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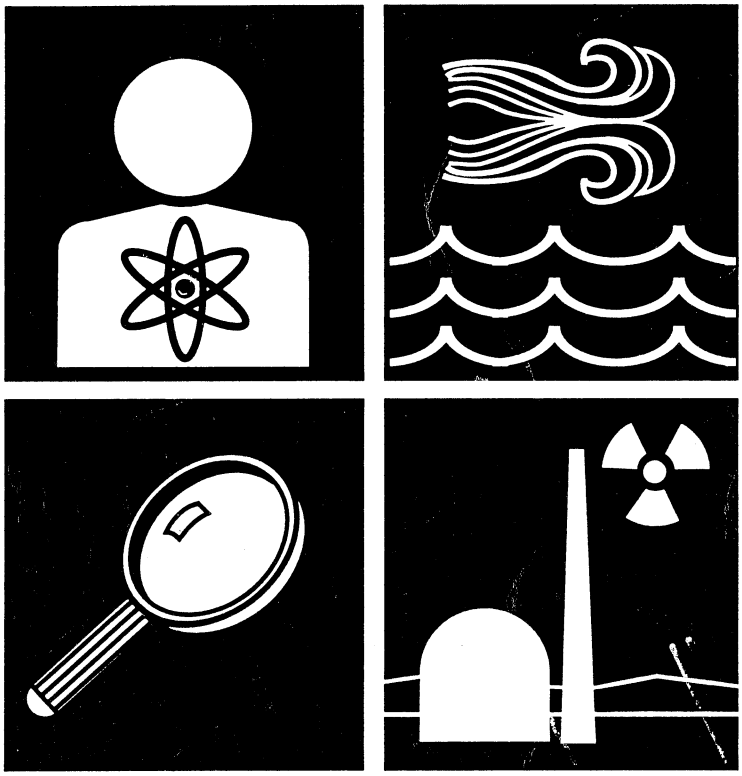
Radionuclide Releases to the Atmosphere from Hanford Operations, 1944 – 1972

C. M. Heeb

May 1994



Prepared for the Technical Steering Panel
and the Centers for Disease Control and Prevention
under Contract 200-92-0503(CDC)/18620(BNW)

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PNWD-2222 HEDR

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Hanford Environmental Dose Reconstruction Project

C. M. Heeb

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Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

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May 1994

This document has been reviewed and approved by the Technical Steering Panel.

John E. Till

J. E. Till, Chair
Technical Steering Panel
Hanford Environmental
Dose Reconstruction Project

May 22, 1994
Date

Preface

In 1987, the U.S. Department of Energy (DOE) directed the Pacific Northwest Laboratory, which is operated by Battelle Memorial Institute, to conduct the Hanford Environmental Dose Reconstruction (HEDR) Project. The DOE directive to begin project work followed a 1986 recommendation by the Hanford Health Effects Review Panel (HHERP). The HHERP was formed to consider the potential health implications of past releases of radioactive materials from the Hanford Site near Richland, Washington.

Members of a Technical Steering Panel (TSP) were selected to direct the HEDR Project work. The TSP consists of experts in the various technical fields relevant to HEDR Project work and representatives from the states of Washington, Oregon, and Idaho; Native American Tribes; and the public. The technical members on the panel were selected by the vice presidents for research at major universities in Washington and Oregon. The state representatives were selected by the respective state governments. The Native American tribes and public representatives were selected by the other panel members.

A December 1990 Memorandum of Understanding between the Secretaries of the DOE and the U.S. Department of Health and Human Services (DHHS) transferred responsibility for managing the dose reconstruction and exposure assessment studies to the DHHS. This transfer resulted in the current contract between Battelle, Pacific Northwest Laboratories (BNW) and the Centers for Disease Control and Prevention, an agency of the DHHS.

The purpose of the HEDR Project is to estimate the radiation dose that individuals could have received as a result of radionuclide emissions since 1944 from the Hanford Site. A major objective of the HEDR Project is to estimate doses to the thyroid of individuals who were exposed to iodine-131. A principal pathway for many of these individuals was milk from cows that ate vegetation contaminated by iodine-131 released into the air from Hanford facilities (Napier 1992).

The HEDR Project work is conducted under several technical and administrative tasks, among which is the Source Term Task. The broad scope of this task is to provide estimates of the amount and timing of radionuclide releases to air and water between 1944 and 1972. The environmental transport of the releases and their doses to people form the scope of other HEDR tasks.

This report provides hourly estimates of iodine-131 released to the air from separations plant operations for 1944 through 1949, the period during which sufficiently detailed release data exist to calculate hourly release estimates. In a previous HEDR report, Heeb (1993) provided hourly release estimates of iodine-131 from 1944 through 1947. Monthly release estimates for iodine-131 from 1950 through 1972 and monthly release estimates for five other radionuclides from 1944 through 1972 are also provided in this report.

These estimates of radionuclides released to the air from Hanford operations provided the input files for the HEDR atmospheric transport model. This report completes HEDR Project Milestone 0303D. It is the final radionuclide releases report, replacing the previous version dated January 1994. Appendix E is a record of the TSP comments and BNW responses that have been addressed in this final report. Changes made in response to the TSP comments are denoted by numbers in the left margin and italicized text.

Summary

The purpose of the Hanford Environmental Dose Reconstruction Project is to estimate the radiation dose that individuals could have received as a result of radionuclide emissions since 1944 from the Hanford Site. The first step in determining dose is to estimate the amount and timing of radionuclide releases to air and water. This report provides the air release information.

Background

The Hanford Site was built in southeastern Washington State during World War II to provide plutonium for the United States nuclear weapons program. Plutonium from the production reactors was processed in chemical separations plants to obtain weapons-grade plutonium. Four chemical separations plants (T, B, REDOX, and PUREX) operated at various times on the Hanford Site from 1944 through 1972. In the separations plants, aluminum cladding was dissolved in a sodium hydroxide solution (caustic). The bare uranium metal was then dissolved in a concentrated nitric acid solution. These operations released radionuclides to the atmosphere.

Radionuclide releases to the air from separations plant operations occurred at the top of the vent stacks. Releases to the air from reactor operations also occurred at the top of the vent stacks of the reactor building and the stack gas system building and at the inlet to the retention basin. Radionuclide releases to the Columbia River occurred at the reactor retention basin outfall pipes.

Heeb (1993) estimated that 685,000 curies of iodine-131 were released from the combined T and B plant operations from 1944 through 1947. Modifications in fuel-processing procedures and installation of emission control equipment in the T and B plant gas vent systems in 1948 significantly reduced the amount of iodine-131 released. In 1948, water scrubbers and sand filters were installed in the T and B plant gas vent systems. The time between fuel discharge from the reactor and reprocessing in the separations plants was increased starting in 1948. The emission control equipment, combined with increases in the cooling time, resulted in significantly lower iodine-131 releases from the separations plants from 1948 through 1972. A combined total of slightly over 10,000 curies of iodine-131 was released from the T and B plants in 1948 and 1949.

Scope

Napier (1992) determined that six radionuclides released to the atmosphere during separations plant operations contributed approximately 99 percent of the potential radiation dose from the air pathways. These radionuclides are iodine-131, ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239. A previous HEDR report (Heeb 1993) provided hourly estimates of iodine-131 releases to the atmosphere from T and B plant operations from 1944 through 1947. Those release estimates are repeated in this report, along with estimates of hourly iodine-131 releases for 1948 and 1949. Because daily plant operating data are not available after 1949, iodine-131 release estimates for 1950 through 1972 were calculated on a monthly basis. Release estimates for the other five radionuclides are provided on a monthly basis for 1944 through 1972, the entire period during which fuel from single-pass reactors was processed in the separations plants.

In addition to release estimates for the six radionuclides released to the air from separations plant operations, release estimates were also calculated for neptunium-239, a precursor of plutonium-239. The decays of neptunium-239 that occur in the time between discharge of the fuel from the reactor and processing of the fuel are counted as additional plutonium-239 activity available for release to the air.

Three volatile radionuclides—tritium (hydrogen-3), carbon-14, and argon-41—were released to the atmosphere from reactor operations. Leakage of air into the reactor stack gas system allowed precursors of the volatile radionuclides to enter the system. These precursors reacted to form the volatile radionuclides. In addition, hot reactor effluent water was vaporized at the retention basin inlet, releasing volatile radionuclides. Estimates of the amount of radionuclides released from reactor operations were calculated based on the few available historical measurements.

Technical Approach

Hourly iodine-131 release estimates for 1948 and 1949 were computed using the Source Term Release Model (STRM), a computer code based on the Monte Carlo method. STRM was used to generate radionuclide release estimates for the entire 1944-1949 period. The 1944-1947 results were reported in Heeb (1993). The 1948-1949 results were calculated for this report. STRM uses estimates of input parameter uncertainty in the form of distribution functions to calculate sets of realizations of hourly iodine-131 release patterns. One hundred realizations of iodine-131 releases were created as input files to the RATCHET atmospheric transport code (Ramsdell 1994). Calculations of monthly releases were made based on monthly estimates of the mass of spent uranium fuel processed, appropriate release factors to the atmosphere, and monthly average cooling times.

Results

Air releases from reactor operations were as follows: 1.4 curies/day of tritium (hydrogen-3), 0.1 curies/day of carbon-14, *and 1,480 curies/day of argon-41.*

Table S.1 provides an annual summary of the monthly release estimates for the six radionuclides released from the separations plants. These releases are based on quantities processed during routine plant operations from 1944-1972. A summary line at the bottom of Table S.1 provides sums of the annual release estimates.

The inherent uncertainty in those values was compiled into a single uncertainty factor, the 95-percent confidence level factor shown in Table S.2. Multiplying and then dividing a monthly release by the 95-percent confidence factor gives the upper and lower bounds, respectively, of a range that includes 95 percent of the results that would be generated under the given assumptions. The uncertainty in the monthly release estimates is higher than the uncertainty in the 1944-1949 monthly aggregates of hourly release estimates because the hourly release estimates were based on more detailed data.

6 **Table S.1.** Annual Summary of Radionuclide Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/yr)

Year	I-131	Ru-103	Ru-106	Sr-90	Pu-239	Ce-144
1944	2139	0.49	0.035	0.021	0.0012	1.57
1945	555089	87	12	6.94	0.39	460.15
1946	96298	87	18	10.53	0.58	650.03
1947	31909	51	12	7.38	0.41	451.30
1948	1842	12	4.6	2.94	0.16	166.82
1949	8694	0.42	0.19	0.12	0.006	6.15
1950	5379	0.81	0.35	0.20	0.010	10.40
1951	27397	2.4	0.58	0.28	0.014	16.92
1952	5108	32	11	0.40	0.013	23.33
1953	1747	266	89	0.52	0.015	31.05
1954	827	485	168	0.67	0.021	40.66
1955	671	6.87	2.00	0.78	0.025	43.30
1956	118	5.76	2.63	1.24	0.014	72.88
1957	274	12.6	4.58	1.90	0.015	118.73
1958	822	16.6	4.38	1.98	0.011	130.08
1959	227	15.2	5.27	2.30	0.008	144.41
1960	232	16.6	5.84	2.58	0.007	161.88
1961	92	15.0	6.16	2.81	0.011	171.68
1962	29	9.13	5.39	2.59	0.009	150.80
1963	78	7.53	5.10	2.47	0.011	139.79
1964	11	9.26	5.77	2.85	0.015	160.78
1965	6.08	7.84	5.40	2.71	0.014	154.25
1966	9.10	5.41	4.75	2.45	0.018	127.84
1967	1.28	3.82	4.35	2.12	0.001	107.41
1968	0.021	1.97	4.78	2.18	0.001	103.48
1969	0.0013	0.73	3.61	1.74	0.0004	72.81
1970	0.0011	0.19	0.89	0.42	0.0001	17.19
1971	0.000063	0.11	1.14	1.09	0.0003	30.34
1972	0.000000	0.00	0.12	0.11	0.00003	3.55
Sum	738999	1160	388	64.32	1.78	3770

Table S.2. Confidence Level Factors

Radionuclide	95-Percent Confidence Level Factor
iodine-131	4.8
ruthenium-103	3.5
ruthenium-106	3.5
strontium-90	2.8
plutonium-239	17.5
cerium-144	2.8

Conclusions

The hourly iodine-131 release estimates for 1944-1949 (the years of the highest iodine-131 releases) provide detailed source term for the atmospheric transport and dose calculations. The estimated monthly releases of iodine-131 and the other radionuclides provide a complete history of separations plant releases over the operating life of those plants.

Abstract

The purpose of the Hanford Environmental Dose Reconstruction Project is to estimate the radiation dose that individuals could have received as a result of radionuclide emissions since 1944 from the Hanford Site. The first step in determining dose is to estimate the amount and timing of radionuclide releases to air and water. This report provides the air release information.

This report provides hourly estimates of iodine-131 released to the air from separations plant operations for 1944 through 1949, the period during which sufficiently detailed release data exist to calculate hourly release estimates. Monthly release estimates for iodine-131 from 1950 through 1972 and monthly release estimates for five other radionuclides (ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239) from 1944 through 1972 are also provided in this report.

Glossary

200 Area - designation for all Hanford separations areas

alpha particle - particle consisting of two protons and two neutrons

B Plant - second bismuth phosphate separation process plant built at the Hanford Site

B Reactor - first of eight Hanford production reactors

batch - amount of irradiated fuel decoded into the dissolver at one time. The term "cut" is synonymous with batch.

Berl saddle - high-surface-area, saddle-shaped beads that were used as packing material in silver reactors. The silver nitrate coating on the Berl saddles reacted chemically with iodine to remove it from the passing gas stream.

bismuth phosphate process - process used at the T and B separations plants to chemically separate plutonium from irradiated fuel

burnup - amount of energy generated by nuclear fuel. Units are megawatt days (MWd).

curie - unit of radioactivity: 3.7×10^{10} disintegrations per second

cut - part of a batch

dissolver - vessel used in the spent-fuel dissolution portion of the separation process

dissolver off-gas line water scrubber - column of water through which off-gas from the dissolver was bubbled to remove contaminants

DOI - "do iodine" HEDR computer code described in detail in Heeb (1993) that was used to simulate separations plant dissolver operations. DOI provides input files to STRM.

downcomer - point in the reactor effluent system where cooling water was brought to atmospheric pressure. A vent at the top of the downcomer vented to the atmosphere.

expected value - sum of all possible values multiplied by the probability of occurrence (commonly the mean or average value)

exposure - thermal energy generation per unit of fuel mass (MWd/ton)

fission yield - fractional amount of a given nuclide per fission event

Green Run - controlled release of radionuclides from the T Plant that occurred in December 1949

half-life - time required for an initial number of radioactive atoms to be reduced to half that number by transformations

load or loading - number of tons of uranium contained in the reactor

Monte Carlo simulation - technique of representing the effect of uncertainty in one or more contributing parameters on the overall uncertainty by randomly sampling distribution functions which express parameter uncertainty. The results of each complete sampling (realization) are recorded for analysis of computed uncertainty of the outcome.

off-gas line - dissolver vent line that exhausted to the 200-foot vent stack

peaking factor - ratio of the average power of a batch of discharged fuel to the average reactor power

pile - earlier term for the graphite-moderated production reactors

power - reactor thermal power. Units are megawatts (MW).

power peaking factor - ratio of the maximum process tube power to the average process tube power

process tube - aluminum tube which held the uranium fuel elements (slugs) and cooling water

push - fuel discharge during a given refueling outage

PUREX Plant - Hanford chemical separations plant (located in the 200-East Area) that employed the PUREX method to chemically separate plutonium from irradiated fuel

9 **radionuclide** - *radioactive* isotope of an element

Reactor Model - computer model developed to provide the ratio of relative power experienced by fuel during its residence in the reactor to the average power of the reactor for the period. The Reactor Model produces input files for the DOI and STRM codes.

realization - a particular calculation of a Monte Carlo simulation where all uncertain parameters have been assigned a value by randomly sampling the parameter distribution function. The realization represents a "possible reality."

REDOX Plant - Hanford chemical separations plant (located in the 200-West Area) that employed a continuous-extraction separation process to separate plutonium from irradiated fuel

reflux condensor - device installed on the top of the dissolver to return vaporized water and volatile liquids

release factor - ratio of radionuclide activity released to the amount of radionuclide activity processed

sand filter - large enclosed volume of sand and gravel designed to filter building ventilation gases

silver reactor - emission-control device that chemically removed iodine from air exiting the dissolver

single-pass reactor - reactors B, C, D, DR, F, H, KE, and KW that were cooled by water which traversed the reactor core once, as distinguished from N Reactor where the water was recirculated

slug - aluminum-clad, cylindrical or tubular uranium fuel element used in Hanford reactors

source term - amount of radioactivity (measured in curies) of a radionuclide released to the environment

specific activity - number of curies of radioactivity per gram of material

spent fuel - irradiated fuel discharged from a reactor

stack - primary release point of exhaust air from a reactor or separation plant building

STRM - Source Term Release Model. STRM is the computer code described in detail in Heeb (1993) which performs Monte Carlo estimates of hourly iodine-131 releases.

T Plant - first bismuth phosphate separation process plant built at the Hanford Site

ton - in the context of this report, ton is always 2,000 pounds (metric tons, 2,200 pounds, were used only within the separations plants).

variance - measure of the variability of a random variable. Specifically, the difference between the expected value of the square and the square of the expected value (see expected value).

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1.0 Introduction

The purpose of the Hanford Environmental Dose Reconstruction (HEDR) Project is to estimate the radiation dose that individuals could have received as a result of radionuclide emissions since 1944 from the Hanford Site. Radionuclide releases to the air came from chemical separations plant operations and from reactor operations. The amounts of the releases were estimated as a first step in determining potential radiation doses to the public.

1.1 Background

Construction of the Hanford Site began in 1943. Its purpose was to provide plutonium for the United States nuclear weapons program. To produce plutonium, it was necessary to irradiate uranium with neutrons. The neutrons were absorbed by the uranium nuclei, resulting in plutonium production. The production of neutrons by the process of nuclear fission also produces a large number of radionuclides from the fragmentation of the uranium nucleus. During the course of operations, some by-product radionuclides were released to the air. Production of six radionuclides that make up 99 percent of the potential radiation dose from the air pathways (Napier 1992) are discussed in this report: iodine-131, ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239. Neptunium-239, a precursor of plutonium-239 with a half-life of 2.35 days, is also discussed because the decays of neptunium-239 that occurred in the time between discharge of the fuel from the reactor and processing of the fuel are counted as additional plutonium-239 activity available for release to the air. Three radionuclides produced and released during reactor operations—tritium (hydrogen-3), carbon-14, and argon-41—are also discussed.

11 The amount of plutonium in the uranium fuel rods increased as the reactor operated. When fuel elements reached the goal exposure, the reactor was shut down and the fuel elements were discharged. In addition to plutonium, *a number of* other radionuclides were contained in the fuel elements at discharge. These radionuclides undergo radioactive decay at varying rates, from an 8-day half-life for iodine-131 to a 24,110-year half-life for plutonium-239. The discharged fuel elements were stored for 30 days or longer to allow for the decay of the fission product radionuclides.

After storage, the fuel elements were sent to the chemical separation facility for plutonium extraction. The first step in the separations process was to load the irradiated fuel element into a large tank called a dissolver. The aluminum cladding of the fuel elements was dissolved with a sodium hydroxide solution. The next step was to dissolve the now-bare uranium fuel elements in concentrated nitric acid. During this dissolving process, some radionuclides were released from the uranium metal and routed through the reflux condenser to the off-gas line and out the stack.

The dissolver tanks were equipped with inlet and outlet pipes as well as a water-cooled reflux condenser on the lid. A dissolver off-gas line, connected near the top of the condenser, led to a large-diameter stack 200 feet high.

After dissolving, the plutonium was left in the acid solution along with the remaining fission product radionuclides. These remaining fission products ended up in the plant high-level waste stream; however, some of them escaped through the air ventilation system. The ventilation system also exhausted up the 200-foot stack, so fission products contained in the fuel rods were vented to the atmosphere after the dissolving step was completed. As emission-control technology advanced, filtration processes on the stack gas ventilation system improved, so the amount of radionuclides released to the atmosphere decreased.

Releases of radionuclides to the air from the separations plants were of concern from the startup of the first separations plant, T Plant, in December 1944 (Roberts 1957). B Plant was brought on line in April 1945. Both of these plants employed the bismuth phosphate process to separate plutonium from production reactor spent fuel. B Plant was shut down in June 1952, in part because the new REDOX Plant, which employed a method of separation unique to itself (called the REDOX process), was started up in January of that year (Roberts 1957). T Plant was shut down in February 1956, a month after the PUREX Plant began operation. The PUREX Plant employed a new continuous-extraction separation process which was different from the processes used at any of the other separations plants. The PUREX Plant processed the last available production-reactor fuel in March 1972 (Roberts 1957). The only other major amount of fuel processed in the PUREX Plant was from the N Reactor from 1983-1985.

In addition to releases from separations plant operations, radionuclides were released to the atmosphere from reactor operations. Three radionuclides from this source are considered important: tritium, carbon-14, and argon-41. These radionuclides were released to the air via the reactor stack gas system and from hot effluent water at the retention basin.

1.2 Purpose

This report documents radionuclide releases to the air from Hanford Site operations from 1944 through 1972. Iodine-131 releases are provided on an hourly basis from 1944 through 1949. Monthly sums of the hourly iodine-131 release estimates for 1944-1947 that were calculated by Heeb (1993) are repeated verbatim in this report to provide a single data source. Reference sources (General Electric Company 1948a) provide sufficiently detailed data to calculate, with the use of the Source Term Release Model (STRM), hourly estimates of iodine-131 releases for 1948-1949 as well. Releases of the five other radionuclides under study, as well iodine-131 releases made after 1949, are provided on a monthly basis.

1.3 Scope

10,12, 31b, 36,37, 38,39 Radionuclide releases *that entered the atmosphere* were calculated for the entire period of separations plant processing of single-pass reactor fuel. Separations were started at the T Plant in 1944 and the last of the single-pass reactor fuel was processed at the PUREX Plant in 1972. Separations plant releases made while processing fuel from all production reactors through the shutdown of the PUREX Plant in 1972 are considered in this study. Fuel discharged from the ninth Hanford Site reactor, the N Reactor, after 1972 was processed at the PUREX Plant in the 1980s and is outside the scope of this report. Releases made while processing fuel from the N Reactor *are* covered in *a forthcoming report.*

The size and shape of the domains affected by radionuclides, and the dose distribution within those domains, are discussed in the HEDR atmospheric dosimetry reports (Farris et al. 1994).

In addition to the six radionuclides released from separations plant operations and the three radionuclides released from reactor operations, release estimates were also calculated for neptunium-239, a precursor of plutonium-239. The decays of neptunium-239 that occur in the time between discharge of the fuel from the reactor and processing of the fuel are counted as additional plutonium-239 activity available for release to the air.

Measurements of iodine-131, ruthenium-103, and ruthenium-106 were available in the historic Hanford Site operating records. More information on iodine-131 releases was available in the Hanford Site documents than for any of the other radionuclides. Measurements of releases of the two ruthenium isotopes were the next most abundant in the Hanford Site documents. Very little reported information on cerium-144, strontium-90, and plutonium-239 was found, but enough release data were located to provide an order of magnitude estimate of release factors for these radionuclides.

Although the three radionuclides released from reactor operations were considered important to the dose reconstruction process, very little historical data were available for use in forming release estimates. Activity monitors were installed in the reactor vent stacks, but they did not provide information on specific radionuclides.

4b,15 *This report addresses routine production releases that entered the atmosphere through the ventilation stack as a result of the normal separations process. These releases are calculated using the mathematical product of the following three factors: 1) the number of tons of spent fuel being dissolved, 2) the radionuclide content per ton, and 3) a "release factor." The release factor is the ratio of radionuclides released to the amount of radionuclides processed and is determined by the efficiency of the release control devices.*

Radioactive particle (hot particle) releases are not within the scope of the HEDR Project because the information needed to estimate them accurately is available only on a case-by-case basis. Particle releases were episodic and not necessarily related to the amount of spent fuel being processed. Detailed estimates of individual hot particle releases can only be simulated by arbitrary adjustments of the release factor. Such estimates are not feasible unless complete records of the number of curies released are provided in the original hot particle release documents. Most often, these documents include monitoring results at specific locations but do not quantify the amount released out the stack. Over the entire period of Hanford Site operations the accumulation of continuous radionuclide releases can be expected to far outweigh the sum of hot particle releases.

1.4 Preview of Report

4a Hourly iodine-131 release estimates are discussed in Section 3.0. Section 4.0 describes the factors required to calculate radionuclide releases and discusses the uncertainty inherent in the assumptions made in the calculations for each of the six radionuclides released during separations plant operations. Radionuclide releases from reactor operations are discussed in Section 5.0. Section 6.0 provides conclusions from the report. Two appendixes follow the reference section. Appendix A presents separations plant historical operating data. The detailed monthly release estimates of the six subject

radionuclides (plus neptunium-239) from the four separations plants are listed in Appendix B. Appendix C lists regressions for the concentration of radionuclides in irradiated natural and enriched uranium. *Appendix D lists the statistical formulas used to estimate monthly release uncertainty.* Appendix E is a record of the TSP comments and BNW responses.

2.0 Data Quality Objectives

The data quality objectives for estimating radionuclide releases to the air are defined in the integrated task plans (Shipler 1993).

2.1 Accuracy

The integrated task plan requirement for accuracy is to provide accurate estimates of source terms that are based on historical records of plant operation. Holding out a subset of data for accuracy testing would have lowered the accuracy of the release estimates. Therefore, all available air release data were used to develop the estimates.

The historical reconstruction of plant operations was the most accurate component of the release estimate because plant operation records relate to plutonium accountability and were the subject of audits and reviews at the time of their creation.

Calculations of radionuclide content were done using the ORIGEN2 computer code (Croff 1980). This code uses a library of spectrum-averaged neutron cross sections to estimate the radionuclide content of fuel. Because no neutron cross-section library exists for single-pass reactors, radionuclide content of fuel in the single-pass reactors was estimated using the N Reactor cross-section library. This application leads to some uncertainty in the radionuclide content of the fuel. However, the limit of the uncertainty was determined by Heeb (1991) and was applied in the uncertainty estimate.

2.2 Completeness

The completeness objective requires that release information cover the period 1944 through 1972 and identify radionuclides contributing up to 99 percent of the potential radiation dose from the air pathways.

Because 1944 was the first year and 1972 was the last year when Hanford single-pass production reactor fuel was reprocessed, the nominal monthly release values provided in this report cover the entire operating life of the single-pass reactors and separations plants. Six radionuclides (iodine-131, ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239) were determined to contribute approximately 99 percent of the potential radiation dose to the air pathways (Napier 1992). The releases from these radionuclides have been estimated using available data in historical documents. In addition, atmospheric releases of tritium, carbon-14, and argon-41 from reactor operations are discussed in this report.

2.3 Representativeness

The representativeness objective requires data to represent all known activities, operating variations, and accidental releases. To ensure representativeness, all recorded incidents must be included in the development of the release data, which must be verified by peer review.

The monthly releases from each separations plant are calculated using release factors which are best estimate values applicable to standard operating conditions. Departures from standard conditions are expressed in the uncertainty estimates which cover the range of unusual operating conditions.

In the case of iodine-131, the release factors for silver reactor operation variability are large and are included in the uncertainty estimate. In the case of the December 1949 Green Run (T Plant), the release factor was set to the original startup value (0.905) to account for the bypass of the water scrubbers. The REDOX Plant release factor in September 1962 was set to produce a known release of 8 curies during a documented atmospheric dispersion test (Brouns et al. 1963). The PUREX Plant release factor for September 1963 was adjusted to produce the known accidental release of 72 curies from inadvertent processing of short-cooled fuel (Soldat 1965).

Ruthenium hot-particle releases at REDOX Plant from startup through 1957 were modeled using quarterly release-rate estimates which incorporated hot-particle releases. The ruthenium hot-particle releases were not related to the number of curies processed during the month of release and could not be represented with this type of release model.

15 The historical records used to estimate radionuclide releases to the air from separations plant operations are discussed in this report. *Further discussion of hot particles can be found in an earlier memo to the TSP.*[a]

2.4 Comparability

14a The comparability objective requires cross-comparisons to be made with multiple historical reference sources where possible. The reasons for any quantitative discrepancies must be resolved, and any discrepancies larger than 10 percent must be resolved *to meet the guidelines of the integrated task plans (Shipler 1993).*

Reconstruction of separations plant operations as presented in Appendix A employed six reference sources which often covered the same time periods and operational parameters. In each of those few instances where there were differences between data sources, a choice was made to use one value instead of another and the reasons were documented in HEDR Project records.[b] In all cases, discrepancies between sources were either so large that the source of error was obvious, or they were within 10 percent. Release information used in determining the release factors tended to be based on

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(a) *Memorandum (HEDR Project Document Number 11910087), "Preliminary Review of Documents Describing Hanford Atmospheric Particulate Releases, 1944-1954," from J. Stohr (BNW) to the TSP, December 26, 1990.*

(b) Document Review Record (HEDR Project Document No. 12930113) by B. E. Schmitt (BNW), July 21, 1993.

too few sources to permit comparisons. This was especially true for cerium-144, strontium-90, and plutonium-239 where only a single source of release information was found. Considerable redundancy existed in available iodine-131 and ruthenium release data.

An independent verification of the reported release estimates is provided by the other HEDR computer models and monitoring data. For example, hourly iodine-131 source term estimates provided in this report are inputs to the atmospheric transport code RATCHET (Ramsdell 1994) which calculates the ground deposition of iodine-131. The deposition is compared to environmental monitoring data collected under the HEDR Environmental Monitoring Task. These cross-comparisons between source term and transport modeling on the one hand and monitoring data on the other hand measure the comparability of all three HEDR task results. The cross-comparisons depend on data from tasks that are still in progress, so no discussion of the comparisons can be presented in this report. These comparisons are included in the HEDR validation report (Napier et al. 1994).

3.0 Hourly Iodine-131 Release Estimates, 1944-1949

The algorithms and computer codes used to calculate hourly iodine-131 releases from reactor and separations plant operations are described in Heeb (1993), which provides iodine-131 release estimates for 1944 through 1947. Hourly release estimates from the B and T separations plants during 1948 and 1949 were calculated using dissolver cut information from the metal history records (General Electric Company 1948a). The metal history records include information on the number of slugs loaded into the dissolver, the number of cuts (acid additions to dissolve a portion of the uranium) taken from each load, the reactor of origin, and the discharge date of the slugs. The records also provide the date that each cut moved into the extraction phase of the separation process. Because this reference gives the day of extraction instead of the day of dissolving and the release occurs during dissolving, the LAG distribution function developed in Heeb (1993) was sampled to calculate the number of days between dissolving and extraction for each Monte Carlo realization.

Records of reactor discharges (pushes) for 1948 were taken from the P Department Reports (General Electric Company 1948b). Records of reactor discharges for 1949 were taken from the monthly reports (General Electric Company 1949) because the P Department Reports stop at the end of 1948. A total of 400 pushes were reprocessed in whole or in part from 1944 through 1949, 226 in 1944 through 1947 and 174 in 1948 and 1949.

For each Monte Carlo realization, the Reactor Model (Heeb 1993) was rerun completely from 1944 through the end of 1949 to maintain continuity of simulated reactor core fuel management through the end of the reporting period for Heeb (1993) and the beginning of the reporting period for this report. The Reactor Model estimated iodine content in the reactor fuel at the time of reactor shutdown for discharge.

Information on the 400 reactor pushes that occurred from 1944 through 1949 provided input to the separations plant logistics code "do iodine" (DOI) (Heeb 1993). These pushes were identified by discharge date, the number of tons discharged, and the cut data (General Electric Company 1948a, Heeb 1993).

Output from DOI was combined with reactor data from the Reactor Model to provide input to the Source Term Release Model (STRM). The entire time period from 1944 through 1949 was run using STRM in the stochastic mode to produce the 100 hourly source term realizations of iodine-131 releases. One run was made for T Plant, another for the B Plant. These runs produced the source term for input into the atmospheric transport code RATCHET (Ramsdell 1994). Unusual release events such as the 1949 Green Run[a] (Jenne and Healy 1950) were also modeled in the STRM.

(a) "Green Run" refers to a test at T Plant that occurred in December 1949. A dissolver was loaded with two metric tons of fuel that had been discharged from the reactor only 16 days previously (normal fuel-cooling times during this period were 90 to 110 days). The aluminum cladding was removed by caustic chemicals, nitric acid sufficient to dissolve one metric ton of fuel was added, and the remaining metric ton of fuel was stored in the dissolver until the following March.

The STRM hourly iodine-131 release estimate files for 100 Monte Carlo realization are too large to print. Copies on electronic media are available from:

Technical Steering Panel, c/o K. CharLee
Office of Nuclear Waste Management
Department of Ecology
Technical Support and Publication Information Section
P.O. Box 47651
Olympia, Washington 98504-7651

The effective release factor in STRM for calculation of releases that occurred after the installation of emission control equipment in 1948 is the result of sampling two separate distribution functions, RFAC and RESIDUAL. RFAC is the fraction of iodine-131 contained in the dissolver that was released to the stack via the dissolver off-gas line. RESIDUAL is the fraction of iodine-131 remaining in solution after the dissolving step. This fraction was released to building air and thence out the stack during subsequent processing steps.

Before installation of water scrubbers in the dissolver off-gas line, RFAC was a piece-wise, uniform distribution approximating a normal distribution centered on 0.83. RESIDUAL was a uniform distribution from 0.05 to 0.10. The most probable value from sampling these distributions is 0.83 + 0.075 = 0.905. These distributions (RFAC and RESIDUAL) were sampled for the period prior to May 1948 when no effective filters or scrubbers were installed in either the dissolver off-gas line or the building ventilation system.

Several attempts were made to measure the effectiveness of the off-gas line water scrubbers. The May 1949 Hanford Monthly Report (General Electric Company 1949) concluded that between 71 and 79 percent of the off-gas line iodine-131 was removed. Because 83 percent of the iodine-131 in the dissolver was volatilized to the off-gas line and the average amount of off-gas iodine removed by the water scrubbers was 75 percent, the effective release factor by this route is 0.83 x (1 - 0.75) = 0.21. During the 6-month period between installation of the off-gas water scrubbers and installation of the sand filters, the residual fraction of iodine-131 remained at 0.075. Thus, the effective release factor calculated for the period of operations between May 1948 and the installation of sand filters in December 1948 is 0.21 + 0.075 = 0.285.

The May 1949 Hanford Monthly Report (General Electric Company 1949) estimated the removal efficiency of the sand filter at between 27 and 68 percent. Therefore, the average fraction released was 1.0 - (0.68 + 0.27)/2 = 0.53. Addition of sand filters in December 1948 lowered the effective release factor to 0.21 + (0.53 x 0.075) = 0.25. The distribution functional forms of RFAC and RESIDUAL were retained in the STRM calculations.

4.0 Monthly Radionuclide Release Estimates, 1944-1972

Table 4.1 lists iodine-131 release estimates with their uncertainty. Hourly iodine-131 release estimates were aggregated into monthly means and standard deviations computed over the 100 realizations. The uncertainty, as shown by the coefficient of variation (standard deviation divided by the mean), is on the order of 10 percent for the post-1947 period. Heeb (1993) reports the total iodine-131 released from the T Plant through the end of 1947 at about 300,000 curies. Releases made during 1948 and 1949 increased this total by about 8,000 curies, to approximately 308,000 curies. The December 1949 Green Run accounted for 7,000 curies of that increase. Iodine-131 releases from the B Plant increased from a total of about 386,000 curies at the end of 1947 to about 388,000 curies by the end of 1949, an increase of only about 2,000 curies.

17,18 *The STRM release for December 1949 is 7,177 curies with a standard deviation of 548 curies. At the 95-percent confidence level the December release range is 7,177 ± 1.96 x 548 = 7,177 ± 1,074. The Green Run was 7,000 curies of the total. M. A. Robkin, using an independent method based on relating measurements of released xenon-133 to iodine-131, arrived at 11,000 curies ± 30 percent. Later this was revised to 9,000 curies ± 30 percent. There is a substantial overlap in the range of the two estimates. The 7,000 curies estimate is close to the original Jenne and Healy (1950, p. 28) measurement of 7,780 curies.*

The monthly iodine-131 results shown in Table 4.1 repeat the 1944-1947 results reported in Heeb (1993), and add the 1948-1949 results from the current STRM production run. Repetition of the

Table 4.1. T and B Plant Monthly Iodine-131 Release Estimates and Uncertainty, 1944-1949 (Ci)

		T Plant			B Plant		
Year	Month	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
1944	December	2139	465	0.218			
1945	January	1221	435	0.357			
1945	February	2126	391	0.184			
1945	March	2082	320	0.154			
1945	April	18024	1160	0.064	10723	879	0.082
1945	May	34947	2271	0.065	39535	2734	0.069
1945	June	22234	1422	0.064	24232	1692	0.070
1945	July	23411	1629	0.070	23624	1659	0.070
1945	August	38379	2484	0.065	33710	2786	0.083
1945	September	38661	2655	0.069	50021	3037	0.061
1945	October	44806	2863	0.064	47260	2759	0.058
1945	November	16451	1279	0.078	21301	1366	0.064
1945	December	19059	1140	0.060	43281	2381	0.055
1946	January	2119	131	0.062	9634	618	0.064
1946	February	2681	159	0.059	4719	285	0.060
1946	March	2091	159	0.076	5862	387	0.066
1946	April	5183	323	0.062	6497	426	0.066
1946	May	4311	250	0.058	8969	542	0.060

Table 4.1. (contd)

Year	Month	T Plant			B Plant		
		Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
1946	June	156	11	0.072	4462	267	0.060
1946	July	874	60	0.069	4682	284	0.061
1946	August	84	30	0.357	8562	524	0.061
1946	September	473	49	0.103	7197	543	0.075
1946	October	439	58	0.131	4381	327	0.075
1946	November	2062	151	0.073	3463	297	0.086
1946	December	1961	142	0.073	5436	363	0.067
1947	January	1671	141	0.084	4487	326	0.073
1947	February	2256	165	0.073	1579	161	0.102
1947	March	1980	164	0.083	3637	244	0.067
1947	April	2006	175	0.087	2847	276	0.097
1947	May	1785	158	0.088	2203	167	0.076
1947	June	780	81	0.104	873	86	0.099
1947	July	1039	74	0.071	1257	86	0.068
1947	August	464	47	0.102	790	68	0.086
1947	September	480	44	0.091	729	50	0.069
1947	October	307	28	0.090	183	16	0.086
1947	November	157	14	0.090	120	11	0.093
1947	December	176	11	0.063	102	9	0.088
1948	January	41	4	0.099	178	15	0.082
1948	February	103	9	0.083	177	11	0.065
1948	March	95	8	0.082	74	7	0.095
1948	April	162	12	0.073	59	5	0.079
1948	May	27	3	0.114	4	1	0.322
1948	June	19	2	0.107	24	3	0.110
1948	July	55	5	0.100	81	8	0.101
1948	August	81	9	0.107	63	6	0.101
1948	September	56	6	0.110	63	7	0.112
1948	October	79	9	0.113	91	9	0.096
1948	November	81	9	0.116	72	8	0.104
1948	December	82	9	0.105	75	8	0.112
1949	January	109	11	0.102	88	9	0.102
1949	February	91	11	0.121	12	2	0.150
1949	March	180	19	0.104	61	6	0.103
1949	April	64	8	0.121	66	8	0.118
1949	May	71	8	0.119	69	7	0.099
1949	June	37	4	0.118	42	5	0.124
1949	July	52	6	0.107	43	5	0.124
1949	August	68	7	0.104	18	2	0.133
1949	September	69	8	0.112	71	9	0.122
1949	October	64	7	0.112	78	8	0.103
1949	November	60	7	0.109	41	5	0.129
1949	December	7177	548	0.076	64	8	0.118
	Total	307999			387971		

earlier data provides a single source for iodine-131 air releases. The mean and standard deviation values from the current STRM, which were run for the 1944-1949 period, differ slightly from the original calculations (which are repeated here) because a longer time period was being sampled; i.e., 1944 through 1949 instead of 1944 through 1947.

The differences occur because random sampling is controlled by a set of computer-generated random numbers. Sampling a larger time period for each realization results in a different set of random numbers because a different number of calls are made to the random-number generator subroutine used by STRM.

Releases of ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239 were estimated on a monthly basis for 1944 through 1972. Estimates of iodine-131 releases after 1949 were also made on a monthly basis. Release estimates for these radionuclides are given in Appendix B.

Monthly release estimates were based on information found in the historical Hanford Site documents for the radionuclides listed below. The half-life and decay mode of each radionuclide are also provided to serve as a reference for the following discussion.

Radionuclide	Half-Life	Decay Mode
iodine-131	8.04 days	beta, gamma emission
ruthenium-103	39.4 days	beta, gamma emission
ruthenium-106	368 days	beta emission
cerium-144	284 days	beta, gamma emission
strontium-90	29 years	beta emission
plutonium-239	24,110 years	alpha emission

With the exception of plutonium-239, all of these radionuclides are fission products. Plutonium-239 is formed when uranium-238, present in the reactor fuel, captures a neutron to form *uranium-239, which decays by beta emission to* neptunium-239. Neptunium-239 then decays by beta particle emission with a 2.35-day half-life to plutonium-239. Because they were created within the fuel element, the six radionuclides remained within the spent reactor fuel when it went to the separations plants. When the fuel was dissolved at the separations plant, some of the radionuclides were released to the air.

4.1 Technical Approach

Monthly releases of ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239, plus iodine-131 releases after 1949, were estimated as follows: 1) A schedule of the number of tons processed, the average burnup, and the fuel-cooling time (time between reactor shutdown for discharge and dissolving of the fuel at the separations plant) was reconstructed; 2) the radionuclide content of the

fuel as a function of average burnup and specific power of the uranium fuel was determined; and 3) release factors for the six radionuclides were estimated.

4.1.1 Separations Plant Operations

Three different separations processes were used at the Hanford Site. The bismuth phosphate process was used at the T and B plants, the REDOX process was used at the REDOX Plant, and a continuous-extraction separation process (PUREX process) was used at the PUREX Plant.

The bismuth phosphate process was the first chemical separation process used at the Hanford Site. It separated product plutonium from uranium and fission product radionuclides contained in spent reactor fuel by adjusting the valence of dissolved plutonium so that it remained in solution while many fission products precipitated from solution. Bismuth phosphate precipitation of by-products occurred in several stages, followed by precipitation of the reduced plutonium with lanthanum fluoride, which was then dissolved. The remaining solid contained plutonium which was dissolved with nitric acid, producing a plutonium nitrate solution as the end product. This was a batch process involving several separation steps in which precipitated solids were removed by centrifuge.

The REDOX process was a continuous-extraction process. It used counter-current extraction columns to separate uranium and plutonium from fission products. The uranium and plutonium were held in aqueous solution by valence manipulation while the fission products were transferred to hexone (methyl isobutyl ketone), an organic solvent. After valence adjustment, uranium and plutonium were separated in the final step. The end product was an aqueous solution of plutonium nitrate.

The PUREX process was similar to the REDOX process. The major chemical difference between them was that the organic solvent used to separate plutonium from uranium and fission products was tributyl phosphate in kerosene instead of hexone (methyl isobutyl ketone). The tributyl phosphate-kerosene solvent had a lower flammability and afforded some process simplification.

All of the separations plant buildings maintained negative pressure with respect to the atmosphere during the dissolving process, thus ensuring that any volatile radionuclides released by dissolving irradiated uranium fuel would remain in the building if the building seals were breached.

All four plants shared a common "head end" or initial processing step, which started with loading the spent fuel into a large steel vessel called a dissolver. After loading, the aluminum cladding of the fuel elements was dissolved with a sodium hydroxide solution. In the next step, the now-bare uranium fuel elements were dissolved in concentrated nitric acid. During this step, a fraction of the radionuclides was released from the uranium metal and routed through the reflux condenser to the off-gas line. The off-gas line contained steam jet pumps that maintained a negative pressure with respect to atmospheric pressure during dissolving. The process building was also equipped with large ventilation fans that maintained a negative-with-respect-to-atmosphere pressure within the building. Both the off-gas line and the ventilation fans exhausted to a single 200-foot vent stack. Any volatile radionuclides released by dissolving the irradiated uranium fuel were thus sent out the vent stack either by the dissolver off-gas line or by the building ventilation system.

Records were kept of the amount of uranium fuel dissolved, the burnup of the fuel, and the average cooling time (General Electric Company 1948a). Enough of these records survived to permit a daily reconstruction of iodine-131 from T and B plant operations through the end of 1949. Thereafter, monthly summary records only permit a monthly reconstruction of the amount of fuel dissolved, the average burnup of the dissolved fuel, and the average cooling time of the fuel throughout the operating life of each separations plant. The following main sources were used in the reconstruction of the monthly releases.

1) PCHIVE (Jungfleisch 1992) is a computer file containing information on monthly tons processed and burnup for each reprocessing plant over the operating life of the plant.

2) Gydesen (1992a; 1992b) are compilations of historical Hanford Site operating documents containing declassified extracts from classified notebooks. These references provide information on tons processed, burnup, and cooling time for each month of operation.

3) Jaech (undated) is a computer printout that contains reactor discharge date, tons dissolved, and burnup.

4) Roberts (1957) contains cooling time, exposure of the fuel (MWd), tons dissolved, burnup, and amount of plutonium separated by month over the life of each of the four separations plants.

5) Heeb (1993) contains monthly tons dissolved and cooling times for 1944 through 1947.

6) The Hanford Works Monthly Reports for April, June, August, October, and December 1952 (General Electric Company 1952a; 1952b; 1952c; 1952d; 1953) supply tons, burnup, and cooling times that were missing in the other data sources.

These sources contain a significant amount of overlapping information. For instance, the same quantity might be reported in more than one data source. In those few instances where there were conflicts between data sources, a choice was made to use one value instead of another and the reasons were documented in HEDR Project records.[a] The separations plant data are provided in detail in Appendix A, which provides a reconstruction of the operating history of the Hanford separations plants.

4.1.2 Calculation of Radionuclide Content in Spent Fuel

The amount of any fission product in uranium fuel is determined by solving the following differential equation:

$$\frac{dN}{dt} = Y\Sigma_f\phi + \lambda_p N_p - N\sigma_a\phi - \lambda N \tag{4.1}$$

where N = fission product concentration in nuclei per cm^3
t = time (sec)
Y = fractional fission yield of the fission product

(a) Document Review Record (HEDR Project Document No. 12930113), reviewed by B. E. Schmitt (BNW), July 21, 1993.

22 Σ_f = macroscopic fission cross section of the fuel in cm^{-1}
ϕ = neutron flux in neutrons per cm^2 per second
λ_p = radioactive decay constant of precursor in sec^{-1}
N_p = precursor concentration in nuclei per cm^3
σ_a = microscopic absorption cross section of the fission product in cm^2
λ = radioactive decay constant of the fission product in sec^{-1}.

Reading the terms on the right side of the equation from left to right, the first term is the production rate from the fission process and the next term is the production rate from decay of a precursor nuclide. The third term is the removal term because of neutron capture and the fourth term is the removal term because of decay.

This equation is solved for each of the radionuclides by the ORIGEN2 computer code (Croff 1980). Neutron flux and all of the cross sections are functions of neutron energy. The energy-dependence of the neutron flux (neutron spectrum) is sensitive to the type of reactor involved. ORIGEN2 has sets of reactor-specific cross sections which are averaged over the appropriate neutron spectrum of the reactor. Unfortunately, no ORIGEN2 library exists for the Hanford single-pass reactors.

23 An ORIGEN2 library does exist for the N Reactor. However, because of design differences between N Reactor and the single-pass reactors, the N Reactor library values may be different from those of the single-pass reactors. The problem with using N Reactor library values to calculate radionuclide content in the single-pass reactor fuel was addressed in an earlier HEDR publication (Heeb 1991). Like the single-pass reactors, N Reactor was a graphite-moderated reactor. However, it was designed with more void space in its graphite stack, so the ratio of graphite moderator to uranium fuel was lower for N Reactor than for the single-pass reactors. This lower moderator-to-fuel ratio resulted in a more energetic neutron spectrum. Heeb (1991) compared the radionuclide content calculated by ORIGEN2 using the N Reactor library with the radionuclide content calculated by ORIGEN2 using the most thermal (least neutron-energetic) spectrum available, the CANDU heavy water reactor cross-section library. The spectrum for this reactor type is far more thermal (less neutron-energetic) than the single-pass reactor neutron spectrum, so the single-pass reactor neutron spectrum lies between that of the N Reactor and that of the heavy water reactor (modeled by CANDU). The percentage of difference between the two ORIGEN2 calculations indicates the level of uncertainty in the estimates. The level of uncertainty was determined for a large number of radionuclides of interest to the HEDR Project (Heeb 1991). The six radionuclides of interest in this report were found to have the following uncertainties (Table 4.2). *The uncertainty in Table 4.2 is (N-C)/N, where N is the radionuclide content from the N Reactor library and C is the radionuclide content from the CANDU library.*

The CANDU spectrum is an extreme example of a very thermal spectrum. The single-pass reactor spectrum is much closer to the N Reactor spectrum than it is to the CANDU spectrum. This is readily apparent in Figures 3.2 and 3.3 of Heeb (1991, p. 3.7). The actual uncertainty that results from using the N Reactor spectrum to calculate radionuclide concentrations for single-pass reactor fuel is, therefore, much less than shown in Table 4.2 and is certainly acceptable in view of the larger uncertainties in other parameters used to estimate the release.

Table 4.2. Differences between the Uncertainties in N Reactor and CANDU Calculated Radionuclide Content

Radionuclide	Difference between N Reactor and CANDU (%)
Iodine-131	-3.6
Ruthenium-103	-7.6
Ruthenium-106	-28.3
Cerium-144	3.6
Strontium-90	7.0
Plutonium-239	17.3

ORIGEN2 cases were applied to a range of specific powers from 1.0 MW/ton to 10 MW/ton and burnups from 100 MWd/ton to 2,500 MWd/ton. The results were fitted to bivariate polynomial expressions in PD (power density) and BU (burnup). Different regressions were required for natural uranium and enriched uranium (0.947 percent uranium-235 by weight). The regressions for natural and enriched uranium are provided in Appendix C. A regression was run for neptunium-239 because it is the precursor of plutonium-239. The decays of neptunium-239 that occur in the time between discharge of the fuel from the reactor and processing of the fuel are counted as additional plutonium-239 activity available for release to the air. Monthly release estimates for neptunium-239 are provided in Appendix B.

The quality of the least squares regression obtained is indicated by the parameter R^2 computed for each regression. R^2 is a measure of the regression accuracy in fitting the data, where $R^2 = 1.0$ is a perfect fit and $R^2 = 0.0$ is no correlation at all. All of the regressions had R^2 values greater than 0.99 except for neptunium-239 (for enriched fuel) and iodine-131. The neptunium-239 regression for enriched uranium fuel had $R^2 = 0.980$. The iodine-131 regression for enriched uranium fuel had $R^2 = 0.984$. For natural uranium, the iodine-131 regression had $R^2=0.986$.

4.1.3 Radionuclide Release Factors

The release factor is defined as the ratio of the radionuclide activity released to the radionuclide activity processed. Release factors are calculated from known values over a short period of time. They provide an estimate of the fraction of radionuclides released from processing operations. This estimate is then applied to time periods during which processing data, but no release data, are available.

A monthly release factor was calculated for each of the six radionuclides under study in this report (iodine-131, ruthenium-103, ruthenium-106, cerium-144, strontium-90, and plutonium-239) for each separations plant in operation. Release factors based on measurements from a given time period were assumed to apply to all time periods when the same release control equipment was in service.

4.1.4 Uncertainty in Release Estimates

Uncertainties in the release estimates could not be directly calculated (other than for early iodine-131 releases) because Monte Carlo modeling was only done on iodine-131 releases and only for 1944-1949. Monte Carlo modeling was not used to estimate iodine-131 releases after 1949 or to estimate the releases of the other five radionuclides from the separations plants from 1944-1972. Instead, global estimates of the uncertainty in these releases were made as discussed in the next section, "Hourly Iodine-131 Uncertainty in Monthly Release Estimates, 1944-1949."

4a,7 ***Hourly Iodine-131 Uncertainty in Monthly Release Estimates, 1944-1949***

The STRM computer code (Heeb 1993) was used to estimate the amount of iodine-131 released from 1944 through 1949. In STRM, the Monte Carlo technique (Heeb 1993) was used to represent how uncertainty in one or more parameters affected the overall uncertainty of the estimates. Using the Monte Carlo method, distribution functions (expressing uncertainty in each of the parameters) were sampled randomly to produce a possible value (realization) of the hourly release. The range in these values expresses the uncertainty in the estimated release; the narrower the range, the less uncertainty there is in the estimate. The monthly mean values in Table 4.1 were estimated by adding all of the hourly releases for the month and averaging this sum over the 100 realizations for that month. The standard deviations shown in Table 4.1 express the uncertainty in the monthly mean release. The coefficient of variation is the ratio of the standard deviation to the mean for each month. The coefficient of variation runs from a high of 0.357 for the T Plant in January 1945 and August 1946 to a low of 0.055 for the B Plant December 1945 release. At the 95-percent confidence level, the true monthly sum will be within a band of ± 1.96 times the standard deviation. Thus, the 95-percent confidence level range of uncertainty for the T Plant release in January 1945 would be 1,221 ± 1.96 x 435 = 1,221 ± 852 curies. For the B Plant release in December of 1945, it would be 43,281 ± 1.96 x 2,381 = 43,281 ± 4,667 curies. In general, smaller releases have a larger coefficient of variation (fractional uncertainty) than the larger releases.

The uncertainty in the early monthly iodine releases have a wide range. When the early iodine source was provided to RATCHET, the HEDR atmospheric transport model, the transport of each hourly release from a given realization was estimated throughout the study domain. The ground deposition pattern was then determined completely for each realization. Comparison of source uncertainty for the monthly mean releases indicates which months had large source term uncertainty and which months had a relatively well known source term.

4a,7,25,26 ***Uncertainty in Monthly Release Estimates***

Table 4.3 shows the estimated uncertainty for the monthly releases. The upper uncertainty range on a given monthly release is obtained by multiplying the release by the uncertainty factor. The lower release is obtained by dividing by the uncertainty factor. The method used to estimate the 95-percent uncertainty factor is the same for all five radionuclides. Each release is calculated using the following equation:

$$R = F\,T\,C(PD,BU)\,e^{-\lambda t} \qquad (4.2)$$

Table 4.3. Uncertainty Factor Estimates

Radionuclide	Half-Life	Mean & Std. Dev.	Curies Processed	Release Factor	Release	95-Percent Uncertainty Factor for Release
Iodine-131, 1950-1972	8.04 days	Mean	1.00	5.7E-3	5.7E-3	4.8
		Std. Dev.	0.370	4.6E-3	5.4E-3	
Ruthenium-103	39.4 days	Mean	1.00	9.6E-8	9.6E-8	3.5
		Std. Dev	0.065	6.7E-8	6.8E-8	
Ruthenium-106	368 days	Mean	1.00	9.6E-8	9.6E-8	3.5
		Std. Dev.	0.082	6.7E-8	6.8E-8	
Cerium-144	284 days	Mean	1.00	4.0E-6	4.0E-6	2.8
		Std. Dev.	0.0104	2.3E-6	2.3E-6	
Strontium-90	29 years	Mean	1.00	9.6E-7	9.6E-7	2.8
		Std. Dev.	0.020	5.4E-7	5.4E-7	
Plutonium-239	24,110 years	Mean	1.00	4.7E-9	4.7E-9	17.5
		Std. Dev.	0.50	1.3E-8	1.3E-8	

where R = *release in curies*

F = *release factor*

T = *mass of spent fuel processed (tons)*

$C(PD,BU)$ = *radionuclide content at discharge from the reactor (curies per ton), a fit from ORIGEN2 (Appendix C) with independent variables PD and BU, respectively the average specific power and burnup of the fuel being dissolved*

$e^{-\lambda t}$ = *decay factor with* λ *the decay constant and t the cooling time.*

The last three factors in Equation (4.2) (T, C(PD,BU) and $e^{-\lambda t}$*) are the number of curies processed during the month. All four of the factors in Equation (4.2) may be considered uncertain. Distribution functions are developed for the uncertainty of each factor. Using standard statistical methods as discussed in Appendix D, the 95-percent uncertainty factor of the product, R, is determined from the mean and variance of each of the factors.*

The distribution functions used are uniform, triangular or lognormal. Where all values within the range are equally probable, a uniform distribution is used. If there is a most probable value within the range, a triangular distribution is selected. Lognormal distributions were used to represent release factor uncertainty for iodine-131, ruthenium-103, ruthenium-106, and plutonium-239.

The release factor, F, is considered uncertain for all radionuclides and the distribution function chosen to represent its uncertainty is discussed under the appropriate radionuclide in the next section.

The number of tons dissolved (T in Equation 4.2) was well known because it played a key part in the plutonium accountability requirements. Uncertainty in the number of tons dissolved is estimated at ± 5 percent. A uniform distribution ranging from 0.95 to 1.05 is chosen to represent it. Using the standard statistical formula from Appendix D, the mean of this distribution function is 1.0 and the variance is 0.000833. It is the same for all radionuclides and is, therefore, not repeated under each radionuclide in the next section.

The uncertainty in radionuclide content, C, is different for each radionuclide and, hence, is discussed in the next section under the appropriate radionuclide. Except for iodine-131 where some additional uncertainty is due to the independent variables specific power (PD) and burnup (BU), this uncertainty is due to ORIGEN2 code uncertainty.

The uncertainty in the decay factor, $e^{-\lambda t}$ is a result of the cooling time uncertainty. Hence, it contributes to the release uncertainty only for the relative short half-life radionuclides, iodine-131 (8 days) and ruthenium-103 (39.4 days). The distribution functions used for these two radionuclides are discussed in the next section under each of these two radionuclides.

4.2 Monthly Radionuclide Release Estimates

Appendix B provides monthly release estimates for the six radionuclides under study from all four separations plants. Monthly release estimates are also provided for neptunium-239, a precursor of plutonium-239 (see Section 4.1.2). The following sections discuss the pattern of monthly releases over the operating period of the four separations plants. This information is also presented in graphical form in Figures 4.3 through 4.7. The releases shown in the figures are the sums from all four separations plants for a given month.

4.2.1 Iodine-131

Iodine-131 Release Factors

T and B Plants. The iodine-131 release factors through the end of 1949 were developed for the T and B separations plants using hourly release estimates found in historical Hanford Site documents. By the end of 1948, each of the two plants had water scrubbers installed in the dissolver off-gas lines and the building ventilation air was filtered through massive sand filters. A new release factor of 0.25 was calculated to take this emission control equipment into account (Section 3.0).

27 The next major development in iodine-131 emission-control technology that required recalculation of the release factor was the installation of silver reactors in the separations plants upstream from the off-gas lines. Silver reactors consisted of columns packed with Berl saddles, a silver nitrate-coated packing material which was designed to present a large surface area to the gas stream passing through the column. Iodine in the air passing through the column reacted chemically with the silver nitrate coating on the Berl saddles to form silver iodide, and was thereby removed. Silver reactors were operational in dissolver cell 3-5R in the T Plant on December 12, 1950 and in dissolver cell 4-5L on

December 28, 1950. They were operational in dissolver cell 4-5L in the B Plant on October 26, 1950 and in dissolver cell 3-5L on January 29, 1951 (Paas and Soldat 1951). *However, the silver reactors were not in continual operation until after January 1951.*

Paas and Soldat (1951, p. 12) reported initial values for the iodine-131 fraction released at T Plant for the period September 1950 through June 1951. Although some reduction from the calculated 25-percent release factor is shown in tests during September through December 1950, it is unlikely that the release factor was reduced substantially below 25 percent until the silver reactors were fully operational in January 1951. Paas and Soldat (1951, p. 12) report release factors for iodine-131 from January through June 1951 in their Figure 3. The reported values are listed in Table 4.4.

Table 4.4. Iodine-131 Release Factors, January-June 1951 (Paas and Soldat 1951)

Month/Year	I-131 Release Factor
January 1951	0.01
February 1951	0.01
March 1951	0.02
April 1951	0.05
May 1951	0.132[a]
June 1951	0.125

(a) The high release factor for May 1951 was attributed to a silver reactor breakthrough.

28 The silver reactors were very efficient, with removal values greater than 99.9 percent (Warren 1961, p. 3). However, they only operated within the temperature range of 375°F to 414°F (Blasewitz 1951). When the temperature was too low (below 375°F), condensate in the column packing interfered with iodine adsorption and could dissolve the silver nitrate coating on the Berl saddles. When the temperature was too high (above 414°F), the silver metal coating could melt and flow from the packing (Blasewitz 1951). The silver reactors were also subject to chloride contamination. Chloride contamination displaced the iodine from the surface of the Berl saddles, thereby rendering them incapable of removing iodine from the gas stream. *Contamination was probably caused by small amounts of chloride impurities in the process reagents, atmospheric chlorine, or both. Over time, thermodynamically favored silver chloride displaced silver iodine on the surface of the Berl saddles, rendering the saddles incapable of removing iodine from the gas stream.* These and other considerations made periodic regeneration and replacement of on-line silver reactors a necessary maintenance activity. On-line monitoring equipment was installed to warn separations plant operators when the performance of a silver reactor was deteriorating. When that happened, dissolving could be suspended until the Berl saddles were replaced or regenerated.

In view of the highly variable performance of the silver reactors, a long-term set of release factor measurements was necessary to determine a generic release factor. Such a data source exists in Warren (1961). This document provides measurements of the iodine-131 release factors that were made from January 31 through December 31, 1959 at the REDOX Plant. The median release factor of the 158

measurements was 0.0125. Figure 4.1 shows a histogram of the release factor measurements. This set of release factors was applied to both T and B plant operations after the initial silver reactor break-in period. Although no measurements for B Plant were reported in Paas and Soldat (1951), a similar situation must have existed at B Plant, where identical silver reactors were being operated for the first time. The same set of release factors was, therefore, applied to the B Plant.

REDOX Plant. The REDOX plant was brought on line in January 1952. Its iodine-removal equipment included silver reactors (Christy 1952). The generic release factor of 0.0125 calculated for the REDOX Plant (Warren 1961) was adjusted to model an unusual event in September 1962 when an 8-curie release resulted from an atmospheric dispersion test (Brouns et al. 1963).

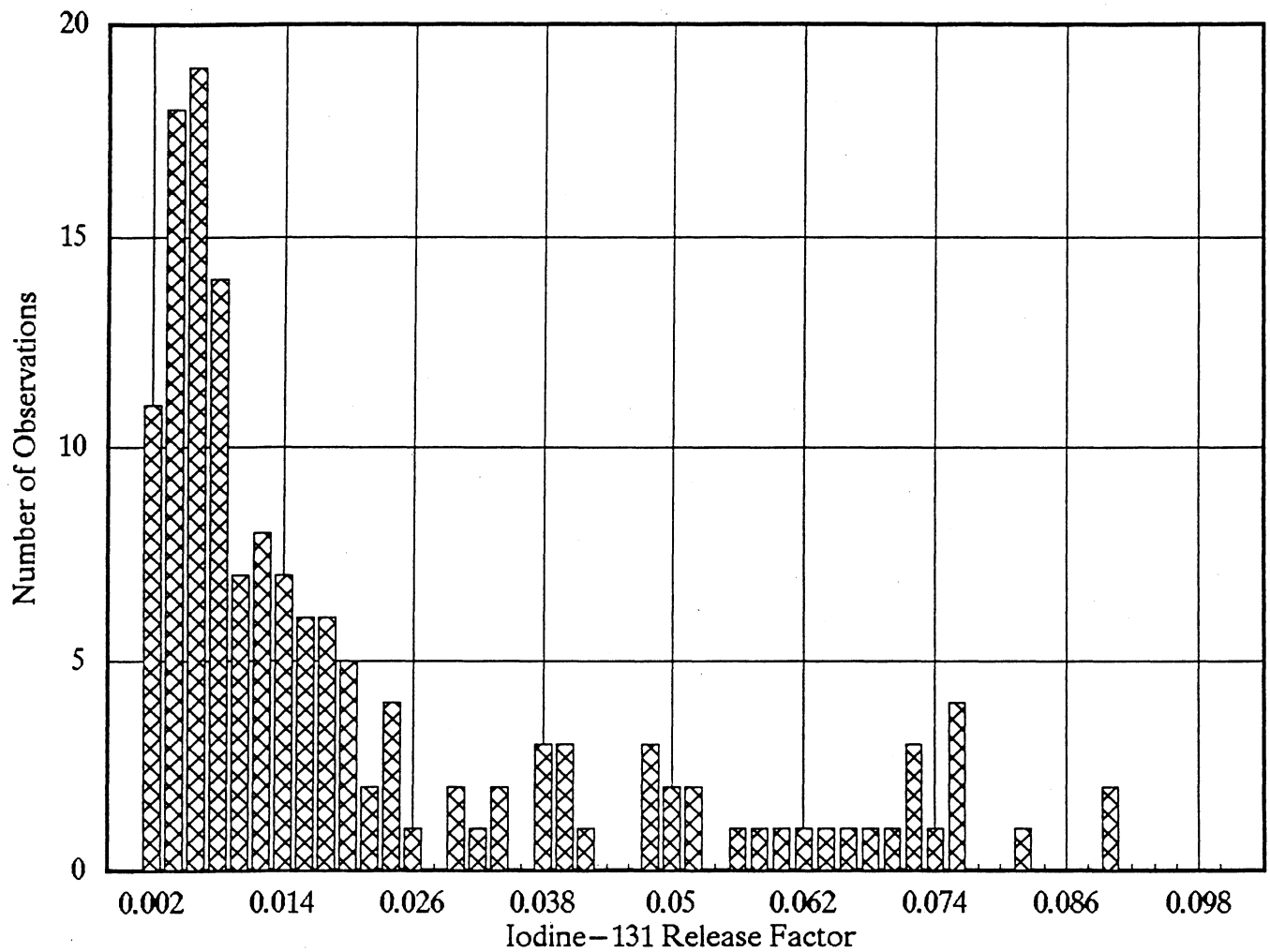

Figure 4.1. Histogram of Iodine-131 Release Factors at the REDOX Plant

PUREX Plant. The PUREX Plant was brought on line in January 1956. Its iodine-removal equipment included water scrubbers, sand filters, silver reactors, and fiberglass filters (Warren 1961). As the last separations plant to be brought on line, its iodine-131 emission control system benefitted from five years of operating experience with silver reactors. Warren (1961) provided PUREX release factor information for 1959 and 1960. Figures 5 and 8 in Warren (1961) display 230 release factor points for the PUREX Plant. The median release factor was computed to be 0.002. A special adjustment was made to this generic release factor to model an unusual event in 1963 when 72 curies of iodine-131 were released to the atmosphere because of the accidental processing of short-cooled fuel (Soldat 1965). Figure 4.2 in this report presents a histogram of the PUREX Plant release factor data.

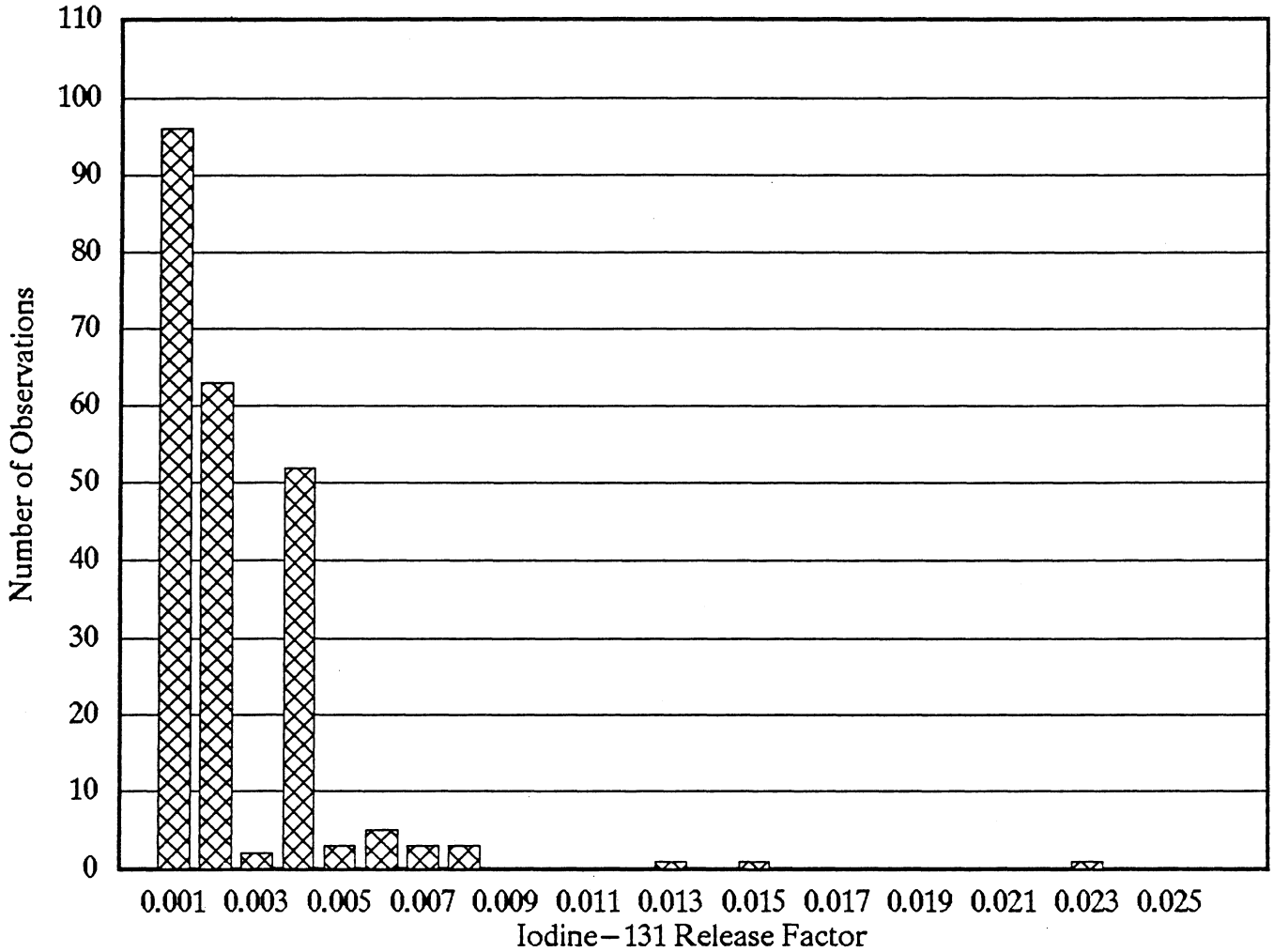

Figure 4.2. Histogram of Iodine-131 Release Factors at the PUREX Plant

Iodine-131 Release Estimates

Figure 4.3 shows a down-trending pattern of iodine-131 releases from the October 1945 peak of 92,066 curies. Iodine-131 releases from all four separations plants after July 1966 were below 1 curie every month. At 92,066 curies, the October 1945 peak was the most notable iodine-131 release. The December 1949 Green Run (Jenne 1950), which released 7,000 curies of iodine-131 from the T Plant, resulted in a monthly iodine-131 release total from all four separations plants of 7,241 curies.

The next iodine-131 release peak occurred in August 1950 and was due to higher processing rates and a reduction in cooling time from the 100- to 90-day range down to the 80- to 70-day range.

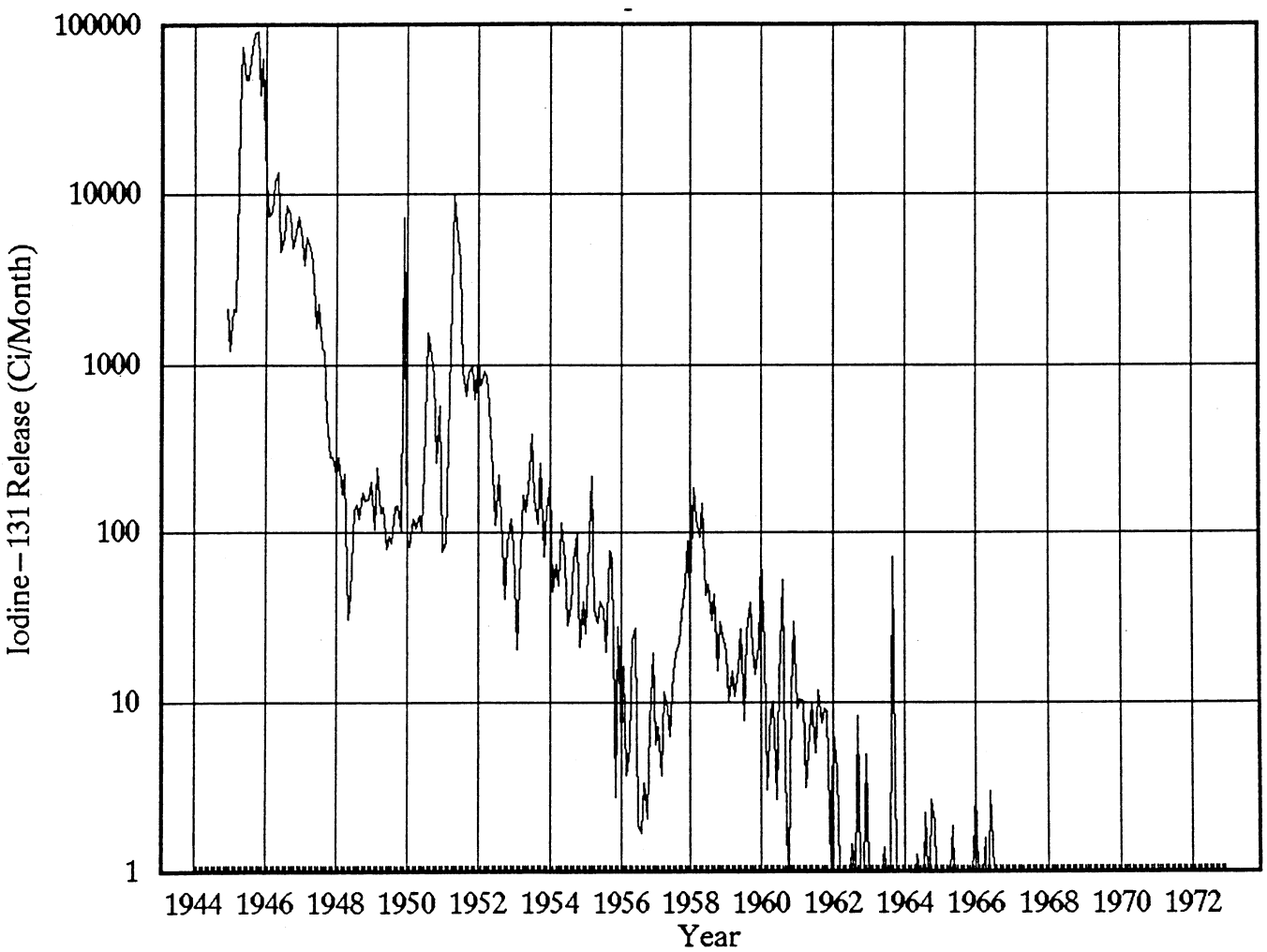

Figure 4.3. Pattern of Estimated Monthly Iodine-131 Releases from Four Separations Plants, 1944-1972

With startup of the silver reactors in January 1951, cooling times were reduced to less than 50 days. This reduction in cooling time, coupled with the break-in problems of the new silver reactor technology, resulted in peak releases centered around the May 1951 release of 9,740 curies.

The next major reversal in the downtrend of iodine-131 releases occurred in the latter half of 1957 through early 1958. Iodine-131 releases increased during this period, reaching a peak of 183 curies in February 1958. This increase was caused in part by increasing power levels in the production reactors, which resulted in increased iodine-131 content in the spent fuel and higher tonnage throughputs. The major cause of increased iodine-131 releases, though, was the reduction in fuel-cooling times from the 200- to 150-day range to ranges of 90 to 100 days.

A controlled-release experiment was conducted at the REDOX Plant in September 1962 (Brouns et al. 1963). This event resulted in an 8-curie iodine-131 release, which was considerably higher than the 1-curie releases normally measured during this period.

An accidental release of 72 curies occurred at the PUREX Plant in September 1963 when a load of short-cooled fuel was mistakenly shipped from the production reactor (Soldat 1965).

Iodine-131 Uncertainty, 1950-1972

Uncertainty in the Curies Processed. The uncertainty in curies processed is the product of five independent factors.

1) **Number of tons processed during the month.** The number of tons processed was well known because it played a key part in the plutonium-accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **Peaking Factor.** The ratio of the average power of fuel in a discharge to the average power of the reactor (a multiplier on iodine-131 content) approaches 1.1 as the reactor attains an equilibrium operating mode (Heeb 1993). The range would run from a low of 0.4 to a high of 1.6 (Heeb 1993) if all the fuel in a discharge came from the low-powered fringe or from the high-powered central zone, respectively. A triangular distribution with a minimum of 0.40, mode of 1.1, and maximum of 1.6 characterizes the peaking factor uncertainty. The mean is 1.033 and the variance 0.0606.

3) **Saturation Factor.** The ORIGEN2 burnup calculation which provided the curie per ton values is done at constant power for the period of time sufficient to reach the burnup specified; that is, the period of time required for iodine-131 to reach a steady-state (saturation) value (Heeb 1993). Roughly 52 days of steady operation are required to reach 99-percent iodine-131 saturation of the fuel, and the average operating period actually ranged from 7 to 14 days. This shorter operating period meant that the fuel was not actually saturated with iodine-131. Therefore, the use of ORIGEN2 to calculate curie per ton values results in overestimation of the iodine-131 curie content at shutdown. The lifetime average time-operated efficiency (TOE) of Hanford single-pass reactors was calculated to be 78.8 percent. However, this figure included construction and maintenance outages of relatively long duration. For normal operation, which was the condition of the reactor when most discharges occurred, the TOE was

closer to 90 percent. The iodine content of the pile was calculated for five operating periods of 9 days each, followed by 1 day down. The iodine-131 content at shutdown after the fifth operating period (day 49) was calculated. This figure was compared to the iodine-131 content after 45 days of continuous operation (98-percent saturated). Hence, the ratio of five-cycle to continuous operation was 0.86 or 86-percent saturation. A similar calculation was completed for 50 ten-day operating cycles, yielding a saturation of 85 percent. A triangular distribution with a minimum of 0.80, a mode of 0.85, and a maximum of 0.90 was chosen to represent saturation uncertainty. The mean is 0.85 and the variance 0.000417.

4) **Cooling Time.** To estimate the uncertainty in curie content of iodine-131 due to the distribution of actual fuel-batch cooling times within the month, it was assumed that the separations plants operated 80 percent of the time. Under this assumption, if the whole block of processing started on the first day of the month, the separations plants were idle during the last six days of the month: 30.5 x (1.0 - 0.80) = 6.1. If the block of processing started on the seventh day of the month, processing continued through the last day of the month. In either case, the maximum error would be 6 days. Given the 8-day half-life of iodine-131 *with a decay rate of* $e^{-0.0862t}$, a uniform distribution with an upper bound of 1.68 ($e^{-0.0862(-6)}$) and a lower bound of 0.60 ($e^{-0.0862(6)}$) results. The mean is 1.137 and the variance is 0.0974.

5) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in iodine-131 release values because of use of a N Reactor spectrum-averaged cross section library for ORIGEN2 was 3.6 percent. A uniform distribution from 0.982 to 1.018 models this uncertainty. The mean is 1.0 and the variance 0.000108.

The five components of the curies-processed uncertainty are summarized in Table 4.5. Statistical variances, medians, and means are calculated using standard formulas (Simpson and Ramsdell 1993).

Table 4.5. Summary of Iodine-131 Curies-Processed Uncertainty Distributions

Component	Distribution	Minimum	Mode	Maximum	Variance	Median	Mean
Tons	Uniform	0.95		1.05	0.00083	1.0	1.00
Peaking Factor	Triangular	0.4	1.1	1.6	0.0606	1.04	1.033
Saturation	Triangular	0.80	0.85	0.90	0.000417	0.85	0.85
Cooling Time	Uniform	0.60		1.68	0.097	1.14	1.14
ORIGEN2 Uncertainty	Uniform	0.98		1.02	0.000108	1.0	1.0

Generic Release Factor Uncertainty. The generic uncertainty factor for iodine-131 released from the PUREX and REDOX plants was based on the measurements provided in Warren (1961). Inspection of the data showed the release factors to be lognormally distributed. The mean values and standard deviations for the two plants are shown in Table 4.6.

Table 4.6. Mean and Standard Deviation of the Natural Logarithm of the Iodine-131 Release Factors for the REDOX and PUREX Plants

Plant	Mean ln(RF)	Standard Deviation	Number of Measurements
REDOX	-4.3	1.43	158
PUREX	-6.30	0.624	230

For the purposes of this discussion, a single standard deviation based on the total amount of fuel processed at the REDOX and PUREX plants was calculated. This standard deviation was calculated using Equations (D.3) and (D.4). This value was then multiplied by a weighting factor to obtain a standard deviation for each plant. The weighting factor was the fraction of fuel processed at the plant. Thus, the weighting factor for the REDOX Plant was 392,000/(392,000+508,000) = 0.435. A similar calculation produced a weighting factor of 0.564 for the PUREX Plant. The combined mean is -5.43 and the variance 0.509.

Using Equations (D.5) and (D.6), the lognormally distributed expected release value is 0.00567 and the variance is 0.000021359.

Release Uncertainty

The expected value for the release using Equation (D.3) is 0.006150 and the variance using Equation (D.4) is 0.00003384.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a 95-percent confidence level factor of 4.8. The ratio of the upper-bound factor to the lower-bound factor is $4.8^2 = 23.0$, the total width of the iodine-131 uncertainty.

4.2.2 Ruthenium-103 and Ruthenium-106

Ruthenium Release Factors

The chemical separations processes did not distinguish between ruthenium-103 and ruthenium-106. In the discussion that follows, elemental ruthenium is referred to simply as "ruthenium." Where data or estimates under discussion are isotope-specific, the isotope number is listed.

T and B Plants. Release factors calculated for the REDOX and PUREX plants were applied to T and B plants because the emission control devices at T and B plants were similar to those in place at the REDOX and PUREX plants.

REDOX Plant. Roberts (1958, p. 6) gives quarterly estimates of the number of curies per day of ruthenium released from the REDOX Plant from 1952 through 1957. Roberts (1958) also calculated

the number of curies of ruthenium processed each month for this period. Apparent monthly values of the effective ruthenium release factor were calculated assuming a uniform monthly release rate for each quarter. These release factors range from 1.7×10^{-4} to 5.1×10^{-8} with an average of 7.5×10^{-6}. The wide range of apparent release factor values does not reflect any variation in the true release factor for ruthenium. Instead, these widely divergent values are required to reproduce the sporadic releases using a production-related method of release estimation. Roberts' estimates included particulate releases of ruthenium that were not directly related to the number of curies processed during the quarter.

McConnon (1962) gives ruthenium release information from the REDOX Plant stack in terms of an average curies per day rate on a monthly basis during 1961. Both particulate and gaseous ruthenium are included. The measurement system employed two mechanisms for trapping ruthenium: 1) HV-70 filter paper, which was capable of retaining particulates as small as 2 microns in diameter and 2) a water scrubber, which retained gaseous ruthenium as well as particulates smaller than 2 microns in diameter. Analysis of the amount of ruthenium removed by the two processes led to calculation of an average removal efficiency of 6.8 percent for the paper filter (McConnon 1962). Thus, 93.2 percent of the ruthenium released must have been in gaseous form (probably ruthenium tetroxide) or associated with particles smaller than 2 microns in diameter.

The amount of ruthenium processed at the REDOX Plant each month was estimated in the present report. The average release factor over the twelve months was determined to be 0.75×10^{-7} with a standard deviation of 0.41×10^{-7}.

PUREX Plant. McConnon (1962) provides a monthly average of curies per day of ruthenium released from the PUREX Plant. These estimates were based on measurements of the amount of activity retained on filter paper. No water-scrubber measurements were reported. The assumption was made that ruthenium release factors for the PUREX Plant were similar to those at the REDOX Plant, so a removal efficiency of 6.8 percent was used to calculate ruthenium release estimates from the PUREX Plant. The amount of ruthenium processed at the PUREX Plant each month was calculated and a monthly effective ruthenium release factor was calculated. The average ruthenium release factor over the twelve months was 1.3×10^{-7}, with a standard deviation of 1.1×10^{-7}.

Generic Ruthenium Release Factors

The release factors calculated for the REDOX and PUREX plants agreed with the monthly estimates of the release factor determined from the Roberts (1958) data for those periods of stable operation when no non-current-production particulates were being released. These periods were characterized by release factors ranging around 1.0×10^{-7}. A generic ruthenium release factor of 1.0×10^{-7} was used for all four separations plants after installation of emission-control equipment in May 1948.

A higher generic ruthenium release factor was applied to T and B plant operations for the period before installation of water scrubbers in May 1948. During this period, no emission control equipment was in operation. The water scrubbers were assumed to be at least 99-percent efficient in removing ruthenium (Uebelacker 1960). Therefore, a generic ruthenium release factor of 1×10^{-5} was used for T and B plant operations before May 1948. (The release factor for prescrubber operation was increased two orders of magnitude to account for increased releases due to the absence of off-gas scrubbers.)

Ruthenium Release Estimates

Figures 4.4 and 4.5 show that ruthenium releases from the four separations plants were below 100 curies every month except for January, February, and March 1954. Release peaks in the calculations are due to incorporation of release factors that were calculated from estimates of quarterly releases that included episodic releases from the REDOX Plant (Roberts 1958). Hot particles were ruthenium-loaded particles from separations plant stacks that were not related to the number of tons of uranium being processed. Creation of these particles depended instead on conditions within the plant. These conditions included 1) creation of ammonium compounds, 2) hyperoxidation, which leads to the formation of volatile and reactive ruthenium tetroxide (REDOX Plant only), and 3) the condition of the building ventilation system ductwork. Flakes containing ruthenium fell off the ductwork at T and B plants, contributing to temporary high ruthenium releases. Because these conditions are not directly

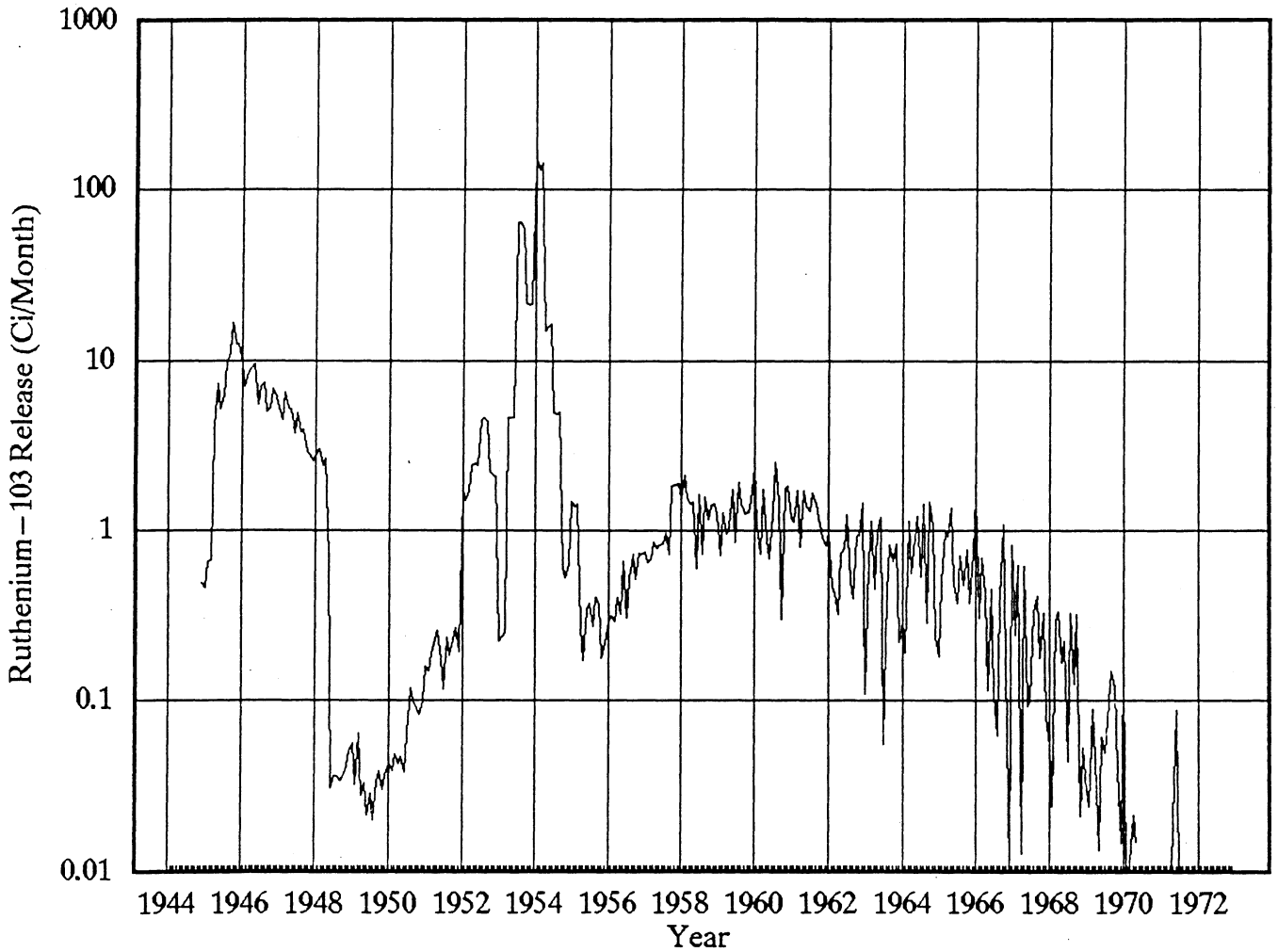

Figure 4.4. Pattern of Estimated Monthly Ruthenium-103 Releases from Four Separations Plants, 1944-1972

related to the number of tons of fuel being processed, the release factors that incorporate the unrelated measurements are artificially high in order to model the release.

Ruthenium Uncertainty

- Ruthenium-103

Uncertainty in Curies Processed. The uncertainty in curies processed is the product of three independent factors.

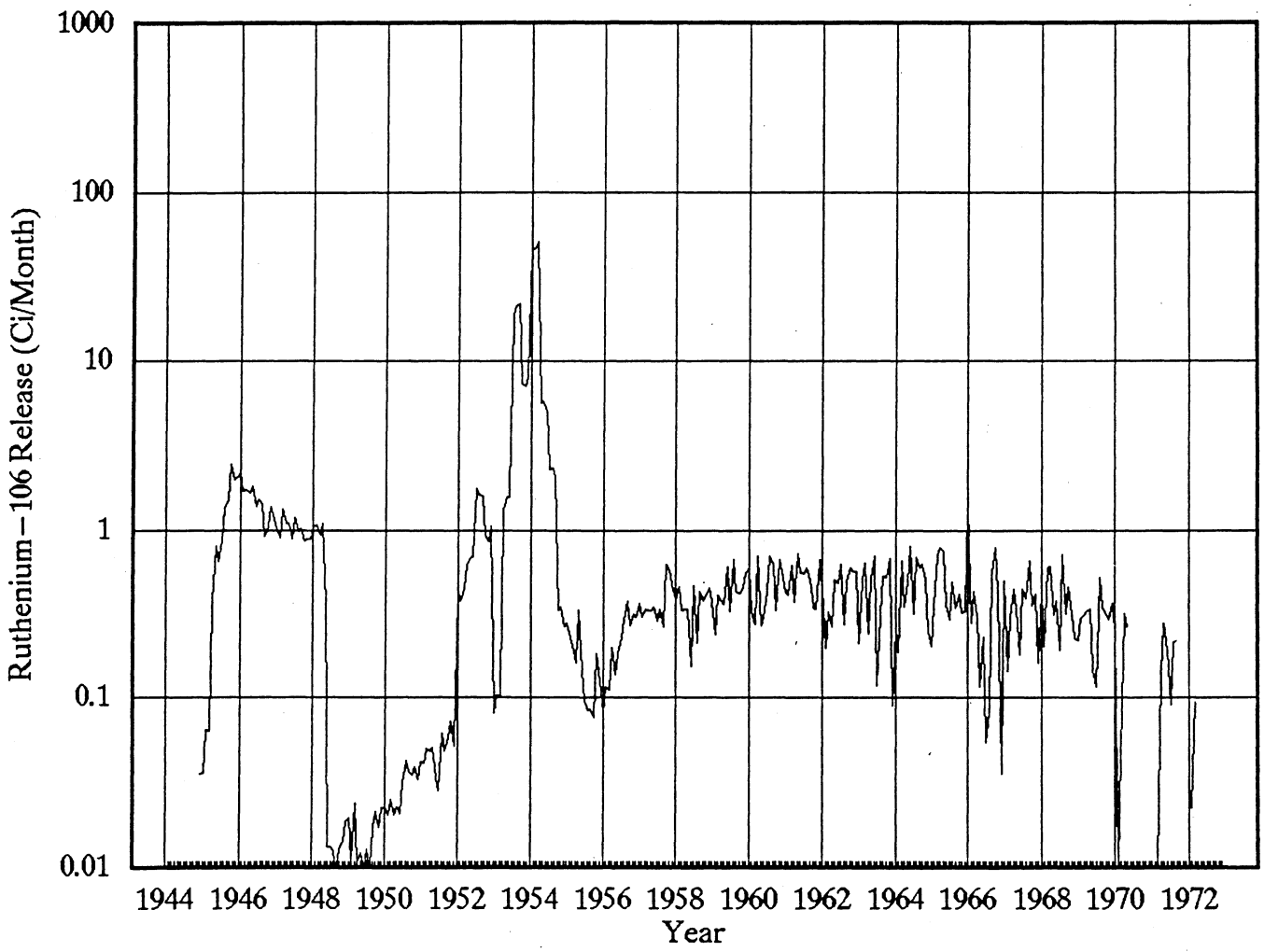

Figure 4.5. Pattern of Estimated Monthly Ruthenium-106 Releases from Four Separations Plants, 1944-1972

1) **Number of tons processed during the month.** The number of tons processed was well known because it played a key part in the plutonium-accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **Cooling time.** To estimate the uncertainty in curie content of ruthenium-103 due to the distribution of actual fuel-batch cooling times within the month, it was assumed that the separations plants operated 80 percent of the time. Under this assumption, if the whole block of processing started on the first day of the month, the separations plants were idle during the last six days of the month: 30.5 x (1.0 - 0.80) = 6.1. If the block of processing started on the seventh day of the month, processing continued through the last day of the month. In either case, the maximum error would be 6 days. Given the 39.4-day half-life of ruthenium-103, a uniform distribution with an upper bound of 1.11 ($e^{-.01759(-6)}$) and a lower bound of 0.900 ($e^{-0.01759(6)}$) results. The mean is 1.006 and the variance is 0.003728.

3) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in ruthenium-103 release values because of the use of a N Reactor spectrum-averaged cross-section library for ORIGEN2 was 7.6 percent. A uniform distribution from 0.962 to 1.038 models this uncertainty. The mean is 1.0 and the variance 0.000481.

Generic Release Factor Uncertainty. The generic uncertainty factor for ruthenium released from the PUREX and REDOX plants was based on measurements provided by McConnon (1962). Inspection of the data showed the release factors to be lognormally distributed. The mean values and standard deviations for the two plants are shown in Table 4.7.

Table 4.7. Mean and Standard Deviation of the Natural Logarithm of the Ruthenium-103 Release Factors for the REDOX and PUREX Plants

Plant	Mean ln(RF)	Standard Deviation	Number of Measurements
REDOX	-16.6	0.813	12
PUREX	-16.2	0.933	12

For the purposes of this discussion, a single standard deviation based on the total amount of fuel processed at the REDOX and PUREX plants was calculated. This standard deviation was calculated using Equations (D.3) and (D.4). This value was then multiplied by a weighting factor to obtain a standard deviation for each plant. The weighting factor was the fraction of fuel processed at the plant. Thus, the weighting factor for the REDOX Plant was 392,000/(392,000+508,000) = 0.435. A similar calculation produced a weighting factor of 0.564 for the PUREX Plant. The combined mean is -16.4 and the variance 0.403.

Using Equations (D.5) and (D.6), the lognormally distributed expected release value factor value is 9.58×10^{-8} and the variance is 4.50×10^{-15}.

Release Uncertainty

The expected value for the release using Equation (D.3) is 9.58×10^{-8} and the variance using Equation (D.4) is 4.62×10^{-15}.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a factor of 3.5. The ratio of the upper bound factor to the lower bound factor is $3.5^2 = 12.2$, the total width of the ruthenium-103 uncertainty.

- Ruthenium-106

32 **Uncertainty in Curies Processed**. The uncertainty in curies processed is the product of *only* two independent factors *because the 368-day half-life eliminated cooling time uncertainty.*

1) **Number of tons processed during the month.** The number of tons processed was well known because it played a key part in the plutonium-accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in ruthenium-106 release values because of the use of a N Reactor spectrum-averaged cross-section library for ORIGEN2 was 28.3 percent. A uniform distribution from 0.86 to 1.14 models this uncertainty. The mean is 1.0 and the variance 0.00667.

Generic Release Factor Uncertainty

The uncertainty analysis used for ruthenium-103 applies to ruthenium-106 because the radionuclides are chemically identical.

Release Uncertainty

The expected value for the release using Equation (D.3) is 9.58×10^{-8} and the variance using Equation (D.4) is 4.62×10^{-15}.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a 95-percent confidence level factor of 3.5. The ratio of the upper bound factor to the lower bound factor is $3.5^2 = 12.2$, the total width of the ruthenium-106 uncertainty.

4.2.3 Cerium-144

Cerium-144 Release Factors

The only data available on cerium releases were found in Anderson (1958b), which provides data on cerium releases from the REDOX Plant during September 1958. One data point provided by this report is a reading of 0.097 curies per 24-hour period from a REDOX stack strip-filter monitor. However, the report cautions that because this value includes both cerium-141 and cerium-144 and the ratio of the two isotopes was unknown, the reported cerium-144 releases could be in error by as much as a factor of ten. A cerium-144 release factor of 5.25×10^{-7} was calculated for the REDOX Plant by multiplying the daily release rate by 30 days then dividing by the 5,520,000 curies of cerium-144 processed at the REDOX Plant in September 1958. This cerium-144 release factor was applied to all four separations plants for the operations period after installation of emission-control equipment in May 1948. A release factor of 5.25×10^{-5} was applied to T and B plant operations for the period before 1948. (The release factor for prescrubber operations was increased two orders of magnitude to account for increased releases because of the absence of off-gas scrubbers.)

Cerium-144 Release Estimates

Figure 4.6 shows that cerium-144 releases reached their maximum value of slightly less than 100 curies per month in 1945. These cerium releases were largely due to the lack of emission control equipment (water scrubbers and sand filters) in the T and B separations plants at that time. Installation of water scrubbers reduced the cerium-144 release factor by an estimated two orders of magnitude in May 1948. However, cerium-144 releases increased steadily despite the installation of emission-control devices because of increased production from additional reactors coming on line and because of increased power levels in the existing reactors. Cerium-144 releases peaked again at 34 curies per month in January 1966.

Cerium-144 Uncertainty

Uncertainty in Curies Processed. The uncertainty in curies processed is the product of only two independent factors because the 284-day half-life eliminates cooling time uncertainty.

1) **Number of tons processed during the month**. The number of tons processed was well known because it played a key part in the plutonium accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in cerium-144 release values because of the use of a N Reactor spectrum-averaged cross-section library for ORIGEN2 was 3.6 percent. A uniform distribution from 0.982 to 1.018 models this uncertainty. The mean is 1.0 and the variance 0.000108.

Generic Release Factor Uncertainty. The generic uncertainty factor for cerium-144 is based essentially on one data point. An uncertainty factor of 15 was assigned to the release factor. A uniform distribution was selected with a lower bound calculated by dividing the release factor value

(5.25×10^{-7}) by 15 to give 3.5×10^{-8}. The upper bound of 7.9×10^{-6} results from multiplying the release factor by 15. The mean of the uniform distribution is 4.0×10^{-6} and the variance is 5.1×10^{-12}.

Release Uncertainty

The expected value for the release using Equation (D.3) is 4.0×10^{-6} and the variance using Equation (D.4) is 5.1×10^{-12}.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a factor of 2.8. The ratio of the upper bound factor to the lower bound factor is $2.8^2 = 7.84$, the total width of the cerium-144 uncertainty.

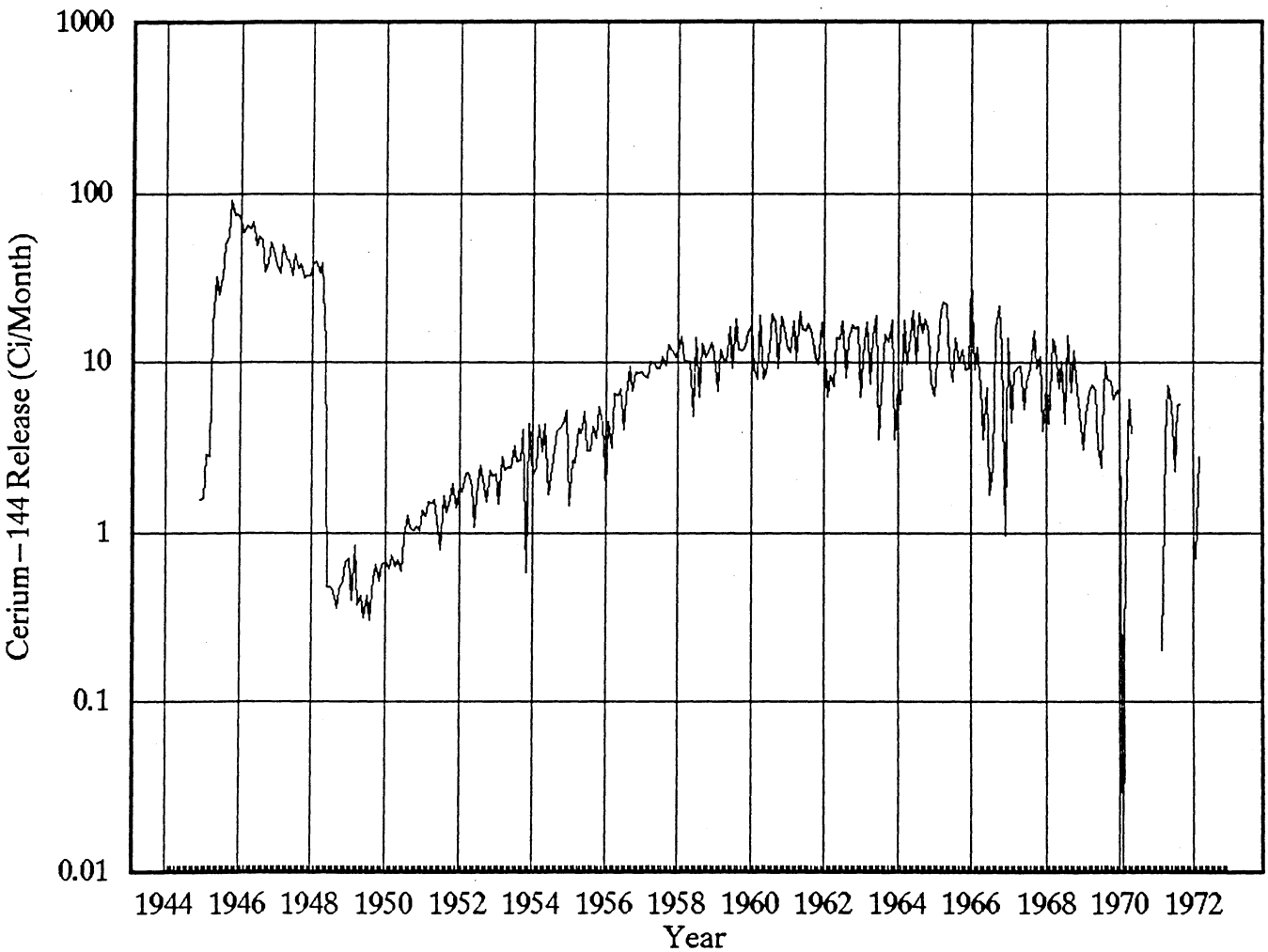

Figure 4.6. Pattern of Estimated Monthly Cerium-144 Releases from Four Separations Plants, 1944-1972

4.2.4 Strontium-90

Strontium-90 Release Factors

33 Anderson (1958a) provides average curies per day for strontium-90 releases from vent stack effluent in the "separations areas" (specific separations plants not listed) during 1957. Using *those* data along with information on the number of curies of strontium-90 processed, *which were determined from the material tons processed and the curie inventory per ton from ORIGEN2*, a generic release factor was calculated: *.005 curies/day * 365 days/year / 9,517,000 curies processed = 1.9 x 10^{-7} release factor.* Emissions control equipment was assumed to have been about 99-percent efficient, so the early period strontium-90 release factor was calculated at 1.9 x 10^{-5}. (The release factor for prescrubber operations was increased two orders of magnitude to account for increased releases due to the absence of off-gas scrubbers.) The release factors were rounded to 2.0 x 10^{-5} for all plants for the operations period before May 1948 and 2.0 x 10^{-7} for all plants for the operations period after installation of emission-control equipment in May 1948.

Strontium-90 Release Estimates

Figure 4.7 shows that strontium-90 releases were largest in the early period of separations plant operations, reaching a maximum of 1.387 curies during the month of October 1945. Releases were reduced after water scrubber installation in May 1948. The late-period maximum was reached in October 1966 with a strontium-90 release estimate of 0.4 curies for the month.

Strontium-90 Uncertainty

Uncertainty in Curies Processed. The uncertainty in curies processed is the product of only two independent factors because the 29-year half-life eliminates cooling time uncertainty.

1) **Number of tons processed during the month.** The number of tons processed was well known because it played a key part in the plutonium accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in strontium-90 release values because of the use of a N Reactor spectrum-averaged cross-section library for ORIGEN2 was 7.0 percent. A uniform distribution from 0.965 to 1.035 models this uncertainty. The mean is 1.0 and the variance 0.000408.

34,35 **Generic Release Factor Uncertainty**. The generic uncertainty factor for strontium-90 is based essentially on one data point *(Andersen 1958a)*. A factor of 10 uncertainty was assigned to the release factor; *this is a standard assumption when there is only one datum available.* A uniform distribution was selected with a lower bound calculated by dividing the release factor value (1.9 x 10^{-7}) by 10 to give 1.9 x 10^{-8}. The upper bound of 1.9 x 10^{-6} results from multiplying by 10. The mean of the uniform distribution is 9.6 x 10^{-7} and the variance is 2.9 x 10^{-13}. *The measured value is the one used in the release calculation, and the uniform distribution expected value is used as the mean of one of the factors determining the variance of that product (the release).*

Release Uncertainty

The expected value for the release using Equation (D.3) is 9.6×10^{-7} and the variance using Equation (D.4) is 2.9×10^{-13}.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a 95-percent confidence level factor of 2.8. The ratio of the upper bound factor to the lower bound factor is $2.8^2 = 7.84$, the total width of the strontium-90 uncertainty.

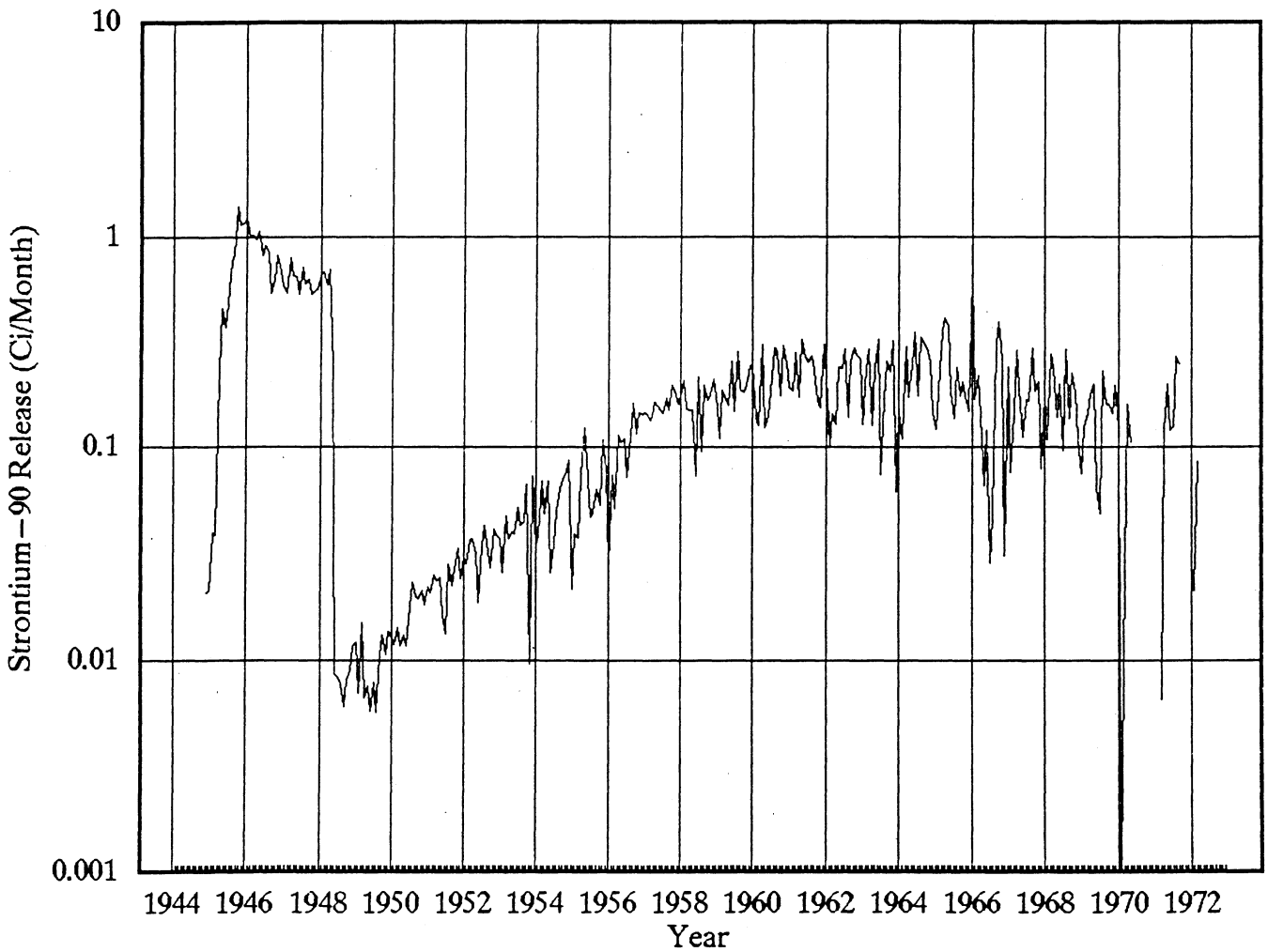

Figure 4.7. Pattern of Estimated Monthly Strontium-90 Releases from Four Separations Plants, 1944-1972

4.2.5 Plutonium-239

Plutonium-239 Release Factors

Records of plutonium release measurements from all four separations plant vent stacks were made available by J. K. Soldat.[a] Generic release factors were calculated by dividing the curies of plutonium-239 released during a given time period by the curies of plutonium-239 processed during that period. Release data and release factor data are provided in Table 4.8. A sample release factor calculation follows the table.

T and B Plants

The T and B plant plutonium-239 release factor was based on the combined plant average monthly release of 3.9×10^{-7} (rounded to 4.0×10^{-7}) for operations after installation of emission-control equipment in May 1948. Emission-control equipment was assumed to have been about 99-percent efficient, so the early period plutonium-239 release factor for the T and B plants was 4.0×10^{-5}. (The release factor for prescrubber operations (1944-1948) was increased two orders of magnitude to account for increased releases because of the absence of off-gas scrubbers.)

REDOX Plant

Based on the data provided in Table 4.8, an average value of 1.5×10^{-7} was calculated for the plutonium-239 release factor at the REDOX Plant. This average was rounded to 2.0×10^{-7} and applied to the entire period of operation, as emission-control equipment was installed before the plant went on line.

PUREX Plant

Based on the data provided in Table 4.8, a 2.0×10^{-9} plutonium-239 release factor was calculated for the PUREX Plant. This value applied to the entire period of operation, as emissions control equipment was installed before the plant went on line.

Plutonium-239 Release Estimates

Figure 4.8 shows that plutonium-239 releases were largest in the early period of separations plant operations, reaching a maximum of 0.0755 curies during the month of October 1945. Releases were reduced after water-scrubber installation in May 1948. The late-period maximum was reached in January 1966, with a plutonium-239 release value of 0.006456 curies for the month.

With a half-life of 24,110 years, plutonium-239 has the longest half-life of any of the six radionuclides being studied in this report. Specific activity is inversely proportional to half-life. With a specific activity of only 0.06 curies per gram, a one-curie release of plutonium-239 represents 16 grams.

(a) Memorandum (HEDR Project Document No. 10930320), "Plutonium and Uranium Releases from Hanford Separations Facilities/Raw Data," from J. K. Soldat (BNW) to HEDR Project Office, October 26, 1993.

Table 4.8. Plutonium-239 Release Factor Estimates

T and B Plant Data					
Plant	Measurement Period	Month/Year	Pu-239 Average Curies/Month	Total Curies Pu-239 Processed	Release Factor
T & B	4th Q '51	10/51	9.61×10^{-4}		
		11/51	9.61×10^{-4}		
		12/51	9.61×10^{-4}		
	Total for the Quarter		2.883×10^{-3}	10520	2.7×10^{-7}
B	1/8-15/52	1/52	5.3×10^{-5}	1610	3.3×10^{-8}
B	2/5-12/52	2/52	2.41×10^{-4}	1620	1.5×10^{-7}
B	2/12/3/6/52	3/52	1.48×10^{-4}	898	1.7×10^{-7}
B	3/6-4/14/52	4/52	1.83×10^{-4}	283	6.5×10^{-7}
			Average		2.5×10^{-7}
T	1/8-15/52	1/52	7.13×10^{-4}	2050	3.5×10^{-7}
T	2/5-13/52	2/52	1.219×10^{-3}	1030	1.2×10^{-6}
T	2/13-3/6/52	3/52	8.5×10^{-4}	1940	4.4×10^{-7}
T	3/6-4/15/52	4/52	6.82×10^{-4}	1240	5.5×10^{-7}
			Average		6.3×10^{-7}
		T and B Plant Average			3.9×10^{-7}
	T and B Plant Standard Deviation				3.0×10^{-7}
REDOX Plant Data					
	Measurement Period	Average Month/Year	Pu-239 Curies/Month	Total Curies Release Processed	Factor
	2/5-13/52	2/52	2.64×10^{-4}	1620	1.6×10^{-7}
	2/13-3/6/52	3/52	9.1×10^{-5}	898	1.0×10^{-7}
	3/26-4/15/52	4/52	5.0×10^{-5}	283	1.8×10^{-7}
		REDOX Plant Average			1.5×10^{-7}
PUREX Plant Data December 1957 PUREX Plant Measurements					
		Date	Pu-239 Release (micro curies/day)		
		12/4-5/57	0.068		
		12/5-6/57	0.039		
		12/6-7/57	1.6		
		12/7-9/57	0.018		
		12/9-10/57	0.03		
		12/10-11/57	4.8		
		12/11-12/57	0.2		
		12/14-16/57	0.036		
		12/16-17/57	1.1		
Average for December 1957			0.877 micro curies/day		
PUREX Release Factor Calculation Average release in December: 0.877 micro curies/day. Total December release: 0.877×10^{-6} curies/day x 31 days = 2.7×10^{-5} curies. Curies of plutonium-239 processed in December: 13,500 curies. Release factor: 2.7×10^{-5} curies/13,500 curies = 2.0×10^{-9}.					

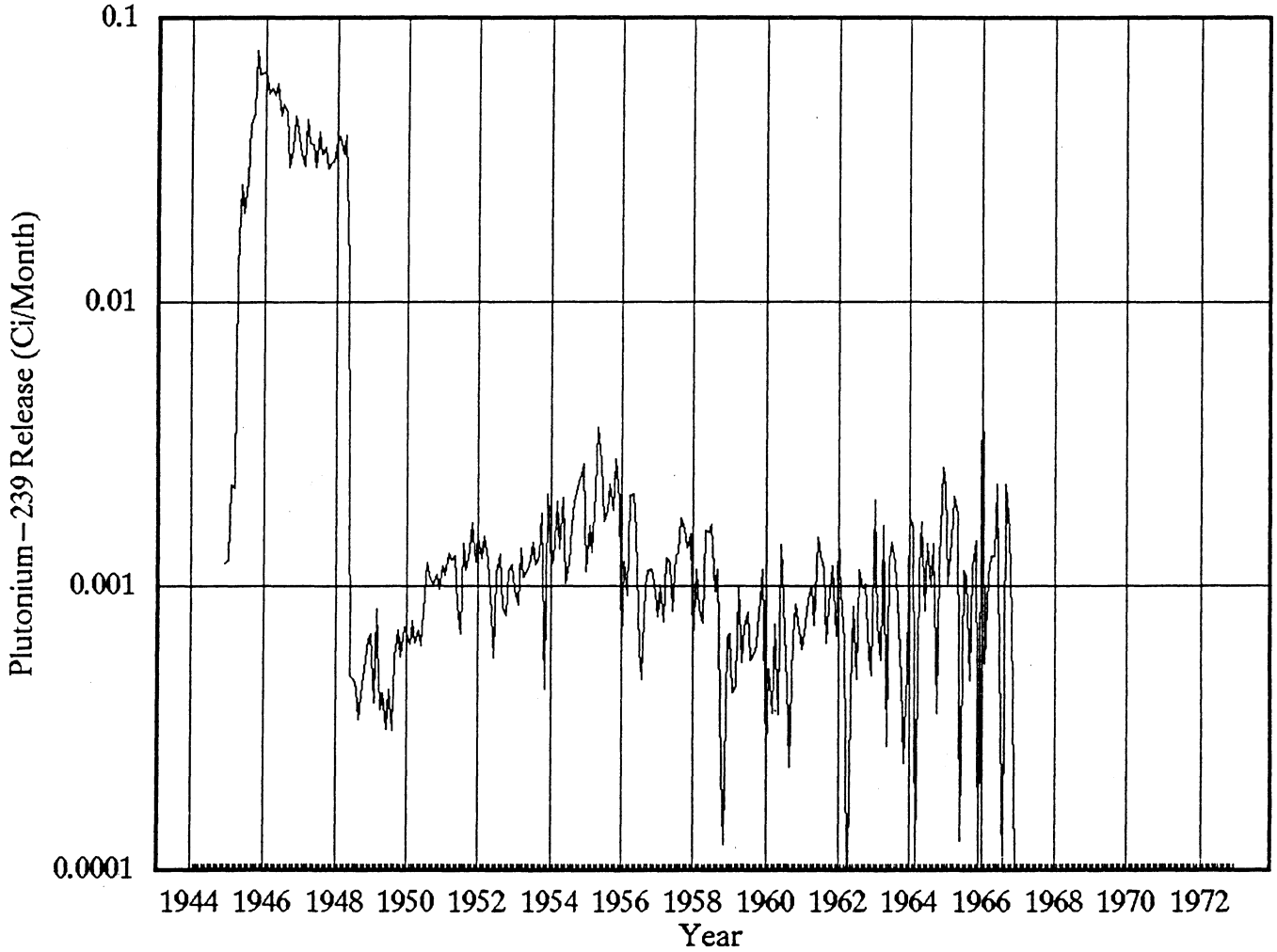

Figure 4.8. Pattern of Estimated Monthly Plutonium-239 Releases from Four Separations Plants, 1944-1972

Plutonium-239 Uncertainty

Uncertainty in Curies Processed. The uncertainty in curies processed is the product of only two independent factors because the 24,000-year half-life eliminates cooling time uncertainty.

1) **Number of tons processed during the month.** The number of tons processed was well known because it played a key part in the plutonium accountability requirements. Some undetected errors may have been made, so a 5-percent allowance was selected to account for this. A uniform distribution with a minimum of 0.95 and a maximum of 1.05 was assumed. The mean is 1.0 and the variance 0.000833.

2) **ORIGEN2 Uncertainty.** As noted in Table 4.2, the uncertainty in plutonium-239 release values because of use of a N Reactor spectrum-averaged cross-section library for ORIGEN2 was 17.3 percent. A uniform distribution from 0.913 to 1.086 models this uncertainty. The mean is 1.0 and the variance 0.002494.

Generic Release Factor Uncertainty. The generic uncertainty factor for plutonium-239 released from all four separations plants was based on the measurements provided by Soldat.[a] Inspection of the data showed the release factors to be lognormally distributed. The mean values and standard deviations for the four plants are shown in Table 4.9.

Table 4.9. Mean and Standard Deviation of the Natural Logarithm of the Plutonium-239 Release Factors for the REDOX and PUREX Plants

Plant	Mean ln(RF)	Standard Deviation	Number of Measurements
T and B Plants	-15.06	0.894	9
REDOX	-15.76	0.250	3
PUREX	- 21.69	1.919	9

For the purposes of this discussion, a single standard deviation based on the total amount of fuel processed at the four plants was calculated. This standard deviation was calculated using Equations (D.3) and (D.4). This value was then multiplied by a weighting factor to obtain a standard deviation for each plant. The weighting factor was the fraction of fuel processed at the plant. Thus, the weighting factor for T and B plants was 193,286/(193,286+882,266+3,389,247) = 0.0432. Similar calculations produced weighting factors of 0.198 for the REDOX Plant and 0.759 for the PUREX Plant. The combined mean is -20.24 and the variance is 2.127.

Using Equations (D.5) and (D.6), the lognormally distributed expected release value factor value is 4.71×10^{-9} and the variance is 1.64×10^{-16}.

Release Uncertainty

The expected value for the release using Equation (D.3) is 4.706×10^{-9} and the variance using Equation (D.4) is 1.64×10^{-16}.

95-Percent Confidence Level Factor

Equations (D.7) and (D.8) yield a factor of 17.5. The ratio of the upper bound factor to the lower bound factor is $17.5^2 = 306.0$, the total width of the plutonium-239 uncertainty.

(a) Memorandum (HEDR Project Document No. 10930320), "Plutonium and Uranium Releases from Hanford Separations Facilities/Raw Data," from J. K. Soldat (BNW) to HEDR Project Office, October 26, 1993.

5.0 Tritium (Hydrogen-3), Carbon-14, and Argon-41 Releases from Reactors

5.1 Reactor Stack Gas Releases

42 Tritium (hydrogen-3), carbon-14, and argon-41 were the major radionuclides released to the air from reactor operations. These radionuclides are produced by the following reactions on a parent nuclide:

- n, gamma: a neutron is absorbed followed by gamma ray emission
- n, p (neutron, proton): a neutron is absorbed followed by proton emission
- *n, alpha: a neutron in is absorbed followed by alpha emission.*

The primary radionuclide releases to the air from the reactor ventilation stacks came from the reactor building[(a)] and from the stack-gas system building.[(b)] The stack gas was a mixture of two makeup gases, carbon dioxide and helium. Both makeup gases were purchased and stored in tanks outside the stack-gas system building. The composition of helium was varied from 0 to 100 percent as a means of reactivity control and also to control the graphite temperature, which was a primary means of controlling the amount of radiation-induced dimensional distortion in the graphite stack.

5.1.1 Tritium in Reactor Stack Gases

Tritium is created by an n, gamma reaction on hydrogen-2; also by an n, p reaction on helium-3. Hydrogen-2 is 0.02 percent abundant in elemental hydrogen. Hydrogen-2 in water (moisture impurity in the reactor stack-gas system) was irradiated and formed tritium. Moisture in the stack-gas system was substantial at times due to process tube leaks, which allowed cooling water to escape to the reactor stack-gas system. The stack-gas system was equipped with silica-gel regenerative driers for moisture control. The other precursor of tritium, helium-3, is 10^{-5}-percent abundant in elemental helium, although there is some variation in this percentage in helium produced from natural gas sources. Purchased helium was purified from commercial natural gas.

The average tritium release rate from reactor operations during 1957 was calculated to be 1.4 curies/day for all reactors. This estimate was based on activity from stack gas that was collected and measured in silica gel scrubbers (Andersen 1958a).

5.1.2 Carbon-14 in Reactor Stack Gases

40a Carbon-14 is produced by an n, p reaction on nitrogen-14, by an n, gamma reaction on carbon-13, *and by an n, alpha reaction on oxygen-17 from the carbon dioxide in the stack gas.* Nitrogen-14

(a) Reactor buildings for the single-pass reactors were assigned the number "105," followed by the letter of the reactor; i.e., the reactor building for B Reactor would be 105B.

(b) Stack-gas system buildings were assigned the number "115."

(99.76 percent abundant in atmospheric nitrogen) present in the reactor stack-gas system came from air leakage into the stack gas from process-tube bellows and from other more minor leakage sources. The carbon-13 precursor was 1.1 percent abundant in the carbon dioxide of the stack gas.

Andersen (1958a) estimates carbon-14 releases at 0.1 curies/day. McConnon (1962, p. 22) gives the sum of average daily carbon-14 releases from all eight single-pass reactors as 0.127 curies/day during 1961. This figure agrees with Andersen's (1958a) estimate of 0.1 curies/day of carbon-14 released during 1957.

5.1.3 Argon-41 in Reactor Stack Gases

Argon-41 is produced by an n, gamma reaction on argon-40, which was present in the air that leaked into the reactor stack-gas system. It was standard practice to maintain a positive stack-gas pressure in order to prevent graphite oxidation from the intake of air. However, to minimize helium losses, which remained a continuing problem and expense, the stack-gas pressure was maintained as low as possible. Inevitably, errors in pressure control occurred and air was drawn into the stack gas. This resulted in a great operational inconvenience because of activation of argon-40 (99.632-percent abundant in elemental argon which is present in air at a level of 0.94 percent). The argon-41 thus formed blew back out of the stack gas when positive pressure was restored. Before the reactor building air exited out the stack, the argon-41 activated the building air activity monitors, forcing evacuation of the parts of 105 Building that were previously habitable during operation. This, combined with the fact that each in-leakage incident resulted in some loss of graphite by oxidation, assured that every effort was made to hold incidents of this type to a minimum.

4c,7, 14b, 40b-e, 42 *Paas (1953) cites measured argon-41 activity concentration in reactor stack gas. The measurements were made over a period of three months at the end of 1952 and beginning of 1953. The number of measurements is not documented, but the maximum and average at each reactor is reported. The nominal stack gas flow rates (General Electric Company 1963) are used to convert the activity concentration in microcuries per cubic centimeter to a daily argon-41 emission rate (curies/day). The measurements from available records are shown in Table 5.1*

Pass (1953) considered the C Reactor values inexplicably low. Excluding this value, the average over the five reactors is .000038 microcuries per cubic centimeter with a standard deviation of .0000239 (0.63 coefficient of variation). An average emission rate for each reactor can be calculated by multiplying the units conversion factor of 40.78 times stack flow (cfm) by the average activity concentration of 0.000038 μCi/cc. The estimated reactor emission rates are shown in Table 5.2.

The uncertainty of release and dose is driven by the uncertainty in the measured average activity concentration. To avoid the problem of negative activity concentrations, HEDR researchers assumed that the uncertainty is lognormally distributed with a mean of 1 and a standard deviation of 0.63 (coefficient of variation of the five data points in the average). The 95-percent uncertainty multiplier (see Equation D.5 and following lines in Appendix D) would be 3.1 for the upper bound and 0.32 for the lower bound. The releases are, therefore, bounded by a factor of 3 at the 95 percent level. The doses at a factor of 3 times the sum of releases from the eight reactors remain low from this source.

Table 5.1. Argon-41 Measured Emission Rates from Reactor Stack Gas

Reactor	1952 and 1953 Sampling Periods	Ar-41 Max (μCi/cc)	Ar-41 Avg (μCi/cc)	Stack flow (cfm)	Ar-41 (Ci/Day)
H	10/28-11/14	.000066	.000048	160000.	313
DR	12/11-12/15	.000106	.000080	85000.	277
D	12/18-12/24	.000039	.000023	100000.	94
F	1/5-2/9	.000027	.000017	100000.	69
B	2/9-2/25	.000039	.000020	100000.	82
C	3/16-3/18	<.000004	<.000004	135000.	22

Table 5.2. Reactor Argon-41 Estimated Reactor Stack Activity

Reactor	Stack Flow (cfm)	Release Rate (Ci/Day)
B	100,000	155
C	135,000	209
D	100,000	155
DR	85,000	132
F	100,000	155
H	160,000	248
KE	142,000	220
KW	135,000	209
Total	957,000	1,483

The annual releases from the three stack gas radionuclides are estimated from the daily release rate:

Radionuclide	Ci/Day	Ci/Year
H-3	1.4	511
C-14	0.1	36.5
Ar-41	1480	540,000

During the 1980s, N Reactor released between 65,000 and 120,000 curies/year of argon-41, as published in the Hanford Site annual reports (Jaquish and Mitchell 1988; Jaquish and Bryce 1989, 1990; PNL 1987; Price et al. 1984, 1985; Price 1986). This compares to 68,000 curies per year/reactor (estimated by dividing 541,000 curies by eight reactors.)

The radiological impact of tritium, carbon-14, and argon-41 releases was estimated using the GENII code (Napier et al. 1988). The dose calculations depend on the height of the stacks. The five old reactors (B, F, D, H, DR) had 200-foot vent stacks (General Electric Company 1963, p. 189). The two K reactors had 300-foot stacks (General Electric Company 1963, p. 131).

An individual living along the northeast border of the Hanford Site, near Highway 24 on the Wahluke Slope was chosen as a likely maximum dose candidate. This location is slightly farther away from the reactors than some other Hanford Site boundary locations, but it is the location of the highest annual average air concentrations because the winds in the 100 Areas blow primarily from west-southwest to the east-northeast along the Columbia River valley (Stone et al. 1983, p. A.IV-2). The doses to individuals were dominated by the argon-41 air submersion component. Because argon-41 has a half-life of only 110 minutes, the average transit time from the release point to the individual location is an important parameter.

The highest dose rate to an individual living at the maximum potential location occurs when all eight reactors are operating. The dose rate from all the reactors together is 2 to 4 millirem/year. For years in which fewer reactors are operating, the doses scale approximately linearly with the number of reactors on line. The reactors are very nearly aligned in a straight line with respect to this location, between 10 and 25 kilometers away. Because the dose is so dependent on travel time, the actual dose contribution by reactor-year ranges from about 0.2 to 0.8 millirem. Doses were estimated using the default Hanford Site maximum individual parameters incorporated in the GENII code.

5.2 Effluent Cooling-Water Releases

The possibility that tritium, carbon-14, and argon-41 were released to the air from effluent cooling water was considered in this report. The temperature of cooling water exiting the reactor increased from 40°C in 1945 to 95°C in the 1960s. This temperature increase resulted from increasing reactor power levels. The vapor pressure of water increases as the temperature increases. At 95°C, the vapor pressure of water is 0.83 atmospheres. *The solubility of gases decreases with the increase of water temperature; therefore, the amount of dissolved gas in the water is estimated to have dropped to about half the concentration after the inlet water was heated in the reactor.* This increased vapor pressure meant that more cooling water evaporated at points where it was vented to the atmosphere. These vent points occurred at the downcomer vent on the roof of the reactor building and at the inlet to the retention basin. No measurement instruments were installed at the downcomer vent or at the inlet to the retention basins. Measurements were performed using hand-held instruments as part of routine radiation monitoring surveys. These hand-held monitors did not provide radionuclide-specific information.

40 ### *5.2.1 Tritium in Reactor Effluent Water*

Tritium in reactor effluent water can be formed by three mechanisms:

- *neutron capture by deuterium (hydrogen-2) which is 0.015 percent abundant in terrestrial water H-2(n,gamma) H-3*
- *ternary fission of native lithium-6 in Columbia River water Li-6 (n,alpha) H-3*
- *ternary fission of native boron-10 in Columbia River water B-10 (n,2alpha) H-3.*

Volatile tritium in reactor effluent water was not considered a source of concern at the time and no nuclide-specific information concerning tritium releases from this source was found.

5.2.2 Carbon-14 in Reactor Effluent Water

Carbon-14 in reactor effluent water can be formed by three mechanisms:

- *neutron capture by carbon-13 dissolved in Columbia River water C-13 (n,gamma)C-14*
- *neutron capture on oxygen-17 in Columbia River water O-17(n,alpha)C-14*
- *neutron capture on nitrogen-14 dissolved in Columbia River water N-14(n,p)C-14.*

Volatile carbon-14 in reactor effluent water was not considered a source of concern at the time and no nuclide-specific information concerning tritium releases from this source was found.

41b ### *5.2.3 Argon-41 in Reactor Effluent Water*

Argon-41 is formed by neutron capture on argon-40, which is a naturally occuring solute in Columbia River water. The dissolved argon was not removed by the Hanford Site water treatment process, and is assumed to have been present in low concentration in the inlet water.

Volatile argon-41 in reactor effluent water was not considered a source of concern at the time and no nuclide-specific information concerning tritium released from this source was found.

6.0 Conclusions

The release estimates presented are based on all known references in the Hanford literature (Gydesen 1992c) and represent the first estimation of air releases ever made for the entire period of single-pass reactor operation and separation processing of Hanford single-pass reactor fuel.

The reconstruction of radionuclide releases shows that the largest releases were from iodine-131 during the first three years of reactor and separations plant operations. Ruthenium releases were the next highest, followed by cerium-144, strontium-90 and finally plutonium-239 releases. Ninety-five-percent confidence factors show an uncertainty range from a factor of 2.8 for cerium-144 and strontium-90 to 17.5 for plutonium-239.

42 Releases of tritium, argon-41, and carbon-14 from *the* reactor stack gas systems and from reactor effluent cooling water were examined and found to be very small. Tritium releases averaged 1.4 curies/day, *and* carbon-14 releases averaged 0.1 curies/day. *The argon-41 release was found to be 540,000 curies/year for all eight reactors with an uncertainty multiplier of 3 at the 95-percent confidence level. The annual dose from 540,000 curies/year of argon-41, 511,000 curies/year of tritium, and 36.5 curies/year of carbon-14 was found to be in the 2 to 4 millirem range. Argon-41 was the dominant contributor to dose.*

The 1944-1949 hourly estimates of iodine-131 release provide a source term for atmospheric transport estimates and dose calculations for the period of highest releases. The monthly release estimates establish an unbroken record of releases of the important radionuclides for the entire 1944 through 1972 period.

7.0 References

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Appendix A

Reconstruction of Hanford Separations Plants Operating History

Appendix A

Reconstruction of Hanford Separations Plants Operating History

Table A.1. T Separations Plant Operating History, 1944-1956

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
T	44	12	3.6	0	22	0	32.7
T	45	1	3.7	0	27	0	38
T	45	2	6.9	0	42	0	53.1
T	45	3	6.7	0	65	0	50.4
T	45	4	23.2	0	108	0	43.9
T	45	5	24.3	0	159	0	37.6
T	45	6	15.8	0	182	0	36.7
T	45	7	18.8	0	214	0	38
T	45	8	31.8	0	241	0	37.4
T	45	9	33	0	224	0	37.6
T	45	10	54.3	0	209	0	40.4
T	45	11	53.2	0	201	0	48.7
T	45	12	48.4	0	240	0	53
T	46	1	33	0	443	0	43.3
T	46	2	25.1	0	348	0	65.8
T	46	3	37.2	0	193	0	72
T	46	4	43.9	0	197	0	58.3
T	46	5	29.9	0	202	0	58.4
T	46	6	18	0	279	0	92.2
T	46	7	28.5	0	209	0	76.2
T	46	8	12.1	0	208	0	82
T	46	9	6.6	0	203	0	71.3
T	46	10	6.6	0	207	0	69.5
T	46	11	23.1	0	202	0	63.7
T	46	12	22.7	0	206	0	65.1
T	47	1	23.8	0	201	0	65.6
T	47	2	23.1	0	201	0	61.3
T	47	3	29.7	0	201	0	65.4
T	47	4	26.4	0	205	0	65.9
T	47	5	26.4	0	208	0	64.6
T	47	6	15.4	0	205	0	71.5
T	47	7	30.8	0	202	0	77

Table A.1. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
T	47	8	25.3	0	202	0	82.2
T	47	9	24.2	0	205	0	80.5
T	47	10	23.1	0	203	0	84.7
T	47	11	25.3	0	204	0	94.3
T	47	12	26.4	0	200	0	99.6
T	48	1	26	0	204	0	108
T	48	2	26	0	194	0	106
T	48	3	26	0	202	0	105
T	48	4	29	0	202	0	101
T	48	5	29	0	202	0	108
T	48	6	36	0	203	0	112
T	48	7	29	0	201	0	105
T	48	8	33	0	207	0	95
T	48	9	26	0	200	0	93
T	48	10	36	0	207	0	100
T	48	11	39	0	204	0	97
T	48	12	53	0	209	0	99
T	49	1	49	0	211	0	96
T	49	2	46	0	208	0	93
T	49	3	63	0	221	0	93
T	49	4	25	0	229	0	95
T	49	5	21	0	248	0	94
T	49	6	16	0	270	0	94
T	49	7	30	0	288	0	96
T	49	8	26	0	275	0	95
T	49	9	26	0	323	0	94
T	49	10	33	0	378	0	98
T	49	11	26	0	358	0	95
T	49	12	32	0	396	0	95
T	50	1	30	0	378	0	100
T	50	2	24	0	397	0	99
T	50	3	33	0	368	0	98
T	50	4	36	0	352	0	99
T	50	5	30	0	377	0	96
T	50	6	20	0	473	0	98
T	50	7	38	0	427	0	90
T	50	8	49	0	408	0	72
T	50	9	43	0	422	0	74

Table A.1. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
T	50	10	43	0	416	0	80
T	50	11	36	0	537	0	83
T	50	12	42	0	255	0	75
T	51	1	64	0	279	0	71
T	51	2	43	0	414	0	72
T	51	3	53	0	443	0	71
T	51	4	56	0	414	0	54
T	51	5	54	0	411	0	48
T	51	6	48	0	415	0	47
T	51	7	30	0	516	0	49
T	51	8	46	0	589	0	46
T	51	9	36	0	569	0	48
T	51	10	41	0	572	0	48
T	51	11	52	0	584	0	51
T	51	12	40	0	577	0	49
T	52	1	53	0	569	0	47
T	52	2	26	0	587	0	50
T	52	3	49	0	588	0	48
T	52	4	33	0	552	0	51
T	52	5	16	0	607	0	52
T	52	6	7	0	624	0	88
T	52	7	30	0	593	0	70
T	52	8	26	0	601	0	63
T	52	9	3	0	622	0	83
T	52	10	13	0	540	0	99
T	52	11	13	0	609	0	76
T	52	12	26	0	633	0	60
T	53	1	3	0	626	0	88
T	53	2	25	0	599	0	91
T	53	3	22	0	558	0	88
T	53	4	17	0	341	0	60
T	53	5	17	0	396	0	66
T	53	6	30	0	401	0	65
T	53	7	17	0	425	0	53
T	53	8	18	0	365	0	68
T	53	9	24	0	446	0	74
T	53	10	17	0	603	0	70
T	53	11	23	0	616	0	66

Table A.1. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
T	53	12	33	0	613	0	91
T	54	1	37	0	617	0	66
T	54	2	32	0	616	0	89
T	54	3	29	0	611	0	96
T	54	4	31	0	203	0	98
T	54	5	83	0	206	0	88
T	54	6	100	0	200	0	99
T	54	7	90	0	200	0	98
T	54	8	100	0	201	0	96
T	54	9	105	0	201	0	91
T	54	10	130	0	194	0	84
T	54	11	130	0	189	0	102
T	54	12	152	0	189	0	100
T	55	1	155	0	198	0	104
T	55	2	155	0	205	0	100
T	55	3	63	0	239	0	119
T	55	4	79	0	204	0	90
T	55	5	147	0	208	0	99
T	55	6	160	0	230	0	112
T	55	7	100	0	262	0	108
T	55	8	109	0	261	0	208
T	55	9	125	0	257	0	102
T	55	10	87	0	255	0	100
T	55	11	47	0	254	0	115
T	55	12	39	0	254	0	138
T	56	1	18	0	256	0	167
T	56	2	27	0	263	0	213

Table A.2. B Separations Plant Operating History, 1945-1952

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
B	45	4	12.2	0	118	0	42.4
B	45	5	25.5	0	163	0	36.4
B	45	6	18.2	0	199	0	36.8
B	45	7	21	0	217	0	36.8
B	45	8	29.5	0	200	0	35.9
B	45	9	37.8	0	194	0	35.3
B	45	10	62.2	0	210	0	41.6
B	45	11	46.7	0	199	0	48
B	45	12	44.5	0	202	0	37.6
B	46	1	36.4	0	201	0	50
B	46	2	47.5	0	189	0	62.7
B	46	3	54.1	0	201	0	61.4
B	46	4	42.3	0	198	0	57.5
B	46	5	62.6	0	204	0	59.8
B	46	6	46.2	0	206	0	63.9
B	46	7	48.5	0	207	0	61.6
B	46	8	60.5	0	204	0	57.4
B	46	9	39.6	0	206	0	54.8
B	46	10	47.4	0	203	0	62.2
B	46	11	48.4	0	202	0	65
B	46	12	37.4	0	199	0	58.1
B	47	1	28.6	0	199	0	57.4
B	47	2	24.2	0	201	0	69.2
B	47	3	39.7	0	204	0	65.3
B	47	4	29.7	0	206	0	65.6
B	47	5	28.7	0	207	0	66.9
B	47	6	30.8	0	205	0	75.6
B	47	7	31.9	0	205	0	73
B	47	8	26.4	0	205	0	76.5
B	47	9	30.8	0	201	0	80.8
B	47	10	23.1	0	203	0	92.1
B	47	11	23.1	0	202	0	92.2
B	47	12	23.1	0	201	0	98.1
B	48	1	32	0	200	0	99
B	48	2	36	0	197	0	100

Table A.2. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
B	48	3	26	0	201	0	106
B	48	4	27	0	241	0	109
B	48	5	18	0	233	0	120
B	48	6	39	0	202	0	113
B	48	7	43	0	207	0	98
B	48	8	33	0	208	0	96
B	48	9	26	0	210	0	79
B	48	10	33	0	207	0	98
B	48	11	39	0	204	0	98
B	48	12	46	0	207	0	99
B	49	1	53	0	211	0	96
B	49	2	13	0	210	0	110
B	49	3	56	0	225	0	104
B	49	4	26	0	230	0	98
B	49	5	36	0	227	0	95
B	49	6	23	0	254	0	100
B	49	7	20	0	273	0	95
B	49	8	10	0	298	0	102
B	49	9	30	0	346	0	94
B	49	10	33	0	333	0	95
B	49	11	26	0	375	0	98
B	49	12	30	0	400	0	98
B	50	1	30	0	392	0	100
B	50	2	30	0	391	0	101
B	50	3	33	0	412	0	98
B	50	4	23	0	363	0	97
B	50	5	33	0	372	0	98
B	50	6	30	0	390	0	96
B	50	7	40	0	403	0	94
B	50	8	53	0	413	0	75
B	50	9	43	0	418	0	73
B	50	10	40	0	424	0	76
B	50	11	49	0	400	0	84
B	50	12	56	0	392	0	82
B	51	1	53	0	408	0	89

Table A.2. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
B	51	2	49	0	403	0	72
B	51	3	53	0	413	0	62
B	51	4	47	0	416	0	53
B	51	5	53	0	420	0	50
B	51	6	22	0	415	0	50
B	51	7	16	0	555	0	47
B	51	8	43	0	585	0	48
B	51	9	36	0	576	0	49
B	51	10	46	0	567	0	46
B	51	11	53	0	592	0	46
B	51	12	37	0	576	0	51
B	52	1	42	0	565	0	49
B	52	2	40	0	603	0	50
B	52	3	23	0	577	0	57
B	52	4	7	0	603	0	64
B	52	5	2	0	603	0	62
B	52	6	4	0	579	0	64

Table A.3. REDOX Separations Plant Operating History, 1952-1966

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	52	1	3.64	0	563.92	0	55
REDOX	52	2	22.66	0	568.81	0	55
REDOX	52	3	43.11	0	599.11	0	55
REDOX	52	4	74.99	0	614.18	0	53
REDOX	52	5	78.08	0	603	0	56
REDOX	52	6	44.82	0	614.37	0	58
REDOX	52	7	77.25	0	598.19	0	79
REDOX	52	8	106.79	0	599.29	0	73
REDOX	52	9	94.94	0	607.19	0	73
REDOX	52	10	71.92	0	601.84	0	83
REDOX	52	11	112.55	0	604.88	0	81
REDOX	52	12	91.38	0	604.72	0	96
REDOX	53	1	111.5	0	602.96	0	82
REDOX	53	2	53.54	0	606.24	0	95
REDOX	53	3	126.95	0	593.75	0	91
REDOX	53	4	132.14	0	470.25	0	83
REDOX	53	5	118.5	0	563.3	0	82
REDOX	53	6	102.9	0	582.07	0	80
REDOX	53	7	157.56	0	560.86	0	73
REDOX	53	8	125.15	0	576.82	0	79
REDOX	53	9	118.86	0	603.85	0	83
REDOX	53	10	186.38	0	608.13	0	76
REDOX	53	11	5.67	0	610	0	76
REDOX	53	12	191.45	0	602.5	0	83
REDOX	54	1	67.4	0	605.58	0	83
REDOX	54	2	85.32	0	608.3	0	94
REDOX	54	3	185.6	0	590.81	0	95
REDOX	54	4	135.18	0	616.85	0	95
REDOX	54	5	175.5	0	631.81	0	92
REDOX	54	6	41.7	0	644.19	0	80
REDOX	54	7	69.01	0	660.33	0	106
REDOX	54	8	111.81	0	650.93	0	109
REDOX	54	9	154.09	0	621.12	0	102
REDOX	54	10	155.16	0	692.62	0	134
REDOX	54	11	182.96	0	641.88	0	145

Table A.3. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	54	12	215.57	0	599.17	0	116
REDOX	55	1	36.77	0	194.76	0	103
REDOX	55	2	181.6	0	203.19	0	92
REDOX	55	3	245.4	0	207.6	0	82
REDOX	55	4	187.5	0	644.31	0	147
REDOX	55	5	256.17	0	810.34	0	456
REDOX	55	6	146.83	0	861.63	0	100
REDOX	55	7	159.18	0	361.73	0	102
REDOX	55	8	228.92	0	260.87	0	109
REDOX	55	9	310.14	0	259.19	0	100
REDOX	55	10	283.06	0	255.5	0	100
REDOX	55	11	236.9	0	816.57	0	157
REDOX	55	12	153.11	0	907.11	0	101
REDOX	56	1	115.46	0	238.89	0	117
REDOX	56	2	246.94	0	248.14	0	114
REDOX	56	3	183.46	0	323.3	0	128
REDOX	56	4	200.6	0	819.84	0	145
REDOX	56	5	214.23	0	764.31	0	109
REDOX	56	6	164.57	0	707.51	0	110
REDOX	56	7	59.83	0	749.78	0	124
REDOX	56	8	104.95	0	262.07	0	134
REDOX	56	9	241.3	0	251.83	0	148
REDOX	56	10	278.33	0	248.56	0	157
REDOX	56	11	278.5	0	248.77	0	137
REDOX	56	12	247.03	0	247.78	0	114
REDOX	57	1	80.78	0	691.81	0	123
REDOX	57	2	112.72	0	638.55	0	120
REDOX	57	3	89.89	0	566.77	0	128
REDOX	57	4	155.07	0	562.95	0	119
REDOX	57	5	147.95	0	575.7	0	121
REDOX	57	6	100.16	0	553.51	0	124
REDOX	57	7	171.79	0	509.48	0	118
REDOX	57	8	153.17	0	605.73	0	113
REDOX	57	9	219.46	0	555.42	0	114
REDOX	57	10	181.64	0	626.13	0	110

Table A.3. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	57	11	163.11	0	581.7	0	103
REDOX	57	12	252.78	0	395.8	0	100
REDOX	58	1	77.45	0	520.1	0	104
REDOX	58	2	147.38	0	519.2	0	90
REDOX	58	3	102.52	0	534.9	0	92
REDOX	58	4	88.54	0	559.4	0	93
REDOX	58	5	210.37	0	512.8	0	95
REDOX	58	6	202.85	0	531.9	0	106
REDOX	58	7	208.25	0	543.3	0	108
REDOX	58	8	120.06	0	548	0	106
REDOX	58	9	142.52	0	545.3	0	109
REDOX	58	10	13.63	9.11	775.5	396.3	203
REDOX	58	11	0	6.66	0	1214.7	211
REDOX	58	12	0	75.02	0	740.3	219
REDOX	59	1	0	69.15	0	867.2	208
REDOX	59	2	0	53.93	0	645.1	278
REDOX	59	3	0	50.65	0	709.4	250
REDOX	59	4	79.58	32.71	621	740.1	219
REDOX	59	5	8.31	42.96	1452.5	801.7	206
REDOX	59	6	0	77.9	0	779.2	166
REDOX	59	7	34.87	56.8	722.7	691.5	182
REDOX	59	8	0	66.27	0	636.3	173
REDOX	59	9	0	64.56	0	751.4	199
REDOX	59	10	0	74.93	0	687.3	179
REDOX	59	11	37.56	59.15	590	876.4	143
REDOX	59	12	101.97	5.28	813.5	505.7	260
REDOX	60	1	0	90.55	0	147.3	166
REDOX	60	2	0	51.31	0	875.5	138
REDOX	60	3	0	43.12	0	661.9	150
REDOX	60	4	0	73.49	0	833.2	145
REDOX	60	5	0	36.7	0	803.3	166
REDOX	60	6	151.54	11.03	599.1	961	169
REDOX	60	7	67.27	0	703.1	0	173
REDOX	60	8	40.37	0	683.7	0	130
REDOX	60	9	0	21.4	0	664.5	260

Table A.3. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	60	10	0	76.98	0	716.05	268
REDOX	60	11	0	96.11	0	746.5	258
REDOX	60	12	0	73.35	0	801.5	241
REDOX	61	1	0	67.76	0	735.4	254
REDOX	61	2	0	84.35	0	742.4	230
REDOX	61	3	0	94.01	0	822.3	163
REDOX	61	4	0	108.1	0	829.3	202
REDOX	61	5	0	93.93	0	596.2	223
REDOX	61	6	0	167.76	0	784	262
REDOX	61	7	0	135.9	0	838.8	167
REDOX	61	8	0	126.04	0	798.2	151
REDOX	61	9	0	69.01	0	747.3	143
REDOX	61	10	0	111.79	0	764.7	142
REDOX	61	11	0	136.71	0	773.9	129
REDOX	61	12	0	66.32	0	825.4	172
REDOX	62	1	0	167.65	0	812.5	129
REDOX	62	2	0.72	112.31	86.43	764.7	130
REDOX	62	3	5.79	70.44	58.04	761.4	147
REDOX	62	4	0	4.05	0	814.8	261
REDOX	62	5	0	39.75	0	815.1	175
REDOX	62	6	0	89.26	0	815.4	174
REDOX	62	7	0	41.15	0	906.9	189
REDOX	62	8	0	127.62	0	804.11	191
REDOX	62	9	0	112.75	0	743.1	205
REDOX	62	10	0	108.65	0	807.4	227
REDOX	62	11	0	55.94	0	833.4	226
REDOX	62	12	0	47.29	0	804.2	196
REDOX	63	1	0	226.83	0	812.5	229
REDOX	63	2	0	70.48	0	902	231
REDOX	63	3	0	48.93	0	916.4	219
REDOX	63	4	0	184.29	0	817.8	162
REDOX	63	5	0	23.87	0	826.1	162
REDOX	63	6	0	129	0	839.4	152
REDOX	63	7	0	153.2	0	873.3	231
REDOX	63	8	0	125.91	0	863.4	309

Table A.3. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	63	9	0	83.29	0	966.9	221
REDOX	63	10	0	42.13	0	924.8	169
REDOX	63	11	0	16.85	0	880.1	185
REDOX	63	12	0	56.18	0	792.1	242
REDOX	64	1	0	191.59	0	834.5	281
REDOX	64	2	0	170.3	0	880.1	222
REDOX	64	3	0	0	0	0	0
REDOX	64	4	0	119.9	0	884.8	246
REDOX	64	5	0	180.76	0	849.7	219
REDOX	64	6	0	78.5	0	875.9	158
REDOX	64	7	0	228.73	0	503.3	237
REDOX	64	8	0	84.79	0	1066.5	271
REDOX	64	9	0	231.8	0	482.8	228
REDOX	64	10	0	51.64	0	441.5	211
REDOX	64	11	0	225.36	0	420.6	251
REDOX	64	12	0	303.41	0	786	207
REDOX	65	1	0	248.73	0	842.1	206
REDOX	65	2	0	113.74	0	786.5	190
REDOX	65	3	0	168.15	0	738.5	177
REDOX	65	4	0	226.24	0	814.9	168
REDOX	65	5	0	193.76	0	820.6	149
REDOX	65	6	0.64	4.3	1250	2000	149
REDOX	65	7	0	90.33	0	1279.8	156
REDOX	65	8	0	204.54	0	399.2	169
REDOX	65	9	0	47.41	0	813.8	171
REDOX	65	10	0	101.18	0	1118.58	209
REDOX	65	11	0	151.51	0	872.1	206
REDOX	65	12	0	0.59	0	2000	200
REDOX	66	1	0	396.43	0	2000	206
REDOX	66	2	0	42.76	0	1170.49	220
REDOX	66	3	0	62.83	0	2027.69	177
REDOX	66	4	0	79.5	0	1882.26	240
REDOX	66	5	0	131.72	0	903.89	187
REDOX	66	6	0	239.78	0	900.12	143
REDOX	66	7	0	59.04	0	875.68	144

Table A.3. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
REDOX	66	8	0	7.41	0	917.68	144
REDOX	66	9	0	233.84	0	901.86	203
REDOX	66	10	25.44	83.67	1401.52	1401.52	281
REDOX	66	11	1.5	52.55	1401.52	1401.52	280

Table A.4. PUREX Separations Plant Operating History, 1956-1972

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	56	1	67.0	0.0	256.2	0.0	151
PUREX	56	2	246.8	0.0	255.1	0.0	181
PUREX	56	3	130.9	0.0	252.0	0.0	163
PUREX	56	4	196.9	0.0	251.1	0.0	105
PUREX	56	5	133.0	0.0	253.3	0.0	127
PUREX	56	6	341.1	0.0	247.4	0.0	101
PUREX	56	7	112.7	0.0	819.9	0.0	145
PUREX	56	8	239.5	0.0	761.9	0.0	135
PUREX	56	9	315.1	0.0	769.3	0.0	118
PUREX	56	10	186.0	0.0	772.2	0.0	117
PUREX	56	11	272.2	0.0	733.7	0.0	108
PUREX	56	12	279.2	0.0	720.6	0.0	114
PUREX	57	1	300.7	0.0	722.8	0.0	120
PUREX	57	2	284.0	0.0	646.8	0.0	125
PUREX	57	3	294.9	0.0	668.9	0.0	126
PUREX	57	4	405.0	0.0	526.5	0.0	121
PUREX	57	5	355.9	0.0	581.5	0.0	122
PUREX	57	6	367.4	0.0	600.8	0.0	121
PUREX	57	7	356.6	0.0	495.8	0.0	114
PUREX	57	8	433.4	0.0	504.8	0.0	115
PUREX	57	9	263.5	0.0	588.9	0.0	112
PUREX	57	10	477.8	0.0	524.3	0.0	107
PUREX	57	11	425.3	0.0	570.8	0.0	103
PUREX	57	12	432.8	0.0	436.5	0.0	100
PUREX	58	1	555.5	0.0	508.9	0.0	101
PUREX	58	2	581.7	0.0	520.4	0.0	91
PUREX	58	3	443.0	0.0	497.8	0.0	91
PUREX	58	4	408.7	0.0	553.1	0.0	93
PUREX	58	5	290.2	0.0	573.9	0.0	89
PUREX	58	6	109.8	0.0	222.3	0.0	110
PUREX	58	7	541.0	0.0	520.0	0.0	108
PUREX	58	8	188.7	0.0	573.1	0.0	105
PUREX	58	9	526.1	0.0	536.6	0.0	103
PUREX	58	10	477.3	0.0	615.5	0.0	106
PUREX	58	11	514.1	0.0	622.7	0.0	99

Table A.4. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	58	12	552.2	0.0	595.0	0.0	102
PUREX	59	1	462.9	0.0	564.4	0.0	104
PUREX	59	2	256.6	0.0	649.0	0.0	105
PUREX	59	3	504.7	0.0	611.3	0.0	108
PUREX	59	4	325.0	0.0	736.6	0.0	107
PUREX	59	5	358.4	0.0	688.5	0.0	104
PUREX	59	6	525.0	0.0	793.3	0.0	102
PUREX	59	7	302.7	0.0	687.1	0.0	110
PUREX	59	8	645.6	0.0	749.4	0.0	105
PUREX	59	9	411.9	0.0	720.6	0.0	95
PUREX	59	10	397.7	0.0	722.7	0.0	102
PUREX	59	11	412.4	0.0	707.9	0.0	107
PUREX	59	12	506.1	0.0	728.0	0.0	104
PUREX	60	1	614.6	0.0	724.2	0.0	93
PUREX	60	2	297.0	0.0	718.6	0.0	100
PUREX	60	3	332.1	0.0	613.6	0.0	124
PUREX	60	4	680.6	0.0	743.9	0.0	120
PUREX	60	5	330.5	0.0	590.8	0.0	109
PUREX	60	6	246.2	0.0	637.5	0.0	122
PUREX	60	7	428.3	0.0	692.1	0.0	109
PUREX	60	8	761.5	0.0	676.3	0.0	100
PUREX	60	9	758.3	0.0	668.4	0.0	129
PUREX	60	10	421.3	0.0	635.7	0.0	187
PUREX	60	11	726.1	0.0	672.9	0.0	117
PUREX	60	12	574.8	0.0	699.0	0.0	103
PUREX	61	1	437.0	0.0	698.1	0.0	114
PUREX	61	2	383.9	0.0	721.8	0.0	111
PUREX	61	3	666.8	0.0	658.4	0.0	118
PUREX	61	4	319.1	0.0	722.4	0.0	123
PUREX	61	5	745.6	0.0	727.4	0.0	124
PUREX	61	6	514.5	0.0	697.1	0.0	115
PUREX	61	7	501.5	0.0	700.0	0.0	123
PUREX	61	8	569.6	0.0	689.2	0.0	115
PUREX	61	9	588.8	0.0	632.7	0.0	121
PUREX	61	10	378.7	0.0	570.1	0.0	114

Table A.4. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	61	11	224.4	0.0	781.7	0.0	116
PUREX	61	12	664.4	0.0	777.6	0.0	166
PUREX	62	1	385.6	0.0	679.6	0.0	142
PUREX	62	2	177.8	0.0	551.6	0.0	145
PUREX	62	3	239.3	0.0	910.0	0.0	162
PUREX	62	4	353.2	0.0	661.7	0.0	174
PUREX	62	5	618.3	0.0	668.5	0.0	162
PUREX	62	6	582.5	0.0	619.2	0.0	156
PUREX	62	7	753.2	0.0	665.3	0.0	142
PUREX	62	8	236.7	0.0	634.7	0.0	136
PUREX	62	9	557.3	0.0	702.2	0.0	199
PUREX	62	10	712.2	0.0	634.7	0.0	155
PUREX	62	11	717.8	0.0	634.1	0.0	153
PUREX	62	12	710.1	0.0	623.0	0.0	127
PUREX	63	1	68.1	0.0	722.2	0.0	228
PUREX	63	2	494.3	0.0	760.2	0.0	160
PUREX	63	3	712.7	0.0	698.0	0.0	146
PUREX	63	4	137.3	0.0	570.8	0.0	136
PUREX	63	5	653.0	0.0	649.3	0.0	146
PUREX	63	6	660.6	0.0	747.4	0.0	149
PUREX	63	7	0.0	0.0	0.0	0.0	0
PUREX	63	8	336.2	0.0	599.6	0.0	155
PUREX	63	9	596.0	0.0	657.8	0.0	154
PUREX	63	10	446.2	0.0	875.7	0.0	160
PUREX	63	11	787.3	0.0	735.1	0.0	170
PUREX	63	12	646.5	0.0	75.8	0.0	150
PUREX	64	1	154.5	0.0	699.7	0.0	142
PUREX	64	2	109.4	0.0	433.3	0.0	153
PUREX	64	3	806.7	0.0	691.7	0.0	153
PUREX	64	4	307.5	0.0	692.1	0.0	142
PUREX	64	5	470.3	0.0	636.2	0.0	139
PUREX	64	6	696.6	0.0	844.3	0.0	152
PUREX	64	7	338.1	0.0	593.3	0.0	148
PUREX	64	8	839.4	0.0	624.9	0.0	139
PUREX	64	9	512.2	0.0	907.3	0.0	228

Table A.4. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	64	10	843.6	0.0	610.7	0.0	137
PUREX	64	11	563.2	0.0	649.4	0.0	136
PUREX	64	12	43.3	0.0	581.8	0.0	139
PUREX	65	1	42.3	0.0	256.3	0.0	139
PUREX	65	2	402.6	0.0	620.7	0.0	169
PUREX	65	3	852.6	0.0	626.4	0.0	169
PUREX	65	4	907.6	0.0	621.1	0.0	186
PUREX	65	5	883.6	0.0	597.1	0.0	157
PUREX	65	6	593.5	0.0	548.5	0.0	178
PUREX	65	7	185.1	0.0	745.0	0.0	165
PUREX	65	8	495.9	0.0	731.4	0.0	167
PUREX	65	9	483.8	0.0	586.9	0.0	175
PUREX	65	10	442.9	0.0	594.0	0.0	141
PUREX	65	11	233.2	0.0	729.0	0.0	163
PUREX	65	12	413.0	0.0	659.2	0.0	137
PUREX	66	1	414.0	268.9	621.7	725.0	367
PUREX	66	2	74.6	358.4	584.0	584.0	516
PUREX	66	3	504.8	123.8	434.3	434.3	212
PUREX	66	4	149.9	2.7	753.2	753.2	135
PUREX	66	5	0.0	0.0	0.0	0.0	0
PUREX	66	6	0.0	0.0	0.0	0.0	0
PUREX	66	7	0.0	0.0	0.0	0.0	0
PUREX	66	8	154.7	0.0	504.8	0.0	228
PUREX	66	9	568.9	0.0	631.0	0.0	220
PUREX	66	10	940.2	0.0	612.0	0.0	163
PUREX	66	11	167.2	331.0	703.6	856.6	651
PUREX	66	12	131.0	0.0	435.4	0.0	440
PUREX	67	1	692.2	8.4	628.1	628.1	168
PUREX	67	2	0.0	149.4	0.0	917.1	917
PUREX	67	3	452.1	0.0	582.5	0.0	150
PUREX	67	4	587.8	0.0	939.7	0.0	401
PUREX	67	5	464.3	0.0	628.2	0.0	155
PUREX	67	6	0.0	218.4	0.0	917.7	918
PUREX	67	7	201.5	0.0	1701.1	0.0	236
PUREX	67	8	337.5	0.0	944.8	0.0	184

Table A.4. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	67	9	598.5	0.0	944.0	0.0	206
PUREX	67	10	475.3	0.0	724.7	0.0	232
PUREX	67	11	524.0	0.0	725.1	0.0	203
PUREX	67	12	180.4	0.0	821.1	0.0	226
PUREX	68	1	220.0	0.0	1647.6	0.0	272
PUREX	68	2	212.0	0.0	974.7	0.0	306
PUREX	68	3	565.7	0.0	931.1	0.0	219
PUREX	68	4	356.4	0.0	1310.1	0.0	194
PUREX	68	5	267.3	0.0	988.5	0.0	210
PUREX	68	6	560.4	0.0	658.4	0.0	224
PUREX	68	7	199.6	0.0	923.6	0.0	267
PUREX	68	8	458.7	0.0	1235.7	0.0	208
PUREX	68	9	227.5	0.0	1163.3	0.0	221
PUREX	68	10	556.1	0.0	758.2	0.0	207
PUREX	68	11	368.8	0.0	956.9	0.0	344
PUREX	68	12	202.3	0.0	1029.2	0.0	260
PUREX	69	1	65.9	0.0	2432.5	0.0	244
PUREX	69	2	148.7	0.0	1730.0	0.0	297
PUREX	69	3	272.8	0.0	1036.5	0.0	247
PUREX	69	4	370.9	0.0	913.0	0.0	300
PUREX	69	5	379.9	0.0	1018.7	0.0	373
PUREX	69	6	120.4	0.0	1030.9	0.0	222
PUREX	69	7	82.4	0.0	1153.6	0.0	215
PUREX	69	8	347.7	0.0	1314.8	0.0	261
PUREX	69	9	325.4	0.0	939.3	0.0	226
PUREX	69	10	391.6	0.0	771.3	0.0	244
PUREX	69	11	255.3	0.0	1098.7	0.0	291
PUREX	69	12	308.1	0.0	1266.2	0.0	361
PUREX	70	1	290.8	0.0	805.8	0.0	215
PUREX	70	2	0.1	0.0	805.8	0.0	549
PUREX	70	3	72.6	0.0	694.9	0.0	277
PUREX	70	4	248.9	0.0	1268.4	0.0	326
PUREX	70	5	100.0	0.0	2185.9	0.0	304
PUREX	70	6	0.0	0.0	0.0	0.0	0
PUREX	70	7	0.0	0.0	0.0	0.0	0

Table A.4. (contd)

Plant	Year	Month	Uranium Processed		Average Burnup		Average
			Natural Tons	Enrich. Tons	Natural MWd/Ton	Enriched MWd/Ton	Cooling Time Days
PUREX	70	8	0.0	0.0	0.0	0.0	0
PUREX	70	9	0.0	0.0	0.0	0.0	0
PUREX	70	10	0.0	0.0	0.0	0.0	0
PUREX	70	11	0.0	0.0	0.0	0.0	0
PUREX	70	12	0.0	0.0	0.0	0.0	0
PUREX	71	1	0.0	0.0	0.0	0.0	0
PUREX	71	2	0.0	0.0	0.0	0.0	0
PUREX	71	3	116.0	0.0	20.3	0.0	454
PUREX	71	4	412.7	0.0	538.9	0.0	454
PUREX	71	5	657.2	0.0	564.3	0.0	363
PUREX	71	6	488.7	0.0	446.4	0.0	254
PUREX	71	7	0.0	310.6	0.0	0.0	738
PUREX	71	8	0.0	647.7	0.0	0.0	771
PUREX	71	9	0.0	577.3	0.0	0.0	784
PUREX	71	10	0.0	0.0	0.0	0.0	0
PUREX	71	11	0.0	0.0	0.0	0.0	0
PUREX	71	12	0.0	0.0	0.0	0.0	0
PUREX	72	1	0.0	0.0	0.0	0.0	0
PUREX	72	2	146.8	0.0	259.2	0.0	413
PUREX	72	3	465.5	0.0	337.0	0.0	418
PUREX	72	4	0.0	0.0	0.0	0.0	0
PUREX	72	5	0.0	0.0	0.0	0.0	0
PUREX	72	6	0.0	0.0	0.0	0.0	0
PUREX	72	7	0.0	0.0	0.0	0.0	0
PUREX	72	8	0.0	0.0	0.0	0.0	0
PUREX	72	9	0.0	0.0	0.0	0.0	0
PUREX	72	10	0.0	0.0	0.0	0.0	0
PUREX	72	11	0.0	0.0	0.0	0.0	0

Appendix B

Estimated Monthly Releases to the Atmosphere from Chemical Separations Plant Operations, 1944-1972

Appendix B

Estimated Monthly Releases to the Atmosphere from Chemical Separations Plant Operations, 1944-1972

Table B.1. Estimated Monthly Iodine-131 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	2363	2139	0	0	0	0	0	0	2139
1945	Jan	1349	1221	0	0	0	0	0	0	1221
1945	Feb	2349	2126	0	0	0	0	0	0	2126
1945	Mar	2301	2082	0	0	0	0	0	0	2082
1945	Apr	19916	18024	11848	10723	0	0	0	0	28746
1945	May	38616	34947	43685	39535	0	0	0	0	74482
1945	Jun	24568	22234	26776	24232	0	0	0	0	46467
1945	Jul	25869	23411	26104	23624	0	0	0	0	47036
1945	Aug	42408	38379	37249	33710	0	0	0	0	72090
1945	Sep	42719	38661	55272	50021	0	0	0	0	88682
1945	Oct	49509	44806	52221	47260	0	0	0	0	92066
1945	Nov	18178	16451	23537	21301	0	0	0	0	37752
1945	Dec	21060	19059	47824	43281	0	0	0	0	62340
1946	Jan	2341	2119	10645	9634	0	0	0	0	11753
1946	Feb	2962	2681	5214	4719	0	0	0	0	7399
1946	Mar	2311	2091	6477	5862	0	0	0	0	7953
1946	Apr	5727	5183	7179	6497	0	0	0	0	11680
1946	May	4763	4311	9910	8969	0	0	0	0	13280
1946	Jun	172	156	4930	4462	0	0	0	0	4618
1946	Jul	966	874	5173	4682	0	0	0	0	5556

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1946	Aug	93	84	9461	8562	0	0	0	0	8646
1946	Sep	523	473	7953	7197	0	0	0	0	7670
1946	Oct	485	439	4841	4381	0	0	0	0	4820
1946	Nov	2279	2062	3826	3463	0	0	0	0	5525
1946	Dec	2167	1961	6007	5436	0	0	0	0	7398
1947	Jan	1847	1671	4958	4487	0	0	0	0	6158
1947	Feb	2493	2256	1744	1579	0	0	0	0	3835
1947	Mar	2187	1980	4019	3637	0	0	0	0	5617
1947	Apr	2216	2006	3146	2847	0	0	0	0	4853
1947	May	1972	1785	2435	2203	0	0	0	0	3988
1947	Jun	862	780	965	873	0	0	0	0	1653
1947	Jul	1148	1039	1389	1257	0	0	0	0	2297
1947	Aug	512	464	873	790	0	0	0	0	1254
1947	Sep	530	480	805	729	0	0	0	0	1209
1947	Oct	339	307	202	183	0	0	0	0	490
1947	Nov	174	157	133	120	0	0	0	0	278
1947	Dec	194	176	113	102	0	0	0	0	278
1948	Jan	45	41	196	178	0	0	0	0	219
1948	Feb	114	103	196	177	0	0	0	0	280
1948	Mar	105	95	81	74	0	0	0	0	168
1948	Apr	180	162	65	59	0	0	0	0	221
1948	May	95	27	14	4	0	0	0	0	31
1948	Jun	67	19	85	24	0	0	0	0	43
1948	Jul	192	55	284	81	0	0	0	0	135
1948	Aug	286	81	223	63	0	0	0	0	145
1948	Sep	197	56	223	63	0	0	0	0	119
1948	Oct	279	79	320	91	0	0	0	0	170
1948	Nov	323	81	289	72	0	0	0	0	153
1948	Dec	327	82	299	75	0	0	0	0	156
1949	Jan	435	109	350	88	0	0	0	0	196

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Feb	363	91	48	12	0	0	0	0	103
1949	Mar	719	180	245	61	0	0	0	0	241
1949	Apr	255	64	264	66	0	0	0	0	130
1949	May	284	71	277	69	0	0	0	0	140
1949	Jun	148	37	168	42	0	0	0	0	79
1949	Jul	207	52	171	43	0	0	0	0	94
1949	Aug	273	68	72	18	0	0	0	0	86
1949	Sep	277	69	282	71	0	0	0	0	140
1949	Oct	257	64	311	78	0	0	0	0	142
1949	Nov	239	60	165	41	0	0	0	0	101
1949	Dec	8802	7177	255	64	0	0	0	0	7241
1950	Jan	183	45.9	184	45.9	0	0	0	0	92
1950	Feb	160	40	168	42.1	0	0	0	0	82
1950	Mar	240	59.9	240	60.1	0	0	0	0	120
1950	Apr	240	59.9	182	45.5	0	0	0	0	105
1950	May	259	64.7	240	59.9	0	0	0	0	125
1950	Jun	146	36.5	259	64.8	0	0	0	0	101
1950	Jul	552	138	411	103	0	0	0	0	241
1950	Aug	3350	839	2800	701	0	0	0	0	1540
1950	Sep	2480	620	2700	676	0	0	0	0	1296
1950	Oct	1480	369	1940	485	0	0	0	0	854
1950	Nov	961	240	1190	14.9	0	0	0	0	255
1950	Dec	2190	548	1620	20.2	0	0	0	0	568
1951	Jan	6520	65.2	1160	11.6	0	0	0	0	77
1951	Feb	4060	40.6	4630	46.3	0	0	0	0	87
1951	Mar	5470	109	11900	237	0	0	0	0	346
1951	Apr	25000	1250	22900	1140	0	0	0	0	2390
1951	May	40400	5330	33400	4410	0	0	0	0	9740
1951	Jun	39200	4890	13900	1730	0	0	0	0	6620
1951	Jul	20700	2490	13200	1580	0	0	0	0	4070

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1951	Aug	41300	516	32500	406	0	0	0	0	922
1951	Sep	27200	340	24900	312	0	0	0	0	652
1951	Oct	31000	387	41300	516	0	0	0	0	903
1951	Nov	30300	379	47600	595	0	0	0	0	974
1951	Dec	27700	346	21600	270	0	0	0	0	616
1952	Jan	51300	642	34200	428	1770	22.1	0	0	1092
1952	Feb	19500	243	30000	375	11000	138	0	0	756
1952	Mar	43600	545	9410	118	21000	262	0	0	925
1952	Apr	22600	283	1570	19.6	43400	543	0	0	846
1952	May	10100	126	533	6.66	34900	436	0	0	569
1952	Jun	198	2.48	895	11.2	16900	211	0	0	225
1952	Jul	4010	50.1	0	0	4750	59.4	0	0	110
1952	Aug	6350	79.4	0	0	11000	138	0	0	217
1952	Sep	131	1.64	0	0	9800	122	0	0	124
1952	Oct	142	1.78	0	0	3130	39.2	0	0	41
1952	Nov	1040	12.9	0	0	5830	72.8	0	0	86
1952	Dec	8240	103	0	0	1300	16.2	0	0	119
1953	Jan	102	1.27	0	0	6340	79.3	0	0	81
1953	Feb	655	8.18	0	0	994	12.4	0	0	21
1953	Mar	744	9.31	0	0	3320	41.5	0	0	51
1953	Apr	6320	79	0	0	6840	85.5	0	0	165
1953	May	3790	47.4	0	0	6730	84.1	0	0	132
1953	Jun	7290	91.2	0	0	6950	86.9	0	0	178
1953	Jul	11600	146	0	0	19400	243	0	0	389
1953	Aug	3370	42.1	0	0	9210	115	0	0	157
1953	Sep	2700	33.7	0	0	6210	77.6	0	0	111
1953	Oct	2720	34	0	0	17800	222	0	0	256
1953	Nov	5200	65	0	0	541	6.77	0	0	72
1953	Dec	865	10.8	0	0	9990	125	0	0	136
1954	Jan	11000	138	0	0	4640	58	0	0	196

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Feb	1310	16.4	0	0	2280	28.4	0	0	45
1954	Mar	651	8.14	0	0	4540	56.7	0	0	65
1954	Apr	554	6.92	0	0	3310	41.4	0	0	48
1954	May	3520	43.9	0	0	5570	69.6	0	0	114
1954	Jun	1640	20.5	0	0	3730	46.6	0	0	67
1954	Jul	1610	20.1	0	0	656	8.2	0	0	28
1954	Aug	2120	26.5	0	0	821	10.3	0	0	37
1954	Sep	3430	42.8	0	0	2060	25.8	0	0	69
1954	Oct	7730	96.7	0	0	132	1.65	0	0	98
1954	Nov	1630	20.4	0	0	60.3	0.753	0	0	21
1954	Dec	2270	28.4	0	0	863	10.8	0	0	39
1955	Jan	1610	20.1	0	0	416	5.2	0	0	25
1955	Feb	2280	28.5	0	0	5320	66.5	0	0	95
1955	Mar	182	2.28	0	0	17000	213	0	0	215
1955	Apr	2750	34.4	0	0	50.7	0.634	0	0	35
1955	May	2360	29.5	0	0	1.89e-10	2.36e-12	0	0	30
1955	Jun	843	10.5	0	0	2310	28.8	0	0	39
1955	Jul	751	9.38	0	0	2040	25.5	0	0	35
1955	Aug	0.148	0.00184	0	0	1580	19.7	0	0	20
1955	Sep	1570	19.6	0	0	4640	57.9	0	0	78
1955	Oct	1300	16.2	0	0	4230	52.8	0	0	69
1955	Nov	193	2.41	0	0	27.3	0.341	0	0	3
1955	Dec	22	0.275	0	0	2210	27.6	0	0	28
1956	Jan	0.99	0.0124	0	0	470	5.88	14.6	0.0293	6
1956	Feb	0.0282	0.000353	0	0	1310	16.3	4.06	0.00812	16
1956	Mar	0	0	0	0	295	3.69	10.2	0.0203	4
1956	Apr	0	0	0	0	77.7	0.971	2260	4.53	6
1956	May	0	0	0	0	1840	23	230	0.459	23
1956	Jun	0	0	0	0	1290	16.2	5530	11.1	27
1956	Jul	0	0	0	0	141	1.76	43.6	0.0873	2

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1956	Aug	0	0	0	0	99.4	1.24	219	0.438	2
1956	Sep	0	0	0	0	68.2	0.852	1250	2.5	3
1956	Oct	0	0	0	0	36.2	0.452	803	1.61	2
1956	Nov	0	0	0	0	203	2.54	2550	5.1	8
1956	Dec	0	0	0	0	1310	16.3	1560	3.11	19
1957	Jan	0	0	0	0	254	3.17	1220	2.45	6
1957	Feb	0	0	0	0	457	5.71	748	1.5	7
1957	Mar	0	0	0	0	182	2.27	714	1.43	4
1957	Apr	0	0	0	0	681	8.51	1490	2.98	11
1957	May	0	0	0	0	547	6.84	1210	2.42	9
1957	Jun	0	0	0	0	286	3.57	1360	2.72	6
1957	Jul	0	0	0	0	818	10.2	2400	4.79	15
1957	Aug	0	0	0	0	1130	14.1	2670	5.35	19
1957	Sep	0	0	0	0	1480	18.5	2120	4.24	23
1957	Oct	0	0	0	0	1740	21.8	5880	11.8	34
1957	Nov	0	0	0	0	2850	35.6	7420	14.8	50
1957	Dec	0	0	0	0	5610	70.1	9660	19.3	89
1958	Jan	0	0	0	0	1450	18.2	13500	27	45
1958	Feb	0	0	0	0	9240	116	33500	66.9	183
1958	Mar	0	0	0	0	5420	67.7	25400	50.9	119
1958	Apr	0	0	0	0	4300	53.8	19900	39.7	94
1958	May	0	0	0	0	8570	107	19900	39.9	147
1958	Jun	0	0	0	0	3210	40.1	1150	2.3	42
1958	Jul	0	0	0	0	2770	34.7	7190	14.4	49
1958	Aug	0	0	0	0	1900	23.8	3260	6.53	30
1958	Sep	0	0	0	0	1740	21.8	10800	21.5	43
1958	Oct	0	0	0	0	0.0838	0.00105	7600	15.2	15
1958	Nov	0	0	0	0	0.0125	0.000156	15000	30	30
1958	Dec	0	0	0	0	0.0693	0.000867	12400	24.8	25
1959	Jan	0	0	0	0	0.187	0.00234	9830	19.7	20

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Feb	0	0	0	0	0.000346	0.000004	5040	10.1	10
1959	Mar	0	0	0	0	0.00364	0.000046	7620	15.2	15
1959	Apr	0	0	0	0	0.118	0.00148	5400	10.8	11
1959	May	0	0	0	0	0.166	0.00207	7690	15.4	15
1959	Jun	0	0	0	0	7.85	0.0981	13500	27	27
1959	Jul	0	0	0	0	2.34	0.0292	3870	7.74	8
1959	Aug	0	0	0	0	3.62	0.0453	12800	25.5	26
1959	Sep	0	0	0	0	0.378	0.00472	19200	38.5	39
1959	Oct	0	0	0	0	2.45	0.0306	10200	20.3	20
1959	Nov	0	0	0	0	71.2	0.89	6840	13.7	15
1959	Dec	0	0	0	0	0.00334	0.000042	10900	21.8	22
1960	Jan	0	0	0	0	8.39	0.105	37800	75.6	76
1960	Feb	0	0	0	0	64.4	0.805	9990	20	21
1960	Mar	0	0	0	0	19	0.238	1400	2.8	3
1960	Apr	0	0	0	0	50.3	0.629	4090	8.18	9
1960	May	0	0	0	0	4.11	0.0513	5070	10.1	10
1960	Jun	0	0	0	0	14.1	0.177	1240	2.47	3
1960	Jul	0	0	0	0	4.18	0.0523	6620	13.2	13
1960	Aug	0	0	0	0	102	1.28	25500	51.1	52
1960	Sep	0	0	0	0	0.000719	0.000009	2090	4.17	4
1960	Oct	0	0	0	0	0.0013	0.000016	7.79	0.0156	0
1960	Nov	0	0	0	0	0.00386	0.000048	5620	11.2	11
1960	Dec	0	0	0	0	0.0128	0.00016	14900	29.8	30
1961	Jan	0	0	0	0	0.00404	0.000051	4620	9.25	9
1961	Feb	0	0	0	0	0.0398	0.000498	5270	10.5	11
1961	Mar	0	0	0	0	14.4	0.18	4980	9.96	10
1961	Apr	0	0	0	0	0.573	0.00716	1560	3.11	3
1961	May	0	0	0	0	0.0802	0.001	3340	6.68	7
1961	Jun	0	0	0	0	0.00503	0.000063	4990	9.99	10
1961	Jul	0	0	0	0	14.7	0.184	2440	4.89	5

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1961	Aug	0	0	0	0	54.1	0.676	5530	11.1	12
1961	Sep	0	0	0	0	58.9	0.736	3390	6.78	8
1961	Oct	0	0	0	0	104	1.3	3960	7.92	9
1961	Nov	0	0	0	0	390	4.88	2010	4.02	9
1961	Dec	0	0	0	0	4.67	0.0583	79.9	0.16	0
1962	Jan	0	0	0	0	488	6.1	371	0.741	7
1962	Feb	0	0	0	0	300	3.75	130	0.261	4
1962	Mar	0	0	0	0	45.7	0.571	41.6	0.0833	1
1962	Apr	0	0	0	0	0.000135	0.000002	21.5	0.043	0
1962	May	0	0	0	0	2.19	0.0274	106	0.212	0
1962	Jun	0	0	0	0	5.37	0.0671	167	0.333	0
1962	Jul	0	0	0	0	0.682	0.00853	723	1.45	1
1962	Aug	0	0	0	0	1.77	0.0221	380	0.76	1
1962	Sep	0	0	0	0	0.467	8.29	3.94	0.00788	8
1962	Oct	0	0	0	0	0.0677	0.000847	222	0.445	0
1962	Nov	0	0	0	0	0.0381	0.000476	266	0.532	1
1962	Dec	0	0	0	0	0.427	0.00533	2470	4.95	5
1963	Jan	0	0	0	0	0.123	0.00153	0.0408	0.000082	0
1963	Feb	0	0	0	0	0.0322	0.000402	104	0.208	0
1963	Mar	0	0	0	0	0.0629	0.000787	500	1	1
1963	Apr	0	0	0	0	32.1	0.401	225	0.451	1
1963	May	0	0	0	0	4.16	0.052	456	0.913	1
1963	Jun	0	0	0	0	53.3	0.666	359	0.718	1
1963	Jul	0	0	0	0	0.0699	0.000874	0	0	0
1963	Aug	0	0	0	0	0.000069	8.63e-07	108	0.215	0
1963	Sep	0	0	0	0	0.0904	0.00113	209	72.1	72
1963	Oct	0	0	0	0	4.04	0.0504	94.8	0.19	0
1963	Nov	0	0	0	0	0.406	0.00507	70	0.14	0
1963	Dec	0	0	0	0	0.00989	0.000124	210	0.42	0
1964	Jan	0	0	0	0	0.00122	0.000015	159	0.318	0

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Feb	0	0	0	0	0.176	0.00219	42.3	0.0845	0
1964	Mar	0	0	0	0	0	0	322	0.643	1
1964	Apr	0	0	0	0	0.0156	0.000195	316	0.633	1
1964	May	0	0	0	0	0.241	0.00301	624	1.25	1
1964	Jun	0	0	0	0	20.1	0.252	306	0.612	1
1964	Jul	0	0	0	0	0.0629	0.000786	206	0.411	0
1964	Aug	0	0	0	0	0.00129	0.000016	1110	2.22	2
1964	Sep	0	0	0	0	0.138	0.00173	0.323	0.000646	0
1964	Oct	0	0	0	0	0.132	0.00166	1330	2.65	3
1964	Nov	0	0	0	0	0.0183	0.000229	969	1.94	2
1964	Dec	0	0	0	0	1.13	0.0142	57.2	0.114	0
1965	Jan	0	0	0	0	1.03	0.0128	52	0.104	0
1965	Feb	0	0	0	0	1.86	0.0232	40.5	0.0811	0
1965	Mar	0	0	0	0	8.4	0.105	85.9	0.172	0
1965	Apr	0	0	0	0	24.7	0.308	21.1	0.0422	0
1965	May	0	0	0	0	109	1.36	250	0.499	2
1965	Jun	0	0	0	0	2.89	0.0362	27.3	0.0546	0
1965	Jul	0	0	0	0	28.3	0.353	26.6	0.0532	0
1965	Aug	0	0	0	0	19.6	0.245	59.9	0.12	0
1965	Sep	0	0	0	0	3.99	0.0499	28.9	0.0579	0
1965	Oct	0	0	0	0	0.326	0.00408	497	0.994	1
1965	Nov	0	0	0	0	0.626	0.00783	39.8	0.0795	0
1965	Dec	0	0	0	0	0.00426	0.000053	658	1.32	1
1966	Jan	0	0	0	0	1.8	0.0225	1470	2.95	3
1966	Feb	0	0	0	0	0.0566	0.000707	7.38	0.0148	0
1966	Mar	0	0	0	0	3.48	0.0435	167	0.335	0
1966	Apr	0	0	0	0	0.0192	0.00024	793	1.59	2
1966	May	0	0	0	0	2.96	0.037	0	0	0
1966	Jun	0	0	0	0	239	2.99	0	0	3
1966	Jul	0	0	0	0	54	0.674	0	0	1

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1966	Aug	0	0	0	0	6.79	0.0848	0.1	0.0002	0
1966	Sep	0	0	0	0	1.32	0.0165	0.745	0.00149	0
1966	Oct	0	0	0	0	0.000762	0.00001	167	0.335	0
1966	Nov	0	0	0	0	0.000409	0.000005	0.0824	0.000165	0
1966	Dec	0	0	0	0	0	0	9.70e-10	1.94e-12	0
1967	Jan	0	0	0	0	0	0	137	0.275	0
1967	Feb	0	0	0	0	0	0	69.3	0.139	0
1967	Mar	0	0	0	0	0	0	248	0.496	0
1967	Apr	0	0	0	0	0	0	1.33e-07	2.66e-10	0
1967	May	0	0	0	0	0	0	166	0.333	0
1967	Jun	0	0	0	0	0	0	0.145	0.000289	0
1967	Jul	0	0	0	0	0	0	0.0709	0.000142	0
1967	Aug	0	0	0	0	0	0	10.2	0.0203	0
1967	Sep	0	0	0	0	0	0	2.71	0.00542	0
1967	Oct	0	0	0	0	0	0	0.225	0.00045	0
1967	Nov	0	0	0	0	0	0	3.02	0.00605	0
1967	Dec	0	0	0	0	0	0	0.144	0.000289	0
1968	Jan	0	0	0	0	0	0	0.0033	0.000007	0
1968	Feb	0	0	0	0	0	0	0.000165	3.30e-07	0
1968	Mar	0	0	0	0	0	0	0.793	0.00159	0
1968	Apr	0	0	0	0	0	0	4.39	0.00877	0
1968	May	0	0	0	0	0	0	0.816	0.00163	0
1968	Jun	0	0	0	0	0	0	0.5	0.001	0
1968	Jul	0	0	0	0	0	0	0.00446	0.000009	0
1968	Aug	0	0	0	0	0	0	1.68	0.00337	0
1968	Sep	0	0	0	0	0	0	0.272	0.000543	0
1968	Oct	0	0	0	0	0	0	2.17	0.00434	0
1968	Nov	0	0	0	0	0	0	0.000011	2.16e-08	0
1968	Dec	0	0	0	0	0	0	0.00832	0.000017	0
1969	Jan	0	0	0	0	0	0	0.0112	0.000022	0

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Feb	0	0	0	0	0	0	0.000257	5.14e-07	0
1969	Mar	0	0	0	0	0	0	0.0341	0.000068	0
1969	Apr	0	0	0	0	0	0	0.000478	9.56e-07	0
1969	May	0	0	0	0	0	0	9.11e-07	1.82e-09	0
1969	Jun	0	0	0	0	0	0	0.13	0.00026	0
1969	Jul	0	0	0	0	0	0	0.164	0.000327	0
1969	Aug	0	0	0	0	0	0	0.0132	0.000026	0
1969	Sep	0	0	0	0	0	0	0.248	0.000495	0
1969	Oct	0	0	0	0	0	0	0.0624	0.000125	0
1969	Nov	0	0	0	0	0	0	0.000722	0.000001	0
1969	Dec	0	0	0	0	0	0	0.000002	4.21e-09	0
1970	Jan	0	0	0	0	0	0	0.55	0.0011	0
1970	Feb	0	0	0	0	0	0	4.75e-17	9.49e-20	0
1970	Mar	0	0	0	0	0	0	0.000651	0.000001	0
1970	Apr	0	0	0	0	0	0	0.000034	6.75e-08	0
1970	May	0	0	0	0	0	0	0.000093	1.86e-07	0
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	1.60e-10	3.20e-13	0
1971	Apr	0	0	0	0	0	0	8.80e-10	1.76e-12	0
1971	May	0	0	0	0	0	0	0.000004	7.18e-09	0
1971	Jun	0	0	0	0	0	0	0.0316	0.000063	0
1971	Jul	0	0	0	0	0	0	9.32e-17	1.86e-19	0

Table B.1. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1971	Aug	0	0	0	0	0	0	7.28e-15	1.46e-17	0
1971	Sep	0	0	0	0	0	0	9.63e-13	1.93e-15	0
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	9.98e-09	2.00e-11	0
1972	Mar	0	0	0	0	0	0	2.13e-08	4.25e-11	0
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.2. Estimated Monthly Ruthenium-103 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	48500	0.485	0	0	0	0	0	0	0.485
1945	Jan	45400	0.454	0	0	0	0	0	0	0.454
1945	Feb	64900	0.649	0	0	0	0	0	0	0.649
1945	Mar	66100	0.661	0	0	0	0	0	0	0.661
1945	Apr	265000	2.65	148000	1.48	0	0	0	0	4.13
1945	May	352000	3.52	380000	3.8	0	0	0	0	7.32
1945	Jun	240000	2.4	281000	2.81	0	0	0	0	5.21
1945	Jul	288000	2.88	329000	3.29	0	0	0	0	6.17
1945	Aug	501000	5.01	463000	4.63	0	0	0	0	9.64
1945	Sep	513000	5.13	596000	5.96	0	0	0	0	11.09
1945	Oct	794000	7.94	891000	8.91	0	0	0	0	16.85
1945	Nov	668000	6.68	592000	5.92	0	0	0	0	12.6
1945	Dec	580000	5.8	679000	6.79	0	0	0	0	12.59
1946	Jan	503000	5.03	446000	4.46	0	0	0	0	9.49
1946	Feb	251000	2.51	460000	4.6	0	0	0	0	7.11
1946	Mar	307000	3.07	543000	5.43	0	0	0	0	8.5
1946	Apr	463000	4.63	453000	4.53	0	0	0	0	9.16
1946	May	317000	3.17	648000	6.48	0	0	0	0	9.65
1946	Jun	110000	1.1	446000	4.46	0	0	0	0	5.56
1946	Jul	222000	2.22	488000	4.88	0	0	0	0	7.1
1946	Aug	85000	0.85	653000	6.53	0	0	0	0	7.38
1946	Sep	55700	0.557	448000	4.48	0	0	0	0	5.037
1946	Oct	57700	0.577	470000	4.7	0	0	0	0	5.277
1946	Nov	223000	2.23	456000	4.56	0	0	0	0	6.79
1946	Dec	214000	2.14	397000	3.97	0	0	0	0	6.11
1947	Jan	222000	2.22	307000	3.07	0	0	0	0	5.29

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Feb	232000	2.32	212000	2.12	0	0	0	0	4.44
1947	Mar	278000	2.78	373000	3.73	0	0	0	0	6.51
1947	Apr	246000	2.46	278000	2.78	0	0	0	0	5.24
1947	May	252000	2.52	263000	2.63	0	0	0	0	5.15
1947	Jun	130000	1.3	242000	2.42	0	0	0	0	3.72
1947	Jul	235000	2.35	262000	2.62	0	0	0	0	4.97
1947	Aug	176000	1.76	204000	2.04	0	0	0	0	3.8
1947	Sep	174000	1.74	220000	2.2	0	0	0	0	3.94
1947	Oct	154000	1.54	135000	1.35	0	0	0	0	2.89
1947	Nov	143000	1.43	135000	1.35	0	0	0	0	2.78
1947	Dec	135000	1.35	122000	1.22	0	0	0	0	2.57
1948	Jan	115000	1.15	166000	1.66	0	0	0	0	2.81
1948	Feb	118000	1.18	183000	1.83	0	0	0	0	3.01
1948	Mar	121000	1.21	119000	1.19	0	0	0	0	2.4
1948	Apr	145000	1.45	121000	1.21	0	0	0	0	2.66
1948	May	128000	0.0128	66000	0.66	0	0	0	0	0.6728
1948	Jun	149000	0.0149	158000	0.0158	0	0	0	0	0.0307
1948	Jul	135000	0.0135	228000	0.0228	0	0	0	0	0.0363
1948	Aug	184000	0.0184	181000	0.0181	0	0	0	0	0.0365
1948	Sep	150000	0.015	193000	0.0193	0	0	0	0	0.0343
1948	Oct	184000	0.0184	175000	0.0175	0	0	0	0	0.0359
1948	Nov	210000	0.021	206000	0.0206	0	0	0	0	0.0416
1948	Dec	276000	0.0276	239000	0.0239	0	0	0	0	0.0515
1949	Jan	270000	0.027	292000	0.0292	0	0	0	0	0.0562
1949	Feb	266000	0.0266	55900	0.00559	0	0	0	0	0.03219
1949	Mar	369000	0.0369	271000	0.0271	0	0	0	0	0.064
1949	Apr	142000	0.0142	140000	0.014	0	0	0	0	0.0282
1949	May	123000	0.0123	204000	0.0204	0	0	0	0	0.0327

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Jun	94600	0.00946	121000	0.0121	0	0	0	0	0.02156
1949	Jul	173000	0.0173	116000	0.0116	0	0	0	0	0.0289
1949	Aug	151000	0.0151	52000	0.0052	0	0	0	0	0.0203
1949	Sep	157000	0.0157	183000	0.0183	0	0	0	0	0.034
1949	Oct	189000	0.0189	197000	0.0197	0	0	0	0	0.0386
1949	Nov	156000	0.0156	149000	0.0149	0	0	0	0	0.0305
1949	Dec	194000	0.0194	173000	0.0173	0	0	0	0	0.0367
1950	Jan	214000	0.0214	215000	0.0215	0	0	0	0	0.0429
1950	Feb	175000	0.0175	211000	0.0211	0	0	0	0	0.0386
1950	Mar	243000	0.0243	247000	0.0247	0	0	0	0	0.049
1950	Apr	259000	0.0259	172000	0.0172	0	0	0	0	0.0431
1950	May	230000	0.023	244000	0.0244	0	0	0	0	0.0474
1950	Jun	152000	0.0152	231000	0.0231	0	0	0	0	0.0383
1950	Jul	328000	0.0328	320000	0.032	0	0	0	0	0.0648
1950	Aug	578000	0.0578	594000	0.0594	0	0	0	0	0.1172
1950	Sep	492000	0.0492	500000	0.05	0	0	0	0	0.0992
1950	Oct	442000	0.0442	442000	0.0442	0	0	0	0	0.0884
1950	Nov	361000	0.0361	467000	0.0467	0	0	0	0	0.0828
1950	Dec	439000	0.0439	551000	0.0551	0	0	0	0	0.099
1951	Jan	960000	0.096	628000	0.0628	0	0	0	0	0.1588
1951	Feb	689000	0.0689	782000	0.0782	0	0	0	0	0.1471
1951	Mar	874000	0.0874	1010000	0.101	0	0	0	0	0.1884
1951	Apr	1230000	0.123	1050000	0.105	0	0	0	0	0.228
1951	May	1320000	0.132	1250000	0.125	0	0	0	0	0.257
1951	Jun	1190000	0.119	519000	0.0519	0	0	0	0	0.1709
1951	Jul	745000	0.0745	416000	0.0416	0	0	0	0	0.1161
1951	Aug	1230000	0.123	1110000	0.111	0	0	0	0	0.234
1951	Sep	922000	0.0922	908000	0.0908	0	0	0	0	0.183

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1951	Oct	1050000	0.105	1220000	0.122	0	0	0	0	0.227
1951	Nov	1270000	0.127	1410000	0.141	0	0	0	0	0.268
1951	Dec	1010000	0.101	901000	0.0901	0	0	0	0	0.1911
1952	Jan	1610000	0.161	1230000	0.123	95900	1.44	0	0	1.724
1952	Feb	752000	0.0752	1160000	0.116	598000	1.31	0	0	1.5012
1952	Mar	1470000	0.147	587000	0.0587	1150000	1.49	0	0	1.6957
1952	Apr	930000	0.093	159000	0.0159	2070000	2.28	0	0	2.3889
1952	May	449000	0.0449	47100	0.00471	2040000	2.45	0	0	2.49961
1952	Jun	105000	0.0105	90300	0.00903	1130000	2.38	0	0	2.39953
1952	Jul	612000	0.0612	0	0	1350000	4.44	0	0	4.5012
1952	Aug	601000	0.0601	0	0	2070000	4.55	0	0	4.6101
1952	Sep	49000	0.0049	0	0	1840000	4.42	0	0	4.4249
1952	Oct	157000	0.0157	0	0	1170000	2.22	0	0	2.2357
1952	Nov	239000	0.0239	0	0	1900000	2.09	0	0	2.1139
1952	Dec	638000	0.0638	0	0	1180000	2.01	0	0	2.0738
1953	Jan	53100	0.00531	0	0	2180000	0.218	0	0	0.22331
1953	Feb	416000	0.0416	0	0	833000	0.192	0	0	0.2336
1953	Mar	381000	0.0381	0	0	2110000	0.211	0	0	0.2491
1953	Apr	425000	0.0425	0	0	2410000	4.58	0	0	4.6225
1953	May	400000	0.04	0	0	2290000	4.57	0	0	4.61
1953	Jun	722000	0.0722	0	0	2070000	4.55	0	0	4.6222
1953	Jul	513000	0.0513	0	0	3560000	64	0	0	64.0513
1953	Aug	400000	0.04	0	0	2560000	63.9	0	0	63.94
1953	Sep	507000	0.0507	0	0	2280000	59.3	0	0	59.3507
1953	Oct	410000	0.041	0	0	4050000	21.9	0	0	21.941
1953	Nov	598000	0.0598	0	0	123000	21	0	0	21.0598
1953	Dec	552000	0.0552	0	0	3670000	21.3	0	0	21.3552
1954	Jan	1220000	0.122	0	0	1650000	150	0	0	150.122

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Feb	707000	0.0707	0	0	1720000	129	0	0	129.0707
1954	Mar	565000	0.0565	0	0	3650000	142	0	0	142.0565
1954	Apr	361000	0.0361	0	0	2690000	15	0	0	15.0361
1954	May	1160000	0.116	0	0	3700000	15.5	0	0	15.616
1954	Jun	1130000	0.113	0	0	1090000	16.4	0	0	16.513
1954	Jul	1040000	0.104	0	0	1150000	4.83	0	0	4.934
1954	Aug	1200000	0.12	0	0	1760000	4.75	0	0	4.87
1954	Sep	1370000	0.137	0	0	2710000	4.88	0	0	5.017
1954	Oct	1880000	0.188	0	0	1600000	0.399	0	0	0.587
1954	Nov	1350000	0.135	0	0	1520000	0.381	0	0	0.516
1954	Dec	1630000	0.163	0	0	2940000	0.47	0	0	0.633
1955	Jan	1580000	0.158	0	0	378000	1.32	0	0	1.478
1955	Feb	1740000	0.174	0	0	2330000	1.21	0	0	1.384
1955	Mar	553000	0.0553	0	0	3800000	1.37	0	0	1.4253
1955	Apr	1050000	0.105	0	0	1480000	0.163	0	0	0.268
1955	May	1690000	0.169	0	0	9220	0.00212	0	0	0.17112
1955	Jun	1550000	0.155	0	0	2800000	0.191	0	0	0.346
1955	Jul	1120000	0.112	0	0	2310000	0.254	0	0	0.366
1955	Aug	210000	0.021	0	0	2510000	0.249	0	0	0.27
1955	Sep	1540000	0.154	0	0	3970000	0.246	0	0	0.4
1955	Oct	1110000	0.111	0	0	3600000	0.256	0	0	0.367
1955	Nov	458000	0.0458	0	0	1640000	0.13	0	0	0.1758
1955	Dec	253000	0.0253	0	0	2900000	0.194	0	0	0.2193
1956	Jan	76600	0.00766	0	0	1130000	0.249	378000	0.0378	0.29446
1956	Feb	52000	0.0052	0	0	2620000	0.225	819000	0.0819	0.3121
1956	Mar	0	0	0	0	1770000	0.23	592000	0.0592	0.2892
1956	Apr	0	0	0	0	2020000	0.153	2460000	0.246	0.399
1956	May	0	0	0	0	3990000	0.204	1140000	0.114	0.318

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1956	Jun	0	0	0	0	2960000	0.201	4540000	0.454	0.655
1956	Jul	0	0	0	0	853000	0.188	1130000	0.113	0.301
1956	Aug	0	0	0	0	809000	0.235	2820000	0.282	0.517
1956	Sep	0	0	0	0	1420000	0.213	5020000	0.502	0.715
1956	Oct	0	0	0	0	1390000	0.208	3020000	0.302	0.51
1956	Nov	0	0	0	0	1970000	0.217	5110000	0.511	0.728
1956	Dec	0	0	0	0	2620000	0.251	4700000	0.47	0.721
1957	Jan	0	0	0	0	1350000	0.202	5370000	0.537	0.739
1957	Feb	0	0	0	0	1930000	0.193	4470000	0.447	0.64
1957	Mar	0	0	0	0	1280000	0.217	4620000	0.462	0.679
1957	Apr	0	0	0	0	2570000	0.216	6310000	0.631	0.847
1957	May	0	0	0	0	2390000	0.218	5670000	0.567	0.785
1957	Jun	0	0	0	0	1510000	0.212	6040000	0.604	0.816
1957	Jul	0	0	0	0	2780000	0.228	6110000	0.611	0.839
1957	Aug	0	0	0	0	2910000	0.224	7360000	0.736	0.96
1957	Sep	0	0	0	0	3950000	0.221	5040000	0.504	0.725
1957	Oct	0	0	0	0	3680000	0.883	9500000	0.95	1.833
1957	Nov	0	0	0	0	3630000	0.908	9400000	0.94	1.848
1957	Dec	0	0	0	0	4950000	0.991	8920000	0.892	1.883
1958	Jan	0	0	0	0	1790000	0.179	13400000	1.34	1.519
1958	Feb	0	0	0	0	4350000	0.435	16900000	1.69	2.125
1958	Mar	0	0	0	0	2970000	0.297	12600000	1.26	1.557
1958	Apr	0	0	0	0	2570000	0.257	11800000	1.18	1.437
1958	May	0	0	0	0	5650000	0.565	9160000	0.916	1.481
1958	Jun	0	0	0	0	4580000	0.458	1310000	0.131	0.589
1958	Jul	0	0	0	0	4580000	0.458	11600000	1.16	1.618
1958	Aug	0	0	0	0	2750000	0.275	4490000	0.449	0.724
1958	Sep	0	0	0	0	3090000	0.309	12600000	1.26	1.569

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1958	Oct	0	0	0	0	95800	0.00958	11500000	1.15	1.15958
1958	Nov	0	0	0	0	29700	0.00297	14100000	1.41	1.41297
1958	Dec	0	0	0	0	252000	0.0252	14100000	1.41	1.4352
1959	Jan	0	0	0	0	327000	0.0327	12000000	1.2	1.2327
1959	Feb	0	0	0	0	65800	0.00658	6990000	0.699	0.70558
1959	Mar	0	0	0	0	106000	0.0106	12700000	1.27	1.2806
1959	Apr	0	0	0	0	405000	0.0405	9060000	0.906	0.9465
1959	May	0	0	0	0	255000	0.0255	10200000	1.02	1.0455
1959	Jun	0	0	0	0	740000	0.074	16500000	1.65	1.724
1959	Jul	0	0	0	0	645000	0.0645	7760000	0.776	0.8405
1959	Aug	0	0	0	0	510000	0.051	18800000	1.88	1.931
1959	Sep	0	0	0	0	338000	0.0338	14000000	1.4	1.4338
1959	Oct	0	0	0	0	537000	0.0537	12000000	1.2	1.2537
1959	Nov	0	0	0	0	1380000	0.138	11300000	1.13	1.268
1959	Dec	0	0	0	0	209000	0.0209	14800000	1.48	1.5009
1960	Jan	0	0	0	0	291000	0.0291	23300000	2.33	2.3591
1960	Feb	0	0	0	0	899000	0.0899	9910000	0.991	1.0809
1960	Mar	0	0	0	0	540000	0.054	6690000	0.669	0.723
1960	Apr	0	0	0	0	1120000	0.112	16200000	1.62	1.732
1960	May	0	0	0	0	379000	0.0379	8490000	0.849	0.8869
1960	Jun	0	0	0	0	1480000	0.148	5250000	0.525	0.673
1960	Jul	0	0	0	0	615000	0.0615	12000000	1.2	1.2615
1960	Aug	0	0	0	0	775000	0.0775	24600000	2.46	2.5375
1960	Sep	0	0	0	0	38800	0.00388	14600000	1.46	1.46388
1960	Oct	0	0	0	0	126000	0.0126	2860000	0.286	0.2986
1960	Nov	0	0	0	0	191000	0.0191	17400000	1.74	1.7591
1960	Dec	0	0	0	0	202000	0.0202	17900000	1.79	1.8102
1961	Jan	0	0	0	0	148000	0.0148	11600000	1.16	1.1748

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1961	Feb	0	0	0	0	282000	0.0282	10900000	1.09	1.1182
1961	Mar	0	0	0	0	1070000	0.107	16000000	1.6	1.707
1961	Apr	0	0	0	0	623000	0.0623	7350000	0.735	0.7973
1961	May	0	0	0	0	317000	0.0317	16900000	1.69	1.7217
1961	Jun	0	0	0	0	328000	0.0328	13400000	1.34	1.3728
1961	Jul	0	0	0	0	1460000	0.146	11400000	1.14	1.286
1961	Aug	0	0	0	0	1750000	0.175	14700000	1.47	1.645
1961	Sep	0	0	0	0	1070000	0.107	13100000	1.31	1.417
1961	Oct	0	0	0	0	1780000	0.178	8970000	0.897	1.075
1961	Nov	0	0	0	0	2760000	0.276	6080000	0.608	0.884
1961	Dec	0	0	0	0	647000	0.0647	7450000	0.745	0.8097
1962	Jan	0	0	0	0	3500000	0.35	6220000	0.622	0.972
1962	Feb	0	0	0	0	2240000	0.224	2410000	0.241	0.465
1962	Mar	0	0	0	0	1060000	0.106	3130000	0.313	0.419
1962	Apr	0	0	0	0	8290	0.000829	3200000	0.32	0.320829
1962	May	0	0	0	0	370000	0.037	6950000	0.695	0.732
1962	Jun	0	0	0	0	845000	0.0845	6980000	0.698	0.7825
1962	Jul	0	0	0	0	313000	0.0313	12000000	1.2	1.2313
1962	Aug	0	0	0	0	890000	0.089	4090000	0.409	0.498
1962	Sep	0	0	0	0	592000	0.0592	3360000	0.336	0.3952
1962	Oct	0	0	0	0	403000	0.0403	8800000	0.88	0.9203
1962	Nov	0	0	0	0	214000	0.0214	9190000	0.919	0.9404
1962	Dec	0	0	0	0	302000	0.0302	14200000	1.42	1.4502
1963	Jan	0	0	0	0	830000	0.083	254000	0.0254	0.1084
1963	Feb	0	0	0	0	261000	0.0261	6270000	0.627	0.6531
1963	Mar	0	0	0	0	225000	0.0225	11100000	1.11	1.1325
1963	Apr	0	0	0	0	2200000	0.22	2260000	0.226	0.446
1963	May	0	0	0	0	286000	0.0286	9730000	0.973	1.0016

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1963	Jun	0	0	0	0	1860000	0.186	10100000	1.01	1.196
1963	Jul	0	0	0	0	559000	0.0559	0	0	0.0559
1963	Aug	0	0	0	0	116000	0.0116	4080000	0.408	0.4196
1963	Sep	0	0	0	0	378000	0.0378	7770000	0.777	0.8148
1963	Oct	0	0	0	0	469000	0.0469	6060000	0.606	0.6529
1963	Nov	0	0	0	0	139000	0.0139	8230000	0.823	0.8369
1963	Dec	0	0	0	0	162000	0.0162	2010000	0.201	0.2172
1964	Jan	0	0	0	0	292000	0.0292	2630000	0.263	0.2922
1964	Feb	0	0	0	0	750000	0.075	1130000	0.113	0.188
1964	Mar	0	0	0	0	0	0	11300000	1.13	1.13
1964	Apr	0	0	0	0	347000	0.0347	5210000	0.521	0.5557
1964	May	0	0	0	0	826000	0.0826	8000000	0.8	0.8826
1964	Jun	0	0	0	0	1060000	0.106	11000000	1.1	1.206
1964	Jul	0	0	0	0	568000	0.0568	4710000	0.471	0.5278
1964	Aug	0	0	0	0	171000	0.0171	14100000	1.41	1.4271
1964	Sep	0	0	0	0	657000	0.0657	2190000	0.219	0.2847
1964	Oct	0	0	0	0	186000	0.0186	14500000	1.45	1.4686
1964	Nov	0	0	0	0	388000	0.0388	10200000	1.02	1.0588
1964	Dec	0	0	0	0	1650000	0.165	699000	0.0699	0.2349
1965	Jan	0	0	0	0	1430000	0.143	374000	0.0374	0.1804
1965	Feb	0	0	0	0	839000	0.0839	4000000	0.4	0.4839
1965	Mar	0	0	0	0	1510000	0.151	8520000	0.852	1.003
1965	Apr	0	0	0	0	2500000	0.25	6690000	0.669	0.919
1965	May	0	0	0	0	3000000	0.3	10600000	1.06	1.36
1965	Jun	0	0	0	0	103000	0.0103	4660000	0.466	0.4763
1965	Jul	0	0	0	0	1480000	0.148	2190000	0.219	0.367
1965	Aug	0	0	0	0	1440000	0.144	5610000	0.561	0.705
1965	Sep	0	0	0	0	497000	0.0497	4180000	0.418	0.4677

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1965	Oct	0	0	0	0	623000	0.0623	7010000	0.701	0.7633
1965	Nov	0	0	0	0	886000	0.0886	2820000	0.282	0.3706
1965	Dec	0	0	0	0	5030	0.000503	7470000	0.747	0.747503
1966	Jan	0	0	0	0	3200000	0.32	13100000	1.31	1.63
1966	Feb	0	0	0	0	230000	0.023	2810000	0.281	0.304
1966	Mar	0	0	0	0	848000	0.0848	6050000	0.605	0.6898
1966	Apr	0	0	0	0	348000	0.0348	3850000	0.385	0.4198
1966	May	0	0	0	0	1130000	0.113	0	0	0.113
1966	Jun	0	0	0	0	4470000	0.447	0	0	0.447
1966	Jul	0	0	0	0	1070000	0.107	0	0	0.107
1966	Aug	0	0	0	0	137000	0.0137	489000	0.0489	0.0626
1966	Sep	0	0	0	0	1520000	0.152	2390000	0.239	0.391
1966	Oct	0	0	0	0	217000	0.0217	10600000	1.06	1.0817
1966	Nov	0	0	0	0	108000	0.0108	1510000	0.151	0.1618
1966	Dec	0	0	0	0	0	0	8940	0.000894	0.000894
1967	Jan	0	0	0	0	0	0	8180000	0.818	0.818
1967	Feb	0	0	0	0	0	0	2410000	0.241	0.241
1967	Mar	0	0	0	0	0	0	6220000	0.622	0.622
1967	Apr	0	0	0	0	0	0	128000	0.0128	0.0128
1967	May	0	0	0	0	0	0	6140000	0.614	0.614
1967	Jun	0	0	0	0	0	0	926000	0.0926	0.0926
1967	Jul	0	0	0	0	0	0	1000000	0.1	0.1
1967	Aug	0	0	0	0	0	0	3350000	0.335	0.335
1967	Sep	0	0	0	0	0	0	4040000	0.404	0.404
1967	Oct	0	0	0	0	0	0	1770000	0.177	0.177
1967	Nov	0	0	0	0	0	0	3240000	0.324	0.324
1967	Dec	0	0	0	0	0	0	798000	0.0798	0.0798
1968	Jan	0	0	0	0	0	0	550000	0.055	0.055

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1968	Feb	0	0	0	0	0	0	241000	0.0241	0.0241
1968	Mar	0	0	0	0	0	0	2920000	0.292	0.292
1968	Apr	0	0	0	0	0	0	3270000	0.327	0.327
1968	May	0	0	0	0	0	0	1660000	0.166	0.166
1968	Jun	0	0	0	0	0	0	2210000	0.221	0.221
1968	Jul	0	0	0	0	0	0	440000	0.044	0.044
1968	Aug	0	0	0	0	0	0	3220000	0.322	0.322
1968	Sep	0	0	0	0	0	0	1240000	0.124	0.124
1968	Oct	0	0	0	0	0	0	3190000	0.319	0.319
1968	Nov	0	0	0	0	0	0	213000	0.0213	0.0213
1968	Dec	0	0	0	0	0	0	530000	0.053	0.053
1969	Jan	0	0	0	0	0	0	295000	0.0295	0.0295
1969	Feb	0	0	0	0	0	0	241000	0.0241	0.0241
1969	Mar	0	0	0	0	0	0	896000	0.0896	0.0896
1969	Apr	0	0	0	0	0	0	453000	0.0453	0.0453
1969	May	0	0	0	0	0	0	135000	0.0135	0.0135
1969	Jun	0	0	0	0	0	0	612000	0.0612	0.0612
1969	Jul	0	0	0	0	0	0	496000	0.0496	0.0496
1969	Aug	0	0	0	0	0	0	977000	0.0977	0.0977
1969	Sep	0	0	0	0	0	0	1480000	0.148	0.148
1969	Oct	0	0	0	0	0	0	1180000	0.118	0.118
1969	Nov	0	0	0	0	0	0	396000	0.0396	0.0396
1969	Dec	0	0	0	0	0	0	147000	0.0147	0.0147
1970	Jan	0	0	0	0	0	0	1470000	0.147	0.147
1970	Feb	0	0	0	0	0	0	1.13	1.13e-07	1.13e-07
1970	Mar	0	0	0	0	0	0	114000	0.0114	0.0114
1970	Apr	0	0	0	0	0	0	215000	0.0215	0.0215
1970	May	0	0	0	0	0	0	148000	0.0148	0.0148

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	1720	0.000172	0.000172
1971	Apr	0	0	0	0	0	0	24900	0.00249	0.00249
1971	May	0	0	0	0	0	0	203000	0.0203	0.0203
1971	Jun	0	0	0	0	0	0	877000	0.0877	0.0877
1971	Jul	0	0	0	0	0	0	852	0.000085	0.000085
1971	Aug	0	0	0	0	0	0	3810	0.000381	0.000381
1971	Sep	0	0	0	0	0	0	9490	0.000949	0.000949
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	10600	0.00106	0.00106
1972	Mar	0	0	0	0	0	0	37900	0.00379	0.00379
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0

Table B.2. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.3. Estimated Monthly Ruthenium-106 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	3510	0.0351	0	0	0	0	0	0	0.0351
1945	Jan	3570	0.0357	0	0	0	0	0	0	0.0357
1945	Feb	6470	0.0647	0	0	0	0	0	0	0.0647
1945	Mar	6310	0.0631	0	0	0	0	0	0	0.0631
1945	Apr	24000	0.24	14000	0.14	0	0	0	0	0.38
1945	May	38500	0.385	41600	0.416	0	0	0	0	0.801
1945	Jun	28900	0.289	36500	0.365	0	0	0	0	0.654
1945	Jul	40600	0.406	46100	0.461	0	0	0	0	0.867
1945	Aug	77600	0.776	59600	0.596	0	0	0	0	1.372
1945	Sep	74700	0.747	74100	0.741	0	0	0	0	1.488
1945	Oct	114000	1.14	131000	1.31	0	0	0	0	2.45
1945	Nov	105000	1.05	91700	0.917	0	0	0	0	1.967
1945	Dec	114000	1.14	90500	0.905	0	0	0	0	2.045
1946	Jan	145000	1.45	72000	0.72	0	0	0	0	2.17
1946	Feb	83900	0.839	86000	0.86	0	0	0	0	1.699
1946	Mar	67700	0.677	105000	1.05	0	0	0	0	1.727
1946	Apr	83700	0.837	81200	0.812	0	0	0	0	1.649
1946	May	58500	0.585	123000	1.23	0	0	0	0	1.815
1946	Jun	46000	0.46	91300	0.913	0	0	0	0	1.373
1946	Jul	55900	0.559	96700	0.967	0	0	0	0	1.526
1946	Aug	23300	0.233	120000	1.2	0	0	0	0	1.433
1946	Sep	12700	0.127	79600	0.796	0	0	0	0	0.923
1946	Oct	13000	0.13	92600	0.926	0	0	0	0	1.056
1946	Nov	44700	0.447	93500	0.935	0	0	0	0	1.382
1946	Dec	44800	0.448	72100	0.721	0	0	0	0	1.169
1947	Jan	45700	0.457	55200	0.552	0	0	0	0	1.009
1947	Feb	44700	0.447	46200	0.462	0	0	0	0	0.909
1947	Mar	57100	0.571	77500	0.775	0	0	0	0	1.346

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Apr	51700	0.517	58500	0.585	0	0	0	0	1.102
1947	May	52600	0.526	56700	0.567	0	0	0	0	1.093
1947	Jun	29800	0.298	59200	0.592	0	0	0	0	0.89
1947	Jul	58200	0.582	61700	0.617	0	0	0	0	1.199
1947	Aug	47300	0.473	50700	0.507	0	0	0	0	0.98
1947	Sep	46100	0.461	57500	0.575	0	0	0	0	1.036
1947	Oct	43200	0.432	42600	0.426	0	0	0	0	0.858
1947	Nov	46700	0.467	42400	0.424	0	0	0	0	0.891
1947	Dec	47300	0.473	41700	0.417	0	0	0	0	0.89
1948	Jan	46800	0.468	57400	0.574	0	0	0	0	1.042
1948	Feb	44600	0.446	63500	0.635	0	0	0	0	1.081
1948	Mar	46600	0.466	46300	0.463	0	0	0	0	0.929
1948	Apr	52400	0.524	57600	0.576	0	0	0	0	1.1
1948	May	51700	0.00517	36300	0.363	0	0	0	0	0.36817
1948	Jun	64000	0.0064	68800	0.00688	0	0	0	0	0.01328
1948	Jul	51700	0.00517	80100	0.00801	0	0	0	0	0.01318
1948	Aug	61800	0.00618	62000	0.0062	0	0	0	0	0.01238
1948	Sep	47200	0.00472	50900	0.00509	0	0	0	0	0.00981
1948	Oct	66800	0.00668	61500	0.00615	0	0	0	0	0.01283
1948	Nov	71700	0.00717	71500	0.00715	0	0	0	0	0.01432
1948	Dec	99500	0.00995	85500	0.00855	0	0	0	0	0.0185
1949	Jan	93400	0.00934	101000	0.0101	0	0	0	0	0.01944
1949	Feb	86900	0.00869	24000	0.0024	0	0	0	0	0.01109
1949	Mar	127000	0.0127	112000	0.0112	0	0	0	0	0.0239
1949	Apr	52000	0.0052	54000	0.0054	0	0	0	0	0.0106
1949	May	47400	0.00474	74100	0.00741	0	0	0	0	0.01215
1949	Jun	39400	0.00394	52600	0.00526	0	0	0	0	0.0092
1949	Jul	78500	0.00785	49700	0.00497	0	0	0	0	0.01282
1949	Aug	65100	0.00651	26800	0.00268	0	0	0	0	0.00919
1949	Sep	76600	0.00766	94600	0.00946	0	0	0	0	0.01712

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Oct	113000	0.0113	100000	0.01	0	0	0	0	0.0213
1949	Nov	84600	0.00846	88000	0.0088	0	0	0	0	0.01726
1949	Dec	115000	0.0115	108000	0.0108	0	0	0	0	0.0223
1950	Jan	109000	0.0109	113000	0.0113	0	0	0	0	0.0222
1950	Feb	91500	0.00915	112000	0.0112	0	0	0	0	0.02035
1950	Mar	117000	0.0117	131000	0.0131	0	0	0	0	0.0248
1950	Apr	121000	0.0121	80300	0.00803	0	0	0	0	0.02013
1950	May	109000	0.0109	118000	0.0118	0	0	0	0	0.0227
1950	Jun	91200	0.00912	113000	0.0113	0	0	0	0	0.02042
1950	Jul	159000	0.0159	156000	0.0156	0	0	0	0	0.0315
1950	Aug	202000	0.0202	220000	0.022	0	0	0	0	0.0422
1950	Sep	183000	0.0183	181000	0.0181	0	0	0	0	0.0364
1950	Oct	178000	0.0178	170000	0.017	0	0	0	0	0.0348
1950	Nov	192000	0.0192	194000	0.0194	0	0	0	0	0.0386
1950	Dec	106000	0.0106	218000	0.0218	0	0	0	0	0.0324
1951	Jan	187000	0.0187	227000	0.0227	0	0	0	0	0.0414
1951	Feb	193000	0.0193	213000	0.0213	0	0	0	0	0.0406
1951	Mar	256000	0.0256	242000	0.0242	0	0	0	0	0.0498
1951	Apr	260000	0.026	220000	0.022	0	0	0	0	0.048
1951	May	251000	0.0251	252000	0.0252	0	0	0	0	0.0503
1951	Jun	226000	0.0226	103000	0.0103	0	0	0	0	0.0329
1951	Jul	178000	0.0178	103000	0.0103	0	0	0	0	0.0281
1951	Aug	316000	0.0316	292000	0.0292	0	0	0	0	0.0608
1951	Sep	237000	0.0237	240000	0.024	0	0	0	0	0.0477
1951	Oct	272000	0.0272	303000	0.0303	0	0	0	0	0.0575
1951	Nov	351000	0.0351	366000	0.0366	0	0	0	0	0.0717
1951	Dec	267000	0.0267	246000	0.0246	0	0	0	0	0.0513
1952	Jan	363000	0.0363	285000	0.0285	24300	0.365	0	0	0.4298
1952	Feb	183000	0.0183	290000	0.029	153000	0.336	0	0	0.3833
1952	Mar	347000	0.0347	157000	0.0157	308000	0.4	0	0	0.4504

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1952	Apr	217000	0.0217	49500	0.00495	552000	0.608	0	0	0.63465
1952	May	117000	0.0117	14200	0.00142	561000	0.673	0	0	0.68612
1952	Jun	49100	0.00491	27100	0.00271	327000	0.687	0	0	0.69462
1952	Jul	206000	0.0206	0	0	527000	1.74	0	0	1.7606
1952	Aug	184000	0.0184	0	0	738000	1.62	0	0	1.6384
1952	Sep	21200	0.00212	0	0	665000	1.6	0	0	1.60212
1952	Oct	76300	0.00763	0	0	490000	0.931	0	0	0.93863
1952	Nov	90900	0.00909	0	0	774000	0.851	0	0	0.86009
1952	Dec	195000	0.0195	0	0	610000	1.04	0	0	1.0595
1953	Jan	21900	0.00219	0	0	790000	0.079	0	0	0.08119
1953	Feb	173000	0.0173	0	0	373000	0.0857	0	0	0.103
1953	Mar	141000	0.0141	0	0	870000	0.087	0	0	0.1011
1953	Apr	65900	0.00659	0	0	706000	1.34	0	0	1.34659
1953	May	77200	0.00772	0	0	778000	1.56	0	0	1.56772
1953	Jun	139000	0.0139	0	0	704000	1.55	0	0	1.5639
1953	Jul	85800	0.00858	0	0	1050000	18.8	0	0	18.80858
1953	Aug	74300	0.00743	0	0	849000	21.2	0	0	21.20743
1953	Sep	123000	0.0123	0	0	842000	21.9	0	0	21.9123
1953	Oct	123000	0.0123	0	0	1350000	7.28	0	0	7.2923
1953	Nov	172000	0.0172	0	0	41200	7	0	0	7.0172
1953	Dec	234000	0.0234	0	0	1350000	7.85	0	0	7.8734
1954	Jan	290000	0.029	0	0	501000	45.6	0	0	45.629
1954	Feb	240000	0.024	0	0	624000	46.8	0	0	46.824
1954	Mar	212000	0.0212	0	0	1310000	51.1	0	0	51.1212
1954	Apr	63000	0.0063	0	0	1000000	5.62	0	0	5.6263
1954	May	175000	0.0175	0	0	1350000	5.66	0	0	5.6775
1954	Jun	199000	0.0199	0	0	335000	5.02	0	0	5.0399
1954	Jul	180000	0.018	0	0	543000	2.28	0	0	2.298
1954	Aug	202000	0.0202	0	0	860000	2.32	0	0	2.3402
1954	Sep	214000	0.0214	0	0	1140000	2.05	0	0	2.0714

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Oct	258000	0.0258	0	0	1220000	0.306	0	0	0.3318
1954	Nov	242000	0.0242	0	0	1290000	0.324	0	0	0.3482
1954	Dec	284000	0.0284	0	0	1490000	0.238	0	0	0.2664
1955	Jan	303000	0.0303	0	0	70600	0.247	0	0	0.2773
1955	Feb	317000	0.0317	0	0	373000	0.194	0	0	0.2257
1955	Mar	148000	0.0148	0	0	527000	0.19	0	0	0.2048
1955	Apr	164000	0.0164	0	0	1320000	0.145	0	0	0.1614
1955	May	306000	0.0306	0	0	1320000	0.303	0	0	0.3336
1955	Jun	365000	0.0365	0	0	1580000	0.108	0	0	0.1445
1955	Jul	267000	0.0267	0	0	624000	0.0687	0	0	0.0954
1955	Aug	240000	0.024	0	0	607000	0.0601	0	0	0.0841
1955	Sep	330000	0.033	0	0	831000	0.0515	0	0	0.0845
1955	Oct	229000	0.0229	0	0	746000	0.053	0	0	0.0759
1955	Nov	120000	0.012	0	0	2160000	0.17	0	0	0.182
1955	Dec	95000	0.0095	0	0	1750000	0.117	0	0	0.1265
1956	Jan	42200	0.00422	0	0	275000	0.0604	162000	0.0162	0.08082
1956	Feb	59900	0.00599	0	0	617000	0.0531	562000	0.0562	0.11529
1956	Mar	0	0	0	0	608000	0.079	304000	0.0304	0.1094
1956	Apr	0	0	0	0	1940000	0.147	507000	0.0507	0.1977
1956	May	0	0	0	0	2040000	0.104	332000	0.0332	0.1372
1956	Jun	0	0	0	0	1420000	0.0968	871000	0.0871	0.1839
1956	Jul	0	0	0	0	540000	0.119	1090000	0.109	0.228
1956	Aug	0	0	0	0	269000	0.0781	2160000	0.216	0.2941
1956	Sep	0	0	0	0	575000	0.0863	2970000	0.297	0.3833
1956	Oct	0	0	0	0	643000	0.0964	1760000	0.176	0.2724
1956	Nov	0	0	0	0	669000	0.0735	2470000	0.247	0.3205
1956	Dec	0	0	0	0	616000	0.0592	2450000	0.245	0.3042
1957	Jan	0	0	0	0	680000	0.102	2680000	0.268	0.37
1957	Feb	0	0	0	0	865000	0.0865	2190000	0.219	0.3055
1957	Mar	0	0	0	0	588000	0.1	2370000	0.237	0.337

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1957	Apr	0	0	0	0	1020000	0.086	2460000	0.246	0.332
1957	May	0	0	0	0	1000000	0.091	2430000	0.243	0.334
1957	Jun	0	0	0	0	642000	0.0898	2610000	0.261	0.3508
1957	Jul	0	0	0	0	1010000	0.0826	2040000	0.204	0.2866
1957	Aug	0	0	0	0	1120000	0.086	2530000	0.253	0.339
1957	Sep	0	0	0	0	1440000	0.0806	1860000	0.186	0.2666
1957	Oct	0	0	0	0	1390000	0.333	2960000	0.296	0.629
1957	Nov	0	0	0	0	1150000	0.289	2940000	0.294	0.583
1957	Dec	0	0	0	0	1130000	0.226	2180000	0.218	0.444
1958	Jan	0	0	0	0	483000	0.0483	3390000	0.339	0.3873
1958	Feb	0	0	0	0	941000	0.0941	3720000	0.372	0.4661
1958	Mar	0	0	0	0	676000	0.0676	2680000	0.268	0.3356
1958	Apr	0	0	0	0	616000	0.0616	2800000	0.28	0.3416
1958	May	0	0	0	0	1310000	0.131	2100000	0.21	0.341
1958	Jun	0	0	0	0	1290000	0.129	244000	0.0244	0.1534
1958	Jul	0	0	0	0	1360000	0.136	3340000	0.334	0.47
1958	Aug	0	0	0	0	794000	0.0794	1320000	0.132	0.2114
1958	Sep	0	0	0	0	932000	0.0932	3410000	0.341	0.4342
1958	Oct	0	0	0	0	143000	0.0143	3640000	0.364	0.3783
1958	Nov	0	0	0	0	77300	0.00773	4030000	0.403	0.41073
1958	Dec	0	0	0	0	471000	0.0471	4070000	0.407	0.4541
1959	Jan	0	0	0	0	543000	0.0543	3210000	0.321	0.3753
1959	Feb	0	0	0	0	259000	0.0259	2110000	0.211	0.2369
1959	Mar	0	0	0	0	287000	0.0287	3830000	0.383	0.4117
1959	Apr	0	0	0	0	707000	0.0707	3120000	0.312	0.3827
1959	May	0	0	0	0	461000	0.0461	3180000	0.318	0.3641
1959	Jun	0	0	0	0	581000	0.0581	5570000	0.557	0.6151
1959	Jul	0	0	0	0	639000	0.0639	2650000	0.265	0.3289
1959	Aug	0	0	0	0	381000	0.0381	6350000	0.635	0.6731
1959	Sep	0	0	0	0	433000	0.0433	3930000	0.393	0.4363

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Oct	0	0	0	0	468000	0.0468	3760000	0.376	0.4228
1959	Nov	0	0	0	0	787000	0.0787	3760000	0.376	0.4547
1959	Dec	0	0	0	0	849000	0.0849	4810000	0.481	0.5659
1960	Jan	0	0	0	0	97500	0.00975	5960000	0.596	0.60575
1960	Feb	0	0	0	0	469000	0.0469	2810000	0.281	0.3279
1960	Mar	0	0	0	0	273000	0.0273	2470000	0.247	0.2743
1960	Apr	0	0	0	0	624000	0.0624	6490000	0.649	0.7114
1960	May	0	0	0	0	286000	0.0286	2410000	0.241	0.2696
1960	Jun	0	0	0	0	1110000	0.111	1930000	0.193	0.304
1960	Jul	0	0	0	0	541000	0.0541	3810000	0.381	0.4351
1960	Aug	0	0	0	0	340000	0.034	6690000	0.669	0.703
1960	Sep	0	0	0	0	111000	0.0111	6210000	0.621	0.6321
1960	Oct	0	0	0	0	430000	0.043	2910000	0.291	0.334
1960	Nov	0	0	0	0	576000	0.0576	6140000	0.614	0.6716
1960	Dec	0	0	0	0	495000	0.0495	5230000	0.523	0.5725
1961	Jan	0	0	0	0	403000	0.0403	3900000	0.39	0.4303
1961	Feb	0	0	0	0	531000	0.0531	3590000	0.359	0.4121
1961	Mar	0	0	0	0	761000	0.0761	5480000	0.548	0.6241
1961	Apr	0	0	0	0	822000	0.0822	2920000	0.292	0.3742
1961	May	0	0	0	0	458000	0.0458	6870000	0.687	0.7328
1961	Jun	0	0	0	0	1060000	0.106	4570000	0.457	0.563
1961	Jul	0	0	0	0	1120000	0.112	4410000	0.441	0.553
1961	Aug	0	0	0	0	1010000	0.101	4990000	0.499	0.6
1961	Sep	0	0	0	0	516000	0.0516	4580000	0.458	0.5096
1961	Oct	0	0	0	0	861000	0.0861	2620000	0.262	0.3481
1961	Nov	0	0	0	0	1100000	0.11	2300000	0.23	0.34
1961	Dec	0	0	0	0	531000	0.0531	6160000	0.616	0.6691
1962	Jan	0	0	0	0	1430000	0.143	3160000	0.316	0.459
1962	Feb	0	0	0	0	886000	0.0886	1110000	0.111	0.1996
1962	Mar	0	0	0	0	540000	0.054	2730000	0.273	0.327

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1962	Apr	0	0	0	0	27000	0.0027	2630000	0.263	0.2657
1962	May	0	0	0	0	312000	0.0312	4770000	0.477	0.5082
1962	Jun	0	0	0	0	702000	0.0702	4130000	0.413	0.4832
1962	Jul	0	0	0	0	359000	0.0359	6000000	0.6	0.6359
1962	Aug	0	0	0	0	955000	0.0955	1800000	0.18	0.2755
1962	Sep	0	0	0	0	745000	0.0745	4270000	0.427	0.5015
1962	Oct	0	0	0	0	763000	0.0763	5220000	0.522	0.5983
1962	Nov	0	0	0	0	410000	0.041	5270000	0.527	0.568
1962	Dec	0	0	0	0	351000	0.0351	5360000	0.536	0.5711
1963	Jan	0	0	0	0	1600000	0.16	513000	0.0513	0.2113
1963	Feb	0	0	0	0	565000	0.0565	4510000	0.451	0.5075
1963	Mar	0	0	0	0	409000	0.0409	5990000	0.599	0.6399
1963	Apr	0	0	0	0	1490000	0.149	913000	0.0913	0.2403
1963	May	0	0	0	0	195000	0.0195	5010000	0.501	0.5205
1963	Jun	0	0	0	0	1100000	0.11	6020000	0.602	0.712
1963	Jul	0	0	0	0	1180000	0.118	0	0	0.118
1963	Aug	0	0	0	0	825000	0.0825	2300000	0.23	0.3125
1963	Sep	0	0	0	0	742000	0.0742	4580000	0.458	0.5322
1963	Oct	0	0	0	0	392000	0.0392	4870000	0.487	0.5262
1963	Nov	0	0	0	0	143000	0.0143	6760000	0.676	0.6903
1963	Dec	0	0	0	0	375000	0.0375	522000	0.0522	0.0897
1964	Jan	0	0	0	0	1270000	0.127	1320000	0.132	0.259
1964	Feb	0	0	0	0	1350000	0.135	501000	0.0501	0.1851
1964	Mar	0	0	0	0	0	0	6630000	0.663	0.663
1964	Apr	0	0	0	0	915000	0.0915	2580000	0.258	0.3495
1964	May	0	0	0	0	1380000	0.138	3570000	0.357	0.495
1964	Jun	0	0	0	0	698000	0.0698	7390000	0.739	0.8088
1964	Jul	0	0	0	0	888000	0.0888	2310000	0.231	0.3198
1964	Aug	0	0	0	0	780000	0.078	6230000	0.623	0.701
1964	Sep	0	0	0	0	870000	0.087	5160000	0.516	0.603

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Oct	0	0	0	0	180000	0.018	6100000	0.61	0.628
1964	Nov	0	0	0	0	687000	0.0687	4410000	0.441	0.5097
1964	Dec	0	0	0	0	2150000	0.215	294000	0.0294	0.2444
1965	Jan	0	0	0	0	1920000	0.192	105000	0.0105	0.2025
1965	Feb	0	0	0	0	833000	0.0833	2800000	0.28	0.3633
1965	Mar	0	0	0	0	1170000	0.117	6000000	0.6	0.717
1965	Apr	0	0	0	0	1810000	0.181	6120000	0.612	0.793
1965	May	0	0	0	0	1620000	0.162	5990000	0.599	0.761
1965	Jun	0	0	0	0	121000	0.0121	3470000	0.347	0.3591
1965	Jul	0	0	0	0	1300000	0.13	1630000	0.163	0.293
1965	Aug	0	0	0	0	684000	0.0684	4260000	0.426	0.4944
1965	Sep	0	0	0	0	376000	0.0376	3100000	0.31	0.3476
1965	Oct	0	0	0	0	1110000	0.111	3070000	0.307	0.418
1965	Nov	0	0	0	0	1220000	0.122	2010000	0.201	0.323
1965	Dec	0	0	0	0	13600	0.00136	3290000	0.329	0.33036
1966	Jan	0	0	0	0	9130000	0.913	5070000	0.507	1.42
1966	Feb	0	0	0	0	489000	0.0489	2290000	0.229	0.2779
1966	Mar	0	0	0	0	1550000	0.155	2760000	0.276	0.431
1966	Apr	0	0	0	0	1590000	0.159	1470000	0.147	0.306
1966	May	0	0	0	0	1160000	0.116	0	0	0.116
1966	Jun	0	0	0	0	2280000	0.228	0	0	0.228
1966	Jul	0	0	0	0	541000	0.0541	0	0	0.0541
1966	Aug	0	0	0	0	72000	0.0072	743000	0.0743	0.0815
1966	Sep	0	0	0	0	1990000	0.199	3670000	0.367	0.566
1966	Oct	0	0	0	0	1480000	0.148	6500000	0.65	0.798
1966	Nov	0	0	0	0	699000	0.0699	3630000	0.363	0.4329
1966	Dec	0	0	0	0	0	0	351000	0.0351	0.0351
1967	Jan	0	0	0	0	0	0	5010000	0.501	0.501
1967	Feb	0	0	0	0	0	0	1430000	0.143	0.143
1967	Mar	0	0	0	0	0	0	3010000	0.301	0.301

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1967	Apr	0	0	0	0	0	0	4490000	0.449	0.449
1967	May	0	0	0	0	0	0	3370000	0.337	0.337
1967	Jun	0	0	0	0	0	0	1810000	0.181	0.181
1967	Jul	0	0	0	0	0	0	4480000	0.448	0.448
1967	Aug	0	0	0	0	0	0	3910000	0.391	0.391
1967	Sep	0	0	0	0	0	0	6640000	0.664	0.664
1967	Oct	0	0	0	0	0	0	3580000	0.358	0.358
1967	Nov	0	0	0	0	0	0	4170000	0.417	0.417
1967	Dec	0	0	0	0	0	0	1610000	0.161	0.161
1968	Jan	0	0	0	0	0	0	4360000	0.436	0.436
1968	Feb	0	0	0	0	0	0	2020000	0.202	0.202
1968	Mar	0	0	0	0	0	0	6000000	0.6	0.6
1968	Apr	0	0	0	0	0	0	6130000	0.613	0.613
1968	May	0	0	0	0	0	0	3110000	0.311	0.311
1968	Jun	0	0	0	0	0	0	3790000	0.379	0.379
1968	Jul	0	0	0	0	0	0	1910000	0.191	0.191
1968	Aug	0	0	0	0	0	0	7140000	0.714	0.714
1968	Sep	0	0	0	0	0	0	3200000	0.32	0.32
1968	Oct	0	0	0	0	0	0	4640000	0.464	0.464
1968	Nov	0	0	0	0	0	0	3200000	0.32	0.32
1968	Dec	0	0	0	0	0	0	2260000	0.226	0.226
1969	Jan	0	0	0	0	0	0	2190000	0.219	0.219
1969	Feb	0	0	0	0	0	0	2980000	0.298	0.298
1969	Mar	0	0	0	0	0	0	3150000	0.315	0.315
1969	Apr	0	0	0	0	0	0	3290000	0.329	0.329
1969	May	0	0	0	0	0	0	3380000	0.338	0.338
1969	Jun	0	0	0	0	0	0	1450000	0.145	0.145
1969	Jul	0	0	0	0	0	0	1160000	0.116	0.116
1969	Aug	0	0	0	0	0	0	5290000	0.529	0.529
1969	Sep	0	0	0	0	0	0	3440000	0.344	0.344

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Oct	0	0	0	0	0	0	3110000	0.311	0.311
1969	Nov	0	0	0	0	0	0	2920000	0.292	0.292
1969	Dec	0	0	0	0	0	0	3700000	0.37	0.37
1970	Jan	0	0	0	0	0	0	2580000	0.258	0.258
1970	Feb	0	0	0	0	0	0	378	0.000038	0.000038
1970	Mar	0	0	0	0	0	0	475000	0.0475	0.0475
1970	Apr	0	0	0	0	0	0	3200000	0.32	0.32
1970	May	0	0	0	0	0	0	2610000	0.261	0.261
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	52700	0.00527	0.00527
1971	Apr	0	0	0	0	0	0	1400000	0.14	0.14
1971	May	0	0	0	0	0	0	2810000	0.281	0.281
1971	Jun	0	0	0	0	0	0	1920000	0.192	0.192
1971	Jul	0	0	0	0	0	0	905000	0.0905	0.0905
1971	Aug	0	0	0	0	0	0	2160000	0.216	0.216
1971	Sep	0	0	0	0	0	0	2190000	0.219	0.219
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	221000	0.0221	0.0221
1972	Mar	0	0	0	0	0	0	951000	0.0951	0.0951

Table B.3. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.4. Estimated Monthly Cerium-144 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	31400	1.57	0	0	0	0	0	0	1.57
1945	Jan	31900	1.59	0	0	0	0	0	0	1.59
1945	Feb	57300	2.86	0	0	0	0	0	0	2.86
1945	Mar	56000	2.8	0	0	0	0	0	0	2.8
1945	Apr	211000	10.5	120000	6	0	0	0	0	16.5
1945	May	310000	15.5	333000	16.6	0	0	0	0	32.1
1945	Jun	225000	11.2	277000	13.9	0	0	0	0	25.1
1945	Jul	302000	15.1	342000	17.1	0	0	0	0	32.2
1945	Aug	558000	27.9	452000	22.6	0	0	0	0	50.5
1945	Sep	549000	27.4	567000	28.4	0	0	0	0	55.8
1945	Oct	852000	42.6	976000	48.8	0	0	0	0	91.4
1945	Nov	794000	39.7	693000	34.6	0	0	0	0	74.3
1945	Dec	815000	40.8	685000	34.2	0	0	0	0	75
1946	Jan	837000	41.9	541000	27.1	0	0	0	0	69
1946	Feb	525000	26.3	653000	32.7	0	0	0	0	59
1946	Mar	508000	25.4	783000	39.1	0	0	0	0	64.5
1946	Apr	630000	31.5	611000	30.5	0	0	0	0	62
1946	May	437000	21.9	920000	46	0	0	0	0	67.9
1946	Jun	306000	15.3	677000	33.8	0	0	0	0	49.1
1946	Jul	410000	20.5	717000	35.9	0	0	0	0	56.4
1946	Aug	171000	8.54	894000	44.7	0	0	0	0	53.24
1946	Sep	93900	4.7	593000	29.7	0	0	0	0	34.4
1946	Oct	95700	4.79	690000	34.5	0	0	0	0	39.29
1946	Nov	334000	16.7	697000	34.8	0	0	0	0	51.5
1946	Dec	332000	16.6	541000	27.1	0	0	0	0	43.7
1947	Jan	341000	17	415000	20.7	0	0	0	0	37.7
1947	Feb	334000	16.7	344000	17.2	0	0	0	0	33.9
1947	Mar	426000	21.3	575000	28.8	0	0	0	0	50.1

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Apr	383000	19.2	433000	21.7	0	0	0	0	40.9
1947	May	389000	19.4	419000	20.9	0	0	0	0	40.3
1947	Jun	221000	11	437000	21.8	0	0	0	0	32.8
1947	Jul	431000	21.5	455000	22.8	0	0	0	0	44.3
1947	Aug	349000	17.5	374000	18.7	0	0	0	0	36.2
1947	Sep	339000	17	425000	21.3	0	0	0	0	38.3
1947	Oct	318000	15.9	312000	15.6	0	0	0	0	31.5
1947	Nov	342000	17.1	311000	15.6	0	0	0	0	32.7
1947	Dec	347000	17.3	306000	15.3	0	0	0	0	32.6
1948	Jan	340000	17	421000	21	0	0	0	0	38
1948	Feb	328000	16.4	467000	23.3	0	0	0	0	39.7
1948	Mar	340000	17	337000	16.9	0	0	0	0	33.9
1948	Apr	382000	19.1	398000	19.9	0	0	0	0	39
1948	May	376000	0.188	252000	12.6	0	0	0	0	12.788
1948	Jun	464000	0.232	499000	0.25	0	0	0	0	0.482
1948	Jul	377000	0.189	582000	0.291	0	0	0	0	0.48
1948	Aug	450000	0.225	450000	0.225	0	0	0	0	0.45
1948	Sep	347000	0.173	373000	0.186	0	0	0	0	0.359
1948	Oct	485000	0.242	447000	0.223	0	0	0	0	0.465
1948	Nov	523000	0.262	522000	0.261	0	0	0	0	0.523
1948	Dec	721000	0.36	621000	0.31	0	0	0	0	0.67
1949	Jan	676000	0.338	731000	0.366	0	0	0	0	0.704
1949	Feb	632000	0.316	173000	0.0864	0	0	0	0	0.4024
1949	Mar	906000	0.453	795000	0.397	0	0	0	0	0.85
1949	Apr	367000	0.184	380000	0.19	0	0	0	0	0.374
1949	May	328000	0.164	526000	0.263	0	0	0	0	0.427
1949	Jun	265000	0.132	360000	0.18	0	0	0	0	0.312
1949	Jul	517000	0.258	333000	0.166	0	0	0	0	0.424
1949	Aug	435000	0.217	174000	0.0868	0	0	0	0	0.3038
1949	Sep	485000	0.242	584000	0.292	0	0	0	0	0.534

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Oct	671000	0.335	626000	0.313	0	0	0	0	0.648
1949	Nov	516000	0.258	526000	0.263	0	0	0	0	0.521
1949	Dec	673000	0.337	630000	0.315	0	0	0	0	0.652
1950	Jan	662000	0.331	678000	0.339	0	0	0	0	0.67
1950	Feb	549000	0.274	676000	0.338	0	0	0	0	0.612
1950	Mar	719000	0.36	774000	0.387	0	0	0	0	0.747
1950	Apr	760000	0.38	498000	0.249	0	0	0	0	0.629
1950	May	668000	0.334	725000	0.362	0	0	0	0	0.696
1950	Jun	510000	0.255	683000	0.341	0	0	0	0	0.596
1950	Jul	930000	0.465	934000	0.467	0	0	0	0	0.932
1950	Aug	1220000	0.609	1320000	0.659	0	0	0	0	1.268
1950	Sep	1090000	0.543	1080000	0.541	0	0	0	0	1.084
1950	Oct	1060000	0.53	1010000	0.504	0	0	0	0	1.034
1950	Nov	1020000	0.512	1170000	0.584	0	0	0	0	1.096
1950	Dec	745000	0.372	1320000	0.662	0	0	0	0	1.034
1951	Jan	1310000	0.657	1390000	0.696	0	0	0	0	1.353
1951	Feb	1190000	0.595	1330000	0.665	0	0	0	0	1.26
1951	Mar	1540000	0.771	1500000	0.75	0	0	0	0	1.521
1951	Apr	1620000	0.809	1370000	0.683	0	0	0	0	1.492
1951	May	1580000	0.788	1560000	0.781	0	0	0	0	1.569
1951	Jun	1410000	0.707	643000	0.322	0	0	0	0	1.029
1951	Jul	1020000	0.511	574000	0.287	0	0	0	0	0.798
1951	Aug	1720000	0.858	1590000	0.795	0	0	0	0	1.653
1951	Sep	1310000	0.654	1310000	0.657	0	0	0	0	1.311
1951	Oct	1490000	0.747	1680000	0.838	0	0	0	0	1.585
1951	Nov	1910000	0.953	1980000	0.992	0	0	0	0	1.945
1951	Dec	1460000	0.731	1340000	0.672	0	0	0	0	1.403
1952	Jan	2040000	1.02	1600000	0.799	136000	0.0681	0	0	1.8871
1952	Feb	1010000	0.506	1580000	0.792	853000	0.427	0	0	1.725
1952	Mar	1920000	0.959	870000	0.435	1680000	0.84	0	0	2.234

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1952	Apr	1230000	0.615	268000	0.134	2980000	1.49	0	0	2.239
1952	May	634000	0.317	77000	0.0385	3050000	1.52	0	0	1.8755
1952	Jun	258000	0.129	149000	0.0746	1760000	0.881	0	0	1.0846
1952	Jul	1120000	0.56	0	0	2840000	1.42	0	0	1.98
1952	Aug	996000	0.498	0	0	3980000	1.99	0	0	2.488
1952	Sep	112000	0.056	0	0	3570000	1.79	0	0	1.846
1952	Oct	424000	0.212	0	0	2630000	1.31	0	0	1.522
1952	Nov	487000	0.243	0	0	4140000	2.07	0	0	2.313
1952	Dec	1040000	0.519	0	0	3240000	1.62	0	0	2.139
1953	Jan	117000	0.0586	0	0	4310000	2.15	0	0	2.2086
1953	Feb	941000	0.47	0	0	2010000	1.01	0	0	1.48
1953	Mar	793000	0.396	0	0	4750000	2.37	0	0	2.766
1953	Apr	448000	0.224	0	0	4250000	2.12	0	0	2.344
1953	May	498000	0.249	0	0	4360000	2.18	0	0	2.429
1953	Jun	890000	0.445	0	0	3900000	1.95	0	0	2.395
1953	Jul	543000	0.272	0	0	5910000	2.96	0	0	3.232
1953	Aug	491000	0.246	0	0	4720000	2.36	0	0	2.606
1953	Sep	757000	0.378	0	0	4590000	2.29	0	0	2.668
1953	Oct	676000	0.338	0	0	7350000	3.68	0	0	4.018
1953	Nov	938000	0.469	0	0	224000	0.112	0	0	0.581
1953	Dec	1260000	0.631	0	0	7380000	3.69	0	0	4.321
1954	Jan	1620000	0.808	0	0	2790000	1.39	0	0	2.198
1954	Feb	1320000	0.66	0	0	3440000	1.72	0	0	2.38
1954	Mar	1170000	0.585	0	0	7310000	3.66	0	0	4.245
1954	Apr	487000	0.244	0	0	5500000	2.75	0	0	2.994
1954	May	1360000	0.678	0	0	7330000	3.66	0	0	4.338
1954	Jun	1550000	0.774	0	0	1820000	0.909	0	0	1.683
1954	Jul	1400000	0.698	0	0	2880000	1.44	0	0	2.138
1954	Aug	1570000	0.783	0	0	4580000	2.29	0	0	3.073
1954	Sep	1660000	0.832	0	0	6200000	3.1	0	0	3.932

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Oct	2030000	1.01	0	0	6260000	3.13	0	0	4.14
1954	Nov	1900000	0.948	0	0	6790000	3.4	0	0	4.348
1954	Dec	2230000	1.11	0	0	8150000	4.08	0	0	5.19
1955	Jan	2340000	1.17	0	0	549000	0.274	0	0	1.444
1955	Feb	2440000	1.22	0	0	2890000	1.45	0	0	2.67
1955	Mar	1090000	0.545	0	0	4090000	2.04	0	0	2.585
1955	Apr	1270000	0.635	0	0	6910000	3.45	0	0	4.085
1955	May	2350000	1.18	0	0	5240000	2.62	0	0	3.8
1955	Jun	2720000	1.36	0	0	7450000	3.72	0	0	5.08
1955	Jul	1930000	0.964	0	0	4120000	2.06	0	0	3.024
1955	Aug	1640000	0.821	0	0	4390000	2.19	0	0	3.011
1955	Sep	2400000	1.2	0	0	6040000	3.02	0	0	4.22
1955	Oct	1670000	0.835	0	0	5440000	2.72	0	0	3.555
1955	Nov	867000	0.433	0	0	10100000	5.04	0	0	5.473
1955	Dec	680000	0.34	0	0	8020000	4.01	0	0	4.35
1956	Jan	299000	0.15	0	0	2030000	1.02	1160000	0.579	1.749
1956	Feb	411000	0.205	0	0	4540000	2.27	3950000	1.98	4.455
1956	Mar	0	0	0	0	4130000	2.07	2170000	1.08	3.15
1956	Apr	0	0	0	0	9240000	4.62	3740000	1.87	6.49
1956	May	0	0	0	0	10200000	5.12	2410000	1.21	6.33
1956	Jun	0	0	0	0	7400000	3.7	6450000	3.23	6.93
1956	Jul	0	0	0	0	2720000	1.36	5190000	2.6	3.96
1956	Aug	0	0	0	0	1930000	0.965	10700000	5.36	6.325
1956	Sep	0	0	0	0	4140000	2.07	14800000	7.4	9.47
1956	Oct	0	0	0	0	4610000	2.31	8780000	4.39	6.7
1956	Nov	0	0	0	0	4850000	2.43	12600000	6.32	8.75
1956	Dec	0	0	0	0	4530000	2.27	12600000	6.3	8.57
1957	Jan	0	0	0	0	3600000	1.8	14000000	6.98	8.78
1957	Feb	0	0	0	0	4740000	2.37	11900000	5.96	8.33
1957	Mar	0	0	0	0	3360000	1.68	12700000	6.34	8.02

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1957	Apr	0	0	0	0	5890000	2.95	14500000	7.24	10.19
1957	May	0	0	0	0	5700000	2.85	13800000	6.9	9.75
1957	Jun	0	0	0	0	3710000	1.85	14700000	7.33	9.18
1957	Jul	0	0	0	0	6020000	3.01	12300000	6.16	9.17
1957	Aug	0	0	0	0	6280000	3.14	15200000	7.59	10.73
1957	Sep	0	0	0	0	8350000	4.17	10600000	5.29	9.46
1957	Oct	0	0	0	0	7700000	3.85	17600000	8.81	12.66
1957	Nov	0	0	0	0	6620000	3.31	17000000	8.5	11.81
1957	Dec	0	0	0	0	7440000	3.72	13900000	6.93	10.65
1958	Jan	0	0	0	0	2910000	1.46	20700000	10.3	11.76
1958	Feb	0	0	0	0	5730000	2.86	22600000	11.3	14.16
1958	Mar	0	0	0	0	4070000	2.03	16600000	8.28	10.31
1958	Apr	0	0	0	0	3640000	1.82	16700000	8.33	10.15
1958	May	0	0	0	0	7990000	4	12300000	6.16	10.16
1958	Jun	0	0	0	0	7740000	3.87	1880000	0.941	4.811
1958	Jul	0	0	0	0	8060000	4.03	20200000	10.1	14.13
1958	Aug	0	0	0	0	4700000	2.35	7700000	3.85	6.2
1958	Sep	0	0	0	0	5520000	2.76	20400000	10.2	12.96
1958	Oct	0	0	0	0	778000	0.389	20600000	10.3	10.689
1958	Nov	0	0	0	0	389000	0.194	22800000	11.4	11.594
1958	Dec	0	0	0	0	2930000	1.46	23400000	11.7	13.16
1959	Jan	0	0	0	0	3220000	1.61	18900000	9.47	11.08
1959	Feb	0	0	0	0	1650000	0.826	11800000	5.91	6.736
1959	Mar	0	0	0	0	1800000	0.901	21900000	11	11.901
1959	Apr	0	0	0	0	3970000	1.99	16600000	8.28	10.27
1959	May	0	0	0	0	2440000	1.22	17400000	8.69	9.91
1959	Jun	0	0	0	0	3680000	1.84	28800000	14.4	16.24
1959	Jul	0	0	0	0	3790000	1.89	14400000	7.22	9.11
1959	Aug	0	0	0	0	2590000	1.3	33500000	16.8	18.1
1959	Sep	0	0	0	0	2730000	1.36	21200000	10.6	11.96

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Oct	0	0	0	0	3080000	1.54	20200000	10.1	11.64
1959	Nov	0	0	0	0	4710000	2.35	20300000	10.2	12.55
1959	Dec	0	0	0	0	4020000	2.01	25700000	12.9	14.91
1960	Jan	0	0	0	0	934000	0.467	32400000	16.2	16.667
1960	Feb	0	0	0	0	2900000	1.45	15300000	7.64	9.09
1960	Mar	0	0	0	0	1870000	0.934	14100000	7.04	7.974
1960	Apr	0	0	0	0	3920000	1.96	34300000	17.2	19.16
1960	May	0	0	0	0	1800000	0.902	14100000	7.03	7.932
1960	Jun	0	0	0	0	6260000	3.13	10800000	5.42	8.55
1960	Jul	0	0	0	0	2840000	1.42	20900000	10.4	11.82
1960	Aug	0	0	0	0	1850000	0.925	37200000	18.6	19.525
1960	Sep	0	0	0	0	711000	0.356	34200000	17.1	17.456
1960	Oct	0	0	0	0	2680000	1.34	15800000	7.9	9.24
1960	Nov	0	0	0	0	3550000	1.77	33900000	16.9	18.67
1960	Dec	0	0	0	0	3000000	1.5	28700000	14.3	15.8
1961	Jan	0	0	0	0	2510000	1.26	21300000	10.7	11.96
1961	Feb	0	0	0	0	3340000	1.67	19400000	9.71	11.38
1961	Mar	0	0	0	0	4780000	2.39	30700000	15.3	17.69
1961	Apr	0	0	0	0	5030000	2.52	15700000	7.85	10.37
1961	May	0	0	0	0	3130000	1.56	36800000	18.4	19.96
1961	Jun	0	0	0	0	6440000	3.22	25000000	12.5	15.72
1961	Jul	0	0	0	0	6960000	3.48	24000000	12	15.48
1961	Aug	0	0	0	0	6440000	3.22	27400000	13.7	16.92
1961	Sep	0	0	0	0	3400000	1.7	26000000	13	14.7
1961	Oct	0	0	0	0	5630000	2.81	15500000	7.75	10.56
1961	Nov	0	0	0	0	7170000	3.59	12000000	6	9.59
1961	Dec	0	0	0	0	3310000	1.65	31300000	15.7	17.35
1962	Jan	0	0	0	0	9190000	4.59	17200000	8.61	13.2
1962	Feb	0	0	0	0	5840000	2.92	6570000	3.28	6.2
1962	Mar	0	0	0	0	3540000	1.77	13000000	6.5	8.27

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1962	Apr	0	0	0	0	161000	0.0806	14300000	7.13	7.2106
1962	May	0	0	0	0	1950000	0.976	25900000	13	13.976
1962	Jun	0	0	0	0	4400000	2.2	23200000	11.6	13.8
1962	Jul	0	0	0	0	2140000	1.07	33000000	16.5	17.57
1962	Aug	0	0	0	0	5960000	2.98	10100000	5.05	8.03
1962	Sep	0	0	0	0	4760000	2.38	22300000	11.1	13.48
1962	Oct	0	0	0	0	4660000	2.33	29000000	14.5	16.83
1962	Nov	0	0	0	0	2470000	1.24	29400000	14.7	15.94
1962	Dec	0	0	0	0	2180000	1.09	30500000	15.2	16.29
1963	Jan	0	0	0	0	9780000	4.89	2610000	1.3	6.19
1963	Feb	0	0	0	0	3300000	1.65	23300000	11.7	13.35
1963	Mar	0	0	0	0	2390000	1.2	32300000	16.2	17.4
1963	Apr	0	0	0	0	9410000	4.7	5360000	2.68	7.38
1963	May	0	0	0	0	1230000	0.614	27800000	13.9	14.514
1963	Jun	0	0	0	0	6900000	3.45	31600000	15.8	19.25
1963	Jul	0	0	0	0	6990000	3.49	0	0	3.49
1963	Aug	0	0	0	0	4700000	2.35	13100000	6.54	8.89
1963	Sep	0	0	0	0	4240000	2.12	25200000	12.6	14.72
1963	Oct	0	0	0	0	2340000	1.17	23700000	11.9	13.07
1963	Nov	0	0	0	0	865000	0.433	35200000	17.6	18.033
1963	Dec	0	0	0	0	2300000	1.15	4710000	2.35	3.5
1964	Jan	0	0	0	0	7480000	3.74	7130000	3.56	7.3
1964	Feb	0	0	0	0	8030000	4.02	3210000	1.6	5.62
1964	Mar	0	0	0	0	0	0	35900000	17.9	17.9
1964	Apr	0	0	0	0	5360000	2.68	14000000	7.02	9.7
1964	May	0	0	0	0	8340000	4.17	20100000	10.1	14.27
1964	Jun	0	0	0	0	4310000	2.16	36800000	18.4	20.56
1964	Jul	0	0	0	0	6370000	3.18	13300000	6.65	9.83
1964	Aug	0	0	0	0	4160000	2.08	35300000	17.7	19.78
1964	Sep	0	0	0	0	6350000	3.17	23900000	11.9	15.07

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Oct	0	0	0	0	1360000	0.679	35000000	17.5	18.179
1964	Nov	0	0	0	0	5140000	2.57	24700000	12.4	14.97
1964	Dec	0	0	0	0	13500000	6.74	1710000	0.857	7.597
1965	Jan	0	0	0	0	11800000	5.88	786000	0.393	6.273
1965	Feb	0	0	0	0	5280000	2.64	15700000	7.84	10.48
1965	Mar	0	0	0	0	7620000	3.81	33500000	16.7	20.51
1965	Apr	0	0	0	0	11400000	5.71	33900000	17	22.71
1965	May	0	0	0	0	10300000	5.15	34200000	17.1	22.25
1965	Jun	0	0	0	0	504000	0.252	20300000	10.1	10.352
1965	Jul	0	0	0	0	6800000	3.4	8530000	4.27	7.67
1965	Aug	0	0	0	0	5440000	2.72	22400000	11.2	13.92
1965	Sep	0	0	0	0	2370000	1.19	17700000	8.83	10.02
1965	Oct	0	0	0	0	6010000	3.01	17800000	8.88	11.89
1965	Nov	0	0	0	0	7380000	3.69	10600000	5.3	8.99
1965	Dec	0	0	0	0	55300	0.0277	18300000	9.16	9.1877
1966	Jan	0	0	0	0	37200000	18.6	31100000	15.5	34.1
1966	Feb	0	0	0	0	2590000	1.29	15500000	7.74	9.03
1966	Mar	0	0	0	0	6390000	3.19	18400000	9.18	12.37
1966	Apr	0	0	0	0	6580000	3.29	7900000	3.95	7.24
1966	May	0	0	0	0	6980000	3.49	0	0	3.49
1966	Jun	0	0	0	0	14100000	7.05	0	0	7.05
1966	Jul	0	0	0	0	3380000	1.69	0	0	1.69
1966	Aug	0	0	0	0	442000	0.221	4360000	2.18	2.401
1966	Sep	0	0	0	0	11900000	5.95	19900000	9.97	15.92
1966	Oct	0	0	0	0	6520000	3.26	36900000	18.4	21.66
1966	Nov	0	0	0	0	3260000	1.63	20700000	10.3	11.93
1966	Dec	0	0	0	0	0	0	1920000	0.962	0.962
1967	Jan	0	0	0	0	0	0	28200000	14.1	14.1
1967	Feb	0	0	0	0	0	0	8740000	4.37	4.37
1967	Mar	0	0	0	0	0	0	17500000	8.76	8.76

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1967	Apr	0	0	0	0	0	0	18700000	9.34	9.34
1967	May	0	0	0	0	0	0	19000000	9.51	9.51
1967	Jun	0	0	0	0	0	0	10600000	5.31	5.31
1967	Jul	0	0	0	0	0	0	15200000	7.62	7.62
1967	Aug	0	0	0	0	0	0	18300000	9.14	9.14
1967	Sep	0	0	0	0	0	0	30700000	15.4	15.4
1967	Oct	0	0	0	0	0	0	18300000	9.14	9.14
1967	Nov	0	0	0	0	0	0	21600000	10.8	10.8
1967	Dec	0	0	0	0	0	0	7840000	3.92	3.92
1968	Jan	0	0	0	0	0	0	14700000	7.35	7.35
1968	Feb	0	0	0	0	0	0	8700000	4.35	4.35
1968	Mar	0	0	0	0	0	0	27600000	13.8	13.8
1968	Apr	0	0	0	0	0	0	24300000	12.1	12.1
1968	May	0	0	0	0	0	0	14000000	7.01	7.01
1968	Jun	0	0	0	0	0	0	20100000	10.1	10.1
1968	Jul	0	0	0	0	0	0	8610000	4.31	4.31
1968	Aug	0	0	0	0	0	0	28900000	14.4	14.4
1968	Sep	0	0	0	0	0	0	13200000	6.62	6.62
1968	Oct	0	0	0	0	0	0	23500000	11.8	11.8
1968	Nov	0	0	0	0	0	0	13600000	6.79	6.79
1968	Dec	0	0	0	0	0	0	9700000	4.85	4.85
1969	Jan	0	0	0	0	0	0	6120000	3.06	3.06
1969	Feb	0	0	0	0	0	0	9660000	4.83	4.83
1969	Mar	0	0	0	0	0	0	13600000	6.78	6.78
1969	Apr	0	0	0	0	0	0	14600000	7.3	7.3
1969	May	0	0	0	0	0	0	13700000	6.85	6.85
1969	Jun	0	0	0	0	0	0	6340000	3.17	3.17
1969	Jul	0	0	0	0	0	0	4830000	2.41	2.41
1969	Aug	0	0	0	0	0	0	20200000	10.1	10.1
1969	Sep	0	0	0	0	0	0	15700000	7.86	7.86

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Oct	0	0	0	0	0	0	15300000	7.67	7.67
1969	Nov	0	0	0	0	0	0	12000000	5.98	5.98
1969	Dec	0	0	0	0	0	0	13600000	6.8	6.8
1970	Jan	0	0	0	0	0	0	12600000	6.32	6.32
1970	Feb	0	0	0	0	0	0	1540	0.000771	0.000771
1970	Mar	0	0	0	0	0	0	2390000	1.2	1.2
1970	Apr	0	0	0	0	0	0	11900000	5.96	5.96
1970	May	0	0	0	0	0	0	7430000	3.71	3.71
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	403000	0.201	0.201
1971	Apr	0	0	0	0	0	0	7080000	3.54	3.54
1971	May	0	0	0	0	0	0	14700000	7.33	7.33
1971	Jun	0	0	0	0	0	0	11500000	5.75	5.75
1971	Jul	0	0	0	0	0	0	4580000	2.29	2.29
1971	Aug	0	0	0	0	0	0	11000000	5.5	5.5
1971	Sep	0	0	0	0	0	0	11500000	5.73	5.73
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	1410000	0.707	0.707
1972	Mar	0	0	0	0	0	0	5670000	2.84	2.84

Table B.4. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.5. Estimated Monthly Strontium-90 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	1040	0.0208	0	0	0	0	0	0	0.0208
1945	Jan	1070	0.0213	0	0	0	0	0	0	0.0213
1945	Feb	1990	0.0397	0	0	0	0	0	0	0.0397
1945	Mar	1930	0.0386	0	0	0	0	0	0	0.0386
1945	Apr	7210	0.144	4140	0.0827	0	0	0	0	0.2267
1945	May	11000	0.221	11900	0.238	0	0	0	0	0.459
1945	Jun	8200	0.164	10300	0.206	0	0	0	0	0.37
1945	Jul	11400	0.229	12900	0.259	0	0	0	0	0.488
1945	Aug	21700	0.434	16800	0.336	0	0	0	0	0.77
1945	Sep	21000	0.419	20900	0.418	0	0	0	0	0.837
1945	Oct	32200	0.645	37100	0.742	0	0	0	0	1.387
1945	Nov	30400	0.608	26400	0.528	0	0	0	0	1.136
1945	Dec	32800	0.657	25600	0.511	0	0	0	0	1.168
1946	Jan	40300	0.807	20800	0.416	0	0	0	0	1.223
1946	Feb	24300	0.487	25500	0.511	0	0	0	0	0.998
1946	Mar	20400	0.408	30900	0.618	0	0	0	0	1.026
1946	Apr	24600	0.492	23800	0.476	0	0	0	0	0.968
1946	May	17200	0.343	36300	0.725	0	0	0	0	1.068
1946	Jun	14100	0.282	27000	0.54	0	0	0	0	0.822
1946	Jul	16900	0.338	28500	0.57	0	0	0	0	0.908
1946	Aug	7130	0.143	35000	0.701	0	0	0	0	0.844
1946	Sep	3800	0.076	23200	0.463	0	0	0	0	0.539
1946	Oct	3880	0.0775	27300	0.546	0	0	0	0	0.6235
1946	Nov	13200	0.265	27800	0.555	0	0	0	0	0.82
1946	Dec	13300	0.265	21100	0.423	0	0	0	0	0.688
1947	Jan	13600	0.272	16200	0.323	0	0	0	0	0.595
1947	Feb	13200	0.264	13800	0.276	0	0	0	0	0.54
1947	Mar	17000	0.339	23000	0.46	0	0	0	0	0.799

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Apr	15400	0.307	17400	0.347	0	0	0	0	0.654
1947	May	15600	0.312	16900	0.337	0	0	0	0	0.649
1947	Jun	8960	0.179	17900	0.358	0	0	0	0	0.537
1947	Jul	17700	0.353	18500	0.371	0	0	0	0	0.724
1947	Aug	14500	0.29	15300	0.307	0	0	0	0	0.597
1947	Sep	14100	0.281	17600	0.351	0	0	0	0	0.632
1947	Oct	13300	0.266	13300	0.266	0	0	0	0	0.532
1947	Nov	14600	0.292	13200	0.264	0	0	0	0	0.556
1947	Dec	15000	0.299	13200	0.263	0	0	0	0	0.562
1948	Jan	15000	0.3	18100	0.363	0	0	0	0	0.663
1948	Feb	14300	0.286	20100	0.402	0	0	0	0	0.688
1948	Mar	14900	0.297	14800	0.296	0	0	0	0	0.593
1948	Apr	16600	0.332	18300	0.367	0	0	0	0	0.699
1948	May	16600	0.00332	11800	0.236	0	0	0	0	0.23932
1948	Jun	20700	0.00414	22300	0.00446	0	0	0	0	0.0086
1948	Jul	16500	0.0033	25200	0.00504	0	0	0	0	0.00834
1948	Aug	19300	0.00387	19400	0.00389	0	0	0	0	0.00776
1948	Sep	14700	0.00295	15500	0.00309	0	0	0	0	0.00604
1948	Oct	21100	0.00422	19300	0.00387	0	0	0	0	0.00809
1948	Nov	22500	0.00451	22500	0.00451	0	0	0	0	0.00902
1948	Dec	31400	0.00627	27000	0.00539	0	0	0	0	0.01166
1949	Jan	29300	0.00585	31600	0.00633	0	0	0	0	0.01218
1949	Feb	27100	0.00542	7720	0.00154	0	0	0	0	0.00696
1949	Mar	39400	0.00787	35600	0.00712	0	0	0	0	0.01499
1949	Apr	16200	0.00323	16900	0.00338	0	0	0	0	0.00661
1949	May	14700	0.00293	23100	0.00462	0	0	0	0	0.00755
1949	Jun	12100	0.00243	16400	0.00329	0	0	0	0	0.00572
1949	Jul	24200	0.00484	15300	0.00307	0	0	0	0	0.00791
1949	Aug	20100	0.00401	8340	0.00167	0	0	0	0	0.00568
1949	Sep	23400	0.00469	28900	0.00578	0	0	0	0	0.01047

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Oct	34600	0.00691	30600	0.00613	0	0	0	0	0.01304
1949	Nov	25900	0.00517	27000	0.00541	0	0	0	0	0.01058
1949	Dec	35000	0.00701	33200	0.00663	0	0	0	0	0.01364
1950	Jan	31400	0.00629	32500	0.00651	0	0	0	0	0.0128
1950	Feb	26400	0.00527	32500	0.00649	0	0	0	0	0.01176
1950	Mar	33700	0.00674	37500	0.00751	0	0	0	0	0.01425
1950	Apr	35200	0.00705	23200	0.00464	0	0	0	0	0.01169
1950	May	31400	0.00627	34100	0.00681	0	0	0	0	0.01308
1950	Jun	25900	0.00519	32400	0.00648	0	0	0	0	0.01167
1950	Jul	44700	0.00895	44600	0.00891	0	0	0	0	0.01786
1950	Aug	55300	0.0111	60500	0.0121	0	0	0	0	0.0232
1950	Sep	50100	0.01	49700	0.00993	0	0	0	0	0.01993
1950	Oct	49400	0.00989	46800	0.00937	0	0	0	0	0.01926
1950	Nov	52600	0.0105	54200	0.0108	0	0	0	0	0.0213
1950	Dec	30200	0.00604	60800	0.0122	0	0	0	0	0.01824
1951	Jan	50200	0.01	59800	0.012	0	0	0	0	0.022
1951	Feb	49300	0.00985	54700	0.0109	0	0	0	0	0.02075
1951	Mar	64800	0.013	60600	0.0121	0	0	0	0	0.0251
1951	Apr	64200	0.0128	54200	0.0108	0	0	0	0	0.0236
1951	May	61500	0.0123	61700	0.0123	0	0	0	0	0.0246
1951	Jun	55200	0.011	25300	0.00506	0	0	0	0	0.01606
1951	Jul	42400	0.00848	24200	0.00484	0	0	0	0	0.01332
1951	Aug	73600	0.0147	68300	0.0137	0	0	0	0	0.0284
1951	Sep	55700	0.0111	56400	0.0113	0	0	0	0	0.0224
1951	Oct	63800	0.0128	71000	0.0142	0	0	0	0	0.027
1951	Nov	82500	0.0165	85200	0.017	0	0	0	0	0.0335
1951	Dec	62700	0.0125	57900	0.0116	0	0	0	0	0.0241
1952	Jan	82100	0.0164	64600	0.0129	5590	0.00112	0	0	0.03042
1952	Feb	41500	0.00829	65400	0.0131	35100	0.00702	0	0	0.02841
1952	Mar	78300	0.0157	36100	0.00722	70000	0.014	0	0	0.03692

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1952	Apr	49700	0.00994	11400	0.00229	125000	0.0249	0	0	0.03713
1952	May	26300	0.00526	3270	0.000654	128000	0.0255	0	0	0.031414
1952	Jun	11800	0.00236	6290	0.00126	74500	0.0149	0	0	0.01852
1952	Jul	48200	0.00965	0	0	125000	0.025	0	0	0.03465
1952	Aug	42300	0.00847	0	0	173000	0.0347	0	0	0.04317
1952	Sep	5040	0.00101	0	0	156000	0.0312	0	0	0.03221
1952	Oct	19100	0.00382	0	0	117000	0.0234	0	0	0.02722
1952	Nov	21400	0.00428	0	0	184000	0.0368	0	0	0.04108
1952	Dec	44400	0.00889	0	0	149000	0.0299	0	0	0.03879
1953	Jan	5070	0.00101	0	0	182000	0.0364	0	0	0.03741
1953	Feb	40600	0.00811	0	0	87800	0.0176	0	0	0.02571
1953	Mar	33400	0.00668	0	0	204000	0.0409	0	0	0.04758
1953	Apr	16200	0.00324	0	0	171000	0.0342	0	0	0.03744
1953	May	18700	0.00374	0	0	182000	0.0363	0	0	0.04004
1953	Jun	33400	0.00668	0	0	163000	0.0325	0	0	0.03918
1953	Jul	20000	0.004	0	0	241000	0.0481	0	0	0.0521
1953	Aug	18300	0.00366	0	0	196000	0.0392	0	0	0.04286
1953	Sep	29600	0.00591	0	0	194000	0.0389	0	0	0.04481
1953	Oct	27800	0.00556	0	0	307000	0.0614	0	0	0.06696
1953	Nov	38400	0.00767	0	0	9370	0.00187	0	0	0.00954
1953	Dec	54700	0.0109	0	0	312000	0.0625	0	0	0.0734
1954	Jan	61900	0.0124	0	0	111000	0.0221	0	0	0.0345
1954	Feb	53400	0.0107	0	0	141000	0.0281	0	0	0.0388
1954	Mar	48000	0.0096	0	0	298000	0.0596	0	0	0.0692
1954	Apr	17900	0.00358	0	0	226000	0.0452	0	0	0.04878
1954	May	48600	0.00972	0	0	300000	0.06	0	0	0.06972
1954	Jun	56900	0.0114	0	0	72600	0.0145	0	0	0.0259
1954	Jul	51200	0.0102	0	0	123000	0.0245	0	0	0.0347
1954	Aug	57100	0.0114	0	0	196000	0.0392	0	0	0.0506
1954	Sep	60000	0.012	0	0	259000	0.0518	0	0	0.0638

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Oct	71800	0.0144	0	0	288000	0.0575	0	0	0.0719
1954	Nov	69900	0.014	0	0	316000	0.0632	0	0	0.0772
1954	Dec	81800	0.0164	0	0	350000	0.07	0	0	0.0864
1955	Jan	87200	0.0174	0	0	20400	0.00407	0	0	0.02147
1955	Feb	90300	0.0181	0	0	105000	0.021	0	0	0.0391
1955	Mar	42500	0.00851	0	0	145000	0.029	0	0	0.03751
1955	Apr	45800	0.00916	0	0	325000	0.065	0	0	0.07416
1955	May	86800	0.0174	0	0	537000	0.107	0	0	0.1244
1955	Jun	104000	0.0208	0	0	333000	0.0666	0	0	0.0874
1955	Jul	73900	0.0148	0	0	160000	0.0321	0	0	0.0469
1955	Aug	79700	0.0159	0	0	168000	0.0337	0	0	0.0496
1955	Sep	90700	0.0181	0	0	227000	0.0454	0	0	0.0635
1955	Oct	62600	0.0125	0	0	204000	0.0408	0	0	0.0533
1955	Nov	33700	0.00674	0	0	510000	0.102	0	0	0.10874
1955	Dec	27900	0.00558	0	0	364000	0.0728	0	0	0.07838
1956	Jan	13000	0.00259	0	0	78000	0.0156	48400	0.00967	0.02786
1956	Feb	19900	0.00398	0	0	173000	0.0346	177000	0.0354	0.07398
1956	Mar	0	0	0	0	166000	0.0332	92900	0.0186	0.0518
1956	Apr	0	0	0	0	435000	0.0869	140000	0.0279	0.1148
1956	May	0	0	0	0	436000	0.0873	95000	0.019	0.1063
1956	Jun	0	0	0	0	312000	0.0624	239000	0.0478	0.1102
1956	Jul	0	0	0	0	120000	0.0239	244000	0.0488	0.0727
1956	Aug	0	0	0	0	77500	0.0155	486000	0.0971	0.1126
1956	Sep	0	0	0	0	171000	0.0343	645000	0.129	0.1633
1956	Oct	0	0	0	0	195000	0.039	382000	0.0764	0.1154
1956	Nov	0	0	0	0	195000	0.0391	534000	0.107	0.1461
1956	Dec	0	0	0	0	173000	0.0346	538000	0.108	0.1426
1957	Jan	0	0	0	0	150000	0.0301	583000	0.117	0.1471
1957	Feb	0	0	0	0	195000	0.039	496000	0.0993	0.1383
1957	Mar	0	0	0	0	139000	0.0278	532000	0.106	0.1338

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1957	Apr	0	0	0	0	238000	0.0476	584000	0.117	0.1646
1957	May	0	0	0	0	232000	0.0464	563000	0.113	0.1594
1957	Jun	0	0	0	0	151000	0.0303	600000	0.12	0.1503
1957	Jul	0	0	0	0	240000	0.0481	486000	0.0972	0.1453
1957	Aug	0	0	0	0	252000	0.0504	601000	0.12	0.1704
1957	Sep	0	0	0	0	333000	0.0666	422000	0.0845	0.1511
1957	Oct	0	0	0	0	308000	0.0617	687000	0.137	0.1987
1957	Nov	0	0	0	0	259000	0.0517	663000	0.133	0.1847
1957	Dec	0	0	0	0	279000	0.0557	524000	0.105	0.1607
1958	Jan	0	0	0	0	111000	0.0222	779000	0.156	0.1782
1958	Feb	0	0	0	0	211000	0.0421	833000	0.167	0.2091
1958	Mar	0	0	0	0	151000	0.0301	608000	0.122	0.1521
1958	Apr	0	0	0	0	136000	0.0271	620000	0.124	0.1511
1958	May	0	0	0	0	297000	0.0594	456000	0.0911	0.1505
1958	Jun	0	0	0	0	296000	0.0593	69400	0.0139	0.0732
1958	Jul	0	0	0	0	310000	0.062	773000	0.155	0.217
1958	Aug	0	0	0	0	180000	0.0361	296000	0.0591	0.0952
1958	Sep	0	0	0	0	213000	0.0426	775000	0.155	0.1976
1958	Oct	0	0	0	0	38400	0.00768	799000	0.16	0.16768
1958	Nov	0	0	0	0	21700	0.00434	871000	0.174	0.17834
1958	Dec	0	0	0	0	154000	0.0309	896000	0.179	0.2099
1959	Jan	0	0	0	0	165000	0.0331	716000	0.143	0.1761
1959	Feb	0	0	0	0	97200	0.0194	452000	0.0905	0.1099
1959	Mar	0	0	0	0	100000	0.02	841000	0.168	0.188
1959	Apr	0	0	0	0	201000	0.0402	644000	0.129	0.1692
1959	May	0	0	0	0	126000	0.0251	667000	0.133	0.1581
1959	Jun	0	0	0	0	169000	0.0338	1110000	0.223	0.2568
1959	Jul	0	0	0	0	178000	0.0355	563000	0.113	0.1485
1959	Aug	0	0	0	0	119000	0.0237	1300000	0.26	0.2837
1959	Sep	0	0	0	0	135000	0.027	801000	0.16	0.187

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Oct	0	0	0	0	144000	0.0289	775000	0.155	0.1839
1959	Nov	0	0	0	0	204000	0.0408	788000	0.158	0.1988
1959	Dec	0	0	0	0	227000	0.0454	992000	0.198	0.2434
1960	Jan	0	0	0	0	39100	0.00782	1200000	0.24	0.24782
1960	Feb	0	0	0	0	125000	0.0249	577000	0.115	0.1399
1960	Mar	0	0	0	0	80400	0.0161	556000	0.111	0.1271
1960	Apr	0	0	0	0	170000	0.0341	1360000	0.273	0.3071
1960	May	0	0	0	0	82100	0.0164	534000	0.107	0.1234
1960	Jun	0	0	0	0	276000	0.0553	427000	0.0854	0.1407
1960	Jul	0	0	0	0	127000	0.0255	803000	0.161	0.1865
1960	Aug	0	0	0	0	74700	0.0149	1400000	0.28	0.2949
1960	Sep	0	0	0	0	39800	0.00796	1370000	0.275	0.28296
1960	Oct	0	0	0	0	154000	0.0307	726000	0.145	0.1757
1960	Nov	0	0	0	0	199000	0.0399	1320000	0.265	0.3049
1960	Dec	0	0	0	0	163000	0.0326	1090000	0.218	0.2506
1961	Jan	0	0	0	0	139000	0.0278	826000	0.165	0.1928
1961	Feb	0	0	0	0	175000	0.0349	749000	0.15	0.1849
1961	Mar	0	0	0	0	215000	0.0431	1190000	0.239	0.2821
1961	Apr	0	0	0	0	249000	0.0498	622000	0.124	0.1738
1961	May	0	0	0	0	158000	0.0316	1460000	0.293	0.3246
1961	Jun	0	0	0	0	365000	0.073	971000	0.194	0.267
1961	Jul	0	0	0	0	317000	0.0634	950000	0.19	0.2534
1961	Aug	0	0	0	0	281000	0.0562	1060000	0.213	0.2692
1961	Sep	0	0	0	0	145000	0.0289	1020000	0.203	0.2319
1961	Oct	0	0	0	0	239000	0.0479	593000	0.119	0.1669
1961	Nov	0	0	0	0	296000	0.0593	471000	0.0942	0.1535
1961	Dec	0	0	0	0	152000	0.0305	1380000	0.277	0.3075
1962	Jan	0	0	0	0	381000	0.0761	710000	0.142	0.2181
1962	Feb	0	0	0	0	241000	0.0482	269000	0.0538	0.102
1962	Mar	0	0	0	0	152000	0.0304	576000	0.115	0.1454

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1962	Apr	0	0	0	0	9140	0.00183	633000	0.127	0.12883
1962	May	0	0	0	0	90200	0.018	1120000	0.224	0.242
1962	Jun	0	0	0	0	203000	0.0405	982000	0.196	0.2365
1962	Jul	0	0	0	0	103000	0.0206	1360000	0.272	0.2926
1962	Aug	0	0	0	0	286000	0.0571	409000	0.0818	0.1389
1962	Sep	0	0	0	0	234000	0.0468	1050000	0.211	0.2578
1962	Oct	0	0	0	0	244000	0.0487	1230000	0.246	0.2947
1962	Nov	0	0	0	0	129000	0.0258	1240000	0.248	0.2738
1962	Dec	0	0	0	0	106000	0.0212	1210000	0.241	0.2622
1963	Jan	0	0	0	0	512000	0.102	132000	0.0264	0.1284
1963	Feb	0	0	0	0	175000	0.0351	1010000	0.202	0.2371
1963	Mar	0	0	0	0	124000	0.0247	1350000	0.269	0.2937
1963	Apr	0	0	0	0	420000	0.084	215000	0.043	0.127
1963	May	0	0	0	0	55000	0.011	1150000	0.231	0.242
1963	Jun	0	0	0	0	302000	0.0603	1330000	0.266	0.3263
1963	Jul	0	0	0	0	370000	0.074	0	0	0.074
1963	Aug	0	0	0	0	299000	0.0598	550000	0.11	0.1698
1963	Sep	0	0	0	0	221000	0.0443	1060000	0.213	0.2573
1963	Oct	0	0	0	0	108000	0.0216	1040000	0.207	0.2286
1963	Nov	0	0	0	0	41100	0.00822	1560000	0.311	0.31922
1963	Dec	0	0	0	0	124000	0.0247	186000	0.0373	0.062
1964	Jan	0	0	0	0	442000	0.0884	293000	0.0586	0.147
1964	Feb	0	0	0	0	415000	0.083	132000	0.0264	0.1094
1964	Mar	0	0	0	0	0	0	1510000	0.302	0.302
1964	Apr	0	0	0	0	293000	0.0586	577000	0.115	0.1736
1964	May	0	0	0	0	426000	0.0852	815000	0.163	0.2482
1964	Jun	0	0	0	0	191000	0.0382	1570000	0.314	0.3522
1964	Jul	0	0	0	0	327000	0.0654	549000	0.11	0.1754
1964	Aug	0	0	0	0	246000	0.0492	1430000	0.286	0.3352
1964	Sep	0	0	0	0	319000	0.0638	1230000	0.245	0.3088

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Oct	0	0	0	0	65200	0.013	1410000	0.282	0.295
1964	Nov	0	0	0	0	271000	0.0542	996000	0.199	0.2532
1964	Dec	0	0	0	0	665000	0.133	69100	0.0138	0.1468
1965	Jan	0	0	0	0	582000	0.116	30800	0.00615	0.12215
1965	Feb	0	0	0	0	250000	0.05	681000	0.136	0.186
1965	Mar	0	0	0	0	348000	0.0697	1450000	0.291	0.3607
1965	Apr	0	0	0	0	515000	0.103	1530000	0.307	0.41
1965	May	0	0	0	0	444000	0.0888	1440000	0.288	0.3768
1965	Jun	0	0	0	0	24400	0.00487	893000	0.179	0.18387
1965	Jul	0	0	0	0	313000	0.0626	371000	0.0742	0.1368
1965	Aug	0	0	0	0	235000	0.047	977000	0.195	0.242
1965	Sep	0	0	0	0	108000	0.0215	776000	0.155	0.1765
1965	Oct	0	0	0	0	308000	0.0617	720000	0.144	0.2057
1965	Nov	0	0	0	0	366000	0.0733	458000	0.0917	0.165
1965	Dec	0	0	0	0	3050	0.00061	741000	0.148	0.14861
1966	Jan	0	0	0	0	2050000	0.411	1250000	0.251	0.662
1966	Feb	0	0	0	0	136000	0.0272	713000	0.143	0.1702
1966	Mar	0	0	0	0	330000	0.0661	765000	0.153	0.2191
1966	Apr	0	0	0	0	389000	0.0779	311000	0.0621	0.14
1966	May	0	0	0	0	330000	0.066	0	0	0.066
1966	Jun	0	0	0	0	601000	0.12	0	0	0.12
1966	Jul	0	0	0	0	144000	0.0288	0	0	0.0288
1966	Aug	0	0	0	0	18900	0.00378	215000	0.043	0.04678
1966	Sep	0	0	0	0	584000	0.117	975000	0.195	0.312
1966	Oct	0	0	0	0	403000	0.0805	1570000	0.314	0.3945
1966	Nov	0	0	0	0	202000	0.0404	1100000	0.221	0.2614
1966	Dec	0	0	0	0	0	0	156000	0.0312	0.0312
1967	Jan	0	0	0	0	0	0	1200000	0.24	0.24
1967	Feb	0	0	0	0	0	0	381000	0.0761	0.0761
1967	Mar	0	0	0	0	0	0	722000	0.144	0.144

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1967	Apr	0	0	0	0	0	0	1440000	0.288	0.288
1967	May	0	0	0	0	0	0	796000	0.159	0.159
1967	Jun	0	0	0	0	0	0	554000	0.111	0.111
1967	Jul	0	0	0	0	0	0	847000	0.169	0.169
1967	Aug	0	0	0	0	0	0	842000	0.168	0.168
1967	Sep	0	0	0	0	0	0	1490000	0.298	0.298
1967	Oct	0	0	0	0	0	0	926000	0.185	0.185
1967	Nov	0	0	0	0	0	0	1020000	0.205	0.205
1967	Dec	0	0	0	0	0	0	395000	0.079	0.079
1968	Jan	0	0	0	0	0	0	895000	0.179	0.179
1968	Feb	0	0	0	0	0	0	539000	0.108	0.108
1968	Mar	0	0	0	0	0	0	1390000	0.278	0.278
1968	Apr	0	0	0	0	0	0	1190000	0.238	0.238
1968	May	0	0	0	0	0	0	693000	0.139	0.139
1968	Jun	0	0	0	0	0	0	998000	0.2	0.2
1968	Jul	0	0	0	0	0	0	485000	0.0969	0.0969
1968	Aug	0	0	0	0	0	0	1450000	0.291	0.291
1968	Sep	0	0	0	0	0	0	683000	0.137	0.137
1968	Oct	0	0	0	0	0	0	1130000	0.226	0.226
1968	Nov	0	0	0	0	0	0	920000	0.184	0.184
1968	Dec	0	0	0	0	0	0	542000	0.108	0.108
1969	Jan	0	0	0	0	0	0	377000	0.0754	0.0754
1969	Feb	0	0	0	0	0	0	630000	0.126	0.126
1969	Mar	0	0	0	0	0	0	736000	0.147	0.147
1969	Apr	0	0	0	0	0	0	889000	0.178	0.178
1969	May	0	0	0	0	0	0	1000000	0.2	0.2
1969	Jun	0	0	0	0	0	0	324000	0.0648	0.0648
1969	Jul	0	0	0	0	0	0	245000	0.0491	0.0491
1969	Aug	0	0	0	0	0	0	1160000	0.232	0.232
1969	Sep	0	0	0	0	0	0	804000	0.161	0.161

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Oct	0	0	0	0	0	0	807000	0.161	0.161
1969	Nov	0	0	0	0	0	0	724000	0.145	0.145
1969	Dec	0	0	0	0	0	0	988000	0.198	0.198
1970	Jan	0	0	0	0	0	0	625000	0.125	0.125
1970	Feb	0	0	0	0	0	0	168	0.000034	0.000034
1970	Mar	0	0	0	0	0	0	135000	0.0271	0.0271
1970	Apr	0	0	0	0	0	0	800000	0.16	0.16
1970	May	0	0	0	0	0	0	518000	0.104	0.104
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	32800	0.00656	0.00656
1971	Apr	0	0	0	0	0	0	600000	0.12	0.12
1971	May	0	0	0	0	0	0	1000000	0.201	0.201
1971	Jun	0	0	0	0	0	0	602000	0.12	0.12
1971	Jul	0	0	0	0	0	0	623000	0.125	0.125
1971	Aug	0	0	0	0	0	0	1360000	0.272	0.272
1971	Sep	0	0	0	0	0	0	1240000	0.247	0.247
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	106000	0.0212	0.0212
1972	Mar	0	0	0	0	0	0	433000	0.0867	0.0867

Table B.5. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.6. Estimated Monthly Plutonium-239 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	29	0.00116	0	0	0	0	0	0	0.00116
1945	Jan	29.9	0.00119	0	0	0	0	0	0	0.00119
1945	Feb	55.7	0.00223	0	0	0	0	0	0	0.00223
1945	Mar	54.1	0.00216	0	0	0	0	0	0	0.00216
1945	Apr	202	0.00806	115	0.00461	0	0	0	0	0.01267
1945	May	305	0.0122	327	0.0131	0	0	0	0	0.0253
1945	Jun	225	0.00899	281	0.0112	0	0	0	0	0.02019
1945	Jul	311	0.0124	351	0.0141	0	0	0	0	0.0265
1945	Aug	586	0.0234	458	0.0183	0	0	0	0	0.0417
1945	Sep	568	0.0227	570	0.0228	0	0	0	0	0.0455
1945	Oct	878	0.0351	1010	0.0404	0	0	0	0	0.0755
1945	Nov	830	0.0332	722	0.0289	0	0	0	0	0.0621
1945	Dec	888	0.0355	697	0.0279	0	0	0	0	0.0634
1946	Jan	1040	0.0414	568	0.0227	0	0	0	0	0.0641
1946	Feb	641	0.0256	700	0.028	0	0	0	0	0.0536
1946	Mar	559	0.0223	844	0.0337	0	0	0	0	0.056
1946	Apr	672	0.0269	651	0.026	0	0	0	0	0.0529
1946	May	468	0.0187	990	0.0396	0	0	0	0	0.0583
1946	Jun	378	0.0151	737	0.0295	0	0	0	0	0.0446
1946	Jul	461	0.0184	777	0.0311	0	0	0	0	0.0495
1946	Aug	195	0.00779	956	0.0383	0	0	0	0	0.04609
1946	Sep	104	0.00415	632	0.0253	0	0	0	0	0.02945
1946	Oct	106	0.00423	746	0.0298	0	0	0	0	0.03403
1946	Nov	362	0.0145	758	0.0303	0	0	0	0	0.0448
1946	Dec	362	0.0145	578	0.0231	0	0	0	0	0.0376
1947	Jan	371	0.0148	442	0.0177	0	0	0	0	0.0325
1947	Feb	360	0.0144	377	0.0151	0	0	0	0	0.0295
1947	Mar	463	0.0185	628	0.0251	0	0	0	0	0.0436

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Apr	419	0.0168	474	0.019	0	0	0	0	0.0358
1947	May	425	0.017	460	0.0184	0	0	0	0	0.0354
1947	Jun	245	0.00978	489	0.0196	0	0	0	0	0.02938
1947	Jul	483	0.0193	507	0.0203	0	0	0	0	0.0396
1947	Aug	396	0.0159	419	0.0168	0	0	0	0	0.0327
1947	Sep	384	0.0154	480	0.0192	0	0	0	0	0.0346
1947	Oct	364	0.0145	364	0.0145	0	0	0	0	0.029
1947	Nov	400	0.016	362	0.0145	0	0	0	0	0.0305
1947	Dec	410	0.0164	360	0.0144	0	0	0	0	0.0308
1948	Jan	411	0.0164	497	0.0199	0	0	0	0	0.0363
1948	Feb	392	0.0157	551	0.022	0	0	0	0	0.0377
1948	Mar	407	0.0163	405	0.0162	0	0	0	0	0.0325
1948	Apr	454	0.0182	497	0.0199	0	0	0	0	0.0381
1948	May	454	0.000182	321	0.0129	0	0	0	0	0.013082
1948	Jun	567	0.000227	611	0.000244	0	0	0	0	0.000471
1948	Jul	452	0.000181	689	0.000276	0	0	0	0	0.000457
1948	Aug	529	0.000212	531	0.000212	0	0	0	0	0.000424
1948	Sep	404	0.000161	422	0.000169	0	0	0	0	0.00033
1948	Oct	577	0.000231	529	0.000212	0	0	0	0	0.000443
1948	Nov	617	0.000247	617	0.000247	0	0	0	0	0.000494
1948	Dec	857	0.000343	737	0.000295	0	0	0	0	0.000638
1949	Jan	799	0.00032	864	0.000346	0	0	0	0	0.000666
1949	Feb	740	0.000296	211	0.000084	0	0	0	0	0.00038
1949	Mar	1070	0.000429	969	0.000387	0	0	0	0	0.000816
1949	Apr	439	0.000176	459	0.000184	0	0	0	0	0.00036
1949	May	397	0.000159	628	0.000251	0	0	0	0	0.00041
1949	Jun	326	0.000131	444	0.000178	0	0	0	0	0.000309
1949	Jul	648	0.000259	412	0.000165	0	0	0	0	0.000424
1949	Aug	539	0.000216	223	0.000089	0	0	0	0	0.000305
1949	Sep	622	0.000249	762	0.000305	0	0	0	0	0.000554

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Oct	905	0.000362	811	0.000324	0	0	0	0	0.000686
1949	Nov	681	0.000272	708	0.000283	0	0	0	0	0.000555
1949	Dec	914	0.000365	864	0.000346	0	0	0	0	0.000711
1950	Jan	823	0.000329	849	0.00034	0	0	0	0	0.000669
1950	Feb	687	0.000275	848	0.000339	0	0	0	0	0.000614
1950	Mar	885	0.000354	975	0.00039	0	0	0	0	0.000744
1950	Apr	929	0.000372	610	0.000244	0	0	0	0	0.000616
1950	May	821	0.000329	893	0.000357	0	0	0	0	0.000686
1950	Jun	663	0.000265	846	0.000338	0	0	0	0	0.000603
1950	Jul	1160	0.000463	1160	0.000464	0	0	0	0	0.000927
1950	Aug	1440	0.000574	1570	0.000628	0	0	0	0	0.001202
1950	Sep	1300	0.000518	1290	0.000514	0	0	0	0	0.001032
1950	Oct	1280	0.000512	1210	0.000484	0	0	0	0	0.000996
1950	Nov	1320	0.00053	1410	0.000565	0	0	0	0	0.001095
1950	Dec	814	0.000326	1590	0.000634	0	0	0	0	0.00096
1951	Jan	1350	0.000538	1550	0.000621	0	0	0	0	0.001159
1951	Feb	1280	0.000511	1420	0.000569	0	0	0	0	0.00108
1951	Mar	1670	0.000666	1570	0.000628	0	0	0	0	0.001294
1951	Apr	1660	0.000665	1400	0.00056	0	0	0	0	0.001225
1951	May	1590	0.000637	1590	0.000637	0	0	0	0	0.001274
1951	Jun	1430	0.000571	654	0.000262	0	0	0	0	0.000833
1951	Jul	1070	0.000428	605	0.000242	0	0	0	0	0.00067
1951	Aug	1820	0.00073	1700	0.000678	0	0	0	0	0.001408
1951	Sep	1390	0.000555	1400	0.000561	0	0	0	0	0.001116
1951	Oct	1590	0.000635	1770	0.000708	0	0	0	0	0.001343
1951	Nov	2050	0.000819	2110	0.000844	0	0	0	0	0.001663
1951	Dec	1560	0.000624	1440	0.000577	0	0	0	0	0.001201
1952	Jan	2050	0.000818	1610	0.000645	139	0.000028	0	0	0.001491
1952	Feb	1030	0.000411	1620	0.000647	874	0.000175	0	0	0.001233
1952	Mar	1940	0.000776	898	0.000359	1730	0.000347	0	0	0.001482

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1952	Apr	1240	0.000497	283	0.000113	3070	0.000615	0	0	0.001225
1952	May	650	0.00026	80.8	0.000032	3160	0.000631	0	0	0.000923
1952	Jun	291	0.000116	157	0.000063	1840	0.000368	0	0	0.000547
1952	Jul	1200	0.000479	0	0	3100	0.00062	0	0	0.001099
1952	Aug	1050	0.000419	0	0	4290	0.000859	0	0	0.001278
1952	Sep	124	0.00005	0	0	3860	0.000772	0	0	0.000822
1952	Oct	481	0.000192	0	0	2900	0.00058	0	0	0.000772
1952	Nov	529	0.000212	0	0	4560	0.000912	0	0	0.001124
1952	Dec	1090	0.000437	0	0	3700	0.00074	0	0	0.001177
1953	Jan	125	0.00005	0	0	4510	0.000902	0	0	0.000952
1953	Feb	1010	0.000402	0	0	2170	0.000435	0	0	0.000837
1953	Mar	836	0.000335	0	0	5070	0.00101	0	0	0.001345
1953	Apr	427	0.000171	0	0	4370	0.000874	0	0	0.001045
1953	May	486	0.000195	0	0	4540	0.000908	0	0	0.001103
1953	Jun	867	0.000347	0	0	4050	0.000809	0	0	0.001156
1953	Jul	516	0.000207	0	0	6010	0.0012	0	0	0.001407
1953	Aug	480	0.000192	0	0	4890	0.000977	0	0	0.001169
1953	Sep	759	0.000304	0	0	4810	0.000962	0	0	0.001266
1953	Oct	687	0.000275	0	0	7590	0.00152	0	0	0.001795
1953	Nov	946	0.000378	0	0	231	0.000046	0	0	0.000424
1953	Dec	1350	0.000541	0	0	7740	0.00155	0	0	0.002091
1954	Jan	1530	0.00061	0	0	2740	0.000548	0	0	0.001158
1954	Feb	1320	0.000527	0	0	3480	0.000696	0	0	0.001223
1954	Mar	1190	0.000475	0	0	7390	0.00148	0	0	0.001955
1954	Apr	489	0.000196	0	0	5570	0.00111	0	0	0.001306
1954	May	1330	0.000531	0	0	7370	0.00147	0	0	0.002001
1954	Jun	1560	0.000623	0	0	1780	0.000356	0	0	0.000979
1954	Jul	1400	0.00056	0	0	3000	0.0006	0	0	0.00116
1954	Aug	1560	0.000626	0	0	4810	0.000961	0	0	0.001587
1954	Sep	1640	0.000657	0	0	6390	0.00128	0	0	0.001937

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Oct	1970	0.000787	0	0	6990	0.0014	0	0	0.002187
1954	Nov	1920	0.000768	0	0	7780	0.00156	0	0	0.002328
1954	Dec	2250	0.000898	0	0	8680	0.00174	0	0	0.002638
1955	Jan	2390	0.000956	0	0	559	0.000112	0	0	0.001068
1955	Feb	2470	0.000987	0	0	2870	0.000574	0	0	0.001561
1955	Mar	1150	0.000462	0	0	3950	0.000791	0	0	0.001253
1955	Apr	1250	0.000501	0	0	7990	0.0016	0	0	0.002101
1955	May	2370	0.000949	0	0	13000	0.0026	0	0	0.003549
1955	Jun	2830	0.00113	0	0	7780	0.00156	0	0	0.00269
1955	Jul	1990	0.000797	0	0	4220	0.000843	0	0	0.00164
1955	Aug	2160	0.000865	0	0	4540	0.000908	0	0	0.001773
1955	Sep	2450	0.000979	0	0	6120	0.00122	0	0	0.002199
1955	Oct	1690	0.000676	0	0	5510	0.0011	0	0	0.001776
1955	Nov	910	0.000364	0	0	12100	0.00241	0	0	0.002774
1955	Dec	755	0.000302	0	0	8420	0.00168	0	0	0.001982
1956	Jan	351	0.000141	0	0	2120	0.000423	1310	0.000003	0.000567
1956	Feb	540	0.000216	0	0	4690	0.000937	4800	0.00001	0.001163
1956	Mar	0	0	0	0	4410	0.000882	2520	0.000005	0.000887
1956	Apr	0	0	0	0	10300	0.00205	3780	0.000008	0.002058
1956	May	0	0	0	0	10400	0.00208	2570	0.000005	0.002085
1956	Jun	0	0	0	0	7550	0.00151	6460	0.000013	0.001523
1956	Jul	0	0	0	0	2870	0.000573	5770	0.000012	0.000585
1956	Aug	0	0	0	0	2090	0.000419	11600	0.000023	0.000442
1956	Sep	0	0	0	0	4640	0.000928	15400	0.000031	0.000959
1956	Oct	0	0	0	0	5290	0.00106	9110	0.000018	0.001078
1956	Nov	0	0	0	0	5300	0.00106	12800	0.000026	0.001086
1956	Dec	0	0	0	0	4680	0.000936	13000	0.000026	0.000962
1957	Jan	0	0	0	0	3650	0.000729	14000	0.000028	0.000757
1957	Feb	0	0	0	0	4780	0.000957	12200	0.000024	0.000981
1957	Mar	0	0	0	0	3470	0.000694	13000	0.000026	0.00072

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1957	Apr	0	0	0	0	5960	0.00119	14700	0.00003	0.00122
1957	May	0	0	0	0	5790	0.00116	14000	0.000028	0.001188
1957	Jun	0	0	0	0	3800	0.000759	14900	0.00003	0.000789
1957	Jul	0	0	0	0	6090	0.00122	12400	0.000025	0.001245
1957	Aug	0	0	0	0	6240	0.00125	15200	0.000031	0.001281
1957	Sep	0	0	0	0	8340	0.00167	10500	0.000021	0.001691
1957	Oct	0	0	0	0	7590	0.00152	17300	0.000035	0.001555
1957	Nov	0	0	0	0	6430	0.00129	16500	0.000033	0.001323
1957	Dec	0	0	0	0	7250	0.00145	13500	0.000027	0.001477
1958	Jan	0	0	0	0	2790	0.000559	19700	0.000039	0.000598
1958	Feb	0	0	0	0	5310	0.00106	21000	0.000042	0.001102
1958	Mar	0	0	0	0	3780	0.000757	15400	0.000031	0.000788
1958	Apr	0	0	0	0	3390	0.000678	15500	0.000031	0.000709
1958	May	0	0	0	0	7500	0.0015	11300	0.000023	0.001523
1958	Jun	0	0	0	0	7450	0.00149	1890	0.000004	0.001494
1958	Jul	0	0	0	0	7780	0.00156	19500	0.000039	0.001599
1958	Aug	0	0	0	0	4520	0.000904	7360	0.000015	0.000919
1958	Sep	0	0	0	0	5340	0.00107	19500	0.000039	0.001109
1958	Oct	0	0	0	0	882	0.000176	19700	0.000039	0.000215
1958	Nov	0	0	0	0	384	0.000077	21400	0.000043	0.00012
1958	Dec	0	0	0	0	2960	0.000593	22200	0.000044	0.000637
1959	Jan	0	0	0	0	3100	0.00062	17900	0.000036	0.000656
1959	Feb	0	0	0	0	1900	0.000381	11100	0.000022	0.000403
1959	Mar	0	0	0	0	1930	0.000387	20700	0.000042	0.000429
1959	Apr	0	0	0	0	4600	0.000921	15400	0.000031	0.000952
1959	May	0	0	0	0	2440	0.000487	16200	0.000032	0.000519
1959	Jun	0	0	0	0	3210	0.000642	26300	0.000053	0.000695
1959	Jul	0	0	0	0	3750	0.000751	13600	0.000027	0.000778
1959	Aug	0	0	0	0	2310	0.000463	31000	0.000062	0.000525
1959	Sep	0	0	0	0	2580	0.000517	19200	0.000038	0.000555

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Oct	0	0	0	0	2790	0.000558	18600	0.000037	0.000595
1959	Nov	0	0	0	0	4180	0.000835	19000	0.000038	0.000873
1959	Dec	0	0	0	0	5360	0.00107	23800	0.000048	0.001118
1960	Jan	0	0	0	0	837	0.000167	28800	0.000058	0.000225
1960	Feb	0	0	0	0	2320	0.000464	13800	0.000028	0.000492
1960	Mar	0	0	0	0	1560	0.000311	13700	0.000027	0.000338
1960	Apr	0	0	0	0	3200	0.000639	32600	0.000065	0.000704
1960	May	0	0	0	0	1550	0.00031	13200	0.000027	0.000337
1960	Jun	0	0	0	0	6670	0.00133	10500	0.000021	0.001351
1960	Jul	0	0	0	0	3080	0.000617	19400	0.000039	0.000656
1960	Aug	0	0	0	0	1810	0.000362	33900	0.000068	0.00043
1960	Sep	0	0	0	0	775	0.000155	33500	0.000067	0.000222
1960	Oct	0	0	0	0	2960	0.000593	17900	0.000036	0.000629
1960	Nov	0	0	0	0	3830	0.000766	32200	0.000064	0.00083
1960	Dec	0	0	0	0	3090	0.000619	26200	0.000053	0.000672
1961	Jan	0	0	0	0	2670	0.000534	19900	0.00004	0.000574
1961	Feb	0	0	0	0	3350	0.000669	18000	0.000036	0.000705
1961	Mar	0	0	0	0	4050	0.00081	29100	0.000058	0.000868
1961	Apr	0	0	0	0	4690	0.000937	14900	0.00003	0.000967
1961	May	0	0	0	0	3110	0.000622	35100	0.00007	0.000692
1961	Jun	0	0	0	0	6960	0.00139	23500	0.000047	0.001437
1961	Jul	0	0	0	0	5950	0.00119	22900	0.000046	0.001236
1961	Aug	0	0	0	0	5300	0.00106	25700	0.000052	0.001112
1961	Sep	0	0	0	0	2750	0.000551	24900	0.00005	0.000601
1961	Oct	0	0	0	0	4540	0.000909	14800	0.00003	0.000939
1961	Nov	0	0	0	0	5610	0.00112	11100	0.000022	0.001142
1961	Dec	0	0	0	0	2860	0.000573	32900	0.000066	0.000639
1962	Jan	0	0	0	0	7150	0.00143	17200	0.000035	0.001465
1962	Feb	0	0	0	0	4570	0.000914	6750	0.000014	0.000928
1962	Mar	0	0	0	0	2900	0.00058	13300	0.000027	0.000607

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1962	Apr	0	0	0	0	173	0.000035	15500	0.000031	0.000066
1962	May	0	0	0	0	1700	0.00034	27300	0.000055	0.000395
1962	Jun	0	0	0	0	3820	0.000764	24200	0.000049	0.000813
1962	Jul	0	0	0	0	1910	0.000383	33100	0.000066	0.000449
1962	Aug	0	0	0	0	5400	0.00108	10000	0.00002	0.0011
1962	Sep	0	0	0	0	4480	0.000896	25600	0.000051	0.000947
1962	Oct	0	0	0	0	4610	0.000922	30200	0.00006	0.000982
1962	Nov	0	0	0	0	2440	0.000487	30400	0.000061	0.000548
1962	Dec	0	0	0	0	2000	0.0004	29700	0.000059	0.000459
1963	Jan	0	0	0	0	9680	0.00194	3190	0.000006	0.001946
1963	Feb	0	0	0	0	3270	0.000653	24100	0.000048	0.000701
1963	Mar	0	0	0	0	2300	0.000459	32500	0.000065	0.000524
1963	Apr	0	0	0	0	7910	0.00158	5360	0.000011	0.001591
1963	May	0	0	0	0	1030	0.000206	28200	0.000056	0.000262
1963	Jun	0	0	0	0	5650	0.00113	31800	0.000064	0.001194
1963	Jul	0	0	0	0	6920	0.00138	0	0	0.00138
1963	Aug	0	0	0	0	5640	0.00113	13600	0.000027	0.001157
1963	Sep	0	0	0	0	4070	0.000814	26000	0.000052	0.000866
1963	Oct	0	0	0	0	1990	0.000398	24100	0.000048	0.000446
1963	Nov	0	0	0	0	766	0.000153	37400	0.000075	0.000228
1963	Dec	0	0	0	0	2350	0.00047	5260	0.000011	0.000481
1964	Jan	0	0	0	0	8360	0.00167	7070	0.000014	0.001684
1964	Feb	0	0	0	0	7740	0.00155	3400	0.000007	0.001557
1964	Mar	0	0	0	0	0	0	36600	0.000073	0.000073
1964	Apr	0	0	0	0	5470	0.00109	14000	0.000028	0.001118
1964	May	0	0	0	0	8000	0.0016	20000	0.00004	0.00164
1964	Jun	0	0	0	0	3560	0.000711	36700	0.000073	0.000784
1964	Jul	0	0	0	0	6550	0.00131	13600	0.000027	0.001337
1964	Aug	0	0	0	0	4470	0.000893	35200	0.00007	0.000963
1964	Sep	0	0	0	0	6410	0.00128	28400	0.000057	0.001337

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Oct	0	0	0	0	1320	0.000264	34700	0.00007	0.000334
1964	Nov	0	0	0	0	5520	0.0011	24300	0.000049	0.001149
1964	Dec	0	0	0	0	12600	0.00252	1720	0.000003	0.002523
1965	Jan	0	0	0	0	10900	0.00219	831	0.000002	0.002192
1965	Feb	0	0	0	0	4730	0.000946	16800	0.000034	0.00098
1965	Mar	0	0	0	0	6650	0.00133	35800	0.000072	0.001402
1965	Apr	0	0	0	0	9680	0.00194	37900	0.000076	0.002016
1965	May	0	0	0	0	8340	0.00167	35800	0.000072	0.001742
1965	Jun	0	0	0	0	391	0.000078	22400	0.000045	0.000123
1965	Jul	0	0	0	0	5430	0.00109	8890	0.000018	0.001108
1965	Aug	0	0	0	0	4780	0.000956	23500	0.000047	0.001003
1965	Sep	0	0	0	0	2030	0.000405	19300	0.000039	0.000444
1965	Oct	0	0	0	0	5520	0.0011	17800	0.000036	0.001136
1965	Nov	0	0	0	0	6840	0.00137	11000	0.000022	0.001392
1965	Dec	0	0	0	0	47.6	0.00001	18100	0.000036	0.000046
1966	Jan	0	0	0	0	32000	0.0064	27800	0.000056	0.006456
1966	Feb	0	0	0	0	2410	0.000483	14600	0.000029	0.000512
1966	Mar	0	0	0	0	5120	0.00102	18900	0.000038	0.001058
1966	Apr	0	0	0	0	6180	0.00124	7370	0.000015	0.001255
1966	May	0	0	0	0	6120	0.00122	0	0	0.00122
1966	Jun	0	0	0	0	11100	0.00222	0	0	0.00222
1966	Jul	0	0	0	0	2680	0.000535	0	0	0.000535
1966	Aug	0	0	0	0	348	0.00007	5470	0.000011	0.000081
1966	Sep	0	0	0	0	10800	0.00217	24100	0.000048	0.002218
1966	Oct	0	0	0	0	7250	0.00145	38800	0.000078	0.001528
1966	Nov	0	0	0	0	3480	0.000696	22400	0.000045	0.000741
1966	Dec	0	0	0	0	0	0	4100	0.000008	0.000008
1967	Jan	0	0	0	0	0	0	29500	0.000059	0.000059
1967	Feb	0	0	0	0	0	0	7020	0.000014	0.000014
1967	Mar	0	0	0	0	0	0	17900	0.000036	0.000036

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1967	Apr	0	0	0	0	0	0	33400	0.000067	0.000067
1967	May	0	0	0	0	0	0	19600	0.000039	0.000039
1967	Jun	0	0	0	0	0	0	10300	0.000021	0.000021
1967	Jul	0	0	0	0	0	0	16700	0.000034	0.000034
1967	Aug	0	0	0	0	0	0	19300	0.000039	0.000039
1967	Sep	0	0	0	0	0	0	34100	0.000068	0.000068
1967	Oct	0	0	0	0	0	0	22400	0.000045	0.000045
1967	Nov	0	0	0	0	0	0	24700	0.000049	0.000049
1967	Dec	0	0	0	0	0	0	9310	0.000019	0.000019
1968	Jan	0	0	0	0	0	0	17900	0.000036	0.000036
1968	Feb	0	0	0	0	0	0	12400	0.000025	0.000025
1968	Mar	0	0	0	0	0	0	31900	0.000064	0.000064
1968	Apr	0	0	0	0	0	0	25300	0.000051	0.000051
1968	May	0	0	0	0	0	0	15700	0.000032	0.000032
1968	Jun	0	0	0	0	0	0	24500	0.000049	0.000049
1968	Jul	0	0	0	0	0	0	11200	0.000022	0.000022
1968	Aug	0	0	0	0	0	0	31300	0.000063	0.000063
1968	Sep	0	0	0	0	0	0	14900	0.00003	0.00003
1968	Oct	0	0	0	0	0	0	27000	0.000054	0.000054
1968	Nov	0	0	0	0	0	0	21200	0.000042	0.000042
1968	Dec	0	0	0	0	0	0	12200	0.000025	0.000025
1969	Jan	0	0	0	0	0	0	6590	0.000013	0.000013
1969	Feb	0	0	0	0	0	0	12500	0.000025	0.000025
1969	Mar	0	0	0	0	0	0	16600	0.000033	0.000033
1969	Apr	0	0	0	0	0	0	20600	0.000041	0.000041
1969	May	0	0	0	0	0	0	22800	0.000046	0.000046
1969	Jun	0	0	0	0	0	0	7290	0.000015	0.000015
1969	Jul	0	0	0	0	0	0	5380	0.000011	0.000011
1969	Aug	0	0	0	0	0	0	24700	0.000049	0.000049
1969	Sep	0	0	0	0	0	0	18500	0.000037	0.000037

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Oct	0	0	0	0	0	0	19300	0.000039	0.000039
1969	Nov	0	0	0	0	0	0	16100	0.000032	0.000032
1969	Dec	0	0	0	0	0	0	21400	0.000043	0.000043
1970	Jan	0	0	0	0	0	0	14800	0.00003	0.00003
1970	Feb	0	0	0	0	0	0	4.07	8.14e-09	8.14e-09
1970	Mar	0	0	0	0	0	0	3300	0.000007	0.000007
1970	Apr	0	0	0	0	0	0	17300	0.000035	0.000035
1970	May	0	0	0	0	0	0	9500	0.000019	0.000019
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	944	0.000002	0.000002
1971	Apr	0	0	0	0	0	0	15400	0.000031	0.000031
1971	May	0	0	0	0	0	0	25400	0.000051	0.000051
1971	Jun	0	0	0	0	0	0	15600	0.000031	0.000031
1971	Jul	0	0	0	0	0	0	12300	0.000025	0.000025
1971	Aug	0	0	0	0	0	0	26500	0.000053	0.000053
1971	Sep	0	0	0	0	0	0	23900	0.000048	0.000048
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	2910	0.000006	0.000006
1972	Mar	0	0	0	0	0	0	11700	0.000023	0.000023

Table B.6. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Table B.7. Estimated Monthly Neptunium-239 Releases to the Atmosphere from Separations Plant Operations, 1944-1972 (Ci/month)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1944	Dec	243	0.00972	0	0	0	0	0	0	0.00972
1945	Jan	52.3	0.00209	0	0	0	0	0	0	0.00209
1945	Feb	1.13	0.000045	0	0	0	0	0	0	0.000045
1945	Mar	2.44	0.000098	0	0	0	0	0	0	0.000098
1945	Apr	57.4	0.0023	46.9	0.00188	0	0	0	0	0.00418
1945	May	381	0.0152	569	0.0228	0	0	0	0	0.038
1945	Jun	321	0.0129	358	0.0143	0	0	0	0	0.0272
1945	Jul	259	0.0103	411	0.0164	0	0	0	0	0.0267
1945	Aug	519	0.0208	756	0.0302	0	0	0	0	0.051
1945	Sep	510	0.0204	1160	0.0463	0	0	0	0	0.0667
1945	Oct	368	0.0147	296	0.0118	0	0	0	0	0.0265
1945	Nov	31.3	0.00125	33.7	0.00135	0	0	0	0	0.0026
1945	Dec	7.93	0.000317	691	0.0276	0	0	0	0	0.027917
1946	Jan	90.5	0.00362	14.6	0.000583	0	0	0	0	0.004203
1946	Feb	0.0921	0.000004	0.45	0.000018	0	0	0	0	0.000022
1946	Mar	0.0227	9.07e-07	0.751	0.00003	0	0	0	0	0.000031
1946	Apr	1.52	0.000061	1.86	0.000074	0	0	0	0	0.000135
1946	May	1	0.00004	1.39	0.000056	0	0	0	0	0.000096
1946	Jun	0.000028	1.11e-09	0.306	0.000012	0	0	0	0	0.000012
1946	Jul	0.00502	2.01e-07	0.634	0.000025	0	0	0	0	0.000026
1946	Aug	0.000385	1.54e-08	2.73	0.000109	0	0	0	0	0.000109
1946	Sep	0.00494	1.97e-07	3.84	0.000154	0	0	0	0	0.000154
1946	Oct	0.00839	3.35e-07	0.519	0.000021	0	0	0	0	0.000021
1946	Nov	0.163	0.000007	0.232	0.000009	0	0	0	0	0.000016
1946	Dec	0.106	0.000004	1.37	0.000055	0	0	0	0	0.000059
1947	Jan	0.0957	0.000004	1.29	0.000052	0	0	0	0	0.000056
1947	Feb	0.33	0.000013	0.0336	0.000001	0	0	0	0	0.000015
1947	Mar	0.127	0.000005	0.174	0.000007	0	0	0	0	0.000012

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1947	Apr	0.0971	0.000004	0.119	0.000005	0	0	0	0	0.000009
1947	May	0.142	0.000006	0.0785	0.000003	0	0	0	0	0.000009
1947	Jun	0.0109	4.34e-07	0.00648	2.59e-07	0	0	0	0	6.93e-07
1947	Jul	0.00429	1.72e-07	0.0144	5.78e-07	0	0	0	0	7.50e-07
1947	Aug	0.00076	3.04e-08	0.00426	1.70e-07	0	0	0	0	2.00e-07
1947	Sep	0.0012	4.80e-08	0.0014	5.59e-08	0	0	0	0	1.04e-07
1947	Oct	0.000332	1.33e-08	0.000037	1.50e-09	0	0	0	0	1.48e-08
1947	Nov	0.000021	8.56e-10	0.000036	1.45e-09	0	0	0	0	2.31e-09
1947	Dec	0.000005	1.87e-10	0.000006	2.55e-10	0	0	0	0	4.42e-10
1948	Jan	3.87e-07	1.55e-11	0.000007	2.71e-10	0	0	0	0	2.87e-10
1948	Feb	6.99e-07	2.80e-11	0.000006	2.27e-10	0	0	0	0	2.55e-10
1948	Mar	9.38e-07	3.75e-11	6.98e-07	2.79e-11	0	0	0	0	6.54e-11
1948	Apr	0.000003	1.36e-10	2.97e-07	1.19e-11	0	0	0	0	1.48e-10
1948	May	4.32e-07	1.73e-13	7.72e-09	3.09e-13	0	0	0	0	4.82e-13
1948	Jun	1.65e-07	6.59e-14	1.33e-07	5.31e-14	0	0	0	0	1.19e-13
1948	Jul	0.000001	4.18e-13	0.000012	4.88e-12	0	0	0	0	5.30e-12
1948	Aug	0.000023	9.08e-12	0.000017	6.76e-12	0	0	0	0	1.58e-11
1948	Sep	0.000032	1.29e-11	0.002	8.01e-10	0	0	0	0	8.14e-10
1948	Oct	0.000006	2.27e-12	0.000009	3.75e-12	0	0	0	0	6.02e-12
1948	Nov	0.000015	5.95e-12	0.000011	4.43e-12	0	0	0	0	1.04e-11
1948	Dec	0.000011	4.48e-12	0.00001	3.89e-12	0	0	0	0	8.37e-12
1949	Jan	0.000025	1.00e-11	0.000027	1.08e-11	0	0	0	0	2.08e-11
1949	Feb	0.000057	2.28e-11	1.07e-07	4.28e-14	0	0	0	0	2.28e-11
1949	Mar	0.000078	3.12e-11	0.000003	1.08e-12	0	0	0	0	3.23e-11
1949	Apr	0.000017	6.84e-12	0.000007	2.94e-12	0	0	0	0	9.78e-12
1949	May	0.000019	7.69e-12	0.000025	9.86e-12	0	0	0	0	1.76e-11
1949	Jun	0.000015	5.83e-12	0.000004	1.43e-12	0	0	0	0	7.26e-12
1949	Jul	0.000015	6.03e-12	0.000014	5.42e-12	0	0	0	0	1.15e-11
1949	Aug	0.000018	7.04e-12	8.55e-07	3.42e-13	0	0	0	0	7.38e-12
1949	Sep	0.000023	9.36e-12	0.000027	1.07e-11	0	0	0	0	2.01e-11

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1949	Oct	0.000009	3.61e-12	0.000022	8.83e-12	0	0	0	0	1.24e-11
1949	Nov	0.000017	6.92e-12	0.000007	2.85e-12	0	0	0	0	9.77e-12
1949	Dec	0.000021	8.45e-12	0.000008	3.27e-12	0	0	0	0	1.17e-11
1950	Jan	0.000006	2.33e-12	0.000006	2.32e-12	0	0	0	0	4.65e-12
1950	Feb	0.000006	2.49e-12	0.000004	1.73e-12	0	0	0	0	4.22e-12
1950	Mar	0.000012	4.62e-12	0.000012	4.58e-12	0	0	0	0	9.20e-12
1950	Apr	0.000009	3.77e-12	0.000011	4.33e-12	0	0	0	0	8.10e-12
1950	May	0.000019	7.57e-12	0.000012	4.62e-12	0	0	0	0	1.22e-11
1950	Jun	0.000007	2.74e-12	0.000019	7.55e-12	0	0	0	0	1.03e-11
1950	Jul	0.000139	5.57e-11	0.000045	1.81e-11	0	0	0	0	7.38e-11
1950	Aug	0.0364	1.46e-08	0.0162	6.50e-09	0	0	0	0	2.11e-08
1950	Sep	0.0177	7.07e-09	0.0238	9.50e-09	0	0	0	0	1.66e-08
1950	Oct	0.00302	1.21e-09	0.00911	3.64e-09	0	0	0	0	4.85e-09
1950	Nov	0.00102	4.07e-10	0.00106	4.24e-10	0	0	0	0	8.31e-10
1950	Dec	0.0133	5.33e-09	0.00219	8.75e-10	0	0	0	0	6.21e-09
1951	Jan	0.091	3.64e-08	0.000363	1.45e-10	0	0	0	0	3.65e-08
1951	Feb	0.0442	1.77e-08	0.0505	2.02e-08	0	0	0	0	3.79e-08
1951	Mar	0.0728	2.91e-08	1.04	4.17e-07	0	0	0	0	4.46e-07
1951	Apr	11.6	0.000005	13.1	0.000005	0	0	0	0	0.00001
1951	May	66	0.000026	35.8	0.000014	0	0	0	0	0.000041
1951	Jun	78.7	0.000032	14.9	0.000006	0	0	0	0	0.000037
1951	Jul	26.7	0.000011	25.5	0.00001	0	0	0	0	0.000021
1951	Aug	98	0.000039	50.8	0.00002	0	0	0	0	0.00006
1951	Sep	42.7	0.000017	31.7	0.000013	0	0	0	0	0.00003
1951	Oct	48.6	0.000019	98.4	0.000039	0	0	0	0	0.000059
1951	Nov	25.4	0.00001	113	0.000045	0	0	0	0	0.000055
1951	Dec	35.2	0.000014	18.1	0.000007	0	0	0	0	0.000021
1952	Jan	99.4	0.00004	43.7	0.000018	0.646	1.29e-07	0	0	0.000057
1952	Feb	20.1	0.000008	30.8	0.000012	4.02	8.03e-07	0	0	0.000021
1952	Mar	68.2	0.000027	2.26	9.03e-07	7.6	0.000002	0	0	0.00003

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1952	Apr	19.1	0.000008	0.0867	3.47e-08	23.8	0.000005	0	0	0.000012
1952	May	6.82	0.000003	0.0447	1.79e-08	10.2	0.000002	0	0	0.000005
1952	Jun	0.000073	2.91e-11	0.0498	1.99e-08	3.25	6.50e-07	0	0	6.70e-07
1952	Jul	0.0634	2.54e-08	0	0	0.0115	2.30e-09	0	0	2.77e-08
1952	Aug	0.433	1.73e-07	0	0	0.0931	1.86e-08	0	0	1.92e-07
1952	Sep	0.000136	5.46e-11	0	0	0.0827	1.65e-08	0	0	1.66e-08
1952	Oct	0.000005	2.14e-12	0	0	0.00328	6.56e-10	0	0	6.58e-10
1952	Nov	0.00467	1.87e-09	0	0	0.00926	1.85e-09	0	0	3.72e-09
1952	Dec	1.04	4.17e-07	0	0	0.00009	1.80e-11	0	0	4.17e-07
1953	Jan	0.000037	1.50e-11	0	0	0.0082	1.64e-09	0	0	1.66e-09
1953	Feb	0.000129	5.18e-11	0	0	0.000085	1.70e-11	0	0	6.88e-11
1953	Mar	0.000278	1.11e-10	0	0	0.000658	1.32e-10	0	0	2.43e-10
1953	Apr	0.865	3.46e-07	0	0	0.00742	1.48e-09	0	0	3.47e-07
1953	May	0.146	5.83e-08	0	0	0.00878	1.76e-09	0	0	6.01e-08
1953	Jun	0.345	1.38e-07	0	0	0.0137	2.74e-09	0	0	1.41e-07
1953	Jul	6.71	0.000003	0	0	0.166	3.32e-08	0	0	0.000003
1953	Aug	0.0861	3.44e-08	0	0	0.0224	4.48e-09	0	0	3.89e-08
1953	Sep	0.0192	7.70e-09	0	0	0.00651	1.30e-09	0	0	9.00e-09
1953	Oct	0.0431	1.72e-08	0	0	0.0804	1.61e-08	0	0	3.33e-08
1953	Nov	0.189	7.57e-08	0	0	0.00244	4.89e-10	0	0	7.62e-08
1953	Dec	0.00017	6.82e-11	0	0	0.0105	2.10e-09	0	0	2.17e-09
1954	Jan	0.403	1.61e-07	0	0	0.00488	9.76e-10	0	0	1.62e-07
1954	Feb	0.000394	1.58e-10	0	0	0.000241	4.82e-11	0	0	2.06e-10
1954	Mar	0.000045	1.81e-11	0	0	0.000391	7.83e-11	0	0	9.64e-11
1954	Apr	0.000029	1.17e-11	0	0	0.000284	5.67e-11	0	0	6.84e-11
1954	May	0.00149	5.97e-10	0	0	0.00089	1.78e-10	0	0	7.75e-10
1954	Jun	0.00007	2.81e-11	0	0	0.00727	1.45e-09	0	0	1.48e-09
1954	Jul	0.000085	3.39e-11	0	0	0.000006	1.12e-12	0	0	3.50e-11
1954	Aug	0.00017	6.80e-11	0	0	0.000004	7.51e-13	0	0	6.88e-11
1954	Sep	0.00078	3.12e-10	0	0	0.000041	8.20e-12	0	0	3.20e-10

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1954	Oct	0.00763	3.05e-09	0	0	3.25e-09	6.49e-16	0	0	3.05e-09
1954	Nov	0.000038	1.51e-11	0	0	1.51e-10	3.01e-17	0	0	1.51e-11
1954	Dec	0.00008	3.19e-11	0	0	9.26e-07	1.85e-13	0	0	3.21e-11
1955	Jan	0.000024	9.72e-12	0	0	0.000008	1.55e-12	0	0	1.13e-11
1955	Feb	0.000079	3.16e-11	0	0	0.00098	1.96e-10	0	0	2.28e-10
1955	Mar	1.17e-07	4.69e-14	0	0	0.0253	5.05e-09	0	0	5.05e-09
1955	Apr	0.000769	3.07e-10	0	0	8.34e-11	1.67e-17	0	0	3.07e-10
1955	May	0.0001	4.02e-11	0	0	0	0	0	0	4.02e-11
1955	Jun	0.000002	9.41e-13	0	0	0.000066	1.32e-11	0	0	1.41e-11
1955	Jul	0.000005	1.90e-12	0	0	0.000043	8.68e-12	0	0	1.06e-11
1955	Aug	8.02e-19	3.21e-25	0	0	0.000008	1.62e-12	0	0	1.62e-12
1955	Sep	0.000035	1.39e-11	0	0	0.000156	3.12e-11	0	0	4.51e-11
1955	Oct	0.000044	1.75e-11	0	0	0.000142	2.85e-11	0	0	4.60e-11
1955	Nov	2.84e-07	1.13e-13	0	0	5.37e-12	1.07e-18	0	0	1.13e-13
1955	Dec	2.66e-10	1.07e-16	0	0	0.000051	1.02e-11	0	0	1.02e-11
1956	Jan	2.84e-14	1.13e-20	0	0	4.64e-07	9.28e-14	1.18e-11	2.37e-20	9.28e-14
1956	Feb	5.44e-20	2.18e-26	0	0	0.000002	4.80e-13	6.26e-15	1.25e-23	4.80e-13
1956	Mar	0	0	0	0	2.82e-08	5.64e-15	6.72e-13	1.34e-21	5.64e-15
1956	Apr	0	0	0	0	1.87e-10	3.75e-17	0.000027	5.43e-14	5.43e-14
1956	May	0	0	0	0	0.000008	1.65e-12	2.79e-08	5.57e-17	1.65e-12
1956	Jun	0	0	0	0	0.000005	9.52e-13	0.000153	3.07e-13	1.26e-12
1956	Jul	0	0	0	0	2.77e-08	5.53e-15	1.05e-10	2.10e-19	5.53e-15
1956	Aug	0	0	0	0	2.79e-09	5.57e-16	4.31e-09	8.62e-18	5.66e-16
1956	Sep	0	0	0	0	1.03e-10	2.07e-17	8.52e-07	1.70e-15	1.72e-15
1956	Oct	0	0	0	0	8.39e-12	1.68e-18	6.76e-07	1.35e-15	1.35e-15
1956	Nov	0	0	0	0	3.06e-09	6.12e-16	0.000014	2.83e-14	2.89e-14
1956	Dec	0	0	0	0	0.000002	4.80e-13	0.000002	4.95e-15	4.85e-13
1957	Jan	0	0	0	0	6.22e-08	1.24e-14	5.58e-07	1.12e-15	1.35e-14
1957	Feb	0	0	0	0	2.12e-07	4.24e-14	1.22e-07	2.44e-16	4.26e-14
1957	Mar	0	0	0	0	1.62e-08	3.24e-15	9.41e-08	1.88e-16	3.43e-15

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1957	Apr	0	0	0	0	3.97e-07	7.94e-14	5.79e-07	1.16e-15	8.06e-14
1957	May	0	0	0	0	2.10e-07	4.19e-14	3.75e-07	7.50e-16	4.27e-14
1957	Jun	0	0	0	0	5.88e-08	1.18e-14	5.18e-07	1.04e-15	1.28e-14
1957	Jul	0	0	0	0	5.97e-07	1.19e-13	0.000004	8.08e-15	1.27e-13
1957	Aug	0	0	0	0	0.000002	4.57e-13	0.000004	7.30e-15	4.64e-13
1957	Sep	0	0	0	0	0.000002	4.92e-13	0.000005	1.06e-14	5.03e-13
1957	Oct	0	0	0	0	0.000007	1.31e-12	0.000043	8.49e-14	1.39e-12
1957	Nov	0	0	0	0	0.000047	9.33e-12	0.000122	2.44e-13	9.57e-12
1957	Dec	0	0	0	0	0.000182	3.63e-11	0.000308	6.17e-13	3.69e-11
1958	Jan	0	0	0	0	0.00002	3.95e-12	0.000344	6.87e-13	4.64e-12
1958	Feb	0	0	0	0	0.00233	4.67e-10	0.00686	1.37e-11	4.81e-10
1958	Mar	0	0	0	0	0.000897	1.79e-10	0.00524	1.05e-11	1.90e-10
1958	Apr	0	0	0	0	0.000574	1.15e-10	0.00265	5.31e-12	1.20e-10
1958	May	0	0	0	0	0.000763	1.53e-10	0.00611	1.22e-11	1.65e-10
1958	Jun	0	0	0	0	0.000029	5.72e-12	0.000005	1.01e-14	5.73e-12
1958	Jul	0	0	0	0	0.000016	3.25e-12	0.000042	8.47e-14	3.33e-12
1958	Aug	0	0	0	0	0.000017	3.37e-12	0.000035	7.09e-14	3.44e-12
1958	Sep	0	0	0	0	0.000008	1.65e-12	0.000179	3.59e-13	2.01e-12
1958	Oct	0	0	0	0	1.09e-18	2.18e-25	0.000066	1.33e-13	1.33e-13
1958	Nov	0	0	0	0	2.56e-20	5.12e-27	0.000562	1.12e-12	1.12e-12
1958	Dec	0	0	0	0	2.82e-20	5.64e-27	0.00025	5.01e-13	5.01e-13
1959	Jan	0	0	0	0	7.46e-19	1.49e-25	0.000132	2.65e-13	2.65e-13
1959	Feb	0	0	0	0	6.41e-28	1.28e-34	0.000054	1.08e-13	1.08e-13
1959	Mar	0	0	0	0	2.31e-24	4.62e-31	0.000044	8.79e-14	8.79e-14
1959	Apr	0	0	0	0	5.57e-20	1.11e-26	0.000037	7.45e-14	7.45e-14
1959	May	0	0	0	0	1.02e-18	2.05e-25	0.0001	2.01e-13	2.01e-13
1959	Jun	0	0	0	0	2.03e-13	4.06e-20	0.000261	5.21e-13	5.21e-13
1959	Jul	0	0	0	0	2.32e-15	4.64e-22	0.000014	2.89e-14	2.89e-14
1959	Aug	0	0	0	0	2.22e-14	4.44e-21	0.000133	2.66e-13	2.66e-13
1959	Sep	0	0	0	0	1.00e-17	2.00e-24	0.00163	3.26e-12	3.26e-12

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1959	Oct	0	0	0	0	4.26e-15	8.52e-22	0.0002	3.99e-13	3.99e-13
1959	Nov	0	0	0	0	2.43e-10	4.86e-17	0.000048	9.50e-14	9.50e-14
1959	Dec	0	0	0	0	3.04e-25	6.07e-32	0.000141	2.81e-13	2.81e-13
1960	Jan	0	0	0	0	2.81e-13	5.61e-20	0.00487	9.75e-12	9.75e-12
1960	Feb	0	0	0	0	5.70e-10	1.14e-16	0.000299	5.98e-13	5.98e-13
1960	Mar	0	0	0	0	1.42e-11	2.83e-18	2.87e-07	5.74e-16	5.77e-16
1960	Apr	0	0	0	0	1.04e-10	2.08e-17	0.000002	3.74e-15	3.76e-15
1960	May	0	0	0	0	1.06e-13	2.12e-20	0.000024	4.78e-14	4.78e-14
1960	Jun	0	0	0	0	2.39e-13	4.77e-20	3.82e-07	7.64e-16	7.64e-16
1960	Jul	0	0	0	0	3.03e-14	6.05e-21	0.000031	6.09e-14	6.09e-14
1960	Aug	0	0	0	0	5.87e-09	1.17e-15	0.000772	1.54e-12	1.54e-12
1960	Sep	0	0	0	0	5.70e-26	1.14e-32	1.48e-07	2.97e-16	2.97e-16
1960	Oct	0	0	0	0	1.93e-26	3.86e-33	3.08e-15	6.17e-24	6.17e-24
1960	Nov	0	0	0	0	4.59e-25	9.17e-32	0.000005	9.79e-15	9.79e-15
1960	Dec	0	0	0	0	5.24e-23	1.05e-29	0.00024	4.79e-13	4.79e-13
1961	Jan	0	0	0	0	1.11e-24	2.22e-31	0.000007	1.50e-14	1.50e-14
1961	Feb	0	0	0	0	1.64e-21	3.28e-28	0.000016	3.18e-14	3.18e-14
1961	Mar	0	0	0	0	6.94e-13	1.39e-19	0.000004	7.07e-15	7.07e-15
1961	Apr	0	0	0	0	8.05e-18	1.61e-24	3.83e-07	7.67e-16	7.67e-16
1961	May	0	0	0	0	1.46e-20	2.92e-27	6.66e-07	1.33e-15	1.33e-15
1961	Jun	0	0	0	0	2.59e-25	5.17e-32	0.000007	1.31e-14	1.31e-14
1961	Jul	0	0	0	0	3.08e-13	6.16e-20	6.04e-07	1.21e-15	1.21e-15
1961	Aug	0	0	0	0	3.21e-11	6.42e-18	0.000007	1.46e-14	1.46e-14
1961	Sep	0	0	0	0	1.87e-10	3.74e-17	0.000001	2.59e-15	2.63e-15
1961	Oct	0	0	0	0	4.06e-10	8.12e-17	0.000007	1.33e-14	1.34e-14
1961	Nov	0	0	0	0	2.30e-08	4.59e-15	0.000002	4.21e-15	8.80e-15
1961	Dec	0	0	0	0	3.44e-14	6.88e-21	2.46e-12	4.91e-21	1.18e-20
1962	Jan	0	0	0	0	2.85e-08	5.71e-15	1.75e-09	3.49e-18	5.71e-15
1962	Feb	0	0	0	0	1.44e-08	2.88e-15	3.40e-10	6.80e-19	2.88e-15
1962	Mar	0	0	0	0	6.63e-11	1.33e-17	2.87e-12	5.74e-21	1.33e-17

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1962	Apr	0	0	0	0	8.50e-27	1.70e-33	1.28e-13	2.55e-22	2.55e-22
1962	May	0	0	0	0	8.67e-15	1.73e-21	7.69e-12	1.54e-20	1.71e-20
1962	Jun	0	0	0	0	2.61e-14	5.23e-21	4.29e-11	8.58e-20	9.10e-20
1962	Jul	0	0	0	0	1.43e-16	2.87e-23	3.42e-09	6.84e-18	6.84e-18
1962	Aug	0	0	0	0	2.48e-16	4.97e-23	6.34e-09	1.27e-17	1.27e-17
1962	Sep	0	0	0	0	3.55e-18	7.10e-25	1.26e-16	2.51e-25	9.61e-25
1962	Oct	0	0	0	0	5.17e-21	1.03e-27	7.02e-11	1.40e-19	1.40e-19
1962	Nov	0	0	0	0	3.57e-21	7.14e-28	1.28e-10	2.55e-19	2.55e-19
1962	Dec	0	0	0	0	2.11e-17	4.21e-24	2.71e-07	5.42e-16	5.42e-16
1963	Jan	0	0	0	0	6.16e-21	1.23e-27	3.04e-21	6.08e-30	1.24e-27
1963	Feb	0	0	0	0	1.05e-21	2.11e-28	1.13e-11	2.25e-20	2.25e-20
1963	Mar	0	0	0	0	2.52e-20	5.04e-27	1.02e-09	2.04e-18	2.04e-18
1963	Apr	0	0	0	0	1.91e-12	3.83e-19	3.83e-09	7.66e-18	8.04e-18
1963	May	0	0	0	0	2.48e-13	4.96e-20	9.41e-10	1.88e-18	1.93e-18
1963	Jun	0	0	0	0	2.55e-11	5.11e-18	3.87e-10	7.73e-19	5.88e-18
1963	Jul	0	0	0	0	2.30e-21	4.59e-28	0	0	4.59e-28
1963	Aug	0	0	0	0	1.93e-31	3.85e-38	3.44e-11	6.87e-20	6.87e-20
1963	Sep	0	0	0	0	2.37e-20	4.73e-27	8.10e-11	1.62e-19	1.62e-19
1963	Oct	0	0	0	0	5.50e-14	1.10e-20	9.99e-12	2.00e-20	3.10e-20
1963	Nov	0	0	0	0	1.97e-16	3.94e-23	9.43e-13	1.89e-21	1.93e-21
1963	Dec	0	0	0	0	3.31e-23	6.61e-30	3.21e-10	6.42e-19	6.42e-19
1964	Jan	0	0	0	0	1.18e-27	2.36e-34	7.48e-10	1.50e-18	1.50e-18
1964	Feb	0	0	0	0	3.78e-20	7.55e-27	2.17e-11	4.33e-20	4.33e-20
1964	Mar	0	0	0	0	0	0	1.52e-10	3.05e-19	3.05e-19
1964	Apr	0	0	0	0	2.24e-23	4.48e-30	1.49e-09	2.98e-18	2.98e-18
1964	May	0	0	0	0	9.73e-20	1.95e-26	5.57e-09	1.11e-17	1.11e-17
1964	Jun	0	0	0	0	2.75e-12	5.50e-19	1.73e-10	3.45e-19	8.95e-19
1964	Jul	0	0	0	0	6.29e-22	1.26e-28	2.84e-10	5.68e-19	5.68e-19
1964	Aug	0	0	0	0	9.80e-27	1.96e-33	9.97e-09	1.99e-17	1.99e-17
1964	Sep	0	0	0	0	9.08e-21	1.82e-27	2.32e-20	4.63e-29	1.87e-27

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1964	Oct	0	0	0	0	3.06e-19	6.12e-26	1.81e-08	3.62e-17	3.62e-17
1964	Nov	0	0	0	0	1.01e-23	2.01e-30	1.61e-08	3.23e-17	3.23e-17
1964	Dec	0	0	0	0	5.66e-18	1.13e-24	5.18e-10	1.04e-18	1.04e-18
1965	Jan	0	0	0	0	6.26e-18	1.25e-24	5.46e-10	1.09e-18	1.09e-18
1965	Feb	0	0	0	0	3.22e-16	6.45e-23	6.93e-13	1.39e-21	1.45e-21
1965	Mar	0	0	0	0	2.21e-14	4.43e-21	1.47e-12	2.93e-21	7.36e-21
1965	Apr	0	0	0	0	4.21e-13	8.42e-20	1.04e-14	2.08e-23	8.42e-20
1965	May	0	0	0	0	9.79e-11	1.96e-17	5.26e-11	1.05e-19	1.97e-17
1965	Jun	0	0	0	0	2.40e-12	4.80e-19	7.28e-14	1.46e-22	4.80e-19
1965	Jul	0	0	0	0	5.60e-12	1.12e-18	1.02e-12	2.03e-21	1.12e-18
1965	Aug	0	0	0	0	2.95e-13	5.90e-20	1.51e-12	3.03e-21	6.20e-20
1965	Sep	0	0	0	0	3.64e-14	7.28e-21	1.43e-13	2.86e-22	7.57e-21
1965	Oct	0	0	0	0	1.03e-18	2.06e-25	2.96e-09	5.92e-18	5.92e-18
1965	Nov	0	0	0	0	3.80e-18	7.61e-25	2.32e-12	4.63e-21	4.63e-21
1965	Dec	0	0	0	0	8.17e-20	1.63e-26	8.88e-09	1.78e-17	1.78e-17
1966	Jan	0	0	0	0	9.89e-18	1.98e-24	3.50e-08	7.00e-17	7.00e-17
1966	Feb	0	0	0	0	1.79e-20	3.57e-27	1.37e-15	2.75e-24	2.75e-24
1966	Mar	0	0	0	0	8.12e-15	1.62e-21	2.92e-11	5.85e-20	6.01e-20
1966	Apr	0	0	0	0	8.79e-23	1.76e-29	1.58e-07	3.15e-16	3.15e-16
1966	May	0	0	0	0	9.47e-16	1.89e-22	0	0	1.89e-22
1966	Jun	0	0	0	0	7.46e-10	1.49e-16	0	0	1.49e-16
1966	Jul	0	0	0	0	1.37e-10	2.74e-17	0	0	2.74e-17
1966	Aug	0	0	0	0	1.72e-11	3.43e-18	7.96e-21	1.59e-29	3.43e-18
1966	Sep	0	0	0	0	1.50e-17	3.00e-24	3.03e-19	6.06e-28	3.00e-24
1966	Oct	0	0	0	0	7.18e-28	1.44e-34	1.01e-11	2.01e-20	2.01e-20
1966	Nov	0	0	0	0	4.61e-28	9.23e-35	1.93e-22	3.87e-31	3.87e-31
1966	Dec	0	0	0	0	0	0	0	0	0
1967	Jan	0	0	0	0	0	0	1.01e-11	2.02e-20	2.02e-20
1967	Feb	0	0	0	0	0	0	3.30e-11	6.59e-20	6.59e-20
1967	Mar	0	0	0	0	0	0	2.27e-10	4.54e-19	4.54e-19

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1967	Apr	0	0	0	0	0	0	1.97e-42	0	0
1967	May	0	0	0	0	0	0	5.29e-11	1.06e-19	1.06e-19
1967	Jun	0	0	0	0	0	0	8.86e-21	1.77e-29	1.77e-29
1967	Jul	0	0	0	0	0	0	8.61e-22	1.72e-30	1.72e-30
1967	Aug	0	0	0	0	0	0	7.08e-15	1.42e-23	1.42e-23
1967	Sep	0	0	0	0	0	0	1.91e-17	3.82e-26	3.82e-26
1967	Oct	0	0	0	0	0	0	7.30e-21	1.46e-29	1.46e-29
1967	Nov	0	0	0	0	0	0	4.18e-17	8.35e-26	8.35e-26
1967	Dec	0	0	0	0	0	0	1.60e-20	3.21e-29	3.21e-29
1968	Jan	0	0	0	0	0	0	2.19e-26	4.38e-35	4.38e-35
1968	Feb	0	0	0	0	0	0	9.90e-31	1.98e-39	1.98e-39
1968	Mar	0	0	0	0	0	0	3.71e-19	7.41e-28	7.41e-28
1968	Apr	0	0	0	0	0	0	3.57e-16	7.14e-25	7.14e-25
1968	May	0	0	0	0	0	0	2.47e-18	4.94e-27	4.94e-27
1968	Jun	0	0	0	0	0	0	8.75e-20	1.75e-28	1.75e-28
1968	Jul	0	0	0	0	0	0	9.30e-26	1.86e-34	1.86e-34
1968	Aug	0	0	0	0	0	0	7.45e-18	1.49e-26	1.49e-26
1968	Sep	0	0	0	0	0	0	8.04e-20	1.61e-28	1.61e-28
1968	Oct	0	0	0	0	0	0	1.29e-17	2.57e-26	2.57e-26
1968	Nov	0	0	0	0	0	0	2.34e-35	4.62e-44	4.62e-44
1968	Dec	0	0	0	0	0	0	7.33e-25	1.47e-33	1.47e-33
1969	Jan	0	0	0	0	0	0	2.40e-23	4.81e-32	4.81e-32
1969	Feb	0	0	0	0	0	0	9.16e-30	1.83e-38	1.83e-38
1969	Mar	0	0	0	0	0	0	4.53e-23	9.06e-32	9.06e-32
1969	Apr	0	0	0	0	0	0	1.02e-29	2.03e-38	2.03e-38
1969	May	0	0	0	0	0	0	4.58e-39	0	0
1969	Jun	0	0	0	0	0	0	3.19e-20	6.38e-29	6.38e-29
1969	Jul	0	0	0	0	0	0	1.70e-19	3.39e-28	3.39e-28
1969	Aug	0	0	0	0	0	0	9.03e-25	1.81e-33	1.81e-33
1969	Sep	0	0	0	0	0	0	2.68e-20	5.36e-29	5.36e-29

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1969	Oct	0	0	0	0	0	0	1.63e-22	3.27e-31	3.27e-31
1969	Nov	0	0	0	0	0	0	9.73e-29	1.95e-37	1.95e-37
1969	Dec	0	0	0	0	0	0	1.25e-37	0	0
1970	Jan	0	0	0	0	0	0	6.08e-19	1.22e-27	1.22e-27
1970	Feb	0	0	0	0	0	0	0	0	0
1970	Mar	0	0	0	0	0	0	1.76e-27	3.53e-36	3.53e-36
1970	Apr	0	0	0	0	0	0	2.97e-33	5.95e-42	5.95e-42
1970	May	0	0	0	0	0	0	7.41e-31	1.48e-39	1.48e-39
1970	Jun	0	0	0	0	0	0	0	0	0
1970	Jul	0	0	0	0	0	0	0	0	0
1970	Aug	0	0	0	0	0	0	0	0	0
1970	Sep	0	0	0	0	0	0	0	0	0
1970	Oct	0	0	0	0	0	0	0	0	0
1970	Nov	0	0	0	0	0	0	0	0	0
1970	Dec	0	0	0	0	0	0	0	0	0
1971	Jan	0	0	0	0	0	0	0	0	0
1971	Feb	0	0	0	0	0	0	0	0	0
1971	Mar	0	0	0	0	0	0	0	0	0
1971	Apr	0	0	0	0	0	0	0	0	0
1971	May	0	0	0	0	0	0	1.61e-37	0	0
1971	Jun	0	0	0	0	0	0	1.12e-23	2.25e-32	2.25e-32
1971	Jul	0	0	0	0	0	0	0	0	0
1971	Aug	0	0	0	0	0	0	0	0	0
1971	Sep	0	0	0	0	0	0	0	0	0
1971	Oct	0	0	0	0	0	0	0	0	0
1971	Nov	0	0	0	0	0	0	0	0	0
1971	Dec	0	0	0	0	0	0	0	0	0
1972	Jan	0	0	0	0	0	0	0	0	0
1972	Feb	0	0	0	0	0	0	1.54e-44	0	0
1972	Mar	0	0	0	0	0	0	1.12e-44	0	0

Table B.7. (contd)

Year	Month	T Plant Processed	T Plant Released	B Plant Processed	B Plant Released	REDOX Processed	REDOX Released	PUREX Processed	PUREX Released	All Plants Released
1972	Apr	0	0	0	0	0	0	0	0	0
1972	May	0	0	0	0	0	0	0	0	0
1972	Jun	0	0	0	0	0	0	0	0	0
1972	Jul	0	0	0	0	0	0	0	0	0
1972	Aug	0	0	0	0	0	0	0	0	0
1972	Sep	0	0	0	0	0	0	0	0	0
1972	Oct	0	0	0	0	0	0	0	0	0
1972	Nov	0	0	0	0	0	0	0	0	0
1972	Dec	0	0	0	0	0	0	0	0	0

Appendix C

Regressions for Natural and Enriched Uranium Radionuclide Content from ORIGEN2 Results (written in FORTRAN code)

Appendix C

Regressions for Natural and Enriched Uranium Radionuclide Content from ORIGEN2 Results (written in FORTRAN code)

FAC = 1.-EXP(-86400*LAM(NUCL)*BU/PD)
where LAM(NUCL) = decay constant of each nuclide.

<u>Natural Uranium Regressions</u>

I-131
```
CPERTN  =  PD*(26450. + 0.9132*BU - 5.448E-05*BU**2 -
           63501.*PD/BU - 5655000.*PD/BU**2)
```

Ru-103
```
CPERTN  =  4522.*FAC*PD**0.5 + 22491.*PD*FAC +
           321.57*PD*FAC*BU**0.5 - 4185./PD**2 + 3078./PD
```

Ru-106
```
CPERTN  =  PD*(5648.9*FAC + 5.0209*BU*FAC -
           0.0005747*FAC*BU**2 - 41.39*FAC*PD -
           0.00928*PD*BU*FAC) + 1.8992*BU - 20.14*BU**0.5
```

Sr-90
```
CPERTN  =  2.9229*BU - 0.0003839*BU**2 + 4.352E-8*BU**3 +
           0.002917*BU*PD + 5.863E-6*PD*BU**2
```

Pu-239
```
CPERTN  =  0.08382*BU - 3.331E-5*BU**2 + 9.163E-09*BU**3 -
           1.163E-12*BU**4 + 9.906E-5*PD*BU
```

Ce-144
```
CPERTN  =  -0.6523*BU + 44216.*FAC*PD - 2.613*PD*FAC*BU +
           0.0003173*PD*FAC*BU**2 + 0.02043*BU*FAC*PD**2
```

Np-239
```
CPERTN  =  PD*(1069300. - 280.67*BU + 0.11281*BU**2 -
           1.786E-05*BU**3)
```

Enriched Uranium Regressions

I-131

CPERTE = PD*(26100. + 0.4593*BU + 5.78E-05*BU**2 - 57270.*PD/BU - 5934000.*PD/BU**2)

Ru-103

CPERTE = 1488.*FAC*PD**0.5 + 23095.*PD*FAC + 263.92*PD*FAC*BU**0.5 - 9510./PD**2 + 10108./PD

Ru-106

CPERTE = PD*(4603.5*FAC + 3.7282*BU*FAC - 0.0003254*FAC*BU**2 - 14.54*FAC*PD - 0.01757*PD*BU*FAC) + 1.3703*BU - 7.93*BU**0.5

Sr-90

CPERTE = 2.9857*BU - 0.0002991*BU**2 + 2.66E-8*BU**3 + 0.002281*BU*PD + 6.488E-6*PD*BU**2

Pu-239

CPERTE = 0.06494*BU - 1.897E-5*BU**2 + 4.086E-09*BU**3 - 4.47E-13*BU**4 + 6.947E-5*PD*BU

Ce-144

CPERTE = -0.5569*BU + 44610.*FAC*PD - 1.867*PD*FAC*BU + 0.0001736*PD*FAC*BU**2 + 0.01605*BU*FAC*PD**2

Np-239

CPERTE = PD*(820840. - 109.48*BU + 0.03306*BU**2 - 3.917E-06*BU**3)

Where CPERTN = specific activity in natural uranium fuel (Ci/ton)
CPERTE = specific activity in enriched uranium fuel (Ci/ton)
PD = power density in MW/Ton
BU = burnup in MWd/Ton.
** = exponentiation; i.e., BU**2 = BU^2

Appendix D

Statistical Formulas Used to Estimate Monthly Release Uncertainty

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Statistical Formulas Used to Estimate Monthly Release Uncertainty

Expected Value and Variance for a Product of Independent Random Variables

Release uncertainty is the product of individual component uncertainty factors. The formulas used to calculate the expected value (E[Y]) and the variance (V[Y]) of the product of component factors are:

$Y = \prod X_i$, where X_i values are random variables with means μ_i and variance σ_i^2.

$$E[Y] = \prod \mu_i \tag{D.1}$$

$$V[Y] = \sum_{i=1}^{n} \left\{ \prod_{\substack{j=1 \\ j \neq i}}^{n} \mu_j \right\}^2 \sigma_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \left\{ \prod_{\substack{k=1 \\ k \neq i,j}}^{n} \mu_k \right\}^2 \sigma_i^2 \sigma_j^2 \tag{D.2}$$

Expected Value and Variance for Linear Combinations of Terms

The expected value and variance of linear combinations of terms

$Y = \sum a_i X_i$ are

$$E[Y] = \sum_{i=1}^{n} a_i \mu_i \tag{D.3}$$

$$V[Y] = \sum_{i=1}^{n} a_i^2 \sigma_i^2 \tag{D.4}$$

Expected Values and Variance for Lognormally-Distributed Variables

For lognormally distributed random variables (Y) such as some of the release factors, the natural logarithm, $X = \ln Y$ is distributed normally with mean μ and variance σ. Then $Y = e^X$ is distributed as a lognormal with

$$E[Y] = e^{(\mu + \frac{\sigma^2}{2})} \tag{D.5}$$

$$V[Y] = e^{[2\mu + \sigma^2]} (e^{\sigma^2} - 1) \tag{D.6}$$

Confidence Level Factors

The 95-percent confidence level factors were developed based on the widely used result by Galton (1879) which states that when multiplying random variables, the product (Y) will tend to be distributed as a lognormal with mean E[Y] and variance V[Y]. If Y is distributed as a lognormal, then the transformed variable Z =lnY will be normally distributed with mean μ and variance σ^2. The normal distribution mean and variance in terms of the lognormal expected value and variance are

$$\mu = \ln(E[Y]) - \frac{\ln(V[Y]/E[Y]^2+1)}{2} \tag{D.7}$$

$$\sigma^2 = \ln (V[Y]/E[Y]^2 +1) \tag{D.8}$$

The 95-percent confidence interval for a normal distribution is $\mu \pm 1.96\sigma$. In terms of the lognormally distributed product Y, the upper bound factor is

$$Y_{upper} = e^{+1.96\sigma}$$

and the lower bound factor is

$$Y_{lower} = e^{-1.96\sigma}$$

This amounts to multiplying and dividing by the factor

$$e^{1.96 \sqrt{\ln(V[Y]/E[Y]^2 + 1)}}$$

This is the factor shown in Table 4.3.

The estimates of the component distributions of uncertainty used for each radionuclide are included under each radionuclide in the sections to follow.

Appendix E

Summary of Technical Steering Panel Comments and Battelle, Pacific Northwest Laboratories Responses

Appendix E

Summary of Technical Steering Panel Comments and Battelle, Pacific Northwest Laboratories Responses

Document Number: **PNWD-2222 HEDR** Document Title: **Radionuclide Releases to the Atmosphere from Hanford Operations, 1944-1972**

Summary Comments by: **M. A. Robkin**

Generally the report was very well-received. The report represents an excellent effort by C.M. Heeb and his Battelle team members on the Source Term task. The explicit comments are included as an attachment to this summary.

Specific comments included:

- Editorial comments regarding organization, presentation or the need for additional inclusion of material
- Suggestion to include an appendix with a more complete explanation of the statistical methodologies and notations. A more complete explanation of the justification for choosing a particular statistical method should be include in the body of the document. There were a number of comments regarding the statistical procedures used.
- Discussion of hot particles should include more isotopes than just ruthenium. Mention should be made as to where, when and how all of the hot particle composition and releases from Hanford will be addressed.
- The geographical extent of the region affected by isotopes other than iodine should be discussed.
- Other sources for tritium, carbon-14, and argon-41 should be discussed. More discussion of the argon-41 release is needed.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
TSP COMMENTS:				
1	G. Caldwell	General Comment	In general, I think this report is well done.	NA. Thank you.
2	G. Roessler	General Comment	As usual, a well-done job by C. M. Heeb. Organized, informative, and interesting.	NA. Thank you.
3	J. Till	General Comment	Overall, an excellent piece of work.	NA. Thank you.
4a	B. Shleien	Full Report	I found the statistical terms for the uncertainty, especially for iodine-131, contained so many different expressions that they were confusing. Is it necessary to employ so many derivations of uncertainty? If so, perhaps an appendix with a full explanation of the terms and their use and relationship, would be clearer to the reader.	Agree. Text added to Section 4.1.4 to clarify the general uncertainty analysis method and identify the uncertainty release equation. Statistical formulas were moved to Appendix D and expected value and variance formulas for uniform and triangular distribution were added.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
4b	B. Shleien	Full Report	Only the release of ruthenium isotopes mentions particulate releases in the form of "hot particles." "Hot particles" are a "hot" issue and the release of radionuclides from the stacks in this form needs to be addressed, or at least mentioned when strontium and cerium isotopes are discussed (as well as for plutonium), since there are reports that these materials were released during stack and/or duct work problems. If the details of "hot particle" releases are not covered in this report, that fact need to be stated for completeness.	Agree. Text added to Section 1.3 explaining why hot particles are out of scope for this report and suggesting that they be treated on a case-by-case basis.
4c	B. Shleien	Full Report	The discussion of tritium, carbon-14, and argon-41 releases are inadequate. There are no estimates for argon-41 and those for tritium and carbon-14 are point estimates. The present state of understanding of reactor operations would permit some educated assumptions about the releases of these materials the period of this study. The treatment given these releases, even though they may be small and of minimal importance, needs to address this.	Text added to Section 5.1 amplifying treatment of reactor stack gas releases; includes quantitative information and release assumptions for argon-41 releases located while the draft report was under TSP review.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
5	M. Robkin	Pg vi, RESULTS	It would be somewhat more logical to put the first paragraph third. The discussion of the uncertainty multiplier makes more sense if the discussion about the summary releases is presented first. Before introducing the uncertainty multiplier, it would be clearer if it could be justified that the release data are log-normally distributed and that a symmetric uncertainty interval in the log-normal distribution is a multiplier/divisor interval in the original data.	Agree. Text changed as suggested.
6	M.L. Blazek	Pg vii, Table S.1.	Scientific notations should not be used in the Annual release summary. It is easier for the public to understand numbers.	Agree. Scientific notation removed.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
7	B. Shleien	Pgs vi & viii	Expression of uncertainty in terms of Confidence Levels: This method of expression of uncertainty usually is based on a Poisson distribution for the results. No evidence is presented that this indeed is the distribution for the data. A minimum and maximum, as well as a standard deviation, were presented for the source term data to the river, why not also here? The answer may be that the release fractions are assumed to be normally distributed (page 3.2). If this is the case, Battelle may wish to mention it in introduction. The uncertainties were determined for iodine-131 using Monte Carlo modeling for the iodine-131 release data before 1949. During this period, uncertainties expressed as 95 percent confidence levels would not be appropriate, unless the data were normally, or lognormally distributed, would they? (My experience with expression of uncertainty is for the most part limited to normal and/or lognormal distributions.)	Text added in Section 4.1.4 and Section 5 clarifying discussion of uncertainty. See response to comment 4a.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
8	P. McGavran	Pg viii	I suggest you put Table S.2. directly under the first paragraph of the results. The second paragraph describing Table S.1. should be after it. Then switch the designation of S.1 and S.2. LIKE THIS: Description * * * * * * * * * * * * * * Table S.1. (Confidence Intervals) Description * * * * * * * * * * * * * * Table S.2. (Annual Summary)	NA. The major results are presented first. Then the uncertainty is discussed.
9	G. Roessler	Pg xii	Radionuclide, "exhibits"?	Agree. Changed definition to "radioactive isotope of an element."
10	M.L. Blazek	Pg 1, Sec 1.1	States in part that "Whatever releases there were from 1983-1987 (from the PUREX Plant) are covered in the annual environmental reports and, therefore, are not included in this report". COMMENT: These releases should be gleaned from the annual reports and be included in this report.	Agree. Sentence removed. Text added to Section 1.3: "Releases from the PUREX N-fuel processing are covered in a report soon to be published. The Hanford environmental annual reports were used as data sources for this as yet unpublished report.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
11	G. Roessler	Pg 1.1, Para 3, Line 3	"several" should be "a number of".	Agree. Text changed as suggested.
12	M. Robkin	Pg 1.2, SCOPE	A sentence should be added about the releases after 1972 and when and how they will be evaluated.	Agree. See response to comment 10.
13	G. Roessler	Pg 1.3, Last Para	"appendixes" should be "appendices".	NA. "Appendixes" is standard BNW terminology and has been used consistently throughout the HEDR Project documents.
14a	P. McGavran	Pg 2.2., Para 1, 2nd Sentence	This sentence may need a "because..." Why must they be resolved? To comply with the quality assurance plan... The reason for any quantitative discrepancies must be resolved, and any...	Text added to Section 2.4. Sentence taken from the Integrated Task Plan (Shipler 1993). It is used here to indicate that sufficient data were located to estimate the releases.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
14b	P. McGavran		Argon-4.1? In the front of the report it is listed as an important radionuclide to consider. In the conclusion, it say releases of argon-4.1 were small, but the very next sentence, in paragraph 3, it says no quantitative release information was found. You might want to add something here to explain this. It reads "we know it was small, but we didn't find any information on it". People might wonder how you know it was small. Pages 5.1 and 5.2 explain why it is "assumed" that argon releases were infrequent and small. Perhaps in the conclusion you could say that based on knowledge or information about measures taken to prevent argon releases...something to add detail.	Agree. Text added to Section 5.1.3 describing recently discovered quantitative argon-41 data.
15	M. Robkin	Pg 2.2, Para 4	REPRESENTATIVENESS: This paragraph is restricted to 1944-1957. To tie the hot particle problem together, a few words about what the total hot particle pathway is and how and when it will be evaluated would be useful here if it is not addressed in any of the other reports.	Agree. Text added to Section 2.3: "Further discussion of hot particles can be found in an earlier memo to the TSP." Text added to Section 1.3 explaining why hot particles are beyond the scope of this report. See also response to TSP comment 4.
16	G. Roessler	Pg 4.1, Table	Put units (Ci) on it	Agree. Text changed as suggested.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
17	M. Robkin	Pg 4.1, Para 1	The Green Run release is stated in absolute terms. There is enough uncertainty in this release that a range should be reported. The reported values range from Anderson's value of around 4,000 curies through Heeb's value of 7,000 curies (reported without uncertainty) to Robkin's value of over 9,000 ± 30 percent curies (after adjustment for newer information). Anderson's value may be the most uncertain, and the uncertainty is not necessarily centered around 7,000 curies. There is no indication as to how Heeb estimated the Green Run release. The Jenne and Healy report is in the list of references but is not referenced or discussed in the text.	Agree. Text added to Section 4.0 specifying STRM 95-percent confidence level range, citing M. A. Robkin's revised 9,000 ± 30 percent estimate, and citing Jenne and Healy reference.
18	B. Shleien	Pg 4.1	There is no mention of M. A. Robkin's publication regarding Green Run. It should be. His estimate was (from memory) about 11,000 Ci ± 30 percent. Comments on his publication led him to re-evaluate that to about 9,000 curies. Because it is independently derived and in the open literature, it is appropriate that it be included.	Agree. Text added to Section 4.0 citing M. A. Robkin's revised 9,000 ± 30 percent estimate.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
19	G. Caldwell	Pg 4.1-4.2, Table 4.1	This table should continue to 1972 or when these two plants ceased operating to show total released from 1944-1972 or when plant ceased operations. If the latter, then a similar table should be included for REDOX and PUREX plants to show source of iodine-131 for title period, or at least through 1966.	NA. Table 4.1 reports the STRM results, which stop with December, 1949. However, tables in Appendix B repeat these 1944 through 1949 results and then add the monthly release calculation results for all plants through 1972.
20	G. Roessler	Pg 4.3, Para 3	Step left out: 238U + n → 239U decays by beta → 239Np	Agree. Text changed to add intermediate step.
21	M. Robkin	Pg 4.5, Equation 4.1	The quantity, Y, should be more clearly defined as the fractional <u>direct</u> yield of the fission product. Very often in this equation, the term $\lambda_P N_P$ is suppressed and Y is taken to represent the cumulative yield of the fission product when the precursors are all short-lived. There is not necessarily only a single precursor for any given fission product. If there is chain branching, an isotope may have two precursors, or even conceivably more. So long as this much detail is being presented, the precursor term can be written as a sum over all direct parents. The first paragraph on page 4.6 should be rewritten to amplify the above ideas.	NA. It would be confusing to the reader to introduce the concepts of direct and cumulative yield from the fission product mass chain.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
22	G. Roessler	Pg 4.5	Equation 4.1: Σf, units should be cm^{-1}.	Agree. Units corrected.
23	M. Robkin	Pg 4.6, Table 4.2	Define the difference between N Reactor and CANDU; i.e., = (C-N)/C or (N-C)/N, that is, which spectrum gives the larger value. This table is labeled "uncertainties." Aren't the values given just the differences between the calculated results, not the variation differences? Label the table as "Differences between N Reactor..."	Agree. Text added to Section 4.1.2: "The uncertainty in Table 4.2 is (N-C)/N, where N is the radionuclide content from the N Reactor library and C is radionuclide content from the CANDU reactor library." Table 4.2 renamed "Differences between uncertainties in the N Reactor and CANDU Calculated Radionuclide Content."
24	M. Robkin	Pg 4.7, Para 3	All of the R^2 are so close to perfect fits as to be a case of gilding-the-lily to attempt to discriminate among them. I doubt if there is any statistically significant difference in the goodness of the correlations from one to the other.	NA. Information retained in the interests of complete reporting.
25	M. Robkin	Pg 4.8, Para 4	How is the distribution of values of a parameter determined? Is it "best personal judgement of the parameter", advice of an "expert," evaluation of whatever data are available, or ? A brief added discussion of the method and reasoning used to decide on the nature of the distribution would be in order.	Agree. Text rewritten for the last part of Section 4.1.4. Basis for distribution selection included, and explicit formula relating means and standard deviations to 95 percent confidence level factor given.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
26	B. Shleien	Pg 4.9	Uncertainty Factor Estimates: Need to relate the standard deviation to the 95-percent confidence level, or use one or the other for consistency. (I see that they are given on pages 4.10 and 4.11..., may be wise to indicate so in introduction to Table 4.3, page 4.8.	Agree. Text added to Section 4.1.4 describing distribution selection and explicit formula relating means and standard deviations to 95-percent confidence level factor given.
27	G. Roessler	Pg 4.11, Para 2 in 4.2.1	Were the silver reactors operational on those days only or were those the days they <u>became</u> operational?	Text added to Section 4.2.1: "However, the silver reactors were not in continual operation until after January 1951."
28	G. Caldwell	Pg 4.12, Para 1, Line 6-8	What was the source of the chlorine? Should chloride be chlorine? What happened to the displaced iodine? Was the chlorine radioactive and if so, how much was released and what was its effect on dose?	Agree. Text added to Section 4.2.1: "Contamination was probably caused by small amounts of chloride impurities in the process reagents, atmospheric chlorine, or both. Over time, thermodynamically favored silver chloride displaced silver iodine on the surface of the Berl saddles, rendering the saddles incapable of removing iodine from the gas stream."
29	J. Till	Pg 4.15, Fig 4.3	This graphic would be improved significantly if it were labeled as to what was happening to create the peaks over the course of operations at the site.	NA. Unfortunately, software did not permit adding text to graph. However, the discussion does cover the major maxima.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
30	G. Roessler	Pg 4.17, 2nd to Last Line in 4	Explain $e^{-0.0862(6)}$ as e^{t}.	Agree. Text changed as suggested.
31a	G. Caldwell	Pg 4.18, Sec 4.2.2	Could or should a table similar to Table 4.1 be constructed for ruthenium-103, 106 and would it improve understanding?	NA. Such a table is provided for all radionuclides including ruthenium-103 and ruthenium-106 in Appendix B.
31b	G. Cadwell	Pg 4.18, Sec 4.2.2	What was the size and shape of the domain affected by ruthenium-103 and ruthenium-106?	Text added to Section 1.3: "The size and shape of the domains affected by radionuclides, and the dose distribution within those domains, are discussed in the HEDR dosimetry reports" (Farris et al. 1994). Size and shape of ruthenium-103 and 106 is out of the source term scope. Scope ends at "loss of engineering control," which is considered to occur at the stack.
32	G. Roessler	Pg 4.23	Ruthenium-106, Uncertainty in Curies Processed: add that it is the product of <u>only</u> two independent factors because the 368-day half life eliminated cooling time uncertainty.	Agree. Text changed as suggested.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
33	M. Robkin	Pg 4.26	Strontium-90 Release Factors: Line 2 - change "that" to "those". Line 3 - how were the curies of processed strontium-90 determined. Remind the reader here of the method used to determine the inventory of a nuclide. Line 4 - identify the numbers in the equation; i.e., 0.005 curies/day released, 365 days/year, 9,517,000 curies processed. Can 4 significant figures for this latter value be justified? Add "(release factor)" after the 1.9E-7.	Agree. Text changed in Section 4.2.4 as suggested. Added text "data...determined from the material tons processed and the curie inventory per ton from ORIGEN2." Added units of measurement. Four significant figures are not necessarily justified but are retained for traceability of number source.
34	M. Robkin	Pg 4.26, Line 2	Generic Release Factor Uncertainty: "one data point". Identify where the data point came from. Is the factor of 10 uncertainty arbitrarily assigned? Please clarify.	Agree. Text added to Section 4.2.4: "this is a standard assumption when there is only one datum available." Listed Anderson (1958a) as reference.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
35	M. Robkin	Pg 4.27	Choosing an uncertainty multiplier of 10 to give a working upper and lower bound does not justify using a mean of (upper + lower)/2. The best estimator of the expected value (mean) is still the measured value. By using the given procedure, the underlying distribution may well have been distorted. A more reasonable distribution may even be a triangular one with the distribution non-symmetric and the peak at the "measured" value. This has the advantage of maximizing the probability at the value measured.	Text added to Section 4.2.4: "The measured value is the one used in the release calculation, and the uniform distribution expected value is used as the mean of one of the factors determining the variance of that product (the release)."
36	G. Caldwell	Pg 4.2.3, Sec 4.2.3	What was the size and shape of the domain affected by cerium-144? Will this be modeled?	See response to comment 31b.
37	G. Caldwell	Pg 4.2.6, Sec 4.2.4	Same as for questions on page 4.18 and 4.2.3, except for strontium-90.	See response to comment 31b.
38	G. Caldwell	Pg 4.2.8, Sec 4.2.5	Same as for questions on page 4.18, 4.2.3, and 4.2.6, except for plutonium-239.	See response to comment 31b.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
39	G. Caldwell	Pg 5.1	Do we need to map the areas affected by tritium, carbon-14, and argon-41? Do we have an estimate of the geographic distribution of these elements (other than iodine-131) or are we assuming their distribution is the same as iodine-131? If so, what data do we have to support that position?	See response to comment 31b.
40a	S. Davis	Pg 5.1	In discussing the origin of H-3, add the following sources: Ternary fission, Li-6 (n,) H-3, B-10 (n, 2) H-3. (The last two reaction might be important owing to the activation of dissolved solids in the water as well as impurities in the fuel rods and cladding.)	Agree. Text added to Section 5.1.3: "Carbon-14 is produced...and by an n, alpha reaction on oxygen-17 from the carbon dioxide in the stack gas."
40b	S. Davis	Pg 5.1	In discussing the origin of C-14, add the following source: 0-17 (n,) C-14 (without doubt, this source is more important than C-13 (n,) C-14 which is listed.)	Agree. Text added to Section 5.1.3.
40c	S. Davis	Pg 5.1	If the flux is high, which seems unlikely, B-11 (,n) C-14 would be important.	Agree. Text added to Section 5.1.3.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
40d	S. Davis	Pg 5.1	In discussing the production of argon-41, the dissolved argon in the river water should be considered. At 10°C, this would be about 0.7 mg/L (by weight). After heating in the reactor, the solubility of argon would drop to about half the original value. Therefore, outgassing rather than evaporation or entrainment of water particles in the moving air mass would be the primary mechanism moving the argon-41 into the atmosphere.	Agree. Text added to Section 5.1.3.
40e	S. Davis	Pg 5.1	Another likely source would be impurities in the He which is circulated. The argon would not be removed by normal chemically based, gas-purification methods. Argpm is a large component in He-rich natural gas. Cryogenic separation would remove most (but not probably all) Ar prior to shipment to Hanford. Analyses of gas delivered to Hanford must have been made, but I have not found any record of the analyses.	Argon contaminant in helium would have had to be a very minor source of argon-41 because the reactor gas system pressure was maintained positive with respect to building air pressure. Significant production of argon-41 from recirculated stack gas would have tripped building air alarms. As discussed in the text, this did occur when gas system pressure inadvertently went negative, causing in-leakage of air to the reactor stack which upon subsequent re-establishment of positive pressure would cause argon-41 to trip rad alarms in the reactor building.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
41a	S. Davis	Pg 5.2	Vast amounts of He were used for the Hanford reactors. If He came from New Mexico, the ration of He-3/He-4 in the gas delivered to Hanford would have been much smaller than the atmospheric ratio. Because of the high thermal neutron cross section of He-3, nevertheless, the content would still be significant. The reaction H-3 (n, p) H-3 must have produced H-3 in amounts in excess of the 1.4 curies/day which is reported.	NA. The 1.4 curies/day reported is a measurement. By definition it must contain tritium from whatever source. There is no basis for the judgment that the n,p reaction must have produced H-3 in excess of 1.4 curies/day.
41b	S. Davis	Pg 5.2	Some H-3 may have evaporated with the cooling water, however, the increased temperature would decrease the solubility of gases such as Ar, Co2, and H2. As stated above, outgassing due to the temperature increase of the water would seem to be the primary mechanism for the release of radionuclides from the water to the atmosphere.	Agree. Text added to Section 5.2 discussing volatiles released by outgassing and in effluent water.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
41c	S. Davis	Pg 5.2	[Last line]: More information on the location and results of hand-held monitoring would be very useful. I assume monitoring was for gamma radiation. If so, some very rough upper limits for concentrations of volatiles such as Kr-85, Ar-41, and Hg-203 might be estimated. If monitoring results were consistently below radiation guidelines; this, also, would be very useful information.	NA. Because there is a lack of data in the Hanford literature on volatile radionuclides sources from reactor effluent water one can only speculate as suggested; i.e., "very rough upper limits" on what they were. Round-the-clock radiation monitoring was part of routine reactor operations. Any results outside the guidelines were reported and action taken to correct the situation. In general, operation was within the guidelines. In every instance where radionuclide releases were a potential problem, the issue was massively addressed with measurements, release control equipment, and revised operational strategies, etc. All of this left an ample record in the Hanford literature.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
42	M.L. Blazek	Page 6.1	Estimates on page 6.1 should be added to page 1.3. Even though quantitative release information is not available for argon-41, an estimate should be attempted and included in this report. Estimates for argon-41, tritium, and carbon-14 should be included in dose estimates.	Agree. Text added to Sections 5.1 and 5.2 amplifying treatment of reactor stack gas releases; includes quantitative information and discussion of release assumptions about argon-41 derived from release records located while report draft was under TSP. Text added to Section 6.0: "The argon-41 release was found to be 540,000 curies/year for all eight reactors with an uncertainty multiplier of 3 at the 95-percent confidence level. The annual dose from 540,000 curies/year of argon-41, 511,000 curies/year of tritium and 36.5 curies/year of carbon-14 was found to be in the 2 to 4 millirem range. Argon-41 was the dominant contributor to dose."
PUBLIC COMMENTS: None.				

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