LA-13219

Radiation Exposure Estimations for the Los Alamos Plutonium Stabilization and Packaging Projects

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Edited by Ann Mauzy, Group CIC-1

LA-13219

UC-721 and UC-722
Issued: November 1996

Radiation Exposure Estimations for the Los Alamos Plutonium Stabilization and Packaging Projects

*Andrew D. McLain**

**Advanced Sciences, Inc.*

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

RADIATION EXPOSURE ESTIMATIONS FOR THE LOS ALAMOS PLUTONIUM STABILIZATION AND PACKAGING PROJECTS

Table of Contents

List of Tables

List of Appendices

Radiation Exposure Estimations for the Los Alamos Plutonium Stabilization and Packaging Projects

by

Andrew D. McLain

Abstract

This report details the methods used for calculating the radiation exposure estimations for the Los Alamos National Laboratory plutonium stabilization and packaging projects, which are underway to meet the requirements of the Defense Nuclear Facilities Safety Board's Recommendation 94-1. The results, which are also contained in this report, are based on the analysis of workers' levels of effort, dosimetry data, and the types of items processed during the period of January 1966 through May 1966. These estimations will allow project managers to consider the impacts of radiation exposures in the assignment and scheduling of tasks as well as provide a basis for determining if dose-reduction measures are justified for specific operations.

1.0 Introduction

To meet the requirements of the Defense Nuclear Facilities Safety Board's Recommendation 94-1, Los Alamos National Laboratory initiated rigorous stabilization and packaging projects to process, stabilize, consolidate, and package special nuclear material (SNM). Through these projects the reprocessed material will meet the Department of Energy (DOE) Plutonium metal and oxide criteria for long-term storage as stated in DOE-STD-3013-94 or meet the current requirements for transfer to the Waste Isolation Pilot Plant (WIPP) as transuranic waste. These projects were started in 1994 and are scheduled for completion in the year 2002.

Throughout the lifetime of this project 8670 items containing plutonium in a variety of matrices will be reprocessed into more stable forms and consolidated to meet the requirements for long-term storage or for transfer to WIPP. Of these items, the majority are plutonium process residues (85.2%) that are in a wide variety of forms and consist of a variety of materials. The balance of material consists of plutonium metals (7.1%) and plutonium oxides (7.7%). In addition to the plutonium items, a number of items containing transuranic elements are also scheduled to be processed and stabilized.

As these projects got underway, questions arose about the potential radiation exposures to Laboratory workers from performing the operations necessary in the completion of the stabilization and packaging projects. At the projects' inception, no data existed that would allow for an adequate approximation of the workers' radiation exposures. However, from the start of the projects, records were kept on the levels of effort by individual workers and the items that were processed. (Levels of effort are calculated based on the number of hours billed to the projects, divided by the number of work hours in that month for TA-55—the Plutonium Facility) These records made it possible to correlate these data back to dosimetry records for the period and develop an approximation of the amount of the radiation exposures that are attributable to these projects.

The next several pages of this report will investigate the levels of the exposures to workers from these projects and break down the exposure data to give an idea as to which areas will contribute the majority of the exposures to the workers. The results presented here will provide project leaders with a tool to compare actual exposures and make decisions based on expected exposure levels. These exposure estimations also provide a basis for determining whether dose-reduction measures are justified for specific operations. The results are estimations based on current data and trends. These values will likely change as more data become available or other factors are introduced into the project.

2.0 Assumptions, Constraints, and Other Factors Influencing the Data

The results determined from this study are heavily impacted by the many assumptions that were made. The results are also limited by constraints that were placed upon the data and other factors that influence the raw data. Without these assumptions, it would be impossible to develop adequate approximations based on the current data. The major assumptions, constraints, and other factors influencing the data are discussed below. The minor assumptions made throughout this project are presented in the methodology and the calculations sections of this document.

The most important constraint on these dose approximations is the limited amount of data. The only months in which a complete set of data could be easily obtained were January through May of 1996. Previous months had many gaps, and necessary dosimetry information was much more difficult to obtain. The data for later months were also not used since at the time that this project started they were not available. For the most part of this project, the limited data did not cause any problems, and estimations were obtained; however, in the case of the aqueous chloride workers, more data are needed to break down the radiation exposures for the specific types of items processed.

The results of this analysis are also constrained because the estimates are based solely on Material Type 52, or weapons grade plutonium, which was the only material being processed and packaged at this time. Once all of the weapons grade plutonium has been processed, other grades of plutonium will be processed. Since these grades vary in the enrichment of specific isotopes, each material will have a different dose profile. Thus, the actual exposures will change as the materials being stabilized and packaged change. However, for this analysis they are assumed to remain the same. It may be possible to scale the dose rates based on the difference in the flux profile of each material, but at this time it is beyond the scope of this study.

Another factor that will greatly impact the analysis is the size of the item and the amount of material it contains. The items that are to be processed vary in size and in the amount of plutonium they contain. These variations will influence the radiation exposures to the workers performing the stabilization and packaging activities. This factor will also impact the number of items able to be packaged in each long-term storage container.

The final major factor influencing the outcome of this analysis is that the workers performed many other tasks, which were not quantified, aside from the processing of these materials. This is especially true in the case of the aqueous chloride workers. Many of the aqueous chloride workers performed work on the neutron source recovery project, which is a high-dose operation. The work on this project has increased monthly exposures for workers also involved with the stabilization project. Thus, the estimates will come out somewhat higher. However, for cases where the impact of other operations appeared to be very large, the data were neglected for that month. Another assumption that was made to help mitigate the impact of doses resulting from other operations was to neglect the doses for individuals with less than a 50% level of effort on the packaging and stabilization projects for the month in question.

3.0 Methodology

The methodology to determine the radiation exposures within this study differs for each of the four categories considered: packaging of plutonium metals, packaging of plutonium oxides, stabilization of plutonium residues, and project support. The available data for these categories were slightly different, and the complexities of the determination of the doses also varied dramatically. Thus, each category was evaluated separately to determine a dose attributable to that category. The resulting dose of each category was then summed over all categories to determine the total exposure resulting from the packaging and stabilization projects.

3.1 Packaging: Plutonium Metals

The first category that was evaluated was that of plutonium metals. There are currently 613 metal items being processed for long-term storage. The exposure attributed to the processing of metal items was determined based on the dosimetry data of the people performing the operations, the individual’s level of effort on the project, and the number of items that were completed. These data were also further broken down as a function of the seven steps involved in the processing based on the estimated time to complete each step and the approximate dose involved with each step. The estimate for each step was normalized over the entire process and scaled to agree with the estimate based on actual dosimetry data.

Once the metal is processed, it is welded into a long-term storage container and returned to the vault for long-term storage. Because this process is performed by another group, combining the data was difficult. The estimated exposure for this process was based on the number of items processed over several months, the dosimetry data for those months, and a rough approximation of the level of effort expended toward the project for that month.

3.2 Packaging: Plutonium Oxides

At this stage in the project, no data exist on the packaging of plutonium oxides. The oxides are not scheduled to be reprocessed until FY98. However, a dose estimation was determined based on historical data from previous oxide roasting and blending operations. The dose estimate for an oxide item is estimated as 1.5 times the dose estimate for a metal item. A breakdown similar to that for the processing of plutonium metals was not performed since the process is different and there are no current data on which to base an approximation. The dose for the welding operation is also estimated to increase by 1.5.

3.3 Stabilization: Plutonium Residues

The stabilization of plutonium residues was by far the most complicated category for which an approximation was made. This category contains 7385 items divided, by material, into 10 subcategories that are being processed at their own work-off rate. These items are also being processed by three different categories of workers, which are designated by the type of work they do and the materials they work with. The worker categories are the nitrate workers, aqueous chloride workers, and pyrochemical workers. The 10 subcategories of residue materials that are being reprocessed are as follows:

- Impure Metals
- High-Priority Residues
- Solutions
- High-Priority Compounds
- Combustibles
- Other Compounds
- Noncombustibles
- Miscellaneous Process Residues
- Containers
- Gases

To develop the estimation for the plutonium residues, we separated the number of items completed each month into the categories of workers processing those items. We then compared these numbers to the monthly dosimetry records of the workers. From these data an approximation was made for the average exposure of all items. This approximation was further divided into the dose per item subcategory, or subcategories, in cases where the results could not be broken down further because of insufficient data.

Once the doses for each subcategory were determined, they were used to determine the dose from all items within that subcategory and used to evaluate the total dose for the entire residue category. To provide an idea of how the exposures are expected to trend compared to the projected schedule, these data were also broken down to determine approximations for yearly exposures based on the projected work-off schedule

Since this material is being reprocessed and returned to the SNM storage vault without being welded into special containers, no dose was calculated for the welding operation. However, eventually this material will be repackaged in DOE-approved containers. Repackaging and welding operations will result in a dose to the individuals who perform these operations. Once data are available for these operations or at least good approximations can be made, further estimates can be calculated and included in the final estimate.

3.4 Project Support Operations

Several other operations supporting the packaging and stabilization projects do receive radiation exposures as a direct result from supporting these projects. These other operations include administrative support, instrumentation support, waste support, Radiological Control Technician (RCT) support, and other support. The data for these support efforts are based on the individuals' levels of effort and the radiation doses they received. Other support efforts that may have been provided but not charged to the project were not considered since there are no data on the levels of support effort put towards the stabilization and packaging projects.

4.0 Radiation Exposure Calculations

4.1 Radiation Dose Estimations for Plutonium Metal Packaging

The radiation dose estimation for plutonium metals was based on the doses of four workers who spent about 90% of their time processing metal items. A fifth worker was also involved in this project, but this person only spent a minimal amount of time on the project in an administrative function and likely received his dose from other sources. These four workers received a total dose of about 160 person-mrem during the month in question and processed 10 items. The resulting dose per item was estimated to be 16.0 person-mrem/item. Since the four workers spent the majority of their time on this project, the estimated monthly dose was assumed to come entirely from the processing of plutonium metals.

The calculated value was used to develop an estimation for the dose per item for various stages involved with the processing and repackaging of plutonium metals. The data used in this approximation are provided in Table I. The estimated dose from the item at the various stages was considered to be a conservative estimate, and its purpose is only to provide an idea of the relative dose attributable to each stage. Finally, the data were normalized to the total dose from all stages and corrected to agree with the overall dose estimate based on the dosimetry data. The result is also summarized within Table I.

The dose to the welders from welding operations was determined based on the number of long-term storage containers, more commonly referred to as "cans," that were processed and the dosimetry data of those performing the welding operations. The data used in this approximation were taken from the months of January, February, April, and May, 1996. Because the welders spent the majority of their time performing maintenance operations on a leaking glove box, the data from March were neglected. The data used in this determination are given in Table II.

Based on the data presented in Table II, the dose per can in the welding operations was determined to be 3.2 person-mrem/can. Each can is estimated to contain two items based on current packaging trends. (This number will likely change as the amount of material in each item is expected to decrease.) Since each can contains about 2 items, the dose was estimated at 1.6 person-mrem/item, which can be related back to the plutonium metal packaging analysis. Thus, the total exposure from processing plutonium metals is estimated at 17.6 person-mrem/item (i.e. 16.0 person-mrem/item from processing and 1.6 person-mrem/item from welding).

Table I
Dose Estimate Breakdown for the Various Stages in the Processing of Plutonium Metals

Stage in Processing of Plutonium Metal	Estimated Time to Perform Work in Stage (min)	Estimated Dose of a Typical Item (Person-mrem/item)	Dose Normalized over All Stages	Corrected Dose Based on Dosimetry Data (Person-mrem/item)
1. Remove Items from Vault and Transport to Room	15	0.5	0.0189	0.3
2. Introduce Item into Glove box	5	1.3	0.0491	0.8
3. Transport Item to Processing Glove box	10	1.7	0.0642	1.0
4. Segregate Material	30	15	0.5660	9.0
5. Weigh Material	30	5	0.1886	3.0
6. Place in Long-term Storage Container	5	2.5	0.0943	1.5
7. Transport to Welders	5	0.5	0.0189	0.3

Table II
Radiation Exposure Data for the Welding Operations of Plutonium Metals

Month	Dose Received by Workers (Person-mrem)	Cans Processed	Dose per Can (Person-mrem/can)
January	21	7	3.0
February	31	8	3.9
March	30	1	30.0
April	36	12	3.0
May	14	5	2.8
Total (excluding March)	102	32	3.2

4.2 Radiation Dose Estimations for Plutonium Oxides Packaging

When the data from the plutonium metals and the estimated scaling factor of 1.5 are used, the dose per item for workers performing the packaging operation for plutonium oxides becomes 24.0 person-mrem/item, and the dose per item for welding operations becomes 2.4 person-mrem/item. The combined total of the two operations yields 26.4 person-mrem/item.

4.3 Radiation Dose Estimations for Plutonium Residues Stabilization

Before the dose approximations were calculated, the process residues were divided among the three nonsupport-worker categories based on which group was working with what material. Table III summarizes the breakdown of which group of workers processed what residues.

Table III
Percentage of Items Processed by Each Category of Worker During FY96

Residue Material	Nitrate Workers	Pyrochemical Workers	Chloride Workers
Impure Metal		90%	10%
High-Priority Residues	100%		
Solutions			100%
High-Priority Compounds			100%
Combustibles	100%		
Other Compounds		10%	90%
Noncombustibles		10%	90%
Miscellaneous Process Residues			100%
Containers	100%		
Gases	100%		

Breaking down the 10 subcategories has its advantages in simplifying the data to determine the doses for each subcategory. The nitrate workers were the only group to process items in the subcategories of high-priority residues, combustibles, containers, and gases. The other two groups overlapped and shared the processing of three of the subcategories, while the final three were processed solely by the aqueous chloride workers. The radiation exposure estimations were developed for the nitrate workers first, the pyrochemical workers second, and the aqueous chloride workers third.

The nitrate-worker category materials were estimated using the level of effort of each worker for a particular month, his/her dosimetry data for that month, and the number of items processed in that month. The calculation consisted of two parts. The first part of the calculation was the determination of an hourly dose rate. This dose rate was determined by summing the doses of all individual workers with at least a 50% level of effort. The dose was then divided by the number of hours those people worked. (To make this approximation a conservative one, people working at least 50% on this project were assumed to have received all of their monthly dose from the project.) After the hourly dose rate was determined, it was then multiplied by the total number of hours billed to the project by those workers and divided by the total number of items completed that month. The estimate was then determined from the average value for all types of items processed, regardless of their subcategory. This was done for the months of January through May of FY96. Then, using the data for each month, a least-squares approximation was made to determine a value for each subcategory of items. Table IV contains a breakdown of the items completed each month by the nitrate workers, and Table V contains data for each month used in the evaluation of the average dose per item. A more detailed breakdown of the raw data is contained in Appendix A.

The doses that were developed for each item are listed in Table VI. The estimations for the high-priority residues and combustibles subcategories were developed using a least-squares approximation upon the data in Table V. The difference between the two estimations seems to agree well with the trends in the number and types of items processed each month. However, the combustible materials that were processed during this period are currently being created by the Cassini project and are not considered part of the legacy material that is being considered in this project. Nonetheless, the dose estimate determined for the combustible materials in this project is assumed to provide a reasonable dose estimate.

Table IV
Items Processed by Nitrate Workers

Residue Material	January	February	March	April	May
High-Priority Residues	19	6	20	37	5
Combustibles	12	10	14	13	17
Containers	0	0	0	0	0
Gases	0	0	0	0	0
Total	31	16	34	50	22

Table V
Data Used in the Evaluation of the Average Exposure per Item

Month	Total Hours on Project	Total Hours for Workers w/ at Least 50% Effort	Total Exposure for Workers w/ at Least 50% Effort (Person-mrem)	Total Items Completed	Average Dose per Item (Person-mrem/item)
January	1102	1032	467	31	16.1
February	1149	1065	209	16	14.1
March	1749.5	1547.5	495	34	16.5
April	1770	1507	465	50	10.9
May	2065.1	1959.1	492	22	23.6
All Months	7835.6	7110.6	2128	153	15.3

Since no containers or gases were processed during this period, exposures from these were estimated using different means. The dose for the gas items was assumed to be equal to the average dose per item for that period because there were no data available to evaluate this category of material. The dose for the container items was based on historical data of previously processed containers. These containers were smaller than those being considered in this study, and a scaling factor based on the container volume was used to adjust the doses from these smaller containers. From the historical data the processing of a container resulted in an average dose of 27.7 person-mrem. Thus, multiplying this dose by a volume-scaling factor of 8, the dose per container for those containers waiting to be processed becomes 222 person-mrem.

The exposures to pyrochemical workers were calculated in much the same way as those for nitrate workers. However, unlike the nitrate workers the pyrochemical workers shared the processing of the residue subcategories with the aqueous chloride workers. Since an approximation of the level of effort by each group of workers was known, it was assumed that the level of effort could be considered the percentage of items processed by that group of workers. Thus, the number of items processed in each month for each subcategory was multiplied by the percent level of effort. (In some cases, this approximation resulted in a partial item being completed by each group.) This approximation made it possible to separate the work of the pyrochemical workers from that of the aqueous chloride workers.

Table VI
Breakdown of the Exposures per Item

Residue Material	Dose per Item (Person-mrem/item)
Average	15.3
High-Priority Residues	5.8
Combustibles	28.3
Containers	222
Gases	15.3

The value determined for the impure metal category was determined as the average value over the months of February, March, and May since it was the only category processed within those three months. January data were discarded because there were no workers with a level of effort of at least 50%. The doses for the compounds and noncombustibles categories were assumed to be the same as those calculated for the aqueous chloride workers. The pyrochemical workers processed very few of these items in comparison to the aqueous chloride workers. Thus, the value determined in the aqueous chloride worker analysis was assumed to be a reasonable estimate for these two categories.

Table VII contains a breakdown of the items processed by the pyrochemical workers. Table VIII contains the data used in the evaluation of the average dose per item for each month, and Table IX contains a breakdown of the resulting exposures for each item. A more detailed breakdown of the raw data is also contained in Appendix A.

Table VII
Items Processed by Pyrochemical Workers

Residue Material	January	February	March	April	May
Impure Metals	63.4	36.9	90	24.3	39.6
Compounds	0	0	0	0.4	0
Noncombustibles	0	0	0	1.3	0
Total	63.4	36.9	90	26	39.6

Table VIII
Data Used in the Evaluation of the Average Exposure per Item for Pyrochemical Workers

Month	Total Hours on Project	Total Hours for Workers w/ at Least 50% Effort	Total Exposure for Workers w/ at Least 50% Effort (Person-mrem)	Total Items Completed	Average Dose per Item (Person-mrem/item)
January	191	0	0	63.4	N/A
February	495.5	365.5	98	36.9	3.6
March	661.5	661.5	385	90	4.3
April	480.5	405.5	281	26	12.8
May	621.5	591.5	250	39.6	6.6
Total (Except January)	2259	2024	1014	192.5	5.9

Table IX
Breakdown of the Doses per Item for Pyrochemical Workers

Residue Material	Dose per Item (Person-mrem/item)
Average	5.9
Impure Metals	4.8
Compounds	12.3
Noncombustibles	12.3

As shown in Table IX, the dose from impure metals is much lower than that from the compounds and the noncombustibles. This difference is due to the fact that during the month of April, which was the only month in which both compounds and noncombustibles were processed, a low number of items was processed while the total monthly exposure for these items was one of the highest. The table also shows that the average dose per item is fairly low, which was driven by including the large percentage of impure metal items, with their attendant low dose, in the average.

The aqueous chloride worker data were calculated as in the previous two worker categories. Since the aqueous chloride workers processed relatively few impure metal items, the estimate determined in the pyrochemical worker analysis was assumed to provide a reasonable estimate. The doses for the remaining five subcategories of residue materials that were processed by the aqueous chloride workers were estimated using the data for January, February, and April. The radiation dose from the impure metal items was subtracted from the estimated monthly doses, and the remaining doses were evaluated based on the results. The months of March and May were neglected since relatively few items were processed during those months, which resulted in very high doses per item. Based on the magnitude of the dose per item and the relatively low numbers during these two months, it was reasonably assumed that the doses received by the aqueous chloride workers during these months was primarily attributable to work with the neutron source recovery project.

The dose determined for the compounds, noncombustibles, solutions, high-priority compounds, and miscellaneous process residues is an averaged value. Because of the lack of data, the doses for these residues items could not be separated. The resulting value was an average of the combined doses of the five types of items over the three months that were considered in this analysis.

A breakdown of the items processed each month by aqueous chloride workers is given in Table X. Table XI contains selected data that were used in the evaluation of the doses for each item, and Table XII contains the resulting doses per item for the aqueous chloride workers. Appendix A contains a more detailed breakdown of the raw data used in this analysis.

Table X
Items Processed by Chloride Workers

Residue Material	January	February	March	April	May
Impure Metals	7.1	4.1	10	2.7	4.4
Solutions	22	0	0	0	0
High-Priority Compounds	2	2	0	12	0
Compounds	0	0	0	3.6	0
Noncombustibles	0	0	0	11.7	0
Miscellaneous Process Residues	26	22	5	6	0
Total	57.1	28.1	15	36	4.4

Table XI
Data Used in the Evaluation of the Average Exposure per Item for Chloride Workers

Month	Total Hours on Project	Total Hours for Workers w/ at Least 50% Effort	Total Exposure for Workers w/ at Least 50% Effort (Person-mrem)	Total Items Completed	Average Dose per Item (Person-mrem/item)
January	998	826	444	57.1	9.4
February	1007	828	397	28.1	17.1
March	1215.5	1148.5	590	15	41.6
April	1028.5	920.5	328	36	10.2
May	1153	1067	351	4.4	86.2
Total (Except March and May)	3033.5	2547.5	1169	121.2	11.5

Table XII
Breakdown of the Doses per Item for Chloride Workers

Residue Material	Dose per Item (Person-mrem/item)
Average (January, February, and April)	11.5
Impure Metals	4.8
Solutions	12.3
High-Priority Compounds	12.3
Compounds	12.3
Noncombustibles	12.3
Miscellaneous Process Residues	12.3

4.4 Radiation Exposures from Project Support Operations

For this analysis the radiation exposures for administrative support, instrument support, and other undefined support were neglected. These support functions were usually performed by people with less than 50% effort and low exposure readings for the period. For example, the instrumentation support people only received 33 person-mrem for the period of January through May. Of this support group only one individual had a greater than 50% effort, but he/she had received a zero exposure reading throughout the period. Thus, neglecting these exposures is not expected to alter this analysis since, given the assumptions made earlier, the dose received for these operations in essentially zero. The RCT support was also neglected because of the wide range of duties impacting exposure for RTC personnel.

The waste support operations are another matter. Sufficient data on radiation exposures received during waste operations exists, and the people who were involved in this operation are known. Using the dosimetry data for the waste support workers involved in the project, a reasonable estimate can be made. The waste support resulted in a total exposure of 714 person-mrem during the period of January through May of 1996. The average monthly exposure was 143 person-mrem/month. Scaling the average monthly exposure over the eight-year life of the project results in a total exposure of 13,700 person-mrem for the waste workers, which corresponds to roughly 1,700 person-mrem per year.

5.0 Results

Once all of the doses for each type of item were determined, they were used to calculate the total exposure for the entire project as well as a breakdown of exposures as a function of the projected work-off rate. The results of this analysis are contained in Tables XIII and XIV. Table XIII summarizes the results for the plutonium metals and oxides packaging project, and Table XIV summarizes the results for the plutonium residues stabilization project. (These tables do not include the dose estimate for the waste support operations, but it is included in the final estimate.) A copy of the item work-off schedule is presented in Appendix B.

From these two tables and the waste-support-operations calculations, the total estimated exposure for the plutonium metal and oxide packaging project and the plutonium residue stabilization project is 118.7 person-rem (118, 700 person-mrem). This value includes all sources of exposure discussed in this report. The majority of the exposure is expected to come from the stabilization of plutonium residues. The packaging project contributes about 24% of the total dose, and the waste support operations contribute only 12% of the total dose.

6.0 Conclusions

The total exposure for the packaging and stabilization projects has been estimated at 118.7 person-rem over the entire project. This estimate roughly translates to an average exposure of about 330 mrem/year per worker. However, this estimate should not be treated as fact but as an approximation. Given the limited data and the sensitivity of this estimate to changes in the work plan, worker ALARA (as low as reasonably achievable) practices, and other factors impacting the dose rates to the individual workers, this value will likely change. Thus, the estimate determined in this study should be viewed as an approximation for the purposes of making administrative decisions on whether or not dose-reduction measures are justified for specific operations. As more data become available throughout the life of this project, better estimates will likely be made, and the estimations presented within this report may be updated to better reflect future and long-range trends.

7.0 Acknowledgments

I would like to thank Carl Hoth of NMT-4 for defining the methodology used to develop the dose estimates, Keith Fife of NMT-2 for supplying the information used to break down the residue material category, and Tom Ricketts of NMT-2 for assisting in the development of the metal and oxide estimations. I would also like to thank Bob Bates of ESH-12 for supplying the dosimetry information that was used to develop the dose approximations. This work was conducted and funded by the Nuclear Material Packaging Project.

Table XIII
Expected Radiation Exposures Resulting from the Packaging of Plutonium Metals and Oxides

Material	Dose per Item (Person-mrem/item)	Exposure for FY95 (Person-mrem)	Exposure for FY96 (Person-mrem)	Exposure for FY97 (Person-mrem)	Exposure for FY98 (Person-mrem)	Exposure for FY99 (Person-mrem)	Exposure for FY00 (Person-mrem)	Exposure for FY01 (Person-mrem)	Exposure for FY02 (Person-mrem)	Totals (Person-mrem)
Metal	17.6	17.6	4136	6635.2	0	0	0	0	0	10788.8
Oxide	26.4	0	0	0	10560	7180.8	0	0	0	17740.8
Totals		17.6	4136	6635.2	10560	7180.8	0	0	0	28529.6

Table XIV
Expected Radiation Exposure Levels Resulting from the Stabilization of Plutonium Residues

Material	Dose per Item (Person-mrem/item)	Exposure for FY95 (Person-mrem)	Exposure for FY96 (Person-mrem)	Exposure for FY97 (Person-mrem)	Exposure for FY98 (Person-mrem)	Exposure for FY99 (Person-mrem)	Exposure for FY00 (Person-mrem)	Exposure for FY01 (Person-mrem)	Exposure for FY02 (Person-mrem)	Totals (Person-mrem)
Impure Metals	4.8	1118.4	1392	1488	1824	1723.2	0	0	0	7545.6
High-Priority Residues	5.8	1972	1421	1276	2204	493	0	0	0	7366
Solutions	12.3	5338.2	0	0	565.8	0	0	0	0	5904
High-Priority Compounds	12.3	0	615	934.8	0	0	0	0	0	1549.8
Combustibles	28.3	2377.2	283	283	283	2009.3	0	0	0	5235.5
Compounds	12.3	1660.5	184.5	184.5	184.5	184.5	5535	5535	5473.5	18942
Noncombustibles	12.3	774.9	184.5	184.5	184.5	1968	2890.5	2890.5	2214	11291.4
Misc. Process Residues	12.3	455.1	246	246	246	2460	3813	3813	4464.9	15744
Containers	222	0	222	444	444	444	444	444	444	2886
Gases	15.3	15.3	0	0	0	0	0	0	0	15.3
Totals		13711.6	4548	5040.8	5935.8	9282	12682.5	12682.5	12596.4	76479.6

Appendix A

Table A.1
Hours Spent on Project by Nitrate Workers

Worker	January	February	March	April	May
n1	0	0	172	120	153.6
n2	39	19	39	48	91
n3	107	120	121	103.5	156
n4	112.5	135	135	113	191.5
n5	129	130	200.5	187	142.5
n6	0	0	0	94	58
n7	112	95	103	81	93
*n8	85	80	80	85	90
n9	114	148	160	136	162
n10	0	0	0	94	16
n11	0	4	16	28	32
n12	0	0	69	66	117.5
n13	108.5	122	217	192.5	133
n14	0	0	0	40	158
n15	137	110	209	133	151
n16	31	61	78	89	130
n17	127	125	150	160	190
Total	1102	1149	1749.5	1770	2065.1
Total (At least 50% Effort)	1032	1065	1547.5	1507	1959.1

* Denotes that the time was estimated.

Table A.2
Percent Time Spent on Project by Nitrate Workers

Worker	January	February	March	April	May
n1	0%	0%	108%	71%	85%
n2	23%	12%	24%	28%	51%
n3	63%	75%	76%	61%	87%
n4	66%	84%	84%	66%	106%
n5	76%	81%	125%	110%	79%
n6	0%	0%	0%	55%	32%
n7	66%	59%	64%	48%	52%
n8	50%	50%	50%	50%	50%
n9	67%	93%	100%	80%	90%
n10	0%	0%	0%	55%	9%
n11	0%	3%	10%	16%	18%
n12	0%	0%	43%	39%	65%
n13	64%	76%	136%	113%	74%
n14	0%	0%	0%	24%	88%
n15	81%	69%	131%	78%	84%
n16	18%	38%	49%	52%	72%
n17	75%	78%	94%	94%	106%

Table A.3
Monthly Radiation Exposure Data for Nitrate Workers
(Doses in Person-mrem)

Worker	January	February	March	April	May
n1	0	0	0	0	0
n2	0	0	0	0	0
n3	52	43	22	24	30
n4	94	???	23	103	96
n5	52	51	134	139	98
n6	43	33	19	42	28
n7	97	21	197	54	61
n8	0	0	0	0	0
n9	21	26	5	4	5
n10	46	29	21	28	38
n11	0	4	23	4	6
n12	37	59	19	63	37
n13	49	49	52	43	25
n14	36	17	32	34	41
n15	47	11	62	41	74
n16	0	0	0	6	2
n17	55	8	0	35	23
Total (Non-zero Hours)	467	213	537	620	564
Total (at least 50% effort)	467	209	495	465	492

Table A.4
Hours Spent on Project by Pyrochemical Workers

Worker	January	February	March	April	May
p1	44	122	158	140	131
p2	0	130	196	155	110
p3	0	70	0	0	0
p4	30	0	0	5	30
p5	19	0	0	0	0
p6	0	0	0	0	0
p7	0	0	0	0	105
p8	0	0	0	0	0
p9	20	113.5	176	70	106
p10	78	60	131.5	110.5	139.5
Total	191	495.5	661.5	480.5	621.5
Total (At Least 50% Effort)	0	365.5	661.5	405.5	591.5

Table A.5
Percent Time Spent on Project by Pyrochemical Workers

Worker	January	February	March	April	May
p1	26%	76%	99%	82%	73%
p2	0%	81%	123%	91%	61%
p3	0%	44%	0%	0%	0%
p4	18%	0%	0%	3%	17%
p5	11%	0%	0%	0%	0%
p6	0%	0%	0%	0%	0%
p7	0%	0%	0%	0%	58%
p8	0%	0%	0%	0%	0%
p9	12%	71%	110%	41%	59%
p10	46%	38%	82%	65%	78%

Table A.6
Monthly Radiation Exposure Data for Pyrochemical Workers
(Doses in Person-mrem)

Worker	January	February	March	April	May
p1	11	37	111	64	92
p2	46	40	138	111	46
p3	16	36	55	62	24
p4	89	56	26	37	63
p5	20	8	0	0	0
p6	9	19	21	28	43
p7	0	0	0	0	0
p8	14	45	9	14	24
p9	5	21	41	0	27
p10	48	24	95	106	85
Total (Non-zero Hours)	173	158	385	318	313
Total (At Least 50% effort)	0	98	385	281	250

Table A.7
Hours Spent on Project by Chloride Workers

Worker	January	February	March	April	May
c1	7	0	0	0	0
c2	99	146	174.5	88.5	169
c3	135	142.5	190	138	184
c4	105	40	0	0	0
c5	0	40	0	0	0
c6	60	65	80	65	45
c7	83	34	67	43	41
c8	147	99.5	224	154	194
c9	22	120	160	200	160
*c10	85	80	80	85	90
*c11	170	160	160	170	180
*c12	85	80	80	85	90
Total	998	1007	1215.5	1028.5	1153
Total (At Least 50% Effort)	826	828	1148.5	920.5	1067

* Denotes that the time was estimated.

Table A.8
Percent Time Spent on the Project By Chloride Workers

Worker	January	February	March	April	May
c1	4%	0%	0%	0%	0%
c2	58%	91%	109%	52%	94%
c3	79%	89%	119%	81%	102%
c4	62%	25%	0%	0%	0%
c5	0%	25%	0%	0%	0%
c6	35%	41%	50%	38%	25%
c7	49%	21%	42%	25%	23%
c8	86%	62%	140%	91%	108%
c9	13%	75%	100%	118%	89%
c10	50%	50%	50%	50%	50%
c11	100%	100%	100%	100%	100%
c12	50%	50%	50%	50%	50%

Table A.9
Monthly Radiation Exposure Data for Chloride Workers
(Doses in Person-mrem)

Worker	January	February	March	April	May
c1	61	139	324	44	73
c2	24	17	24	0	0
c3	77	62	84	64	76
c4	112	93	73	79	81
c5	80	21	32	25	50
c6	3	0	0	0	0
c7	13	2	0	0	0
c8	132	63	133	23	52
c9	?	39	193	141	130
c10	12	145	11	10	5
c11	87	71	145	90	85
c12	0	0	0	0	3
Total (Non-zero Hours)	521	513	590	328	351
Total (At Least 50% Effort)	444	397	590	328	351

Appendix B

Table B.1
Projected Item Work-off Schedule

Material	*FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	Totals
Metal	1	235	377	0	0	0	0	0	613
Oxide	0	0	0	400	272	0	0	0	672
Totals	1	235	377	400	272	0	0	0	1285

*The numbers for FY95 are actual work-off numbers and not projections.

Table B.2
Projected Item Work-off Schedule

Material	*FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	Totals
Impure Metals	233	290	310	380	359	0	0	0	1572
High-Priority Residues	340	245	220	380	85	0	0	0	1270
Solutions	434	0	0	46	0	0	0	0	480
High-Priority Compounds	0	50	76	0	0	0	0	0	126
Combustibles	84	10	10	10	71	0	0	0	185
Compounds	135	15	15	15	15	450	450	445	1540
Noncombustibles	63	15	15	15	160	235	235	180	918
Misc. Process Residues	37	20	20	20	200	310	310	363	1280
Containers	0	1	2	2	2	2	2	2	13
Gases	1	0	0	0	0	0	0	0	1
Totals	1327	646	668	868	892	997	997	990	7385

*The numbers for FY95 are actual work-off numbers and not projections.

This report has been reproduced directly from the best available copy.

It is available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831. Prices are available from (615) 576-8401.

It is available to the public from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Rd. Springfield, VA 22616.

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545