TABLE I

SAMPLE WORKSHEET FOR COMPUTING DAILY WEIGHTED AVERAGE EXPOSURE

OPERATOR: PROCESS HELPER – BIRD FILTER 1 man/shift; 3 shifts/day; 4 men/day

Operation or Operating Area	Time per Opera. (Min)	Opera. per Shift	Time per Shift (Min)(T)	No. of Samples	Concentration ug/m³ Low	High	(C) Aver.	Con'c. Times Total time (T X C)
Building bird filter cake	8	3	24	4	60	125	83	2,000
Plowing off cake	6.5	3	19	3	110	530	232	4,400
Bird centrifuge area	—	-	121	2	20	175	97	11,700
Digester and recovery tanks	—	-	80	5	5	38	19	1,500
Denitration pot area	—	-	90	12	5	85	31	2,800
Filter press room	—	-	60	4	20	45	30	1,800
Cleaning press	11	1	11	4	190	615	376	4,100
Lunch and breaks	—	-	60	4	6	56	31	1,900
Locker room	—	-	15	4	4	71	39	600
	ΣT		480			$\Sigma(T \times C)$		31,800

$$\Sigma \frac{(T \times C)}{T} = 67 \text{ ug/m}^3$$

TABLE II

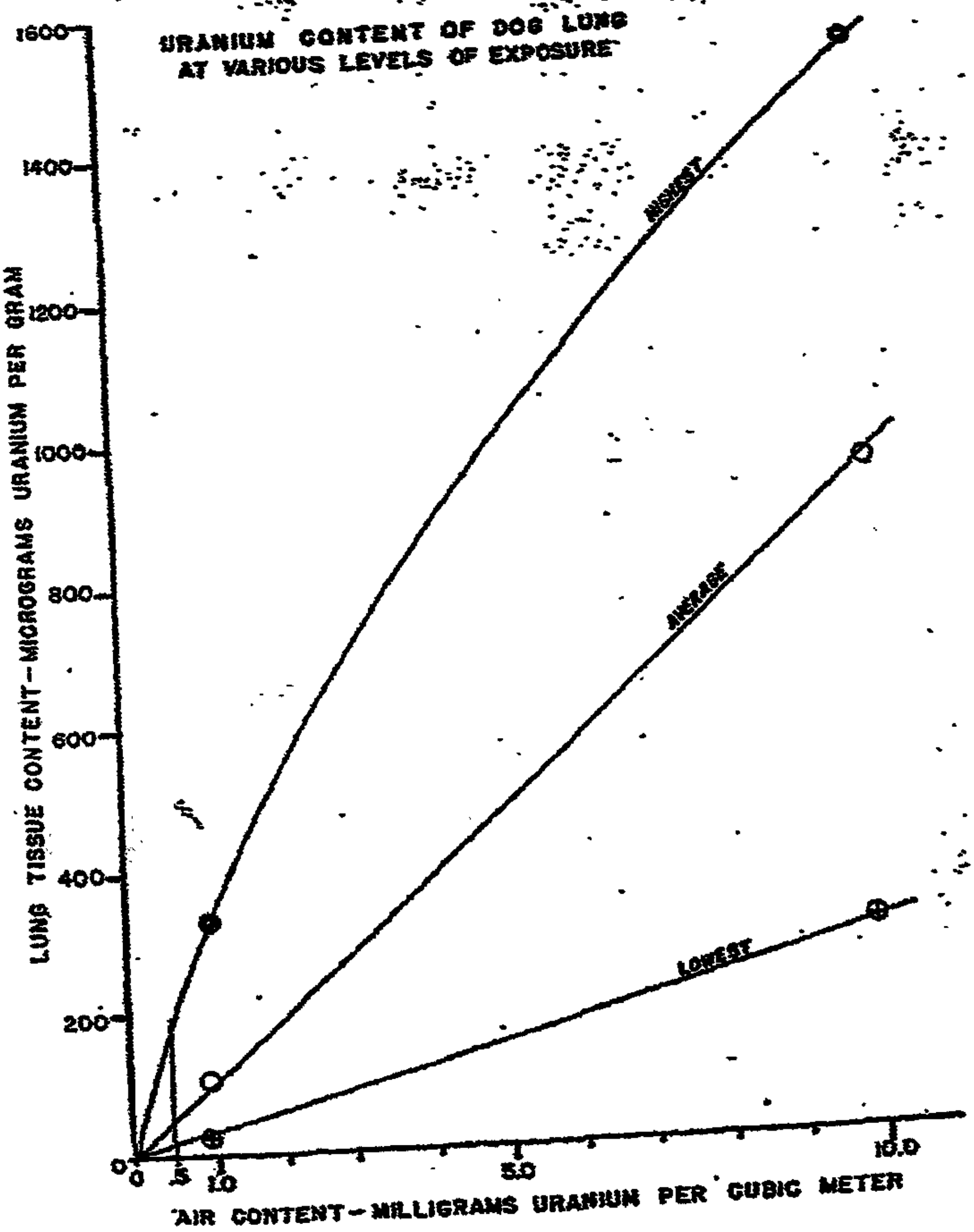
ORGAN	CONTRIBUTING EXPOSURE
Skin	External beta and gamma radiation
Lung	External gamma radiation and internal alpha radiation from uranium and radium
Bone	External gamma radiation, internal alpha irradiation from uranium, radium and radium decay products

In order to provide a basis for calculating the lung dose in individuals exposed to uranium and radium dusts, we have made the following assumptions:

1. The build-up of the relatively insoluble dusts in the human lung is comparable to the data reported in the University of Rochester dog exposures to an uranium compound UO_2 of low solubility. (2) In Figure 1, we present a curve showing the equilibrium lung concentrations versus exposure. This curve is taken from UR-67. It is used as the basis for our estimate of human exposure because it is, at the present time, the only basis for making such an estimate. The University of Rochester found that at any given exposure level, the equilibrium lung concentration is reached in from 1 to 2 years. Their data show that from 70 to 75% of equilibrium is reached at the end of one year and our estimations of lung uranium concentration are based on the assumption that this is likewise true in man.

We have had an opportunity to study the concentration of uranium in the lung of one individual having a known exposure to the dust of uranium compounds. He was exposed for 24 months to an average concentration which we estimate at 17,000 micrograms uranium per cubic meter of air. His exposure was to UF_4 and to UF_6 in the ratio of 3:1. Assuming lung retention from the latter compound to be negligible because of its high solubility, we may limit our consideration to his UF_4 exposure, which was, therefore, of the order of 12,000 ug uranium per cubic meter of air. He died of pulmonary tuberculosis approximately ten months after his last exposure and following autopsy, his lungs were assayed for uranium. A concentration of 0.34 micrograms of uranium per gram of wet tissue was reported. There is animal evidence that the biological half life of UF_4 in the lung is approximately 30 days. Assuming this to be valid in man, one can calculate that the pulmonary concentration just prior to the sessation of exposure was 350 ug per gram.

This is lower by a factor of 4 than the concentration which would be estimated on the basis of the Rochester UO_2 experiments. A limited amount of animal studies involving exposure to UF_4 have in fact shown that the equilibrium lung concentrations are somewhat lower than those found in the case of UO_2 exposure. This factor may be partially explained on the basis of the somewhat higher solubility of UF_4.


URANIUM CONTENT OF DOG LUNG
AT VARIOUS LEVELS OF EXPOSURE
LUNG TISSUE CONTENT—MICROGRAMS URANIUM PER GRAM
1600
1400
1200
1000
800
600
400
200
0
HIGHEST
AVERAGE
LOWEST
0
.5
1.0
5.0
10.0
AIR CONTENT—MILLIGRAMS URANIUM PER CUBIC METER

Estimate of Bone Dose:

The skeletal dose originates from external radiation and uranium and radium deposited in the bone.

There are no good animal data by which one can approximate the uranium skeletal burden of an individual having known exposure. For this study, we have taken advantage of the availability of two autopsies and one biopsy from individuals having known uranium exposure.

One individual ( ) was employed 3 months in an operation involving exposure to UF_6 at an average estimated level of 1000 ug/m^3. For the next 40 months, he was employed at an operation with an estimated 150 ug/m^3, predominantly UF_6. He died of carcinoma of the stomach 9 weeks after the termination of employment. A post mortem showed uranium concentration in the bone of 0.40, 0.43 and 0.67 ug/g from three samples.

Another case ( ) was employed for 24 months at an operation involving an estimated exposure of 17,000 ug/m^3 (80% UO_2 and UF_4 and 20% UF_6). This man died of tuberculosis 10 months after termination of employment and an autopsy showed an uranium concentration in the bone of an average of 16.8 ug/g from five samples.

One biopsy was obtained from an individual ( ), still employed, whose work record indicated a variety of exposures to UO_2 and UF_4, as follows:

Length of Time	Estimated Exposure
2 months	4500 ug/m^3
3½ "	None
7½ "	4500 ug/m^3
19 "	850 "
5 "	None
46 "	850 "

From the above figures, an estimated average exposure level of 1200 ug/m^3 for a total period of 81 months was used. The biopsy indicated a uranium concentration in a specimen of bone from the knee of 4.9 micrograms per gram of bone.

These data have been plotted (Figure 2) in order to arrive at a tentative working relationship between exposure and bone burden. In plotting, it was assumed that there is a direct relationship

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SOME OBSERVATIONS ON URANIUM EXPOSURES WITHIN THE NUCLEAR INDUSTRY

A. F. Becher, Consultant, ERDA Health & Mortality Study

I. HISTORY

A. Since inception of the Atomic Energy Program, it has been a requisite that contractors "maintain all health physics records on an indefinite record schedule"; without the foregoing policy the feasibility of this study would be purely academic. Unfortunately, the specifics as to what data were to be included in this compendium of data were not and to this date still have not been finalized. In retrospect, one readily sees the problems which have plagued us over the years in establishing such requirements. These may be summarized as follows:

1. Those charged with early responsibilities and control measures had little, if any, precedent to fall back on except for the acute cases involving the Schneeburg miners of Bavaria, the radium dial painters in the United States, thorotrast workers and the anklyosing spondylitis cases in Great Britain, and those involving roetenologists in all countries. Then too, the early efforts were directed on a crash basis, the completion of the atomic weapons of WW II were envisioned as the time interval of concern.

2. Personnel monitoring, detection devices and measuring devices were crude, cumbersome appliances with rather poor sensitivity and reliability. Collections of samples and laboratory techniques too were rather crude by modern comparison; however, since the initial exposures were addressed mainly to the wartime applications, the long-term low level exposures to ionizing radiation had a much lower priority.

3. Intrinsic to the establishment and perhaps initially forming the bulk of the records were the recorded or postulated exposures to personnel as established by use of pocket chambers and finally film meters. Unfortunately, this feature continues with us to this date, where most antagonists or even protagonists of the increased use of atomic energy continue to equate radiation effects with whole body penetrating radiation which then is readily associated with the "prompt" and residual effects of a major radiation accident--detonation of an atomic weapon, etc.

4. To a far lesser degree have people been concerned with the less predictable effects of internal radiation and even within the present

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state of the art today, we are not much further along the path of being able to predict with reasonable credibility, what these effects are or may become with the advancing age of the exposed populations. Despite the numerous ongoing animal studies which are vitally needed, when one reflects on the multi-variants which must be considered in assessing the effects of multiple exposures, one must consider, among others, such factors as:

a. Particle size and solubility in body fluids.

b. Uptake and distribution in the body organs and tissue.

c. Combined effects of internal and external radiation.

d. Intensity and quality of the radioactive substances.

e. Exposure to other toxic substances which may also be capable of producing comparable effects within the human body, hence, leading to false positive findings or which may in conjunction with radiation have a synergistic, antagonistic, additive or independent singular effect.

5. a. With the peaceful applications of the use of atomic energy, contractors with an interest and capability in the field were employed to carry on the various areas of research and production, with the Federal Government exercising the general administrative and contractual controls necessary to ensure the cost of effective completion of its myriad activities. These contractors were permitted within the broad framework of the AEC manual chapter to exercise their normal corporate practices in accomplishing their mission. Thus the individual programs and associated records operating within the broad outlines of the later recommendations of the WHO, ICRP, NCRP and AEC guidelines varied widely.

b. We do not have an ideal homogenous population exposed at varying levels to a single or even a few sources of ionizing radiation or other toxic substances; detection control, investigation and recording of data was and still is in many instances peculiar to the particular installation. However, even if this were not true, it has been clearly stated by the study group that it would be unwarranted to conclude or extrapolate if the population in the Hanford and Oak Ridge Operations experience no adverse effects; that this is necessarily the answer to the question of the biological effects of low level ionizing radiation in all other AEC facilities. This has been expressed in subsequent progress reports in the following terms:

> That even if our study of Hanford were to prove conclusively no adverse effects, it would be unwarranted with presently available insights to generalize such findings to apply to all forms of ionizing radiation and associated exposures in all other AEC plants.

The recommendation for the extension of the study to include as many of the employees of the AEC contractors as possible, is not merely to enlarge the study population, but to broaden the multiplicity of circumstances under which radiation may have effects not otherwise observed. The most important consideration for this is the realization that our only avenue to assure ourselves of including all the radiation that individuals in the study have had, is through such extension; plus exposure incident to weapons testing in which these employees may have participated.

6. Problem areas within the existing programs pertaining to the HMS may be summarized as follows:

a. Systems were designed basically to ensure personnel control by stipulated period, i.e., initially daily, then weekly, quarterly, and annual records were kept; these resulted in values being established for recording to ensure that the lifetime average 5(N-18) Rem, was not exceeded.

b. Lifetime accumulative records by contractor for individual employees were, and in several areas still are, incomplete. Records as found were kept by a variety of procedures over time, which had to be reworked, extracted and converted to a taped program; and updating even after rework of the records was also charged to the study budget on an annual cost basis.

c. Total lifetime accumulative dose from all sources, i.e., former employers, off site (DASA tests, etc.), significant therapeutic doses, or the experience even between installations of a single contractor were not available. Additionally, records of early contractors whose missions were absorbed by another are in a number of cases simply not available. For example, Y-12 records commence in 1950, since records of the earlier contractor, Tennessee Eastman Corporation, are not available. Where possible, such as at ORNL, the records for UCC-ND and its predecessor contractors were completely reworked and updated through study funds and programming.

d. Records for internal exposure varied widely; in no case had an assessment been made of body or organ burden overtime for all recorded bio-assay or whole body count. Conversion to Rem dose or other equivalent nomenclature had not been done. Hanford had the foundation for such a system which has been completely updated with study funding and programming. Oak Ridge has not. Body count data at Oak Ridge has been taped, in terms of lung burden, and bio-assay results computerized to reflect excretion rates per 24 hr. voiding.

e. The systematic destruction of other vital supporting records such as PSQ's, payroll, etc., had to be curtailed by project action.

f. Records as found which would permit the segregation of risk vs. non-risk employees were unusable and had to be reworked.

II. VARIANCES IN LOWER LIMIT OF DETECTION, PRECISION OF MEASUREMENT, ETC.

A. Early use of film dosimeters on a weekly basis limited lower detection limit for sensitive film to approximately 30 mRad; generally speaking, a value of 50 mRad is universally accepted as the minimum detectable for the various film emulsions employed.

B. With extension of badging cycles to biweekly, monthly, and finally to quarterly intervals, the lower limit of detection for low levels of chronic exposure should have been reduced by as much as 360 mRad/Qtr. These changes, although known, were not recorded.

C. Where zero values were obtained on film, some contractors recorded them as such whereas others gave all negative readings the value of the lower limit of detection, i.e., 30 mRem per use period. Similarly, automated mechanical read out of film without visual scanning of film reading fields for irregularities such as exposure to heat, light, badge contamination or processing effects permitted doses of as much as 300 mRem exposure to gamma radiation and double the value for beta radiation. Above these values the dose was validated.

D. Bio-assay sampling practices varied from randomly attained spot samples to regularly scheduled "Friday afternoon" or "Monday morning" samples. In some cases 150 ml samples were used and weighted to reflect a standard 24 hr. voiding (1500 ml) whereas in others complete voiding were recovered. The exceptions to these practices were in the case of known accidental exposure where complete voiding, usually including fecal samples, were collected and total body or organ burden was assessed.

III. IDENTIFICATION OF THE RISK POPULATION

A. Varied from monitoring all employees to selecting those with a 10% of MPD risk potential or greater. For example, at ORNL where the practice of badging all personnel since startup of operation was accompanied by a lack of records for those personnel who were considered radiation workers or who had access to radiation areas. The only available records source was the Health Physics log books for those areas, and the radiation permit data. 16,131 log books with their hundreds of entries and several thousand radiation work permits had to be extracted, keypunched and taped.

B. Payroll records reflecting changes in occupational assignments were incomplete; in fact, a large segment of these records were missing and had to be replaced by project funding and programming to Social Security numbers, etc.

C. Identification of the individual worker with his work activity could not be accomplished. This has largely been completed as a result of study funding and programming except for transient and service personnel whose work assignments cover a number of areas. This, too, is scheduled for more accurate placement of the individual in a specific work environment.

IV. OTHER CONTRIBUTORY STRESS FACTORS

A. Since we are concerned with establishing the effects or lack thereof on the health and mortality of radiation workers, it is important that other stress factors such as exposure to toxicants which may have synergistic, antagonistic, additive or singular effects, which could mistakenly be interpreted as having been radiation induced had to be identified, these data have been accumulated and are being reworked.

B. Industrial hygiene air sampling or bio-assay data was nearly completely lacking at Hanford and had to be reconstructed by special study. In Oak Ridge, while most of the basic data were available, they were not usable due to their bulk, without conversion to the computer program and taped. This also was accomplished through project funding and programming.

V. STUDY ACCOMPLISHMENTS AND REMAINING PROBLEMS

A. Union Carbide Corporation's Nuclear Division, Y-12, K-25, X-10 installations and their predecessor contractors records keeping has been standardized and converted to tape. This involved more than 650,000 records for approximately 113,000 UCC-ND or its predecessor contractor employees at Oak Ridge.

B. An additional 8,500 feed mill employees of National Lead of Ohio and

Mallinckrodt Chemical Works have been partially converted to tape; however, the relevant data for radiation exposure and exposure to toxics as well as identification of the exposed vs. no-exposed population are incomplete. The MCW records were all retrieved during FY74 and prepared for keypunching and taping through 1965 (MCW closeout). The NLO records are also incomplete as above and have not been updated since 1967 due to funding limitations; these should also receive consideration for completion during FY76.

C. More than 5,000 employees of the Monsanto Company's Mound Laboratory are also being processed and the same problem exists with respect to records completion as outlined in B and C above. A breakout of the records data to be completed follows:

1. External radiation records (available from contractor or AEC archives).

2. Internal data.

a. Bio-assay data in terms of excretion rate / 24 hr. for the radionuclides of concern (in some cases these data must be reworked since the units given are in terms of mass / unit volume excreted and must be corrected for specific alpha activity).

b. Whole body counting results.

3. Payroll and work records completed for all years of employment to provide:

a. History of job changes.

b. Identification with activity or work location.

c. Identification by occupational groups.

d. Identification by risk groups, i.e., "Risk," "Potential Risk" and "No Risk" populations.

4. Environmental data keyed to location, activity and/or supervisory code.

5. Other stress factors, i.e., Industrial Hygiene data.

D. Accomplishment of the above permits:

1. Identification of individual at risk, the risk factors subjected to, i.e., radiation (internal and external), exposure to toxicants and multiple exposures such as exposure to stress factor 1, 1 + 2 + 3, etc.

2. Placement of the individual in his work environment throughout his employment history.

3. Characterization of the work environment; this includes exposure to penetrating radiation, internal emitters, toxics, etc., and quantifies the maxi, mini and median values for the various air concentrations

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within the work area.

4. Identification of the work activity, i.e., reactor operations, fuel recovery, fabrication, decontamination, feed plant operation, metal machining, wet chemistry processes, etc., and the associated exposure levels for the worker groups of concern.

5. Ranges for external exposure, excretion rates for internal exposure and single or multiple exposure to toxics with or without radiation.

6. Identification of craft or occupational work groups as in 5 above.

C. National Lead and Mallinckrodt Chemical Feed Plants.

1. Mallinckrodt Chemical Company (MCW)

a. Preliminary taping of job histories has been accomplished to provide for a roster of 3,228 personnel (approximately 50% follow-up) currently this is being reworked on a small scale to include later information on the Destrehan Plant, Weldon Springs and Main Plant payroll personnel assigned to the project. It is important that the Destrehan, Main Plant and Weldon Springs be subdivided as clearly as possible in that:

b. The Destrehan population includes a risk group who were exposed to relatively high doses of external radiation from the Ra content of the pitchblende ores being processed, coupled with an internal exposure to Rn daughter products and high levels of exposure to uranium particulates. It is estimated that approximately 180 employees from this group who were recorded as having MPBB's were carried over to the Weldon Springs operations.

c. The Weldon Springs facility included lower exposures to uranium dusts than those of Destrehan, but also included handling and processing of Thorium ores; additionally, processing included such toxic hazards as exposures to HCL mists, HF, NO_x, Hexane and a variety of other solvents used in the extraction process.

d. A number of the MCW Main Plant chemical personnel who were also associated with the total effort from time to time are not as readily identifiable. The former director of Health and Safety for MCW was contacted and retained to ensure transfer of all of the relevant health physics data to Oak Ridge. All of the job assignment data and related exposure data have been brought to Oak Ridge where it has been reworked and prepared for keypunch and transfer to tape when funds become available. From these records it was found that all of the University of Rochester data had been pg 8

left out of the original data since the employee roster was furnished to the Social Security Administration; and a subsequent search for deaths forwarded to the states. A total of 333 death certificates have been received to date. From these some 81 cancer sites, specific blood dyscrasia and brain tumor cases have been identified. Currently we are trying to identify these cases with the related personnel exposures and place of work or occupational groups involved, since it is felt that the multiple exposure potential (internal and external radiation) for the original Destrehan Plant group will be among the highest within the industry.

2. National Lead of Ohio (NLO)

a. A roster comprising 5,316 personnel has been prepared covering the work histories of this group (about 1,220 names require additional follow-up).

b. The related radiation dose data for external and internal radiation exposure was furnished, complete on tape through 1967, but has neither been proof tested nor updated.

The exposures at this facility have largely been associated with relatively high (nearly 100 x current MPC_a) concentrations of uranium dusts.

3. Files for other early feed mills and processing facilities, i.e., Middlesex, Linde Air Products, Ferclave Corporation, Houdaille-Hershey, and Sam Laboratory have been brought together for review and possible rework. Also of interest was the locating of the records of former Oak Ridge employees involved in the ANP project under the Fairchild Engine and Aircraft Company and General Electric Company. These activities were later transferred to Cincinnati, Ohio and subsequently shut down. Gleaning of the above records will permit an assessment to be made as to how many of the UCC-ND population had a previous work exposure at these sites since they were all either intimately associated with the Oak Ridge efforts or were actually located there.

F. Due to the lack of specific guidance on the content of radiation dose and the related records such as work histories, occupation groups, work activities, toxic exposure and the like at the request of Headquarters, Germantown, general proposed standards were submitted to the operational safety division. (See Appendix A.) Recommendation was made that accumulation and recording of base data, at least on a prospective basis, to enhance the present AEC contractor systems since with minor exception all of these data are germane to the total records. Such an effort would not only enhance the present systems but would also minimize the costs of retrieving and reworking the data being maintained by AEC contractors by a wide variety of methods. The standards were arrived at considering not only study needs, but also the many applications, admissibility of data as evidence in cases of litigation, etc. Thus the implementation thereof should enhance the control program, provide easily retrievable, accurate information for defense of litigation as well as to further the study with a minimum of cost since some form of record has to be maintained in any event. Thus far support of this proposal has not yet been realized.

G. The study group had also activated an Ad Hoc Task Group of leaders within the field who were especially competent in assessment of internal body burden. The findings of the group have been made available to the AEC Headquarters Biology and Medicine and the Operational Safety groups. Further active support by the ERDA representatives is needed to resolve this aspect of the work. Not only does the study depend on our ability to establish total dose to the organ of reference or total body but ultimately the ERDA also must face up to the validity or lack thereof of the body burden assessments being made by its contractors. Recent reworking of the Hanford records is an attempt to fit the findings with the recommendations of the Ad Hoc committee; this work was recently reviewed with Dr. W. S. Snyder, chairman of the Ad Hoc group (also serves similarly with ICRP and NCRP, internal dose committees). He recommended that we use the computed dose and exposure with the body burden / time assessment to see if there be any agreement or significant variances. It would be well to look at the problem, particularly as regards those cases where the exposures were to highly insoluble U compounds which exhibit a much longer than expected biological half-time for elimination.

H. Off site radiation exposure data was recognized as a problem by the project personnel. First, since it was apparent that the records of transferees within the AEC-Contractor complex were not being updated to reflect prior exposures, but also because off site testing (DASA exposure data) and previous employment data on exposures for other agencies (Armed Services, DHEW, etc.) were not included in the occupational lifetime accumulative exposure records. In the case of exchange between AEC contractor or other outside agency exposure, these problems have been brought to the attention of both contractor and ERDA personnel. In the case of DASA records, we have acquired the microfilm records and have since obtained the punch card records and associated tapes. A code identifier has been obtained partly from Wright-Patterson Air Force Base and partly from Reynolds Electric Company which it is hoped will permit identification of ERDA-Contractor personnel with their test exposure records. These data will be tested during FY76 to evaluate their effects on ranking of dose for the exposed populations.

I. Future Efforts

1. Testing of the data bases via the 1% sampling method as the schedule permits during the remainder of FY75 will be expedited to ensure completeness and relevancy of the data.

2. Preliminary checkout of the Oak Ridge data for the K-25 Plant for roster completeness revealed that about 9,000 of the employees could not be accounted for. Based on a sampling of the names commencing with the letter "K" against the various records sources, it was determined that the K-25 Medical Department linedex file appeared to promise the highest chance of successfully completing the search for the "missing" population; accordingly, the following actions were taken:

a. Approval and funding was received to establish the feasibility of the search to eliminate these disparities; completion of the feasibility study in January 1975 revealed the following:

1) No recorded Social Security number,

2,780	
567	will not be traceable from existing folders
783	will be non-Carbide, such as consultants, service personnel, etc.
1,215	will be valid K-25 employees matching with work history files
135	will be additions to K-25

2) Unmatched medical linedex with Social Security number,

6,105	
305	will not be traceable
2,745	will be non-Carbide, such as consultants, contractors, etc.
975	will match work history file
2,080	will be additions to K-25 roster

3) Summarizing,

32,359	records initially matched
2,215	estimated additions
1,215	corrected to Social Security number from "no SS No."
975	corrected to SS No. from "with SS No. group" (errors)
36,764	verifiable K-25 employees
872	without a SS No. or an invalid one will be traceable in Oak Ridge
3,528	will be non-Carbide employees
4,400	

Accordingly, work loading has been rearranged and clerical support authorized to complete this work at an estimated cost of $23,000 from FY75 budget, by the close of this Fiscal Year. Work was commenced during the week of February 24, 1975. Upon completion of the above UCC-ND modified roster as verified on February 28, 1975 will be within approximately 5% of total completeness; the breakdown by installations is as follows:

ORNL	approximately	18,000	employees	1%	deviation
K-25		37,636	"	5%	"
Y-12		57,044	"	7%	"

Total UCC-ND, approximately 112,680

4) Of a total of approximately 22,000 deaths, 18,712 have been forwarded to the states as of the first quarter FY75; thus far nearly 11,000 death certificates have been returned, or nearly 60% of the total.

5) Conversion of the relevant job assignment sheets, total exposure records and associated environmental factors for the major "risk" areas of NCW operations will be pursued within limitations of the funds available.

6) Special risk or occupational groups with both single and multiple exposure potentials together with their cohort non-risk groups will be studied for causes of death, also within the limitations of manpower and funding.

7) Compilation of an historical operations and technology manual for the UCC-ND facilities has been approved and work has commenced to compile all of the relevant procedure and data.

VI. SUMMARY

The feasibility stage has been passed and we are now probing, on a very limited scale, the question of the biological effects of low level ionizing radiation.

The national nature and importance of this question, and indeed the deliberations under consideration by the NCRP members here this week, requires that every effort be made, that every means be explored, to ensure that we do not write off this last opportunity to gain direct information on the radiation effects on man by failing to assign to the study the high priority in support that it merits.

Although indications of preliminary findings within the constraints of the present data may indicate no gross effect on large numbers of workers at Hanford, Because of their exposure to external radiation, it would be unwarranted, with the information we now have, to conclude that no employees were adversely affected by radiation at Hanford. We wish to emphasize that even if the Hanford study were to prove conclusively that no large scale adverse effects existed, it would be unwarranted with presently available insights, to generalize such findings to apply to all forms of ionizing radiation in all other AEC plants.

In subsequent analyses, the non-radiation occupational exposure to industrial chemicals and the socio-economic variables must be considered, in any subsequent interpretation of radiation gradients and biological effects.

Further, the latent period may be critical to the study and observations with a longer period of years may alter the present pattern of findings.

It is also important that the project be subjected to the adversary review by the most critical experts in the country, to identify any bias in the data prior to any consideration of publication of any of the findings of this study.

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Proposed Finding

Workers at Mallinckrodt in St. Louis were exposed to excessive levels of airborne uranium dust relative to the standards in effect during the time, and many workers were exposed to 200 times the preferred levels of exposure. The chief safety officer for the Atomic Energy Commission described Mallinckrodt (St. Louis) as one of the two worst plants with respect to worker exposures. Workers were excreting in excess of a milligram of uranium per day causing kidney damage. A recent epidemiological study found excess levels of nephritis and kidney cancer from the inhalation of uranium dusts.

Dupree-Ellis E, Watkins J, Ingle JN, Phillips J. *External radiation exposure and mortality in a cohort of uranium processing workers.* Am J Epidemiol 2000;152(1):91-95.

Among nonmalignant outcomes, the SMR for chronic nephritis was 1.88 The scope of the study did not include morbidity from renal failures, only mortality.

This study was done by Oak Ridge Institute for Science and Education under contrat to NIOSH.

Eisenbud points out that workers were inhaling getting large doses of uranium dises

HUMAN RADIATION STUDIES: REMEMBERING THE EARLY YEARS

Oral History of Merril Eisenbud

United States Department of Energy
Office of Human Radiation Experiments
May 1995

ORAL HISTORY OF MR. MERRILL EISENBUD

Conducted on January 26, 1995, in Chapel Hill, North Carolina, by Thomas J. Fisher, Jr. and David S. Harrell from the Office of Human Radiation Experiments (OHRE), U. S. Department of Energy (DOE).Merril Eisenbud was selected for the oral history project because of his former positions as Director of the U. S. Atomic Energy Commission's (AEC's) Health & Safety Laboratory (HASL) and Manager of the New York Operations Office, and because of his research into the effects of environmental radioactivity. The oral history covers Mr. Eisenbud's long career, focusing on the years spent founding and managing the Health & Safety Laboratory, his research on radioactive fallout in the United States and abroad, and his experiences with early occupational exposure, especially in uranium processing.

Short Biography

Mr. Eisenbud was born in New York City on March 18, 1915. He received his BSEE (Electrical Engineering) from New York University (NYU) in 1936. Mr. Eisenbud is married and has three children. Mr. Eisenbud began his career as an Industrial Hygienist with the Liberty Mutual Insurance Co. (1936 to 1947). In 1945, he was appointed an Associate Professor of Environmental Medicine at NYU Medical Center.In 1947, he was asked to serve as Director of the AEC's new Health & Safety Laboratory in New York, a position he held until 1957. During this time, HASL was instrumental in alerting people to start monitoring fallout and participated fully in Operation Sunshine. From 1954 to 1957, Mr. Eisenbud concurrently managed the New York Operations Office for the AEC, which was responsible for the procurement of all uranium for the entire Complex. In 1959, he retired from the AEC to teach and perform research full-time at

NYU, eventually serving as Director of the University's Laboratory for Environmental Studies. As New York City's first Environmental Protection Administrator, from 1968 to 1970 during the Lindsay Administration, Eisenbud was perhaps the first official in the United States to have that title.Mr. Eisenbud has also served in the following positions:
1956-1982, Member, Board on Radioactive Waste Management, National Academy of Science;
1957-1985, Member, Expert Panel on Radiation, The World Health Organization;
1964 to present, Member, National Council on Radiation Protection and Measurements;
1969-1981, Member, New York State Health Advisory Council;
Member, the National Advisory Council of the Electric Power Research Institute; and,
1964-1966, President, Health Physics Society.Today he is Professor Emeritus of Environmental Medicine at NYU's Institute of Environmental Medicine, Adjunct Professor of Environmental Science and Engineering at the University of North Carolina (UNC), and Scholar in Residence at Duke University.Mr. Eisenbud has published many times on environmental radioactivity, urban pollution, environmental effects of power generation and human ecology. Early Days as an industrial hygienist

And, for lack of institutional memory, of which there's a great deal, when somebody from ORAU called me and asked something about Mallenkrodt, and I asked them what they were doing, they said they were doing an epidemiological study of the delayed effects on the workers. I said, "Well, have you seen our report?" They had never heard of it.
FISHER: Reinventing the wheel.
EISENBUD: Well, we found it for them. We found it. I think I mentioned that in my book.
FISHER: Actually, in an interview with Newell Stannard that you gave, you said that Mallenkrodt and Harshaw were the worst.
EISENBUD: Yes. They were the worst.
FISHER: Now, what does that mean? The worst what?
EISENBUD: Well, they were-these were plants that were designed to operate for, perhaps, 60 days, just to make enough uranium for a couple of bombs. They went on for five years, six years, something like that, and the exposures were very high.

Against the standards of -I don't remember exactly, but I think the maximum amount of uranium in air was supposed to be 50 micrograms per cubic meter; we were measuring milligrams per cubic meter, and they were excreting as much as a milligram a day in their urine.

So I would say our group was, for that time, uniquely epidemiologically conscious. We even hired the first biostatistician that the AEC ever had, a fellow named Brandt. He worked for us at a time when even the national laboratories didn't know what a biostatistician was.

HARRELL: Did your work get those plants closed, or were they closed because they were no longer needed?
EISENBUD: It was obvious that they either had to be fixed up or closed, and, for the most part, they were closed, and Fernald [(an AEC uranium processing facility in Ohio)] was (*inaudible*).
Worker's Compensation History

FISHER: It was an interesting time in the evolution of the insurance industry for workers at that time, because there was some conflict between work man's compensation for accidents versus repeated exposure.

This was an issue that keeps coming up in insurance branch stuff, where, if any employee fell down on the plant floor and broke his leg, that would be covered, but repeated exposure to a substance during the course of work, like uranium in a mill, would not be covered by a workman's compensation provision in the state that they worked. It's especially true in Tennessee and Washington.

EISENBUD: Well, it depended on the state. I discuss that in my book. This helps to put the whole subject into perspective, because it was not until after the war that all the states had workman's compensation coverage for the workers. Imagine that! The first one didn't have it until, I think it was 1922, which was long before you folks were born, but not so long ago in historic terms. Europe was 50 years, 75 years ahead of us.

The first state was Wisconsin. In 1922, I believe, they got a workman's compensation policy, but for occupational disease. And there were bona fide historical reasons why occupational disease wasn't included. People recognized that they were [creating] reservoirs of silicosis cases, lead poisoning cases.

Whose cases were they? If a man worked for 10 different companies and was exposed to silica and now has silicosis, who pays?

And they finally worked that out, but it wasn't until well after the war that the rest of the states had workman's occupational disease coverage. And then the question of statute of limitations came up, and it took time to resolve that.

The people that get into the field now, they think, "Oh, these are easy questions, and we should have thought about them." But no, it wasn't easy at all; it was tough. It was a tough fight.

FISHER: You point out in your book that when information on health was forth coming from employers to employees and to industrial hygienists and such, it was always done on the employer's terms. They kept a lot of that health data rather close to the vest. Was that true with the AEC early on?

incident was the plugging of floor drains, with the consequent formation of puddles of contaminated liquids on the floor at Plant 6 (AEC 1950k).

5.5 OTHER DATA OF DOSIMETRIC INTEREST

5.5.1 Number of Workers

The initial April-July 1942 uranium pilot plant effort included 24 people working as a single project group under a project manager (Fleishman-Hilliard 1967). In 1944, there were 55 guards; 330 workers (including guards) with a clearance for MED work, and 1500 workers on the entire site (presumably including non-MED workers) (MED 1944b). Regarding the total number of workers with potential for exposure, Fleishman-Hilliard (1967) and Mallinckrodt (1994) list the total number of workers as 250, the former stating that this was in 1948; AEC (1948b) lists the total number as 250 at Plant 6, but 400 if Plant 4 was included; AEC (1949) lists the number of workers at Plant 6 as 272 and the number at Plant 4 as 94. Mason (1958a) states that as of the beginning of 1948, more than 100 of the original employees working during the period 1943-1946 were still on the payroll. AEC dust study reports in the 1950's give the number of each classification of workers and the number on each shift (e.g., AEC 1954b); some AEC reports even list the names of process and supervisory workers and their job classifications in an appendix. As noted above in Section 5.4.3.1, over 2000 film badges a month were processed in the 1950's.

5.5.2 Number of Hours Worked per Week

From AEC dust study reports (e.g., AEC 1954b), the following information regarding time spent is provided as follows:

Length of work day, including breaks and locker room time	480-520 minutes (8-8.6 hours)
Lunch break	30 minutes
Smoking breaks	30-40 minutes
Clean locker room	20 minutes
Regulated locker room	15 minutes

The longer work day applied to operators and craftsmen, who presumably had to leave their work areas to smoke. There was a 10-15 minute variation in the work day among plants as well. The total smoking break time was 30 minutes for Plants 6E and 7, but 40 minutes for Plants 4 and 6 through about 1955; after that it was 30 minutes for all plants.

While AEC-NYOO took the weekly number of hours to be 48 (or six 8-hour days) in calculating some of their early time-weighted average airborne concentrations (AEC 1949), Lippmann (1958) used 40 hours in reporting data regarding Harshaw workers. It can be assumed in the case of the Mallinckrodt workers that they typically worked for a full 8 hours a day, 5 days a week, or 40 hours per week, since that will conservatively cover both the actual 5-day and the actual 6-day cases. When using daily weighted average dust sampling data (e.g., in Tables 13-17 and 21-24), it is important to understand that break, lunch, and locker time was factored into the weighted averages reported by AEC and Mallinckrodt in their air dust studies.

Fleishman-Hilliard (1967) states that once the Plant 2 operations started (ether extraction), it was carried out 24 hours per day. It is not clear what other processes ran 24 hours per day. Guardhouses were manned around the clock, with three shifts per day (MED 1944b).

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Notes: Mallinckrodt

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Section F2. is supplemented as follows

Based on our review of the records and NIOSH site profile, there was no isotope specific monitoring by AEC or Mallinckrodt for internal exposures to actinium 227, protactinium and ionium at the Destrehan facility during its operation. Internal dose moitoring, when it was done, was for uranium. Due to a lack of information , NIOSHs site profile lacks a credible basis for estimating uptakes of these isotopes and internal deposition. The liquors and raffinates would be aerosolized during processing, and also combined with dusts. Certain processes would concentrate these isotopes in the process of refining.

Gross alpha and beta measurements in urine bioassay are inadequate to distinguish between uranium uptakes and the far more radiotoxic substances such as actinium and protactinium. NIOSH's general assumptions about dose from the raffinates and filter cake do not capture the full range of potential uptakes, particulary inhalation.

Furthermore, the poor working condition and inadequate personal protective equipment will result in intakes through wounds. NIOSH has failed to adequately account for dermal contact with powerful beta emitters such as actinium.

NIOSH should also take note there is a September 20, 1951 notice that the laboratory would accept no urine samples for internal dosemitry monitoring in the 4th quarter of 1951 for Mallinckrodt personnel-except for emergency situatuions-because of an "unusual workload" on the chemical laboratory. It would be infeasible to estimate internal dose for this time period.

[redacted]