MASTER

FEASIBILITY STUDY OF THE CORRELATION
OF LIFETIME HEALTH AND MORTALITY
EXPERIENCE OF AEC AND AEC CONTRACTOR
EMPLOYEES WITH OCCUPATIONAL
RADIATION EXPOSURE

Progress Report

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ABSTRACT

This report is the third annual progress report of activities under AEC Contract No. AT(30-1)-3394, which was approved in June, 1965, to continue as a five year feasibility study sponsored by the Division of Biology and Medicine and the Division of Operational Safety of the U. S. Atomic Energy Commission. The objective of this project will continue to be the same for the third project year: to carry out test runs of cohort employee populations of selected AEC Contractor installations, in order to assess the feasibility of using personnel, employment, medical, and radiation records in establishing the relationships, if any, between mortality patterns and levels of radiation exposure. The reason for the study is the absence of comparable information pertaining to human populations exposed to recorded low levels of radiation over long periods of time. The general procedure initially established will be continued: to establish a series of cohorts at each facility, including those employed as well as those separated, for each year; to trace these individuals through Social Security records to determine those who have died and their place and date of death; to obtain death certificates to establish the mortality pattern; and to evaluate the relationships, if any, of the mortality patterns of these cohorts with radiation, length of employment, and other environmental data. The following AEC Contractor facilities were selected for the test runs: the three Oak Ridge facilities, Hanford, and several small feed materials plants, providing large populations with long intervals of operation. At the end of the second year or early in the third year of this five year study, all available radiation exposure records will have been compiled or abstracted by annual readings and recorded on ADP equipment

for Oak Ridge and Hanford. Also, the Hanford Occupational Health Foundation will have completed recording the necessary personal identification and sibling data from 1944 through 1966, and a study of medical x-ray exposures received by employees from 1946-1956. During the third project year, the recording of personal data on Oak Ridge employees and feed materials centers will be intensified, other phases of the project will be continued, and the searching for deaths through the Social Security Administration will begin.

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REFERENCES

I. INTRODUCTION

In June, 1965, this study was initiated to test over a five-year period the feasibility of utilizing accumulated routinely-recorded personnel and radiation exposure data in AEC facilities for longitudinal studies of the health and mortality experience of atomic energy workers. Previous renewal proposals and two annual progress reports--NYO-3394-3 (Revised April 21, 1965) and NYO-3394-5 (submitted in January, 1967) have discussed in detail the project objectives, design, and data abstracting procedures initiated in previous years. This report will review the progress made during the second year of the five-year study, and will outline the work planned for the third year. For reasons stated in previous reports, the five-year runs have been focused on AEC plants at Oak Ridge (including early groups of the Manhattan Engineer District), Hanford, and several feed materials centers. Cohorts of atomic energy workers will be followed who began employment in the years 1943 through 1967. The five-year study was divided in the beginning into three phases (see NYO-3394-3): I -organizing, arrangements with other agencies, statistical design, data abstracting and conversion to magnetic tape; II -data processing, programming, tracing death records (through Federal and state agencies), and obtaining death certificates; III -coding deaths, data processing, data analysis, presentation of results, and phasing into further studies (including a possible continued follow-up of all AEC Contractor employees).

Parts of Phase I have now progressed to the point where they should be completed by June, 1967, or early in FY 1968, in regard to the personnel and radiation exposure data at Hanford, and radiation exposure and certain other environmental data from the three facilities at Oak Ridge. However, there

has been a lag in the collection of personnel data from PSQ's and other sources at Oak Ridge, for reasons given in this and in previous reports, and additional recording personnel will be needed to speed up this work. A special study of other environmental agents is recommended to begin at Hanford immediately, while the appropriate professional staff is available, to avoid the possibility of attributing to radiation the health hazards that might result from other environmental agents. In order to make up for the destruction of data that occurred when General Electric turned over activities to other contractors, we must take advantage of professional staff who will soon retire, to reconstruct records on environmental hazards of particular work locations. Personnel data on the early Manhattan Project workers at duPont have already been returned to the Hanford Occupational Health Foundation, and the radiation exposure data on the early duPont workers at Hanford and Oak Ridge, and University of Chicago employees at Oak Ridge, have been transferred to ORNL. Abstracting of these data and incorporation with the other project data on magnetic tape will be completed early in FY 1968. ORNL has established a complete roster of cohorts of all radiation workers since 1943 in the process of searching for and abstracting the radiation data from the various record sources.

The identities of eight feed materials plants to be included in the study have been sent to the Bureau of Old Age, Survivors, and Disability Insurance (OASDI) and a report has been received from OASDI regarding the completeness of their records on these populations. The study of medical x-ray exposures on Hanford employees over the years 1946-1956 is nearly complete, forms for transferring the data of interest to magnetic tape have been designed, and studies of the relative magnitudes of the medical x-ray and

occupational radiation exposures at Hanford are planned for FY 1968 to assist in the statistical design of methods for evaluating project results. The remaining summaries of radiation exposure data at ORNL, not yet available in FY 1966, are presented in this progress report. Further details on the progress of this study during the past year will be summarized in the following sections of this report. A proposal has been submitted with this report requesting continuation of the five-year study during FY 1968.

II. BACKGROUND

A more detailed discussion of the scientific reasons for carrying out this project has been given in previous proposals and progress reports. (1-4) During the past year there have been several additional studies that support the need for the continuation of this project. A recent report by Saxon Graham and associates, (5) on a study of several hundred children who had leukemia during the first fifteen years after birth, has given additional support to previous studies indicating that only one to two roentgens from diagnostic x-ray films on mothers (and perhaps fathers) prior to birth may as much as double the leukemia incidence in children. This finding seems to confirm previous studies mentioned in the 1962 U. N. report, (6) which indicated that the foetus, or preceding generations of reproductive cells, may be as much as 40 times as sensitive to radiation as adult somatic cells, in regard to changes that eventually may lead to leukemia and perhaps other types of cancer. Thus, information on occupational radiation exposures and medical x-ray exposures to be gathered in the present study, together with the methodology of investigating mortality patterns, may later be useful in a variety of future studies including those of the offspring of persons exposed to ionizing radiation.

A study reported by Larson et al (7) to compare the mortality experience of Union Carbide employees in Oak Ridge over the period 1950-1965 may be regarded as inconclusive, since only active employees and those who had earned Carbide benefit plans through long employment were compared against the general white population of the United States. The pitfalls of such comparisons have been pointed out previously. (1,2) The mortality among

Industrial employee groups may generally be expected to be lower than that of the general population. (8,9) Indeed, without further examination, the increasing mortality rates observed over the 1950-1965 period among the Carbide employees by Larson et al (7) may be loosely interpreted as a rapid decline in the initially favorable death rates of highly selected employees after a duration of employment at Oak Ridge. Of course, such a speculation would also be untenable without proper adjustments for the various demographic and employment characteristics of the population, and merely illustrates the need for a more comprehensive examination of all of the variables influencing mortality, including radiation, initial selection, and other exposures to toxic influences.

III. ACTIVITIES AND OBSERVATIONS OF SECOND YEAR (FY 1967)

The previous annual progress reports of this project^(1,4) have presented the procedures developed for recording the personnel and exposure data required in this project, as well as the scientific background and reasons for the project. Table 1 illustrates the additional progress made during the past year. The radiation exposure abstracting phase for Oak Ridge, illustrated in Figure 1, has been completed as far as data available in the files of current operating contractors are concerned, and by the early part of the next project year it is expected that ORNL will also have completed recording supplementary data on early population workers at ORNL whose records have been located and transferred to ORNL within the past two years. Thus, all existing information on personnel radiation exposures, including estimates from pocket chambers in years when no film badge data were available, will have been recorded according to the methods of Hart^(10,11) in a format that can be entered on magnetic tape to form a practically complete record of radiation exposures for all cohorts and employees at X-10 or ORNL.

The central data processing facility has provided printouts of the average exposures and frequency distributions of exposure for each of the years of operation of ORNL under Carbide (Tables 2-5), similar to those printouts given for Y-12 and K-25 in the previous annual report.⁽⁴⁾ Mr. Hart and his clerical staff are now abstracting the remaining radiation exposure data from records received covering pocket chamber data for University of Chicago employees and duPont employees during the years 1943-1945. Mr. Hart has also abstracted the exposure data on employees of the Monsanto Chemical Company at X-10 during the years 1945-1947, so that he will have abstracted all of the known available external radiation

exposure data by the end of the current fiscal year, or early in FY 1968. He has also made arrangements to continue the accumulation of this data in subsequent fiscal years, as the other facilities at Oak Ridge and Hanford have done. Table 6 presents a summary of various population exposure parameters from Carbide records of ORNL, calculated from the data of Tables 2-5, as done for ORGDP and Y-12 in last year's progress report.⁽⁴⁾ Table 7 compares the population exposure parameters for the three plants at Oak Ridge. As emphasized in last year's report, these preliminary exposure parameters are presented only for possible use in project planning. Final analyses of project results will be based on the classification of each employee according to his particular history of radiation and other occupational exposures and parameters.

At Hanford, the abstracting of radiation exposure data and the summarizing of annual exposures to gamma radiation, plutonium x-radiation, beta radiation, neutron radiation, plutonium body burden estimates, tritium whole body dose equivalent estimates, and extremity exposures as recorded by film ring badges, will have been completed by Mr. John M. Selby⁽¹²⁾ by the end of the current fiscal year. The data was listed on a total of 180,000 punch cards representing the annual entries from all individuals on the radiation exposure record at Hanford (see the examples in Figure 2). The health physics staff at Hanford has been auditing the information on these cards correcting any known errors in names, social security numbers, and payroll numbers.

The more recent work has been connected with making the necessary corrections to previously recorded exposures to include present methods of interpretation of neutron dose, x-ray dose from plutonium, and the addition

of tritium dose to the whole body dose record for the years 1949-1954. These tritium exposures had not previously been included on magnetic tape records of occupational exposure. Also, external dose as recorded from film ring badges were not included until 1963 on magnetic tapes, and although this data was not requested for this project, the Hanford staff is presently searching the old records for this data to obtain a complete record of all radiation exposure information in organized form on magnetic tape. The extremity dose information, although difficult to relate quantitatively to biological effects, may ultimately be of some additional value to the project in the event that it might be used later to fill in for missing data on the employment of certain individuals or as proof of the likelihood that observed effects may later be relatable to these extremity exposures in certain cases.

The corrections for neutron and x-ray exposures are complete as of April, 1967 and approximately 10,000 cards containing the tritium bioassay sample results have been produced. A special computer program has also been prepared to calculate the dose to whole body water from these bioassay cards. When these doses are calculated they will be added to the 180,000 cards containing the other annual dose information on employees. It is expected that the tritium and extremity doses will be completely transferred to the 180,000 punch cards by July 1, 1967. Also work has been initiated to produce cards for the 1965-1966 period, which includes the writing of another program. These cards should also be finished and audited by July 1, 1967, or soon thereafter.

The data on the plutonium deposition cases have been completed and are contained on a separate set of cards. It was necessary to go back in the

plutonium deposition cases and recalculate the exposures in order to provide the amount of plutonium taken in during any one year. The cards will contain the quantity of plutonium incorporated systemically in microcuries for each incident in which an employee was involved. All individuals who have a positive deposition, as indicated by urinalysis, exceeding 5% of the maximum permissible body burden will be indicated. One exceptional point that should be considered in regard to the plutonium deposition estimates is the fact that these data are not necessarily firm until many years have elapsed to observe urinary excretion patterns. An entry on a man's plutonium deposition record is subject to change in years to come if additional bioassay data are collected that may indicate perhaps an additional lung deposition or wound deposition of insoluble plutonium that is slowly feeding additional plutonium into the system. In a number of cases, Hanford has found after several years that the deposition for a particular individual may increase perhaps by as much as a factor of two as new data becomes available. Thus, at any point in the analysis of the epidemiological data, plutonium depositions may be used only to indicate those individuals who have been exposed to plutonium. No finely divided gradient of plutonium exposure between groups of the population may be expected.

Thus, in general it has been possible to obtain all of the data from Hanford on radiation exposures as indicated in our original proposal. (1,2) Data on magnetic tape by the summer or fall of 1967 will include all exposure data listed by individuals for each of the years 1944 to the present and will be recorded by the type of radiation exposure. Recommendations will also be made by the Battelle Northwest staff for combining these different types of radiation exposures to obtain an estimate of the whole body "rem"

doses, based on currently used quality factors extrapolated for control purposes from acute exposure data, radium dial painter data, or animal data. However, the separate dose from each type of radiation will be retained permanently so that other quality factors may later be utilized in this study as more information on radiobiological effects becomes available.

In regard to our progress in abstracting data for the eight feed materials processing centers to be included in this study, (1,4) some progress has been made in arranging for the preservation of data at Mallinckrodt, and in submitting selected rosters of the plants to the Bureau of Old Age, Survivors, and Disability Insurance (OASDI) of the Social Security Administration in Baltimore to check their ability to identify the work histories and present status of these employees in detail. We have begun arrangements to have our recently hired records librarian supervise the abstracting of the Mallinckrodt records at St. Louis. This work began in April 26, 1967, and should be completed before the end of the summer.

We have also found records of the early SAM Laboratory at Columbia University during the past year and will include in the study this population of early workers who were engaged in developing methods of producing fissionable materials. Arrangements have been worked out to abstract the necessary information for the study.

The OASDI was able to identify the quarterly payroll records for most of the feed materials centers that we submitted to them, and it seems likely that they will be able to do a more complete job when we take full advantage of all of the sources of information available to us in the parent companies of these feed materials centers. In a case such as the SAM Laboratory, they were not able to identify the population as such, but this is understandable since at the time of the Manhattan project the SAM Laboratory was engaged in highly classified work.

We also visited the University of Rochester this year since they had been given some of the early responsibility of developing methods of radiation detection and measurement. Unfortunately, we found that their records had been destroyed. Whatever remaining employee records that they still have could be made available to the project, but we do not believe that a few hundred people working at Rochester would be worth including in this study since their main assignment was the development of methods of evaluating radiation exposures.

The abstracting of populations of University employees who participated in the early development of the Atomic Energy Program from 1943-1945, has proceeded to the point where most of these employees have been identified either in University records or in rosters of military members of the scientific teams.⁽⁴⁾ The records of University of Chicago employees were transferred to ORNL in February, 1967, and Mr. James Hart has begun abstracting from these records the population of workers who received pocket chamber monitoring and health surveillance. The pocket chamber exposures are being summed and recorded for each individual according to the methods already developed by Hart.^(10,11) This work should also be completed soon and the data will be transferred to magnetic tape by early FY 1968.

Mr. Hart also has received the records from duPont (Wilmington) of those Hanford employees who did not remain with General Electric when operations at Hanford were transferred to the General Electric Company.⁽¹⁻⁴⁾ The pocket chamber exposures from these records are also being summed and included in the same format as the radiation exposure data from ORNL so that these data may be later compared with the radiation exposure data at Hanford for the early years. Also, Mr. Hart has located another source to identify

the population of radiation workers whose records had been inadvertently destroyed at Wilmington. ⁽⁴⁾ Thus, some of the information available on these early radiation exposure records may also be utilized to identify populations that may be included in the study.

As mentioned in our recent progress report, ⁽⁴⁾ the abstracting of the personnel identification data, including the sib data, from PSQ's has been proceeding on schedule at Hanford according to the procedures outlined in our reports, ^(1,4) and by Kirklin and Perry. ⁽¹³⁾ A staff of ten clerks is presently working under the supervision of Mrs. Kirklin at the Hanford Occupational Health Foundation, and a few additional employees will be hired as needed to complete this work by about July 1, 1967. At that time all of the data requested for personnel identification ^(1,2) will have been converted to magnetic tape records for purposes of the study. Hanford has completed about 19,000 records as of March, 1967. The remaining 11,000-12,000 will be completed by early FY 1968.

In Oak Ridge the work has been moving relatively slowly in regard to abstracting personnel data for reasons given in our last progress report. ⁽⁴⁾ Also, AEC-ORO has lost some of the clerks working on this project during the past year, and a freeze of employment has prevented their replacing the employees who left. Some of the difficulties in abstracting the required information from the PSQ's at Oak Ridge have been presented in detail in our recent progress report. ⁽⁴⁾ Additional procedures introduced during FY 1967 to speed up the collection of personal data in Oak Ridge or ensure its completeness are presented in Appendix A.

At Oak Ridge, we now have between ten and eleven thousand employee records abstracted as of April, 1967, and we estimate that about 28 to

30 thousand remain to be done. Thus, we will need to employ additional clerical staff at Oak Ridge to speed up this work. Some additional assistance will now be available of course, from the records librarian recently hired by the University of Pittsburgh to over-see and coordinate project work at Oak Ridge from the University standpoint. The records librarian will continue to work through the same channels and procedures already established for the project.

It does appear, from preliminary tests made at OASDI,⁽⁴⁾ that a larger percentage of sibs abstracted from the PSQ's at Oak Ridge will be identifiable through OASDI than the sibs abstracted from Hanford PSQ's, but this cannot be ascertained until more data are available. In some cases at Hanford the ages of the siblings were not given and thus the sibs are difficult to identify at OASDI. However, it seems that both at Oak Ridge and at Hanford a sufficiently large fraction of sibs will be identifiable with which we can construct one of the types of control populations that we had planned for this study. (1,2)

One important lag in the project that should be emphasized at this point is the lack of data on exposures other than environmental radiation. Immediate efforts to accumulate information on other environmental exposures, in addition to the limited bioassay data that has already been abstracted and transferred to magnetic tape,⁽⁴⁾ have been recommended previously. (1-4) Consistent with the suggestions of our consultant, Dr. Schull,⁽⁴⁾ we must control the extraneous variables such as medical x-ray exposures or other environmental exposures to be homogeneous between groups having various levels of occupational radiation exposure. Otherwise, we must have auxiliary data in order to properly group the individuals along gradients of different types

of exposure or combinations of exposure, so that we may study the effects of these extraneous variables on any conclusions that may be derived regarding occupational exposure to radiation. As we have mentioned previously, this project cannot be properly done without giving this attention to other environmental agents and to medical x-radiation, since previous experience indicates that these other types of exposure may be at least as important in producing bionedical effects as low-level occupational radiation exposure. One of the main purposes of this study is to determine in an actual human population just what may be the effects of low-level occupational radiation exposure. To attain this, we must consider other toxic agents to make sure that they are not responsible for any differences found in the exposed group and the appropriate controls. Since some of the industrial hygiene personnel who have been involved over the years in the Atomic Energy program will soon be retiring, it is now very urgent that we employ these industrial hygiene personnel to assist us immediately in reconstructing the various plant situations, jobs, and environmental agents of exposure to which the employees at Hanford and at Oak Ridge may have been exposed. Thus, requests for certain industrial hygiene investigations have been made in this year's renewal proposal.

Arrangements have been made with OASDI to carry out various phases of the project in regard to identification of work histories, siblings, and the mortality status of employee populations from the Atomic Energy facilities. As mentioned above, tests have been carried out by OASDI to determine their ability to follow siblings of the Oak Ridge employees, and a report has been obtained from OASDI of the availability of data on the feed materials centers populations (see Appendix A).

OASDI has begun searching for information on the Social Security Numbers of sibs of the Hanford employees. However, as indicated above, about 2/3 of the sibs listed on the Hanford PSQ's have no information in the PSQ to

indicate the year in which they were born. This may reduce the size of the control population that can be constructed from siblings of employees. Of course, the bulk of the work to be carried out by OASDI on the sampling and matching of Social Security covered workers for use as controls, and the accumulation of work history and mortality data on the employees themselves, has yet to be initiated at OASDI.

Plans have been made for obtaining the samples of covered workers through OASDI but we have found that a larger sample than the 0.1% originally planned^(1,2) will have to be used for this study. Arrangements are being made to obtain a 1% sample matched in certain respects to the AEC employee population, for use in constructing suitable control populations.

The medical x-ray exposure study initiated at Hanford during this past year has been progressing even more rapidly than scheduled. The phantom measurements of the direct exposures to the skin and to deeper body tissues have been carried out by Battelle Northwest in conjunction with the Hanford Occupational Health Foundation, using the original x-ray equipment⁽¹⁴⁾ employed at Kadlec Hospital, Richland, Washington, for medical examinations during the 1946-1956 period. A list of nominal exposures for each type of x-ray examination has been submitted by Battelle, including proposed weighting factors to convert the direct beam exposure to equivalent "whole body dose."⁽¹⁵⁾ However, these weighting factors are not intended to represent an accurate accounting of the mass of the radiosensitive portion of the involved tissues, with the current uncertainties in this type of radiobiologic information. Forms have been prepared to convert the medical x-ray exposure data to punch cards for all persons working in the period 1946-1956, or all who died within that period, totalling about 3,400 individuals all together.

The collection of this medical x-ray exposure data from Hanford will also be completed by about July 1, 1967.

Most of the rationale for the project, the scope, the design of data-abstracting forms and procedures, and the general recommendations for the continuation of the project and the development of centers for expanding and continuing the project for all AEC facilities, remain the same as given in previous proposals and reports. (1-4) In the following sections of this report we shall summarize the work proposed for FY 1968, and our present conclusions and recommendations.

IV. OUTLINE OF PROCEDURES FOR FY 1968

As planned in previous project proposals and reports, (1-4) a continuation of the scope outlined at the beginning of the project (2) has been recommended for the new fiscal year. In Table 1 the five-year phasing of the current test run is again reproduced, and the approximate amount of progress through May 31, 1967 is indicated for each task. Table 1 shows that much of the project is on schedule or will be on schedule early in FY 1968, but that the abstracting of personal data and sib data at Oak Ridge is still far behind schedule. Thus, recommendations have been made in our contract renewal proposal for increasing the staff at Oak Ridge during the next project year so that the personnel data phase at Oak Ridge can be brought into schedule with the rest of the project. As shown in Table 1, all of the available radiation exposure data, as well as bioassay data connected with the assessment of internal radiation exposures, will have been completely abstracted by year of employment and converted to automatic data processing format by early FY 1968. However, other industrial hygiene studies that are needed to define the environmental exposures from agents other than radiation will be continued during the next project year.

In summary, the project activities during the next year will include the following:

(1) An increase in clerical personnel at Oak Ridge, as well as an increase in the University of Pittsburgh staff for supervision and coordination of the personnel and sib data abstracting, will be provided during the following year in an attempt to bring the personnel data collection phase at Oak Ridge to completion within FY 1968. The records librarian has already been added to the University staff and stationed at Oak Ridge. A clerk and clerk-typist have

been requested in Section 10 of the renewal proposal to assist the records librarian in carrying out her duties in regard to coordinating project activities, and in performing supplementary audits on the data as well as assisting where necessary in the actual data abstracting.

(2) The conversion of the employees names and their employers from the Manhattan Engineer District card file will be completed early in FY 1968, and a roster will be prepared by computer listing all operations employees and their contractors, including military personnel who were assigned to work areas where they may have received occupational exposures. This roster will then be used to check the completeness of other rosters, and will itself be checked for completeness, as a working device for insuring the accuracy of project data, and speeding up the work by eliminating from the project those personnel who were not actually involved in plant operations.

(3) Since the personnel data phase will have been completed at Hanford by early FY 1968, rosters will be prepared by computer of the names of operating personnel, Social Security numbers, and their birth dates to send to the OASDI, Social Security Administration, to obtain their work histories and identify those who are deceased. Then, as outlined in previous progress reports, (1-4) death certificates will be requested from State Health Departments to determine causes of death. Thus, funds are requested in the budget section of the proposal to pay for these death certificates. In order to properly evaluate the information on the death certificates, an additional physician has been added to the proposed budget to assist with the analysis of project data.

(4) The medical x-ray study at Hanford, for those employed in the years 1946-1956, will be completed and a report will be prepared showing the medical

x-ray exposure received by each employee for each year of employment, and his corresponding occupational radiation exposure. An estimate of the possible influence of medical x-radiation as an extraneous variable on the study will be made from these results.

(5) Abstracting of data from feed materials centers will continue, and arrangements will be made to have this work coordinated through our records librarian.

(6) Since the radiation records at Hanford will be completely abstracted and converted to magnetic tape format by early FY 1968, a complete report on the methods of data abstracting and the types and quantities of data obtained will be prepared during FY 1968. This report will include printouts presenting information on average exposure and exposure parameters as obtained at Oak Ridge. (4) Also, recommendations will be made for combining various types of radiation exposures, i.e., gamma, x-ray, neutron, tritium, plutonium, beta, in order to obtain estimates of rem dose for purposes of the study.

(7) Further studies of environmental exposures at Oak Ridge and Hanford, as well as the feed materials centers, will also be initiated during FY 1968 in order to define the occupational exposure parameters other than those internal and external radiation exposures already identified. The importance of examining the possible effects of environmental agents other than radiation in our study has been discussed in detail in our previous reports. (1,4)

(8) Control populations will be constructed as discussed in previous reports, except that the 1% work history sample will be used to match controls, instead of 0.1% as considered previously.

(9) Other activities, including discussions with statistical consultants and systems experts in developing further plans for data flow and

analyses, as discussed in previous reports, will continue during the next project year.

(10) Recommendations will be made during the next project year to the Atomic Energy Commission regarding steps that should be taken immediately to begin preserving and collecting the necessary data at other AEC Contractor facilities so that this study population can be expanded to include the major populations of all AEC Contractor employees working in Atomic Energy plants throughout the country. The importance of obtaining the largest possible population for this study, and the intention of recommending an expansion have been discussed in our previous reports. (1-4) We have found additional evidence during the past project year that records invaluable to our study are being destroyed and it appears imperative that positive steps be taken immediately to accumulate the necessary data for the study throughout all AEC Contractor facilities so that the nature, meaning, and importance of the data required for the study will be clear to all AEC and AEC Contractor personnel who will be depended upon to provide the necessary data for a continued epidemiological follow-up of the AEC Contractor employee populations.

The other recommendations made in our previous reports (1-4) remain valid and will be extended in the following section.

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are extensions of those made previously, (1-4) which are still considered valid:

(1) The previous conclusions concerning the need for retaining all records that may produce personal or exposure data pertinent to this study, the need for a permanent national center to continue this study, and the need to expand the study to all AEC Contractor facilities having been further emphasized by the experience of the past year.

(2) The project should be expanded immediately to include all AEC Contractor facilities having any appreciable population exposed to radiation with or without other environmental agents, rather than at the end of this five-year contract period as originally planned. Despite the request for retention of records and the cooperation of AEC personnel in this regard, we have found instances where necessary records that could be valuable to the study were still being destroyed. Thus, it is necessary to expand the study now, since it appears necessary that each installation understand the nature of the type of records required for this study and the extensive efforts that must be required to reconstruct data that have been destroyed. Another reason for the expansion of the study at this time is the insufficient number of person-roentgen-years of population exposure represented by the population included in the study so far (1-4) (see also Table 7). Also, since the methodology for the study and the forms for obtaining the necessary data have been designed, it now appears more efficient to begin collecting the necessary data at other AEC Contractor installations at the same time that the project staff is carrying out the current scope of the study. Furthermore, we have found in many installations that individuals knowledgeable in the

history of environmental exposures at AEC Contractor installations will be soon reaching retirement age and will no longer be available to provide the necessary data and help in the proper interpretation of any findings.

(3) The experience of the past three years also leads us to the conclusion that the recommended AEC health evaluation center should also be established as soon as possible. It is important that this AEC center be developed now to participate in the collection and analysis of project data so that there can be better coordination between project activities at various AEC installations as well as a smooth transition into a continuing study and a permanently established agency. The reasons for requiring a continuation of this study into future years, as well as an expansion of the study to include all or nearly all AEC Contractor installations, have been discussed in previous reports. (1-4) The preliminary printouts of exposure data given in last year's progress report (4) as well as in Tables 2-7 of this report indicate the need for more person-roentgen-years to obtain enough data to search for diseases and incidence rates that might be expected from extrapolation of biological effects of radiation at high doses. (1-4)

(4) The project should include a study of all environmental exposures other than radiation, as well as both internal and external radiation, and should include enough different Atomic Energy installations to give different spectra of exposures from the various sources so that the effects of the various types of environmental agents may be studied independently as well as together. It is sometimes difficult in a given facility to be sure that we have identified all the exposures of a given individual to all of the agents which may potentially be present in his work environment and detrimental to his health. This is another reason for expanding the project to include all or nearly all AEC Contractor operations.

APPENDIX A

A.1 Introduction

The following paragraphs of this Appendix present in more detail some of the additional procedures and instructions introduced during the past project year. Also, pertinent preliminary data and reasons for these additional procedures are presented. This material is included here for ready reference particularly in the event that these studies are expanded to additional facilities or similar studies are developed by other agencies. The material is presented approximately in the chronological order in which the procedures were introduced.

A.2 Punching of Manhattan Engineer District (MED) Card Files

Last May, 1966, at a meeting in the AEC office in Oak Ridge representatives of AEC headquarters and the University of Pittsburgh staff decided to put the MED card file at the Security Division, Oak Ridge Operation Office, on punch cards and eventually list and classify the names. The files were estimated to contain 421,200 names and were believed to represent all the individuals that were given security clearances to work with MED from 1943 to 1947, at Oak Ridge and elsewhere. The meeting in Oak Ridge was called because the University staff learned that no PSQ or other personnel information was available for persons in MED files. Since the quality of the Mancuso Study depends on completeness in the roster of all of the employees who over the years participated as AEC contractor employees, it was deemed that we should have objective means to ascertain that this requirement was satisfied. Presumably, the MED files contained the names of all those employed before the AEC came into being.

This project is not concerned with construction contractor employees or other service contractors who worked on the site before the production of fissionable material began. An experimental trial of a sample has indicated that 50 percent of the employees found in MED files are employees of construction contractors. Similarly, there are five to six percent service personnel who also would not be of interest to the study. We planned, therefore, to select only employees of employers whose personnel actually worked in an operating atomic energy facility and who may have been exposed to ionizing radiation incident to their work.

An attempt was made to prepare a comprehensive list of employers of interest to the study. This list included over 30 companies, and over the years there have been numerous changes in company names. Rather than rely on keypunchers to identify the name of a given company, especially when there were varying styles used in abbreviating the names over the year, we prepared a list of construction contractors whose employees were not to be put on punch cards. All the rest, except obvious exclusions such as Coca Cola Company or the Board of Education, would be punched and sorted later by computer. However, wherever doubt exists regarding the possible exposure status of an employee, he should be included on the punched cards. Punching would include names of transferred employees and others for whom no employer is shown. Employees for whom no employer is shown would be identified, and the reason for the absence of an employer indicated, if known. Perhaps a brief one-column code might be used for this. The list* of contractors in the MED files whose employees would not be included is as follows:

*This list was expanded many fold with the aid of the AEC Contracts Division. The present list of several hundred eliminates about 25 percent of the recorded population.

Amos Maude Market	Oak Service Association
Ande Paint Company	Pre-school P.T.A.
Board of Education	Prog. Cage
Borden Company	R & H Valet
Campbell Foods	Recreation & Welfare
Campbell's Food Market	Richland Laundry
Canteen Food	Sargent Laundry
Coca Cola Company	School District
E. Vill. Bar	T & C Cafe
F & M Ice Company	The Drug Center
Grove Dining Room	U. S. Post Office
Knox News Service	U. S. Sign Corporation
Local Bus Lines	Village Food Store
Oak Ridge Hospital	Westown Cafe

From preliminary work done, it was evident that the full information found on the MED cards may require two punch cards for each person. Provisions will be made to have some sort of a serial number that would tie these two cards together.

The instructions regarding information to be punched from the MED card file were as follows:

1. The full name of the employee--last, first, and any middle name--in the order given on the MED card. No abbreviations should be used since we want the maximum information with respect to the employee's name.
2. The Social Security Number of the employee. This information would be punched even though it is known that less than five percent of the MED cards carry the Social Security Number.
3. The name of the employer. Again, give the fullest information given on the card without abbreviations or eliminations.

4. Address of the employer. The address desired is where the employee was working. The information necessary should include the name of the town and abbreviated name of the state.
5. The birth place of the employee.
6. The date of birth of the employee.
7. Citizenship of employee. Please code: (1) U. S. Citizen; (2) Non-citizen; (3) Information not given or unknown.
8. The earliest date appearing on the card, giving month, day and the last two digits of the year. Of course, the month names and the date should be preceded by zero in all cases where there is only one digit. The purpose of having a date is to have some idea of how early contact was established with the employees. The earliest date was used because of the wide range of variation in the dates given on MED cards. On some of the cards the date that clearance was requested is given and labeled; this is followed by the date when clearance was obtained, and the date the individual actually started work. However, very often the dates are not labeled properly. Therefore, to have some idea of the earliest contact with the individual, even where the nature of the contact is not indicated, only one date (the earliest) is to be recorded to simplify selection.
9. The security clearing agencies. This should be coded so that each agency involved in the clearance can be identified. In some instances, this information may not be given. In others, only one clearing agency may be shown, or two, three or more agencies are shown. This information should be recorded in such a way that it can be retrieved completely.
10. If there is more than one card for an employee, give the same number to each card and punch the information from each card.
11. With respect to cards without any employer, punch zero in column 80 of card 1, and in card 2 punch whatever additional information is on the card in columns 8 through 65.

A.3 Tests at OASDI on Retrieval of Employer Data for Feed Materials Centers

A preliminary test was made of the ability of OASDI to identify employees of atomic energy plants when OASDI is provided with only minimal information of the type listed in typical records of industrial hygiene surveys. As the following results of this test imply, a better retrieval could undoubtedly be obtained after we have supplied all of the company identification and

employee identification data ultimately available to the project. Thus, it is believed that the preliminary findings given on the following pages of this sub-section indicate the feasibility of following through OASDI the feed materials cohorts and other sub-populations of this study, through a combination of resources. The cooperation of the individual companies, and their records, would also serve to supplement and cross check the data completed.

Company No. 1

Mallinckrodt Chemical Corporation
St. Louis, Missouri

Information Requested:

1. Broadway Plant Operation	1942 - 1946
2. Destrehan Street Plant Operation	1946 - 1958
3. Welden Springs Plant Operation	1958 - to date

Findings:

From 1942 through March 1962 all employees of all three plants were reported in Unit No. 1 so no separation is possible for these years.

Beginning in June, 1962, Unit No. 1 also contains pages identified as Uranium Division, St. Charles, Missouri. Beginning in January, 1963, the Uranium Division is reported in a separate unit and is further identified as Welden Springs.

Welden Springs employees can be identified from January, 1963, to date. Also, it is probable that the reports filed from June, 1962 - December, 1962, showing "Uranium Division", represent the Welden Springs plant.

We did not receive a list of employees of this organization.

Company No. 2:

Harshaw Chemical Company
Cleveland, Ohio

Information Requested:

Cleveland, Ohio employees or Entire Company?	1942 - 1956
	1942 - 1956

Findings:

Reports are available for all years.

Cleveland, Ohio employees can be identified in all specified years. There are a number of plants in Cleveland. Separate plants cannot be identified in all years.

List of names furnished for this company. Two names were checked and located on reports. Each earnings record shows substantial employment with Harshaw in different Cleveland plants.

Company No. 3:

Middlesex Sampling Plants
Middlesex, New Jersey

Findings:

This company cannot be identified on the basis of available data.

Company No. 4:

Vitro Manufacturing Company
Canonsburg, Pa.

Information Requested:

Canonsburg, Pa. employees

1943 - 1956

Findings:

If Canonsburg is the same as "Washington County", Canonsburg employees can be identified from 6/44 through 12/56. The affected pages of the report are marked to show "Washington County", until 3/54 -- then show "Reporting Unit #8 - Canonsburg."

Unless plants other than Canonsburg are located in Washington County (of which we are not aware), it appears that the specified cohort can be identified.

Lists of employees received from Dr. Mancuso and names found on reports.

Company No. 5:

Simmonds Saw and Steel Corporation
Lockport, New York

Information Requested:

Lockport, New York employees 1948 - 1955

Findings:

Employees can be identified by State of New York only.

Lists of employees received from Dr. Mancuso and names
found on reports.

Company No. 6:

Lindsay Chemical Company
W. Chicago, Illinois

Information Requested:

W. Chicago, Illinois employees 1943 - 1944 and 1952 - 1954
or 1943 - 1953?

Findings:

Employees located in State of Illinois (but not W. Chicago,
Illinois) can be identified in years 1943 through 1953.

Lists of employees received from Dr. Mancuso and names
found on reports.

Company No. 7: (See No. 8)

Linde Air Products
Division of Union Carbide and Carbon
Buffalo, New York

Information Requested:

Buffalo, New York employees 1944 - 1949

Findings:

Reports related to Buffalo, New York employees cannot be identified until September, 1947. The Buffalo group represents a small portion of the entire report - approximately three pages of a total of about 135-150 pages per quarter. Buffalo available through December, 1949.

No list of Buffalo employees was received from Dr. Mancuso.

Company No. 8: (See No. 7)

Linde Air Products
Division of Union Carbide and Carbon Ceramics Plant
Tanowanda, New York

Information Requested:

Tanowanda employees 1942 - 1946

Findings:

Tanowanda employees can be identified beginning January, 1943, through September, 1944. Tanowanda cannot be identified from October, 1944, through December, 1946.

Lists of employees received from Dr. Mancuso and names found on reports.

Company No. 9:

Fercleve Corporation
Subsidiary of H. R. Ferguson of Cleveland, Ohio

Information Requested:

Fercleve Corporation employees 1944 - 1945

Findings:

Our records show the Fercleve Corporation, Oak Ridge, Tennessee, filed reports in July, 1944, through 1945.

No EIN was located for H. R. Ferguson.

Assuming that the Fercleve Oak Ridge installation is the plant of interest, we would have no problems in identifying these employees starting July 1, 1944 through December 31, 1945.

Company No. 10:

Clinton Engineer Works - Tennessee Eastman Corporation
Oak Ridge, Tennessee

Information Requested:

Oak Ridge employees 1945 - 1947

Findings:

Reports from Clinton Engineer Works Division of Tennessee Eastman Corporation located for January 1945 through June, 1947.

Oak Ridge, Tennessee employees can be identified.

This company does not appear to be a problem with respect to identification.

Company No. 11:

Monsanto Chemical Company
St. Louis, Missouri

Information Requested:

1. Oak Ridge, Tenn. employees	1945 - 1947
2. Mound Laboratories, Dayton, Ohio employees	1945 - 1947

Findings:

Identification by State of employment (not city) is possible for Ohio and Tenn. employees during specified period.

Establishment identification is possible only in last two periods of 1947.

Company No. 12:

Kellex Company
Kellex Engineering Company
Division of Kellogg Company, N. Y., N. Y.

Information Requested:

New York employees

1943 - 1945

Findings:

Reports located for the Kellex Corporation, 233 Broadway
N. Y. C., N. Y. No connection with Kellogg Co. apparent.

Pages reporting both New York City and New York State
employees can be identified.

Cannot separate N. Y. C. and N. Y. State employees.

Company No. 13:

Houdaille-Hershey Industries Inc.
Decatur, Illinois

Information Requested:

Decatur, Illinois employees

1943 - 1945

Findings:

Reports designated as Oakes Products Division, Rept. Unit 4,
and Garfield Divisions, Rept. Unit 8, in Decatur, Illinois
filed by this company beginning April 1943 through December
1945. Our records show the company as Houdaille-Hershey
Corporation, Detroit, Michigan rather than Houdaille-Hershey
Industries Inc., Decatur, Illinois.

Rept. Unit 4 reports filed 3/46-6/47 showing Oakes Decatur
Div. of Houdaille-Hershey Corp., Decatur, Illinois. Rept.
Unit reports filed 9/47-12/51 showing Decatur Div., Decatur,
Illinois.

Rept. Unit 8 reports filed 3/46 showing Garfield Div. of
Houdaille-Hershey Corp.

6/46 reports for Garfield Div. filed in Rept. Unit 9. No
reports filed for Rept. units 8 or 9 from 9/46-12/51.

Rept. Unit 6 reports showing Macon Arms. Div., Decatur,
Illinois filed 6/51-12/51. No reports showing this plant
3/46-3/51.

Company No. 14:

Union Carbide and Carbon Company
Oak Ridge, Tennessee

Information Requested:

1. Carbide and Carbon Chemicals Company, 1943 to date--
Tenn. EEs.
2. Union Carbide, Nuclear Division, or Union Carbide and
Chemicals, May 1947 to date -- Tennessee Employees.
3. Union Carbide Nuclear Company or Union Carbide and
Chemicals Company, March 1948 to date -- Tenn. Employees.

Findings:

1. Carbide and Carbon Chemicals Company filed reports from
January 1, 1943, through 1949. State of Tennessee
employees can be identified beginning January 1944
through 1949. From 1949 through 6/55 reports were filed
by Union Carbide Corporation showing Carbide and Carbon
Corporation. State of employment can be identified in
some quarters but not all.
2. Returns were not filed under Nuclear Division and "Nuclear
Division" was not identified on Union Carbide Corporation
Reports.

Summary:

This company involves several subsidiaries engaged in
various chemical and metallurgical business activities.
With the exception of the early reports filed by the
Carbide and Carbon Chemicals Company identification
by State is not available in all years. Oak Ridge,
Tennessee employees can be identified on the "tape"
reports filed in July 1965 and October 1965.

A.4 Sampling of Servicemen from MED Cards to Check for Availability
of PSQ's at DOD. (9/11/99)

The AEC records management staff informed us that for men in the service
the armed services (or Department of Defense(DOD)) have preserved the PSQ's.*
Therefore, a small sample was obtained of servicemen to see what information
the Defense Department would have on these individuals--particularly with

* The results proved negative. No PSQ's could be found for these individuals.

respect to sibs--and what problems might be encountered in abstracting this information. A list of 106 names of servicemen who worked for the MED was obtained. Then the names of these servicemen were checked against the larger MED files, where we had supplementary information.

This also provided an opportunity to have some sort of check on the completeness of the MED files. The clerks were instructed to record servicemen even when the MED file gave no indication that these individuals had actually worked at Oak Ridge or Hanford, which probably could be ascertained from the DOD files. In selecting 100 cases, we found six servicemen with cards in the servicemen's files, but no card in the MED files. The DOD records might show that these men were cleared to work for the MED, but never actually worked. On the other hand, it might show that these men did work at Oak Ridge or Hanford. Then, we shall have an indication of the degree of the current incompleteness of the MED files. This knowledge should be helpful in determining how much expense would be warranted to punch the information from the MED files.

Another check on the "integrity" of the MED file was made using the Roster of Scientific and Key Personnel of the MED.⁽⁴⁾ The servicemen's card file could have names of persons who were cleared to join the staff of the MED but who may never have actually worked. Such persons would not be listed in the Roster of Scientific and Key Personnel. Thus, about 10 percent of the names in the Roster were checked and it was found that a number of names that should have been in the MED Card file were not there. These tests indicate the value of having several record sources available for determining the completeness of personal and sib data.

Procedures were also set up for the punching and listing of about 300 records abstracted in duplicate in order to determine the nature and frequency of errors occurring in the process of abstracting data from security folders.

A.5 Estimates of the Total Number of Employees at Oak Ridge (9/11/66)

Independent estimates were made of the total number of employees at Oak Ridge. Workers hired in the post MED period are obtained from the Master Index Card File, contained in 94 drawers. As of September, 1966, the names of employees listed in 70 of these drawers were abstracted as described previously. On the average, there were about 400 cases per drawer. On this basis, we have about 28,000 cases listed and expect to list an estimated 9,600 remaining cases. This gives a post-MED period count of 37,600 employees. It is estimated that during the MED period the employees at Oak Ridge numbered between 60,000 to 65,000. The stored records of Tennessee Eastman alone was estimated to cover some 50,000 employees, not counting those who transferred to Carbide when the latter took over Y-12. DuPont had about 1,000 employees, Monsanto close to 3,000. When we consider University personnel, the total could easily reach or exceed 60,000. This is the same general magnitude as the estimate in Carbide's official cost estimate for FY 1966. (See Appendix Section A.8 also)

A.6 Transfer of Records of Early duPont Employees to Hanford Occupational Health Foundation (HOHF)

Early in September, 1966, arrangements were made with Mr. F. M. Burns in Wilmington to transfer the data on early duPont workers abstracted by Mr. Burns' staff⁽⁴⁾ to Mrs. C. W. Kirklin at HOHF. The data abstracted would be checked at HOHF and data on these early employees (who did not transfer to General Electric in 1946) would be incorporated with the rest of the Hanford population data. Approximately 10,000 record forms were transferred to HOHF, plus about 1,700 specially designed forms containing some addition information on monthly salaried workers. Later, HOHF found that

about half of these need not have been abstracted since they are included among those to be obtained from HOHF records.

Most of the information abstracted at Wilmington was obtained from salary or wage cards and medical records. Medical records were available for about two-thirds of the personnel, and contained the following data: 1) full name, 2) Social Security Number and Pay Number, 3) birth date, 4) sex, 5) race, 6) spouse's full name, 7) area codes where the employee worked, 8) changes in areas where the employer worked, but without dates, 9) dates when employment began and terminated, and 10) children's names, given only occasionally. No records were filled out for military personnel, service personnel who worked in the city of Richland, or individuals who did not actually report for employment. The salary or wage cards were given preference for obtaining the name, Social Security Number, and pay number; medical records, where available, were considered more reliable for the other data. Place of birth was not available for weekly wage earners (most of the cases). Also, in some cases the Social Security Number could not be found. Information on the buildings in which employees worked could be obtained only sporadically.

It is possible that some of the missing information on the early duPont workers at Hanford will be obtained from other sources. Mr. James C. Hart has located a list of all duPont employees who worked at Oak Ridge. Mr. Hart has also found the radiation exposure data on these employees together with the University of Chicago records.⁽¹¹⁾ We had previously been informed that the radiation records had probably been destroyed inadvertently at Wilmington.⁽⁴⁾ This indicates the necessity of a thorough and persistent effort in this type of study to gather and search all possible record sources

for the necessary data, as well as the necessity of maintaining records that might be useful for this purpose.

A.7 Procedures Introduced at Hanford to Identify Sub-Population Card Files

In November, 1966 a method was introduced to assist in identifying data collected for different sub-groups at Hanford. The nature of the data, changes in the data recording form, and identification of control populations, are all factors contributing to the need for a method of properly identifying the various sub-groups of data under collection. On the following page is a table identifying the presently known groups. Each group is assigned: 1) an identification number, 2) the data processing card to be used when punching the data, and 3) the form on which the data groups will be recorded. The appropriate group number will be recorded on each form as the data is abstracted. Also, when the data are submitted for any punching, the envelope containing the data can be identified using the same numbering system. This schedule will probably be extended in the future as other groups of data are identified. Although colors may have to be re-used, we can introduce supplementary identification using marking pencils.

AEC HEALTH DATA - IDENTIFICATION SCHEDULE

November 4, 1966

<u>Data Group Number</u>	<u>Punched Card Form Number and Color</u>	<u>Recording Data Form No.</u>	<u>General Description of Data Comprising Each Group</u>
I	54-8171-034 Manila	BD-8800-105 (9-65)	Data from which first control sample was taken, using original form.
II	54-8171-038 Yellow Stripe	BD-8800-105 (9-65)	Data gathered using form but from which control sampling has not occurred as of above date.
III	54-8171-030 Blue Stripe	BD-8800-105 (9-65)	Pre-Employments - using original form.
IV	54-8171-053 <u>Solid Green</u>	BD-8800-105 (9-65)	"Never Starts" - using original form.
I-S	54-8171-032 Gray Stripe	BD-8800-105 (9-65)	Control sample from Group I using original form.
I-N	54-8171-035 Red Stripe	BD-8800-105 (9-66)	First group of data using <u>new</u> form (BD-8800-105 (9-66)).
III-N	54-8171-033 Green Stripe	BD-8800-105 (9-66)	Pre-Employments - using <u>new</u> form.
IV-N	54-8171-039 <u>Solid Red</u>	BD-8800-105 (9-66)	"Never Starts" - using <u>new</u> form.

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(42)

A.8 Preparation of a Roster of Union Carbide Corporation (UCC) Employees and Recording of Job, Department, and/or Work Area Changes

The pre-1950 Carbide wage records were compared with the list of employees who have worked for Carbide at any time since 1950 to obtain a complete roster of all Carbide workers who ever worked at Oak Ridge. The work followed the alphabetic order of names of employees. In November, 1966, they had gone through A to H. The processing of Wage Record Cards from A to H added about 15,000 new names to the roster of UCC employees employed at Oak Ridge prior to 1950 who were never employed after 1949. Assuming that the proportion of names in A to H would constitute about one-third of the total, Union Carbide at Oak Ridge employed an estimated total of nearly 75,000 over all years of operation. Of these, about 30,000 represent employees who were employed sometime during 1950 to 1965, and 45,000 represent employees who worked for Union Carbide prior to 1950. For these early cases, the only known information available is on the wage card, which includes:

- a. Name of the employees.
- b. The social security number (as a rule).
- c. Date of birth (as a rule).
- d. Date of hire.
- e. Date of termination.

As of November, 1966, 325 cases did not have a Social Security number listed. About 250 cases occurred with multiple Social Security numbers, and about 30 cases had no date of birth listed.

A.9 A Check on the Integrity of MED Files

A list of staff members of the Manhattan Engineer District which was made available to us by Mrs. O'Leary, ⁽⁴⁾ allows us to check on the relative

integrity of the MED Card File at Oak Ridge. In checking against Mrs. O'Leary's list, the clerical staff did not find about 12% of the names on the list in the MED files. However, we checked the clerical staff's check and found that many of the names believed not to be in the file were actually in the file, but in some of these cases the first and last name had either been transposed or there were some differences in initials, or there were simply oversights. Moreover, it is possible that when all of the names are punched and mechanically alphabetized the difficulty will be overcome.

A.10 Exploration of the possibility of Punching the MED Military Population from the MED Card File and Following it through the Veterans Administration

We wish to obtain a trial run of our study on some sub-population, we explored the possibility of punching the names of military personnel who worked with the Manhattan Engineer District, whose names are contained on a separate MED card file at Oak Ridge. These same military personnel are also included in the more extensive MED card files that are being punched at this time. In December, 1966, we proposed to the Oak Ridge staff that it probably would not take any more work to punch the military from the military MED files separately since then they would not have to be included when punching the more extensive MED card file. We have determined that these personnel could probably be followed through the Veterans Administration, in regard to whether or not they had put in any claims for disability or death. The possibility of carrying out this study during the next project year will be explored more thoroughly. The file of military men has been found grossly incomplete--only about 1,100 names compared to an estimated total of about 5,000.

A.11 Selection of Hanford Data to be Sent to Social Security for Initial Processing by OASDI

As of December 12, 1966, there were approximately 14,325 record forms completed for employees at Hanford. Of this total, about 825 were "non-starts",

i.e., persons medically approved for employment who were never actually employed. It was assumed, therefore, that by mid-January, at least 15,000 cases would be available for processing through OASDI, including the "non-starts". A significant fraction of these 15,000 would be on punched cards ready to be shipped to OASDI. The information available on these punched cards would consist of the following:

- (a) Columns 1-9: Social security number.
- (b) Columns 10-28: Last name, first name, and middle name or initial, when available.
- (c) Columns 39-44: Date of birth in terms of month, day, and year.
- (d) Columns 45-58: Place of birth, with as much information on city, state or country as the abstractors had obtained.

Cards would be serially numbered, and the number would be punched in the card. Then, cards would be gathered in batches of 100 for shipment to OASDI.

A.12 Status of Hanford Sib Data for Shipment to OASDI, December, 1966

As of December, 1966, records for approximately 25,000 sibs of the same sex as the respective employee were abstracted at Hanford. These data were expected to be ready for shipment to the Social Security Administration by January 15, 1967. A method would be found to duplicate the printing so that there would be a record of what was shipped to OASDI. The records shipped would be alphabetized and batched in groups of 100. The information included on the forms would be as follows (sample only):

NAME - JANE S. PERR
BORN 02-07-35 AT VERNAL UTAH

SOC SEC = 943-92-2400

S - NILA SIDDOW
FEMALE WHITE ADDRESS - OREM

BORN ABOUT 1929
UTAH

FATHER - STEPHAN C. PERR
MOTHER - CLARA GLINES

Where step-parent(s) are involved, all available names of all the parents would be recorded. The following tabulations would be prepared at Hanford:

- (a) The frequency distribution of "living" sibs reported by the employee as follows - separately for male and female employees.

Number of sibs per employee	Frequency of employees with indicated number of sibs
0	
1	
3	
.	
.	
.	
20+	

- (b) Age distribution of employees, separately for male and female, as follows:

Under 20
 20-24
 25-29
 30-34
 35-39
 40-44
 45-49
 50-54
 55-59
 60-64
 65+

- (c) For employees in each age-sex group, and with specified number of "living" sibs, tables giving the age distribution of the youngest, next youngest, etc., up to the oldest, would be prepared also in quinquennial age groupings. For sibs the age grouping would start from 0-5 and up.
- (d) There should be shown also an age distribution of employees without a living sib reported - separately for male and for female. The hope is that when OASDI has identified the sibs that they can, sibs would be tabulated and compared with the universe to determine whether there is any evidence of selective bias in identifying the sibs. The age would be the age of the employee at the time when he first came on the job that entered him in our study population. The age of the sibs also would be given as of this date of initial employment of the employee at Hanford.

The first batch of 8,000 sib records processed at the Bureau of OASDI, Social Security Administration in Baltimore gave a ratio of about 1.9 sibs per employee. For these cases, about 63 percent of the sibs had no information on age. Perhaps the recorders looked for age only in the earliest PSQ. The earliest PSQ forms made no provision for the ages of relatives, but the later ones did. Since without an approximate date of birth, it would be almost impossible to trace any of the sibs, we considered in March, 1967, bringing back a few of the boxes of records which show no age for sibs to check whether there is any information with respect to age on at least one of the PSQ's in each respective folder.

As of March, 1967, OASDI was preparing to search Social Security records to identify the data available for sibs having dates of birth recorded.

A.13 Selected Benchmark Data to be Tabulated for AEC Installations Included in the Study

The following tentative type benchmark data were selected in December, 1966, as items that should be tabulated for use in further planning and conducting this study.

1. Employees, including all persons who ever worked at Hanford as "operating" employees.
 - (a) Number of employees as of 1/1/67.
 - (b) Total non-duplicated count of employees who at one time worked at Hanford.
 - (c) Total man-years of employment. Obtained by integrating the number of individuals who ever worked (b) times the respective durations of employment at Hanford, summing all products in terms of man-years.
 - (d) Total man-years from initial exposure until death, up to 1/1/67.
 - (e) The number of employees who were badged and whose radiation exposures were recorded at any time when working at Hanford.

- (f) Number of badged man-years.
 - (g) Number of employees who, while working at Hanford, had received exposure to:
 - (1) Penetrating radiation (exclusive of medical)
 - (2) Skin radiation (exclusive of medical)
 - (3) Internal emitters
 - (h) Man-years of exposure:
 - (1) obtained by summing, over all employees the number of years each employee had a non-zero recorded exposure to penetrating radiation (i.e., one employee having 10 years exposure would contribute 10 man-years, etc.)
 - (2) Obtained by integrating for (g)(2) by the number of years in which the employee had a non-zero recorded exposure to skin radiation.
 - (i) Man-years following earliest exposure to radiation, for penetrating, skin, and internal irradiation.
2. "Non-starts", (i.e., persons who received the pre-employment examination one or more times and were found qualified for employment, but who for one reason or another were never actually employed at Hanford).
- (a) Number of "non-starts".
 - (b) Man-years of non-starts.
3. Sibs of employees.
- (a) The total number of sibs of Hanford employees. Exclude those sibs that were not living at the time when the employee first became an employee at Hanford.
 - (b) Man-years of exposure of sibs. Obtained by summing the sibs in (a) by the lapse of time between the date of first employment at Hanford by the sib and 1/1/67 for all sibs.
4. Sibs of "non-starts"
- (a) The total number of sibs of "non-starts".
 - (b) Man-years of exposure of sibs.
 - (c) Number of "non-starts" without a living sib reported.

A.14 Checks on Consistency of Recording Cases at Hanford

An important source of error, through an over and under-inclusion of pertinent cases, may occur in the selection of cases who were actually employed in the production plant as distinct from applicants who were never examined medically, those who were found medically ineligible, and employees who worked only on construction. We requested that a certain proportion of the boxes completed by each recorder be checked independently, and that the number of workers recorded be counted and compared with the number of records abstracted from the box. A record would be kept of this sort of check indicating the number of cases overlooked, or the number of inappropriate cases included. Since 16 boxes are delivered each time, the check was requested for one box out of 16. In making the consistency check, first the information from the initial recording should be punched and verified. There should be codes identifying the recorder, and the job. Also, there should be a code identifying the first recording from the replicate recording of the same information. The replicate recording should be punched and verified the same way. Then, the two sets should be serialized according to the Social Security Number of the employee, and collated into pairs by the Social Security Number.

If the job were done perfectly, there would be no cards unmatched. The first measure of quality is the numbers that do not match. The next step will be to match with respect to each column to see that the first and the corresponding replicate card have the identical entry in all columns, except the column that gives the recorder number (which must be always different) and the column differentiating the initial recording from the replicate. After the cards with inconsistent entries are identified, tabulations should be prepared showing the frequency of inconsistencies in a double entry table

for each field. In such a table the vertical columns would represent the original recorder, the horizontal lines the replicate recorder, and the cells the frequency of errors in a given field. To illustrate a field for card A the following would be the fields:

- a. Pay number 10-14
- b. Last name 15-27
- c. First name 28-42
- d. Initial 43
- e. Month of birth 44-45
- f. Day of birth 46-47
- g. Year of birth 48-49
- h. City of birth 50-57
- i. State or country of birth 58-63
- j. The branch of military service 64
- k. Year of entry 65-66
- l. Year of discharge 67-68
- m. Sex 69
- n. Race
- o. Number of records 69-70
- p. Source 73
- q. Record month 74-75
- r. Record day 76-77
- s. Recorder's Number 78
- t. Type of card 79

A.15 Plans for Completing Medical X-ray Study at Hanford

In February, 1967, we worked out specific details for completing the current x-ray study. The study encompasses about 3,000 individuals. Persons who died in the interval of 1/1/46 to 12/31/56 had been excluded. We recommended that these be included, and they will be. A record form was designed analogous to the record form for personnel data. The form includes: (1) the Social Security Number, (2) the Payroll Number, (3) the date of Birth, (4) the date of hire (5) the date of separation, and (6) the job identification code. Item (5) would be for the death cases only, since the cases included in the study were persons on the payroll prior to 1/1/46 who remained (unless they died) until 12/31/56.

In the rest of the record, each line will represent one x-ray procedure, giving for each procedure the nature of the examination (i.e., chest, G. I. series, etc.) by numerical code. The numerical code would be the code assigned to the list of x-ray procedures given in the letter of September 22, 1966 from L. A. Braby and W. E. Wilson of Battelle to Dr. W. D. Norwood. This letter presented preliminary data on rads for whole body dose, and also the skin dose associated with each procedure. The estimates were made as follows: exposures at 12 locations in or on a water filled phantom were measured for 27 common diagnostic x-ray procedures. Exposures were made with the old G. E. X-ray unit at Kadlec Methodist Hospital, which had been used for the population under study. The x-ray machine was operated without filtration other than that inherent in the tube, and the old fixed cone collimator was used. The number of exposures, dates of exposure, and types of x-ray procedure will be recorded for each employee for each year over the period 1946-1956. The tabulations that could be derived from the data compiled would include:

- (a) the number of different x-ray examinations; (b) the amount of skin and

whole body radiation from each examination by type of procedure; (c) cumulative radiation dose for type of examination; (d) radiation exposure for each year; (e) average x-ray radiation dosage for each year; and (f) cumulative dosage from all examinations over time. Of course, for our purpose the most important aspect would be to compare the extent of medical x-ray exposure with the occupational exposure received by different Hanford employees.

Phasing of Test Run Over 5-Year Period and Estimated Progress in First Year

Phase I (18 months)

Organizing, arrangements with other agencies, planning, statistical design, data abstracting & conversion

Phase II (18 months)

Data processing, programming, tracing deaths, obtaining death certificates

Phase III (18-24 months)

Coding deaths, data processing, data analysis, presentation of results phasing into further studies

↑ = Progress to Feb 28, 1966 (estimated);

⬆ = " " Mar., 1967

= Progress to May 31, 1966

= " " May 31, 1967

Table 1 (contd.)

Phase I

Phase II

Phase III

↑ = Estimated progress through Feb 28, 1966; = Progress to May 31, 1966

④ = " " " Mar. 31, 1967

= " " May 31, 1967

(57)

ANNUAL EXTERNAL RADIATION EXPOSURE READINGS FREQUENCY DISTRIBUTION.
WHOLE BODY OR PENETRATING DOSE (GAMMA).

READINGS MONITORED FROM ORNL PERSONNEL.

PENETRATING DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL READINGS
0.00- 0.49	412	784	1748	2562	1959	2293	2963	3048	2963	3189	3204	3441	3299	3292	3558	3849	4321	4465	4727	4904	5267	66248
0.50- 0.99	35	35	51	93	87	117	91	138	96	142	152	181	289	509	396	284	261	258	228	241	209	3886
1.00- 1.99	14	23	22	31	41	72	82	106	118	86	139	150	205	249	227	193	141	163	179	150	123	2514
2.00- 2.99	6	6	7	12	30	26	53	49	43	28	80	75	77	74	92	34	20	44	26	38	38	858
3.00- 3.99	2		8	7	17	5	15	24	26	29	38	32	35	21	36	15	9	10	10	9	10	358
4.00- 4.99					5	1	15	27	25	13	22	17	26	12	22	10	2	7	5	1	1	211
5.00- 7.99			3		3	3	3	35	16	27	11	16	31	10	11	5	5		1			180
8.00-11.99								4	2	3	3	1	5	1	1							20
12.00-14.99														1								1
15.00-ABOVE														1								1
*	469	848	1839	2705	2142	2510	3222	3431	3289	3517	3649	3913	3969	4168	4343	4390	4759	4947	5176	5343	5648	74277
**	184	391	1238	1522	1419	1488	2244	1962	1567	1755	1603	1470	500	185	319	1257	973	231	371	479	2726	23884
***	.21	.16	.10	.10	.17	.15	.16	.27	.24	.23	.28	.27	.41	.43	.40	.21	.16	.18	.16	.14	.12	
****	.34	.29	.33	.24	.50	.38	.55	.63	.47	.46	.51	.44	.47	.45	.43	.30	.21	.19	.18	.15	.23	
*****	.34	.29	.33	.24	.50	.38	.55	.63	.47	.46	.51	.44	.45	.45	.43	.30	.21	.19	.18	.15	.23	

TOTAL NUMBER OF PEOPLE MONITORED.

11457

- * NUMBER OF PERSONS MONITORED.
- ** NUMBER OF PERSONS MONITORED HAVING ZERO EXPOSURE READINGS.
- *** AVERAGE ANNUAL EXPOSURE FOR ALL MONITORED PERSONS.
- **** AVERAGE ANNUAL EXPOSURE FOR MONITORED PERSONS EXCLUDING THOSE WITH ZERO READINGS.
- ***** AVERAGE ANNUAL EXPOSURE FOR PERSONS WITH READINGS (GREATER THAN ZERO AND LESS OR EQUAL TO 15 REMS).

DOSES EXCEEDING 14.99 REMS.

000000011378 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 66.6 .0 .0 .0 .0 .0 .0 .0 .0

Table 2 - Frequency Distributions of Annual Whole Body Dose Readings-ORNL

ANNUAL EXTERNAL RADIATION EXPOSURE READINGS FREQUENCY DISTRIBUTION.
SKIN DOSE (BETA + NEUTRON + GAMMA).

READINGS MONITORED FROM ORNL PERSONNEL.

SKIN DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL READINGS
0.00- 0.49	390	701	1586	2324	1735	2050	2773	2802	2747	2906	2826	3252	3075	2926	3213	3734	4156	4247	4550	4723	5062	61778
0.50- 0.99	38	74	104	122	113	122	114	196	178	241	284	232	397	723	627	282	283	305	278	265	268	5246
1.00- 1.99	26	39	74	121	86	146	106	150	156	158	170	185	247	303	244	256	228	244	235	227	190	3591
2.00- 2.99	6	10	29	59	50	43	68	85	56	50	87	79	91	118	122	59	48	77	63	61	70	1331
3.00- 3.99	3	12	11	30	47	48	50	37	26	44	48	45	56	50	62	29	18	35	31	35	30	747
4.00- 4.99	4	6	6	12	18	28	36	38	22	19	52	37	32	19	32	19	8	17	10	18	13	446
5.00- 7.99	2	5	13	15	45	43	54	46	58	37	96	53	42	20	37	10	16	17	8	11	14	642
8.00-11.99			12	13	35	23	17	65	41	33	53	26	26	6	6		1	5	1	2	1	366
12.00-14.99			3	7	5	5	4	11	5	16	23	4	2	2			1					88
15.00-ABOVE		1	1	2	8	2		1		13	10		1	1		1				1		42
*	469	848	1839	2705	2142	2510	3222	3431	3289	3517	3649	3913	3969	4168	4343	4390	4759	4947	5176	5343	5648	74277
**	183	388	1138	1271	1090	1261	1919	1572	1336	1639	1436	1304	367	159	276	980	199	177	345	477	2718	20235
***	.31	.35	.35	.38	.70	.56	.44	.62	.52	.56	.81	.48	.58	.57	.53	.29	.25	.31	.26	.25	.21	
****	.51	.65	.91	.73	1.43	1.13	1.09	1.14	.88	1.06	1.34	.73	.64	.59	.56	.38	.27	.32	.27	.27	.41	
*****	.51	.61	.91	.73	1.29	1.11	1.09	1.13	.88	.98	1.26	.73	.62	.59	.56	.37	.27	.32	.27	.27	.41	

TOTAL NUMBER OF PEOPLE MONITORED. 11457

- * NUMBER OF PERSONS MONITORED.
- ** NUMBER OF PERSONS MONITORED HAVING ZERO EXPOSURE READINGS.
- *** AVERAGE ANNUAL EXPOSURE FOR ALL MONITORED PERSONS.
- **** AVERAGE ANNUAL EXPOSURE FOR MONITORED PERSONS EXCLUDING THOSE WITH ZERO READINGS.
- ***** AVERAGE ANNUAL EXPOSURE FOR PERSONS WITH READINGS (GREATER THAN ZERO AND LESS OR EQUAL TO 15 REMS).

DOSES EXCEEDING 14.99 REMS.

000000012432	.0	16.7	15.3	17.5	17.2	17.8	.0	21.9	.0	15.0	19.5	.0	72.3	15.0	.0	40.5	.0	.0	.0	20.7	.0	
000000006754	.0	.0	.0	17.3	16.8	17.7	.0	.0	.0	20.4	18.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
000000006748	.0	.0	.0	.0	21.1	.0	.0	.0	.0	15.3	20.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
000000006863	.0	.0	.0	.0	18.5	.0	.0	.0	.0	19.1	15.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
000000007247	.0	.0	.0	.0	27.1	.0	.0	.0	.0	24.1	19.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	
000000007566	.0	.0	.0	.0	26.7	.0	.0	.0	.0	15.0	19.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	

Table 3 - Frequency Distributions of Annual Skin Dose Readings-ORNL

52

000000008350	.0	.0	.0	.0	26.2	.0	.0	.0	.0	15.8	18.2	.0	.0	.0	.0	.0	.0	.0	.0
000000008699	.0	.0	.0	.0	15.5	.0	.0	.0	.0	15.6	21.5	.0	.0	.0	.0	.0	.0	.0	.0
000000009078	.0	.0	.0	.0	.0	.0	.0	.0	.0	16.1	20.7	.0	.0	.0	.0	.0	.0	.0	.0
000000009485	.0	.0	.0	.0	.0	.0	.0	.0	.0	17.6	19.4	.0	.0	.0	.0	.0	.0	.0	.0
000000009078	.0	.0	.0	.0	.0	.0	.0	.0	.0	20.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
000000009485	.0	.0	.0	.0	.0	.0	.0	.0	.0	22.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
000000009594	.0	.0	.0	.0	.0	.0	.0	.0	.0	17.4	.0	.0	.0	.0	.0	.0	.0	.0	.0

Table 3 (continued)

ANNUAL EXTERNAL RADIATION EXPOSURE FREQUENCY DISTRIBUTION.
WHOLE BODY OR PENETRATING DOSE (GAMMA).

NUMBER OF PEOPLE RECEIVING DOSES AT ORNL

PENETRATING DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	ACCUM PLANT TOTAL
0.00- 0.99	447	819	1799	2655	2046	2403	3054	3186	3059	3331	3356	3622	3588	3801	3954	4133	4582	4723	4955	5145	5476	8575
1.00- 1.99	14	23	22	31	41	72	82	106	113	86	139	150	205	249	227	193	141	163	179	150	123	1195
2.00- 3.99	8	6	15	19	47	31	68	73	69	57	118	107	112	95	128	49	29	54	36	47	48	738
4.00- 7.99			3		8	4	18	62	41	40	33	33	57	22	33	15	7	7	6	1	1	499
8.00-15.99								4	2	3	3	1	6	1	1							333
16.00-31.99																						135
32.00-ABOVE														1								51
TOTAL PEOPLE	469	848	1839	2705	2142	2510	3222	3431	3289	3517	3649	3913	3969	4168	4343	4390	4759	4947	5176	5343	5648	11457
NUMBER PEOPLE WITH ZERO PLANT TOTAL																						2675

SEE NEXT PAGE

Table 4 - Frequency Distributions of Annual Whole Body Doses and Cumulative Plant Totals for all Employees in Carbide Monitoring Records at ORNL

DOSES EXCEEDING 24.99 REMS.

D	SE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOT
000000000541		.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	37.5 ✓
000000001386		.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	53.5 ✓
000000001646		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.9 ✓
000000001780		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	34.4 ✓
000000001858		.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.3 ✓
000000001877		.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	38.8 ✓
000000002286		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.9 ✓
000000002357		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	75.8 ✓
000000002387		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	42.2 ✓
000000002420		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.5 ✓
000000002436		.C	.0	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	46.3 ✓
000000002552		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	38.2 ✓
000000002758		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	85.3 ✓
000000003321		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.2 ✓
000000003621		.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.9 ✓
000000003699		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	76.3 ✓
000000003750		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.2 ✓
000000003783		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.0 ✓
000000003941		.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.2
000000003943		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.9
000000004110		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.8
000000004188		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.7 ✓
000000004317		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.4
000000005048		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.5
000000005301		.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.1 ✓
000000006005		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.3
000000006016		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.1
000000006095		.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.8
000000006199		.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.8

Table 4 (continued)

26 121.6

000000006204	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32.4
00000000659C	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	29.4
000000006712	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	42.9✓
000000006748	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	81.9✓
000000006846	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	42.5✓
000000006894	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31.4
000000006965	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	39.3✓
000000007021	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31.7
000000007037	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	37.1✓
000000007118	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	28.2
000000007193	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32.8✓
000000007204	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	25.5
000000007247	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	51.3✓
000000007337	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	27.8
000000007394	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	25.6
000000007421	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	34.3
000000007521	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	35.4✓
000000007566	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	59.5✓
000000007581	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32.6
000000007652	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	25.6
000000007689	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	30.3
000000007768	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	57.4✓
000000007804	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	47.5✓
000000007831	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	39.2
000000007861	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	55.3✓
000000007888	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	36.8✓
000000008101	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	26.4
000000008132	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31.9
000000008135	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	25.3

Table 4 (continued)

17 777.0

DOSAGE REMS. EXCEEDING 24.99 REMS.

DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000008237	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	52.3 /
000000008423	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	35.1 /
000000008435	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	27.1
000000008475	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.1
000000008487	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.0
000000008549	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.0
000000008767	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	27.5
000000008771	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.C	.0	.C	.0	.0	36.1 /
000000008783	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	59.2 ✓
000000008843	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	28.0
000000008911	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.5
000000009019	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	51.5 /
000000009078	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	56.8 /
000000009114	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	35.2
000000009451	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.7
000000009485	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.8 ✓
000000009594	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.5 /
000000009613	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.8
00000000980C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	42.9 /
000000009961	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	28.9
000000009970	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.1 /
000000009988	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	27.7
000000009989	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	29.3
000000009997	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	26.8
000000010077	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	28.3
000000010721	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	27.8
000000011378	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	57.6 ✓
000000011935	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.9
000000012032	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	35.5 /

Table 4 (continued)

1-1 /

51.2 /

ANNUAL EXTERNAL RADIATION EXPOSURE FREQUENCY DISTRIBUTION.
SKIN DOSE (BETA + NEUTRON + GAMMA).

NUMBER OF PEOPLE RECEIVING DOSES AT ORNL

SKIN DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	ACCUM PLANT TOTAL
0.00- 0.99	428	775	1690	2446	1848	2172	2887	2998	2925	3147	3110	3484	3472	3649	3840	4016	4439	4552	4828	4988	5330	7493
1.00- 1.99	26	39	74	121	86	146	105	150	156	158	170	185	247	303	244	256	228	244	235	227	190	1353
2.00- 3.99	9	22	40	89	97	91	118	122	82	94	135	124	147	168	184	89	66	112	94	96	100	1052
4.00- 7.99	6	11	19	27	63	71	90	84	90	56	148	90	74	39	69	29	24	34	18	29	27	614
8.00-15.99			16	20	41	28	21	76	46	54	77	30	28	9	6		2	5	1	2	1	486
16.00-31.99		1		2	7	2		1		8	9									1		258
32.00-ABOVE													1									191
TOTAL PEOPLE	469	848	1839	2705	2142	2510	3222	3431	3289	3517	3649	3913	3969	4168	4343	4390	4759	4947	5176	5343	5548	11457
NUMBER PEOPLE WITH ZERO PLANT TOTAL																						2393

DOSES EXCEEDING 24.99 REMS.

SEE NEXT PAGE

Table 5 - Frequency Distributions of Annual Skin Doses and Cumulative Totals for all Employees in Carbide Monitoring Records for ORNL

DOSES EXCEEDING 24.99 REMS.

DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000000517	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	58.7
000000000541	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	117.3
000000001072	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.7
000000001383	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	34.2
000000001385	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.3
000000001386	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	139.3
000000001543	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	27.8
000000001646	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	73.3
000000001780	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	86.2
000000001858	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	52.1
000000001877	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	72.1
000000001932	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	34.5
000000001986	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	50.9
000000002088	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.6
000000002286	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.4
000000002294	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.1
000000002357	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	193.0
000000002387	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	94.0
000000002420	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.1
000000002436	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	91.5
000000002500	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	41.4
000000002520	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	44.4
000000002538	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.0
000000002552	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	55.6
000000002647	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.0
000000002668	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.1
000000002688	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	27.8
000000002758	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	178.5
000000002799	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	39.5

Table 5 (continued)

000000003047	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	45.7
000000003186	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.0
000000003283	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.2
000000003321	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	133.8
000000003350	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.5
000000003520	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	38.4
000000003621	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	91.9
000000003688	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.4
000000003693	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.0
000000003699	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	151.5
000000003750	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	121.2
000000003783	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	64.2
000000003894	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.0
000000003941	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	59.1
000000003943	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	46.9
000000003977	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.6
000000004003	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	54.9
000000004070	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.0
000000004094	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	54.2
000000004110	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	57.3
000000004136	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.3
000000004159	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.C	.0	.0	66.9
000000004162	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.9
000000004165	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.7
000000004188	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	76.9
000000004234	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.1
000000004278	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	40.2
000000004296	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.9
000000004317	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.C	.0	.0	51.0

Table 5 (continued)

DOSES EXCEEDING 24.99 REMS.

DOSAGE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000004325	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	30.1
000000004335	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.0
000000004439	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	58.5
000000004448	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	44.4
000000004500	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	40.7
000000004501	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.4
000000004530	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.1
000000004550	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	40.6
000000004593	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	43.3
000000004628	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.8
000000004744	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	51.0
000000004777	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.9
000000004901	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.3
000000004960	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	35.2
000000004994	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	27.4
000000005031	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.3
000000005048	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.0
000000005088	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	45.1
000000005116	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.3
000000005141	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.4
000000005277	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.5
000000005301	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	94.1
000000005399	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.1
000000005416	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.0
000000005428	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.C	.0	.0	.0	29.6
000000005434	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.9
000000005513	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.7
000000005709	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.6
000000005753	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.9

Table 5 (continued)

65

000000005788	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	28.0
000000005795	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.8
000000005893	.C	.0	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	35.2
000000005998	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.5
000000006005	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	77.0
000000006016	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	77.1
000000006020	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.2
000000006095	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	46.5
000000006199	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	75.1
000000006204	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	77.4
000000006206	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.2
000000006207	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.4
000000006218	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.5
000000006270	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.0
000000006383	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.3
000000006553	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.4
000000006590	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.8
000000006610	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	70.4
000000006620	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	44.5
000000006648	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.8
000000006655	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.2
000000006660	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.1
000000006707	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.8
000000006712	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	118.0
000000006728	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.7
000000006732	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	41.4
000000006748	.C	.C	.0	.0	27.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	187.1
000000006754	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	73.7
000000006798	.C	.C	.C	.0	26.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.0

Table 5 (continued)

DOSES EXCEEDING 24.99 REMS.

DOSE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000006841	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	48.7
000000006846	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	.C	.0	.0	.0	70.2
000000006863	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	43.9
000000006878	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	40.1
000000006894	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	43.0
000000006904	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.7
000000006965	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	75.0
000000006972	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.8
000000006981	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	66.2
000000007021	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	61.2
000000007024	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.4
000000007037	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	61.6
000000007039	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	45.0
000000007056	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.0
000000007062	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.6
000000007099	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.9
000000007118	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.2
000000007145	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.9
000000007193	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	70.0
000000007204	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	60.6
000000007247	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	109.0
000000007311	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.6
000000007337	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	.C	.0	.0	.0	43.3
000000007394	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	60.0
000000007421	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	66.4
000000007521	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	72.2
000000007566	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	110.9
000000007578	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.2
000000007581	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	77.1

Table 5 (continued)

000000007652	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.1
000000007685	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	29.3
000000007689	.0	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	48.5
000000007713	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.1
000000007720	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.3
000000007724	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.9
000000007734	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.C	.0	.0	.0	36.4
000000007738	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	40.3
000000007768	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	134.7
000000007776	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.6
000000007789	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	39.5
000000007794	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	34.4
000000007804	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	91.2
000000007831	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	87.5
000000007861	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	76.5
000000007887	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	47.5
000000007888	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	57.1
000000007893	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	29.2
000000007920	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.1
000000007948	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.3
000000008077	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	33.3
000000008094	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.2
000000008101	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	70.5
000000008104	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	51.6
000000008105	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	48.8
000000008111	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	30.1
000000008132	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	71.5
000000008135	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	65.9
000000008137	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.4

Table 5 (continued)

DOSES EXCEEDING 24.99 REMS.

DOSE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000008215	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.0
000000008237	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	72.5
000000008291	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.7
000000008318	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	51.8
000000008319	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.1
000000008342	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.7
000000008350	.C	.0	.0	.0	26.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	49.9
000000008423	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	77.4
000000008435	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	56.0
000000008442	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	37.2
000000008473	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	48.2
000000008475	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	51.2
000000008487	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	52.0
000000008489	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.7
000000008491	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	57.8
000000008527	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	50.3
000000008549	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	35.8
000000008565	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.5
000000008652	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.6
000000008686	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	31.2
000000008687	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	36.6
000000008699	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	50.3
000000008702	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	25.9
000000008762	.C	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	26.5
000000008767	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	53.4
000000008771	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	70.2
000000008783	.C	.C	.0	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	119.5
000000008786	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	32.1
000000008826	.C	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	27.5

Table 5 (continued)

000000008841	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	29.1
000000008843	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	51.8
000000008875	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	27.9
000000008889	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	79.2
000000008911	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	44.5
000000008917	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	26.6
000000008934	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	36.7
000000008993	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	25.0
000000009019	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	131.2
000000009072	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	28.1
000000009078	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	115.4
000000009079	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	25.1
000000009114	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	91.8
000000009121	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	27.4
000000009204	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	38.7
000000009210	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	29.2
000000009250	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	40.5
000000009260	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	28.0
000000009287	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	27.9
000000009398	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	39.7
000000009414	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	26.3
000000009451	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	53.7
000000009485	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	97.9
000000009535	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	26.3
000000009541	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	34.7
000000009548	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	30.2
000000009557	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	42.5
000000009583	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	34.4
000000009594	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	.C	100.9

Table 5 (continued)

DOSES EXCEEDING 24.99 REMS.

DOSE REM	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	TOTAL
000000009611	.C	.C	.C	.C	.0	.0	.3	.3	.3	.3	.0	.7	.0	.0	.0	.0	.0	.0	.0	.3	.3	32.8
000000009613	.C	.C	.0	.C	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	44.2
000000009800	.C	.C	.C	.C	.0	.0	.3	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	51.7
000000009806	.C	.C	.0	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.3	.0	32.5
000000009886	.C	.C	.C	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	28.7
000000009887	.0	.C	.C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.C	.0	.0	.0	26.6
000000009961	.C	.C	.C	.0	.0	.0	.3	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	59.2
000000009970	.C	.C	.0	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	53.6
000000009988	.C	.C	.C	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	61.0
000000009989	.C	.C	.C	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	46.9
000000009997	.C	.C	.C	.C	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	47.6
000000010047	.C	.C	.0	.C	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	34.6
000000010077	.C	.C	.C	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.0	43.9
000000010137	.C	.C	.0	.0	.0	.0	.3	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	29.5
000000010521	.C	.C	.C	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	29.5
000000010682	.C	.C	.0	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	28.7
000000010721	.C	.C	.C	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	40.6
000000010726	.C	.C	.0	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	32.3
000000010883	.C	.C	.0	.C	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	25.7
000000011154	.C	.C	.C	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	31.3
000000011309	.C	.C	.0	.0	.0	.0	.3	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	28.1
000000011341	.C	.C	.0	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	29.6
000000011378	.C	.C	.C	.C	.0	.0	.0	.3	.3	.0	.0	.0	72.3	.0	.C	.0	.0	.C	.0	.0	.3	73.6
000000011912	.C	.C	.0	.0	.0	.0	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	26.6
000000011935	.C	.C	.0	.C	.0	.0	.0	.3	.3	.7	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.7	49.4
000000012032	.C	.C	.0	.0	.0	.0	.0	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	43.6
000000012202	.C	.C	.C	.C	.0	.0	.3	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	26.1
000000012282	.C	.C	.C	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	25.5
000000012288	.C	.C	.C	.C	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.C	.0	.0	.3	35.2

Table 5 (continued)

(17)

0000000012370	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	28.2
0000000012432	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	40.5	.0	.0	.0	.0	.0	41.7
0000000013174	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	35.6

(72)

Table 5 (continued)

Table 6

Population Exposure Parameters Estimated from
ORNL Printouts

(a) Total number of people monitored for whole body radiation for years 1945-1965 (from Tables 2 and 4) (not including 1943-1944, as discussed in Section III.)	<u>11,457</u>
(b) Total number of people monitored for whole body radiation who had only zeros listed in their records (Table 4)	<u>2,675</u>
(c) Total number of people with non-zero plant total in records, $11,457 - 2,675 =$	<u>8,782</u>
(d) Total man-rem whole body radiation exposure for years 1945-1965, estimated as follows:	
(1) Under the assumption that monitored persons including those with recorded zeros in the lowest-dose groups of Table 2 received exposure near zero dose. $66,248(0.10)* + 3,886(0.75) + 2,514(1.5)$ $+858(2.5) + 358(3.5) + 211(4.5) + 180(6.5)$ $+20(10.0) + 1(13.5) + 1(66.6) =$	<u>19,109 man-rem</u>
(2) Under the assumption that all recorded zeros are truly zero (23,884 readings in Table 2), and the rest of the population has the same frequency distribution as in (1) above	
$19,109 - 23,884(0.1) =$	<u>16,721 man-rem</u>

* Answers obtained are obviously very sensitive to the average dose assumed for this lowest-dose groups. This value of 0.10 rem was taken as a more reasonable estimate (than 0.25) of the average exposure received by those persons in the 0-0.49 rem range, for reasons given in our previous report. (4)

Table 6 (continued)

- (3) Under the assumption that the average cumulative plant total dose of all employees in the 0.00-0.99 group of Table 4 is about 0.34 Rem:

$$\begin{aligned}
 & 8575(0.34) + 1186(1.5) + 708(3.0) \\
 & + 499(6) + 303(12) + 135(24) \\
 & + 37.5 + 63.6 + 36.9 + 34.4 \\
 & + 37.0 + 38.8 + 33.9 + 76.8 + 42.2 + 33.6 \\
 & + 46.3 + 38.2 + 85.0 + 47.2 + 36.9 + 76.3 \\
 & + 49.2 + 36.0 + 37.7 + 47.1 + 32.3 + 42.9 \\
 & + 81.9 + 42.6 + 39.0 + 37.1 + 32.8 + 61.0 \\
 & + 34.0 + 35.4 + 59.5 + 32.6 + 67.4 + 47.5 \\
 & + 39.2 + 55.0 + 36.8 + 52.3 + 36.1 + 39.1 \\
 & + 36.1 + 59.2 + 61.5 + 56.8 + 35.2 + 53.8 \\
 & + 53.5 + 42.9 + 33.1 + 67.6 + 35.5 = \underline{19,056 \text{ man-rem}}
 \end{aligned}$$

- (4) Under the assumption that the average cumulative plant total dose for employees in the 0.00-0.99 group of Table 4 with non-zero plant totals is about 0.34 Rem:

$$19,056 - 0.34(2675) = \underline{18,146 \text{ man-rem}}$$

- (e) Average recorded cumulative plant total dose per person monitored, for 1945 through 1965, (from (a), (d1), and (d3) above) about

$$\frac{19,056}{11,457} \text{ to } \frac{19,109}{11,457} = \underline{1.66 \text{ to } 1.67 \text{ Rem}}$$

- (f) Average recorded cumulative plant total dose for persons having non-zero plant totals (from (c), (d2), and (d4) above), (two methods)

$$\frac{16,721}{8,782} \text{ to } \frac{18,146}{8,782} = \underline{1.90 \text{ to } 2.07 \text{ Rem}}$$

Table 6 (continued)

Average annual dose reading per monitored individual (from Table 2 and (d1) above)

$$\frac{19,109 \text{ man-rem}}{74,277 \text{ total readings (man-years, approx.)}} = \underline{0.26 \text{ Rem/year}}$$

(h) Average non-zero annual dose reading, 1945-1965 (from Table 2 and (d2) above)

$$= \frac{16,721 \text{ man-rem}}{74,277 - 23,884} = \underline{0.33 \text{ Rem/year}}$$

(i) Average number of years of monitoring (since 1945) per monitored employee (from (e) and (g)) = $\frac{1.67 \text{ Rem}}{0.26 \text{ Rem/year}} =$
or (from Table 2) = 74,277 man-years (approx)/11,457 men monitored =

$$\underline{6.4 \text{ years}}$$

$$\underline{6.5 \text{ years}}$$

(j) Average number of years in which persons (employed since 1945) with non-zero plant totals received non-zero annual readings (from Table 2 and (c) above)

$$\frac{(74,277 - 23,884) \text{ non-zero annual totals (man-years)}}{8,782 \text{ persons with non-zero cumulative totals}} = \underline{5.7 \text{ years}}$$

Table 7

Comparison of Population Exposure Parameters
for the Three Plants at Oak Ridge

Parameter	ORNL	Y-12	ORGP
Total number of people monitored for whole body radiation for all years of operation in Carbide records	11,457	6,930	3,448
Total number of people monitored who had only zeros	2,675	284	1,582
Total number of people, non-zero plant total in records	8,782	6,646	1,866
Total man-rem whole body radiation exposure for all years:			
Range of estimates	16,721 to 19,109	4,841 to 5,692	724 to 1,623
Most Probable Value (from Table 6, (d3))	19,056	5,692	1,549
Average recorded cumulative plant total dose per person monitored, Rem	1.66 to 1.67	0.79 to 0.82	0.45 to 0.47
Average recorded cumulative plant total dose for persons having non-zero plant totals, Rem	1.90 to 2.07	0.73 to 0.85	0.39 to 0.54
Average annual dose reading per monitored individual, Rem/year	0.26	0.15	0.12
Average non-zero annual dose reading 1945-1965 Rem/year	0.33	0.165	0.159

Parameter	ORNL	Y-12	ORGP
Average number of years of monitoring per monitored employee	6.4 to 6.5	5.1 to 5.4	3.8 to 3.9
Average number of years in which persons with non-zero plant totals received non-zero annual readings	5.7	4.4	2.4

Sample IBM Cards Containing Annual Radiation Exposure Data for Hanford Employees

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