	29	(5.9)	1.10 0.43 - 2.85 (0.84)	1.16 0.44 - 3.04 (0.76)
	Unknown	52	(53.1)	200	(51.1)	252	(51.5)	1.10 0.69 - 1.76 (0.70)	1.17 0.69 - 2.00 (0.55)
	No	40	(40.8)	168	(43.0)	208	(42.5)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
E. Paints	Yes	3	(3.1)	12	(3.1)	15	(3.1)	0.98 0.26 - 3.77 (0.98)	0.84 0.21 - 3.34 (0.81)
	Unknown	51	(52.0)	206	(52.7)	257	(52.5)	0.97 0.61 - 1.54 (0.91)	1.00 0.60 - 1.68 (0.99)
	No	44	(44.9)	173	(44.2)	217	(44.4)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
F. Non-Ionizing Radiation	Yes	14	(14.3)	27	(6.9)	41	(8.4)	2.32 1.11 - 4.82 (0.02)	1.98 0.93 - 4.23 (0.07)
	Unknown	48	(49.0)	203	(51.9)	251	(51.3)	1.02 0.63 - 1.65 (0.93)	1.05 0.61 - 1.81 (0.85)
	No	36	(36.7)	161	(41.2)	197	(40.3)	1.00	1.00
	TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, gender, and longest facility worked.
Source: 1) ccbase10.db 2) mmian22 (10/6/96) 3) mmian26 (11/26/96)

Table 4.23: Model 1[1] and Model 2[2] Odds Ratios for Number of Occupationally Related Chest Xrays[3] Under Three Lag Assumptions

Number of Xrays	Model 1[1] Odds Ratio 95% CI (p-value)			Model 2[2] Odds Ratio 95% CI (p-value)		
	Number of Xrays			Number of Xrays		
	0 - 1[3]	2 - 9	10+	0 - 1[3]	2 - 9	10+
5 Year	1.00	1.06 0.64 - 1.75 (0.83)	0.94 0.51 - 1.71 (0.83)	1.00	0.91 0.51 - 1.60 (0.75)	0.71 0.34 - 1.50 (0.38)
10 Year	1.00	1.13 0.70 - 1.83 (0.62)	0.82 0.43 - 1.60 (0.55)	1.00	0.98 0.58 - 1.68 (0.95)	0.61 0.28 - 1.33 (0.21)
20 Year	1.00	1.26 0.78 - 2.04 (0.34)	0.74 0.32 - 1.75 (0.49)	1.00	1.13 0.67 - 1.91 (0.75)	0.58 0.21 - 1.60 (0.28)

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, gender, and longest facility worked.
[3] Workers without medical records were counted in the 0-1 Xray group because as a group they worked less than 2 years, and the number of chest Xrays was highly correlated with the number of years worked.
Source: mmian28 (10/30/96)

Table 4.24: Model 1[1] and Model 2[2] Odds Ratios for Estimates of Exposure to Chemicals and Non-Ionizing Radiation

Chemical/Physical Agent	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
A. Aromatic Hydrocarbons								
Exposed	24	(24.5)	74	(18.9)	98	(20.0)	1.51 0.86 - 2.67 (0.15)	1.24 0.67 - 2.31 (0.49)
Uncertain	35	(35.7)	133	(34.0)	168	(34.4)	1.23 0.74 - 2.03 (0.43)	1.11 0.65 - 1.87 (0.70)
Unexposed	39	(39.8)	184	(47.1)	223	(45.6)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
B. Halogenated Hydrocarbons								
Exposed	26	(26.5)	112	(28.6)	138	(28.2)	0.98 0.57 - 1.71 (0.95)	0.79 0.44 - 1.44 (0.45)
Uncertain	32	(32.7)	109	(27.9)	141	(28.8)	1.25 0.74 - 2.11 (0.41)	1.12 0.64 - 1.95 (0.70)
Unexposed	40	(40.8)	170	(43.5)	210	(42.9)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
C. Any Metal								
Exposed	30	(30.6)	125	(32.0)	155	(31.7)	0.98 0.58 - 1.66 (0.95)	0.77 0.44 - 1.36 (0.37)
Uncertain	24	(24.5)	86	(22.0)	110	(22.5)	1.14 0.66 - 1.97 (0.64)	0.96 0.54 - 1.71 (0.88)
Unexposed	44	(44.9)	180	(46.0)	224	(45.8)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian50 (11/11/96)

Table 4.24 (cont): Model 1[1] and Model 2[2] Odds Ratios for Estimates of Exposure to Chemicals and Non-Ionizing Radiation

Chemical/Physical Agent	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
D. Beryllium								
Exposed	11	(11.2)	52	(13.3)	63	(12.9)	0.85 0.42 - 1.72 (0.65)	0.70 0.32 - 1.52 (0.37)
Uncertain	34	(34.7)	127	(32.5)	161	(32.9)	1.07 0.67 - 1.72 (0.77)	0.95 0.57 - 1.56 (0.83)
Unexposed	53	(54.1)	212	(54.2)	265	(54.2)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
E. Cadmium								
Exposed	9	(9.2)	39	(10.0)	48	(9.8)	0.89 0.41 - 1.95 (0.78)	0.65 0.27 - 1.55 (0.33)
Uncertain	37	(37.8)	152	(38.9)	189	(38.7)	0.94 0.59 - 1.50 (0.79)	0.81 0.49 - 1.34 (0.42)
Unexposed	52	(53.1)	200	(51.1)	252	(51.5)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
F. Lead								
Exposed	23	(23.5)	80	(20.4)	103	(21.1)	1.22 0.69 - 2.15 (0.50)	0.96 0.52 - 1.78 (0.89)
Uncertain	31	(31.6)	125	(32.0)	156	(31.9)	1.05 0.63 - 1.76 (0.84)	0.88 0.51 - 1.53 (0.66)
Unexposed	44	(44.9)	186	(47.6)	230	(47.0)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian50 (11/11/96)

Table 4.24 (cont): Model 1[1] and Model 2[2] Odds Ratios for Estimates of Exposure to Chemicals and Non-Ionizing Radiation

Chemical/Physical Agent	Cases #	Cases (%)	Controls #	Controls (%)	Total #	Total (%)	Model 1[1] Odds Ratio 95% CI (p-value)	Model 2[2] Odds Ratio 95% CI (p-value)
G. Mercury								
Exposed	14	(14.3)	55	(14.1)	69	(14.1)	1.03 0.54 - 1.97 (0.93)	0.80 0.40 - 1.60 (0.52)
Uncertain	32	(32.6)	125	(32.0)	157	(32.1)	1.04 0.64 - 1.70 (0.87)	0.89 0.53 - 1.51 (0.68)
Unexposed	52	(53.1)	211	(53.9)	263	(53.8)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
H. Nickel								
Exposed	6	(6.1)	23	(5.9)	29	(5.9)	1.14 0.44 - 2.95 (0.79)	1.07 0.39 - 2.92 (0.90)
Uncertain	38	(38.8)	135	(34.5)	173	(35.4)	1.22 0.76 - 1.94 (0.41)	1.07 (0.65 - 1.77) (0.78)
Unexposed	54	(55.1)	233	(59.6)	287	(58.7)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
I. Uranium								
Exposed	18	(18.4)	58	(14.8)	76	(15.5)	1.36 0.75 - 2.50 (0.31)	1.17 0.61 - 2.28 (0.63)
Uncertain	30	(30.6)	112	(28.6)	142	(29.0)	1.18 0.71 - 1.95 (0.52)	1.09 0.63 - 1.87 (0.77)
Unexposed	50	(51.0)	221	(56.5)	271	(55.4)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian50 (11/11/96)

Table 4.24 (cont): Model 1[1] and Model 2[2] Odds Ratios for Estimates of Exposure to Chemicals and Non-Ionizing Radiation

Chemical/Physical Agent	Case-Control Status: Cases #	Cases (%)	Controls #	Controls (%)	Total #	Total (%)	Model 1[1] Odds Ratio 95% CI (p-value)	Model 2[2] Odds Ratio 95% CI (p-value)
J. Welding Fumes								
Exposed	13	(13.3)	45	(11.5)	58	(11.9)	1.36 0.69 - 2.71 (0.37)	1.32 0.77 - 2.24 (0.46)
Uncertain	31	(31.6)	95	(24.3)	126	(25.8)	1.53 0.92 - 2.54 (0.10)	1.32 0.64 - 2.70 (0.31)
Unexposed	54	(55.1)	251	(64.2)	305	(62.4)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
K. Other Metals								
Exposed	17	(17.3)	192	(49.1)	91	(18.6)	0.94 0.51 - 1.75 (0.85)	0.82 0.43 - 1.58 (0.55)
Uncertain	34	(34.7)	125	(32.0)	159	(32.5)	1.11 0.68 - 1.80 (0.68)	0.95 0.56 - 1.62 (0.86)
Unexposed	47	(48.0)	74	(18.9)	239	(48.9)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
L. Radiofrequency/ Microwave Radiation								
Exposed	1	(1.0)	20	(5.1)	21	(4.3)	0.21 0.03 - 1.59 (0.13)	0.17 0.02 - 1.34 (0.09)
Uncertain	26	(26.5)	84	(21.5)	110	(22.5)	1.23 0.74 - 2.04 (0.43)	1.18 0.69 - 2.01 (0.54)
Unexposed	71	(72.5)	287	(73.9)	358	(73.2)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian50 (11/11/96)

Table 4.24 (cont): Model 1[1] and Model 2[2] Odds Ratios for Estimates of Exposure to Chemicals and Non-Ionizing Radiation

Chemical/Physical Agent	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	(%)	#	(%)	#	(%)		
M. ELF EMF								
Exposed	13	(13.3)	77	(19.7)	90	(18.4)	0.67 0.35 - 1.28 (0.23)	0.62 0.32 - 1.21 (0.16)
Uncertain	21	(21.4)	62	(15.9)	83	(17.0)	1.34 0.76 - 2.37 (0.31)	1.28 0.71 - 2.32 (0.41)
Unexposed	64	(65.3)	252	(64.4)	316	(64.6)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
N. Static Magnetic Fields								
Exposed	7	(7.1)	35	(8.9)	42	(8.6)	0.80 0.35 - 1.86 (0.75)	0.78 0.33 - 1.87 (0.58)
Uncertain	19	(19.4)	69	(17.7)	88	(18.0)	1.10 0.62 - 1.95 (0.61)	1.06 0.58 - 1.93 (0.86)
Unexposed	72	(73.5)	287	(73.4)	359	(73.4)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
O. Asbestos								
Exposed	28	(28.6)	106	(27.1)	134	(27.4)	1.12 0.66 - 1.89 (0.67)	0.87 0.49 - 1.55 (0.63)
Uncertain	26	(26.5)	97	(24.8)	123	(25.2)	1.13 0.66 - 1.93 (0.65)	0.99 0.56 - 1.75 (0.97)
Unexposed	44	(44.9)	188	(48.1)	232	(47.4)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates. All facilities are included in same model.
[2] Adjusted for birth cohort, race, longest facility worked, and gender.
Source: mmian50 (11/11/96)

Table 4.25: Model 1[1] and Mode 2[2] Odds Ratios for Ever Monitored[3] for Internal Contamination by Select Radionuclides for Cases and Controls

Internal Monitoring	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	%	#	%	#	%		
A. Plutonium[3]								
Monitored	31	(31.6)	144	(36.8)	175	(35.8)	0.79 0.49 - 1.28 (0.34)	0.69 0.41 - 1.19 (0.19)
Not Monitored	67	(68.4)	247	(63.2)	314	(64.2)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
B. Uranium								
Monitored	9	(9.2)	45	(9.2)	45	(9.2)	1.00 0.46 - 2.16 (1.00)	0.87 0.37 - 2.01 (0.74)
Not Monitored	89	(90.8)	355	(90.8)	444	(90.8)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
C. Strontium								
Monitored	5	(5.1)	16	(4.1)	21	(4.3)	1.25 0.45 - 3.48 (0.66)	0.76 0.24 - 2.46 (0.65)
Not Monitored	93	(94.9)	375	(95.9)	468	(95.7)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, gender, and longest facility worked.
[3] Monitoring 5 years prior to calendar date of age at risk not included.
[4] Bioassay or nasal swipes.
Source: mmian61 (11/13/96)

Table 4.25 (cont): Model 1[1] and Mode 2[2] Odds Ratios for Ever Monitored[3] for Internal Contamination by Select Radionuclides for Cases and Controls

Internal Monitoring	Case-Control Status						Model 1[1]	Model 2[2]
	Cases		Controls		Total		Odds Ratio 95% CI (p-value)	Odds Ratio 95% CI (p-value)
	#	%	#	%	#	%		
D. Other								
Monitored	18	(18.4)	80	(20.5)	391	(80.0)	0.87 0.49 - 1.55 (0.65)	0.72 0.38 - 1.37 (0.31)
Not Monitored	80	(81.6)	311	(79.5)	489	(100.0)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
E. Whole Body Counting								
Monitored	12	(12,2)	73	(18.7)	85	(17.4)	0.61 0.31 - 1.17 (0.14)	0.50 0.24 - 1.05 (0.07)
Not Monitored	86	(87.8)	318	(81.3)	404	(82.6)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		
F. Any Internal Monitoring								
Monitored	35	(35.7)	165	(42.2)	200	(40.9)	0.76 0.48 - 1.21 (0.25)	0.64 0.8 - 1.09 (0.10)
Not Monitored	63	(64.3)	226	(57.8)	289	(59.1)	1.00	1.00
TOTAL	98	(100.0)	391	(100.0)	489	(100.0)		

[1] From conditional logistic regression with no covariates.
[2] Adjusted for birth cohort, race, gender, and longest facility worked.
[3] Monitoring 5 years prior to calendar date of age at risk not included.
[4] Bioassay or nasal swipes.
Source: mmian61 (11/13/96)

Table 4.26: Odds Ratios[1] for Total External Radiation Doses Under Three Lag Assumptions

Lag (Years)	Model[1] Odds Ratio 95% CI (p-value)
5	1.01 0.98 - 1.05 (0.49)
10	1.01 0.97 - 1.04 (0.72)
20	0.95 0.85 - 1.06 (0.36)

[1] Adjusted for race, birth cohort, longest facility worked, gender, hire before/after 1948, and whether monitored for internal radiation.

Source: mmian37 (11/26/96)

Table 4.27: Odds Ratio for Cumulative External Radiation Doses Received Before and after Age 45, with 5-Year Lag

Age at Exposure	Odds Ratio[1] 95% CI (p-value)
Younger Than 45	0.93 0.83 - 1.05 (0.24)
45 or Older	1.07 1.01 - 1.13 (0.02)

[1] Estimated relative risk for 10mSv from conditional logistic regression adjusted for race, sex, facility, birth cohort, WWII hire, internal monitoring, and external dose in the other age group.
Source:

Appendix I

Multiple Myeloma Study: Bibliography

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