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Letter Report: References For Radioactive Releases to the Columbia River From Hanford Operations, 1944-1957

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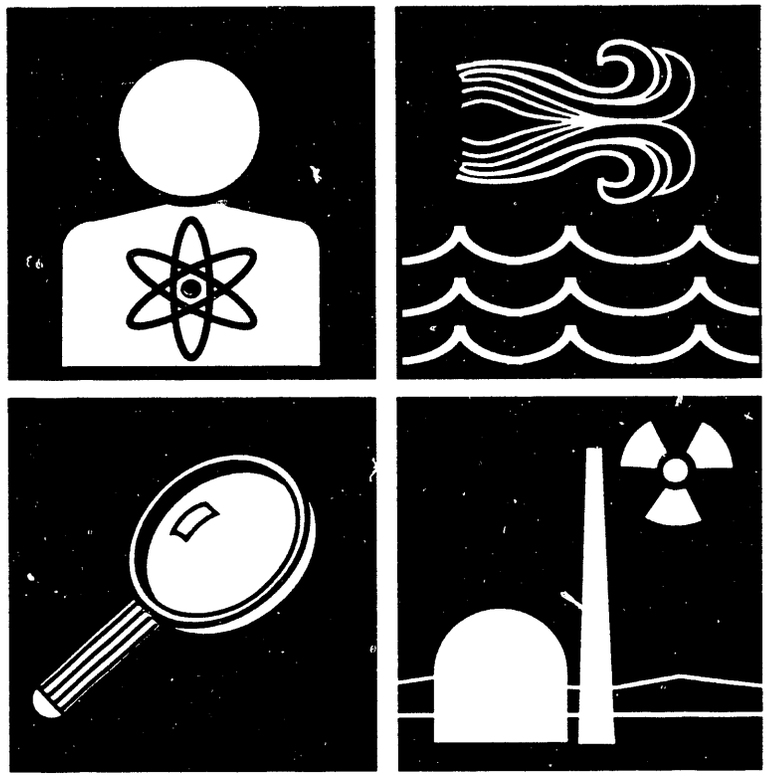
R. B. Hall

November 1991



Prepared for the Technical Steering Panel

Battelle

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PNL--7869-HEDR

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LETTER REPORT: REFERENCES FOR RADIOACTIVE RELEASES TO THE COLUMBIA RIVER FROM HANFORD OPERATIONS, 1944-1957

Hanford Environmental
Dose Reconstruction Project

R. B. Hall

November 1991

Prepared for the
Technical Steering Panel

Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

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SUMMARY

A search was made for published documents related to discharges of radioactive material from Hanford Site facilities to the Columbia River from 1944-1957. The purpose was to list documents that contain data that might be useful in developing a source term for waterborne releases. Source term development work will take place in FY 1992, and FY 1993.

This tabulation of published summaries of release data shows the type of measurements that were being made from 1944-1957 and the magnitude of discharges to the Columbia River. In the early years, very little data were collected that related to specific radionuclides. However, most of the key radionuclides were known to be present in effluents from occasional specific radionuclide analyses.

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1.0 INTRODUCTION

The goal of the work to which this report contributes is to develop daily release data for key radionuclides selected by the Technical Steering Panel for their significance in environmental dosimetry or for public concern. The purpose of this letter report was to review published data with foreknowledge that this data was summaries and averages that would not fulfill the daily release requirements of the goal. The task was intended as a start for work planned in FY 1992 and FY 1993. Documents listed in the appendix tables will aid in the development of source terms and provide confirmation of source terms as they are developed.

Documents related to the release of radioactive materials to the Columbia River were reviewed, including accidental and unintentional releases as well as deliberate discharges. Results of a similar search for documents on release of materials to the atmosphere are provided in a companion document, "Letter Report: References for Radioactive Releases to the Atmosphere from Hanford Operations, 1944-1957."

Though information on releases from all Hanford facilities was searched for, almost all of the data related to release of radioactive materials to the Columbia River was concerned with effluent water from the reactors. Hanford facilities were described in detail in Ballinger and Hall (1991).

Information on two categories of significant waterborne radionuclides was searched for: dosimetry-related and those of dosimetry-related additional public concern radionuclides included arsenic-76, chromium-51, copper-64, iodine-131, manganese-56, neptunium-239, phosphorous-32, sodium-34, tellurium-132, and zinc-65. Radionuclides of additional public concern included cesium-137, strontium-90, and tritium.

The time period of interest extended from 1944 through 1957. Because almost all the releases to the river came from reactor facilities, the period began with the start up of the B Reactor in September 1944.

This document fulfills HEDR Milestone 0304A, "Documented Significant Waterborne Radionuclides, 1944-1957." All documents listed are publicly available and may be found in the DOE Field Office, Richland (RL), Public Reading Room.

2.0 TECHNICAL APPROACH

More than 800 documents were reviewed that contained information relevant to releases to the river. Documents were included that tended to show the state of understanding and knowledge at the time. Documents were also included that described emissions control or lack thereof and problems with equipment and facilities. Some documents were included that were published later than 1957 because information could assist in the development of source terms. Document searches were conducted in accordance with Shipler (1991).

Creating these tables of documents did not involve data generation or judgement of the quality of data included. The ability to measure specific radionuclides improved greatly over the years. When daily release data are generated, it will be necessary to judge the quality of the data in the documents. Some of the quality control measures used at the time of data generation are included in documents listed in Table A.5, "Routine Sampling and Counting Methods."

3.0 SUMMARY OF RELEASES TO THE COLUMBIA RIVER

The only significant releases of radioactive materials to the Columbia River from 1944-1957 were contained in reactor effluent water. Most of the radioactivity was caused by short-lived radionuclides such as nitrogen-16, oxygen-19, aluminum-28, magnesium-27 and chlorine-38, so the water was sent to retention basins where it was detained for a few hours. The water was then discharged to the main stream of the Columbia River where it was quickly diluted by the river flow.

3.1 DATA SOURCES

In the 1944-1957 time period, the only significant discharges to the Columbia River resulted from operations of the single-pass reactors. Only B, D, and F Reactors were operating in early years. H Reactor was added in 1949, DR in 1950, C in 1952, and KE and KW in 1955. Table A.1 is a timeline of significant topical reports. The Health Instruments Operations group collected samples of reactor effluent water from the discharge side of the 107 Retention Basins once each shift and measured the beta activity with an electroscope exposed to a shallow pan of water. This beta measurement was reported along with the gamma dose rate measured by an ionization chamber suspended over the water near the discharge side of the 107 Retention Basin. Because these data were not collected during reactor outages, averages reflect only operating periods and are not time-weighted. These data were regularly reported by H. M. Parker in his reports to management, beginning with HW7-1228 (Table A.1).

The Health Instruments Regional Monitoring group collected weekly grab sample of reactor effluent water, which were evaporated and counted. The results of these measurements were reported in the series of routine Regional Monitoring reports staff (Table A.2).

Analyses of reactor effluent water for individual radionuclides was uncommon until 1951. No data for 1947, 1948, and 1949 were found. From 1951 on, grab samples were regularly analyzed. However, the data for 1954 and most of 1955 were not published. The documents that have been found are listed in Table A.3, "Reactor Effluent Water Analyses."

Releases of fission products caused by fuel element failures were not included in routine isotopic analyses because the reactor was shut down very soon after there was enough fission product activity in the reactor effluent water to detect a fuel failure. Care should be taken when reviewing data on fuel failures because some, such as RL-REA-2247, include both fuel failures and target element failures. The summary documents (HW31059, HW-61325, Table A.1) evaluated the environmental impact of fuel failures. Radiometallurgical data, exposure history, and other relevant information, a

description of failed fuel is included in documents listed in Table A.4, "Fuel Failure Data." This information may be needed to reconstruct source terms.

Miscellaneous release data includes several documents describing purges. These purges involved injection of a slurry of diatomaceous earth into the reactor cooling water in an effort to remove film by mild abrasion. This should not be confused with the chemical cleaning described in HW-56242. Chemical cleaning was adopted to reduce dose rates on the discharge face of the reactor by injecting a proprietary cleaning agent, Turco 4306-B, into the reactor when it was shut down. That cleaning removed the film from within the reactor as well as from reactor piping.

One document (Richman HW45070) was included to describe water treatment methods. That information may be useful in the development of source terms. A few of the documents relating to the study of the activation process were included in Table A.1 for the same reason. Much of the study of the activation processes occurred at a later time and those documents were not reviewed.

3.2 DOSIMETRY-RELATED RADIONUCLIDES

3.2.1 Phosphorus-32

The significance of this radionuclide in the river was known very early. A fish laboratory was established at 100-F Area in 1945; phosphorus-32 was quickly discovered in fish. However, analyses of reactor effluent water for individual radionuclides was uncommon before 1951. Documents that were found are listed in Table A.3. It is likely that additional data could be found in documents and data related to aquatic biology.

The data in documents listed in Table A.2 were collected by Regional Monitoring personnel to provide source term data with which to compare with their environmental data. Measurements were made according to procedures contained in documents listed in Table A.5.

Because phosphorus-32 emits only beta particles and because its quantity was small in comparison to other shorter-lived radionuclides, neither total beta counts nor immersion dose rate measurements would have been influenced by fluctuations in phosphorus-32 activity. It is unlikely that either total beta

or dose rate measurements could be considered corroborating sources of information. On the other hand, phosphorus-32 largely resulted from activation of phosphorus in river water (HW-49485 and HW69083). Therefore, estimates based on total reactor production rates might be sufficiently accurate.

3.2.2 Zinc-65

The likely presence of zinc-65 in reactor film was known before the reactors started up. However, zinc is much more easily measured by gamma detection instruments, which were not widely used until about 1957. Therefore, specific analytical data for this radionuclide is rare in the period 1944-1957.

3.2.3 Arsenic-76

All analyses of individual radionuclides include arsenic-76. Samples were obtained by Regional Monitoring staff; sampling and analytical procedures are included in documents listed in Table A.5.

3.2.4 Neptunium-239

Because this radionuclide was first recognized in documented data in the mid-1950s, data for earlier periods would not be available. Neptunium-239 resulted from retention and activation of natural uranium from river water in the film on reactor tubes and fuel elements.

3.2.5 Sodium-24

This radionuclide, like arsenic-76, was noted in all analyses of individual radionuclides. Samples were obtained by Regional Monitoring staff who followed sampling procedures included in documents listed in Table A.5. That table also includes documents that discuss sample analysis and counting procedures.

3.2.6 Manganese-56

This was the radionuclide that contributed most to the radioactivity at the time of discharge of reactor effluent water to the river. The concentration of manganese-56 increased greatly in the spring when the Spokane River

experienced its freshet. Discharge data are noted in all analyses that identified individual radionuclides. Sampling and analytical procedures are listed in Table A.5.

3.2.7 Copper-64

This is another radionuclide included in all isotopic analyses. Sampling and analytical procedures are listed in Table A.5.

3.2.8 Chromium-51

Until sodium iodide crystals were used for gamma counting, this radionuclide was difficult to measure. It was formed by activation of sodium dichromate which was added to reactor cooling water as a corrosion inhibitor. It was included in some, but not all, isotopic analyses. Sampling and analytical procedures are listed in Table A.5.

3.2.9 Iodine-131

There were two sources of iodine-131. The constant discharge was caused by fission of uranium from river water. That discharge was measured with other radionuclides when isotopic analyses were performed (Table A.3). The sampling and analytical procedures are listed in Table A.5.

After 1948, iodine-131 would also have been discharged as a result of fuel failures. Effluent sampling procedures in place between 1948-1957 would not have included bursts of activity caused by fuel failures. Therefore, Table A.5 has been included to facilitate estimates of releases. Estimates of releases are included in HW31059, HW-61325 and RL-REA-2160.

3.2.10 Tellurium-132

No data were found that indicated a measurement of this radionuclide. Estimates of discharge rates will need to include both a normal or constant discharge rate plus bursts from fuel failures as discussed under iodine-131.

3.3 RADIONUCLIDES OF ADDITIONAL CONCERN

3.3.1 Strontium-90

This radionuclide was difficult to separate from its shorter-lived companion strontium-89. Often, measurements were recorded as strontium-89 and -90. Data on the release of strontium-90 can be found in much of the isotopic analysis data in documents listed in Table A.3.

As with other fission products such as iodine-131, strontium-90 would have been released as a result of fuel failures. Estimates of those releases are included in HW31059, HW61325, and RL-REA-2160.

3.3.2 Tritium

Tritium was not measured in reactor effluent water in this time period. One document (HW-23178Del) discusses its origin, but does not indicate release rates.

3.3.3 Cesium-137

This radionuclide was often measured; data are found in documents listed in Table A.3. As with iodine-131, discharges caused by fuel failures will need to be estimated.

3.4 CORROBORATING DATA

3.4.1 Total Beta

Documents listed in Table A.2 provide continuous data on total beta measurements on evaporated samples of reactor effluent water from 1945-1957. Most of the values are monthly averages.

The data were collected by Regional Monitoring personnel to provide a source term. Sampling and analytical procedures are listed in Table A.5.

3.4.2 Immersion Dose Rate

Documents are included in Table A.1. The immersion dose rate of reactor effluent water was measured throughout the period 1945-1957; procedures are described in HW46104. These data were collected by the Operations section of Health Instruments to show compliance with discharge limits. The gamma com-

ponent of the dose rate was measured by an ionization chamber suspended over the 107 Retention Basins near the discharge end. That dose rate was recorded and the chart was examined once each shift when the reactor was operating. No data were collected during the shutdown periods, so averages were biased. Beta measurements were obtained once each shift during operating periods. An effluent water sample was poured into a shallow pan and the beta dose rate was measured with an electroscope. The procedure is described in HW46104.

3.4.3 Other Radionuclides

Beginning in 1951, an attempt was made to identify all the contributing radionuclides in analyses. Because all sample counting measured beta emissions, it was felt that the parts should add up to the whole, with suitable allowance for losses in chemical separation of radionuclides. These efforts failed because of imperfect analytical procedures, but measurement of a very long list of radionuclides persisted into the 1960s and beyond. Radionuclides were included because they ranked high in number of curies released, because they were readily measured, and because they were felt to be significant. Phosphorus-32 fell into this latter category, as did fission products.

3.4.4 Other Discharges

The only non-reactor discharges of radionuclides from 1944-1957 resulted from waste disposal practices in the 300 Area. Uranium was released to the river because of seepage as described in HW-52401 and because of a dike failure described in HW-11534. Discharges of uranium to the Columbia River were not monitored.

4.0 REFERENCES

Ballinger, M. Y. and Hall, R. B. 1991. A History of Major Hanford Facilities and Processes Involving Radioactive Material. PNL-6964 HEDR, Pacific Northwest Laboratory, Richland, Washington.

Shipler, D. B. 1991. Document Search and Declassification for Phase I of the HEDR Project. PNL-7713 HEDR, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX

DOCUMENTS CONTAINING DATA ON RADIOACTIVE RELEASES TO THE COLUMBIA RIVER, 1944-1957

Note: The documents listed in this appendix are all publicly available and can be found in the RL Public Reading Room in Richland, Washington and are available for purchase from the National Technical Information Service.

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TABLE A.1. Source Term Timeline for Releases to the Columbia River

Time Period	Data	Comments	Reference Author	Document
1943		Forecast of radioactivity in reactor effluent water	EO Hollan	DUH10159
1943		Design of discharge line	TB Drew	DUH10548
1943		Discusses sources of radionuclides	CWJ Wende	DUH10645
1944		Anticipated radionuclides in reactor effluent water	WE Kirst	DUH292
1944		Sets limit of 4.17 mrep/hr for discharge to river.	LL German	DUH12344
1944 to 1965		Historical events. Power levels, fuel failures. All events of significance in reactor operations.	DL DeNeal	RL-REA-2247
1944		Limits for fission products in air and water	WE Cohn	DUH4517
1944		100 mrep/day immersion dose limit for release of reactor effluent to river	LK Wyatt	DUH13548
1944	Cu-64 Mn-56	First reactor effluent water radioactivity measurements; 100-B at 100 MW	LL German	DUH12536
1944 to 1990		History of major Hanford facilities	MY Ballinger RB Hall	PNL-6964HEDR
1945		Statistical study of radioactivity as water flowed through 107-B Basin	HJ Paas	HW3-2286
1945	Total Beta Dose Rate	105-F Start-up 2/25/45 107-F Dose Rates	LL German	DUH13013
1945	Mn-56	Abnormal activity in 105-F effluent water	JM West JJ O'Connor	HW3-2400
1945	Total Beta	Statistical analysis of 105-B effluent decay curves.	HJ Paas	HW3-2475
1945	Dose Rate Al-28, Na-24	Retention basin delay affect on dose rates	JJ O'Connor JM West	HW3-2985
1945	Total Beta	Relates effluent activity to silicate analysis	HJ Paas	HW3-3092

Time Period	Data	Comments		Reference Author	Document
1945	Immersion Dose Rates	Monthly Report HI Section		HM Parker	HW7-1228
1945	Immersion Dose Rates	Weekly report on 100 and 300 Areas		HM Parker CC Gamertsfelder	HW7-1635
1945	Immersion Dose Rates	Discusses dose rate measurement problems. Includes Jan. - Aug. data.		HM Parker	HW7-2346
1946		Tolerance doses; state of knowledge about dose measurements		HM Parker	DUH12744
1946	Total Beta	Quarterly environmental reports; summarized in 3-5402		JW Healy/LD Turner LD Turner/ JW Healy LD Turner LD Turner	HW3-3495 HW3-3603 HW3-5055 HW3-5402
1946	Dose Rates	HI monthly reports	Jan. Feb. Mar. April June July Aug.	CC Gamertsfelder CC Gamertsfelder CC Gamertsfelder CC Gamertsfelder CC Gamertsfelder CC Gamertsfelder CC Gamertsfelder	HW7-3322 HW7-3517 HW7-3694 HW7-3933 HW7-4312 HW7-4474 HW7-4699
		Also indicates 100F effluent line broken off at shoreline			
1946	Total Beta	100F effluent water 0.2 μCi/l in Dec.		HM Parker	HW7-5605
1946		Total curies discharged to date in all effluents		FP Semour	HW7-5463
1948 Oct.	U	300 Area pond dike broke 10/24/48; lost 14.5 million gallons of water containing 12 to 61 pounds of natural uranium.		W Singlevich	HW11534
7/48-9/48		High dose rates from reactor effluent water attributed to high manganese in film		GB Carlton	HW-11380
1948		Discusses activation of radionuclides in reactors and biological significance in river		KE Herde	HW-11509
1949	Immersion Dose Rates	B, D, F effluent water		UM Staebler	HW12335

Time Period	Data	Comments	Reference Author	Document
1948		Preparing 100-B for restart; fuel failure at 100-F	HM Parker	HW10421
1948	Many radio-nuclides	Summary data and limits reactor discharge to river	HM Parker	HW10592
1948		Limits for discharge to river	CM Patterson	HW12710
1949		Report to Congress - waste disposal practices	HM Parker	HW12895
1950		Meeting of Columbia River advisory group (3rd quarterly meeting). Discusses analytical procedures, reactor effluent water radionuclides and 300 Area dike break.	FE Adley WK Crane	HW17595
1950		Sample counting methods	JW Healy LC Schwendiman RC Thorburn	HW18258
1951	Many radio-nuclides	Dec. '50 to July '51 for 5 reactors. Analytical procedures. Radionuclides presented as % of total beta. Mu-54, Na-24, Cu-64, As-76, rare earths, Si-31, Mo-99 & P-32.	EE Larkin RL Watters ZE Carey W Singlevich	HW21844
1951	Many radio-nuclides	Same analysis as above. Lists radionuclides by half life and by abundance at discharge.	JW Healy	HW23177Del
1951	Tritium	Discusses tritium formation; no effluent data	JW Healy	HW23178Del
1952		Permissible limits for release of reactor effluent water. Definition of "rep."	HM Parker	HW24356
1952		Same as above, proposes limits based on organ doses	JW Healy	HW24577
1952	Many radio-nuclides	Isotopic analyses of reactor effluent water, normal effluent, purge during reactor operation, purge during reactor outage	JW Healy	HW24578
1952	Gamma Emissions	Short-lived gamma emitting radionuclides in reactor effluent water, rupture detection	RL Dickeman	HW-24832 HW-25052Del
1951 to 1952	Many radio-nuclides	About 12 months data by radionuclide and by reactor; 85% of total beta identified	RL Watters EE Larkin	HW-24956

Time Period	Data	Comments	Reference Author	Document
1952	Many radio-nuclides	Reactor effluent analyses from 2/51 to 7/52 for 100 B, D, DR, F and H Reactors.	ZE Carey	HW25044
1952		Standards for release of reactor effluent water	EP Lee	HW25167
1947 to 1952	Total beta	Data from 5/47 to 12/52. Also shows correction factors for absorption, backscatter, geometry.	GE Pilcher HT Norton	HW27584
1953		A study of retention time for the 107 Basins	JK Soldat GR Quimby	HW28830
1953	P-32	Proposed analytical procedure for P-32 in reactor effluent	WB Silker PL Koehmstedt	HW29215
1953	Cu-64	Proposed analytical procedure for Cu-64 in reactor effluent	RW Perkins	HW29319
1954	F.P.	Release of fission products to river from fuel element failures	JW Healy	HW31059
1954	Mn-56	Analytical procedure for reactor effluent water	RW Perkins	HW-33723
1951 to 1954	Many radio-nuclides	Summary report of isotopic analysis of reactor effluent water	WY Matsumoto DL Reid ZE Carey	HW32141
1955	Many radio-nuclides	Reactor effluent data during purges	WN Koop	HW45125
1955	Many radio-nuclides	History of reactor effluent water measurements, fuel element failures and limits. Includes normal effluent radionuclides and fission products. First dose estimates.	JW Healy RE Rostenbach	HW-36862
1955	Na-24	Radiochemical analytical procedure for sodium-24	RW Perkins	HW-38573
1955	Many radio-nuclides	Routine quarterly analytical report on reactor effluent water analyses. Data for prior 18 months and following 3 months are lost.	WY Matsumoto DL Reid	HW41632
1945 to 1956		Reactor process water treatment history	RB Richman	HW45070

Time Period	Data	Comments	Reference Author	Document
1956	Many radio-nuclides	Reactor effluent activity during purges	WY Matsumoto	HW43830
1956		Proposes expansion of reactor effluent monitoring	JW Healy	HW45725
1956 Dec.	Many radio-nuclides	Reactor effluent activity during purges	WY Matsumoto	HW48308
1953 to 1957	Total beta 20 radio-nuclides	Data summary	BV Andersen	HW89066
1957		Proposed monitoring program; 60 references	RB Hall	HW50137
1957	Na-24, P-32 Np-239 Cu-64	The origin of certain radionuclides in reactor effluent water	RE Ewing	HW49485
1958		Analytical procedures for 11 radio-nuclides in reactor effluent water	RW Perkins	HW51216
1957		"The Regional Monitoring Programs;" includes stack and effluent water monitoring	BV Andersen JK Soldat	HW-52038
1957	U	Describes water flow from 300 Area ponds to river	WA Haney	HW-52401
1952 to 1958	F. P.	Significance of ruptured fuel element debris in the Columbia River. Discusses release to river.	JD McCormack LC Schwendiman	HW-61325
1955 to 1964	F. P.	Release of radioactivity from fuel element failures	PC Jerman WN Koop FE Owen	RL-REA-2160
1961	P-32	On the origin of radiophosphorus	WB Silker	HW69083
1961		Source of reactor-effluent water radioisotopes	RW Perkins	HW69969
1958	Many radio-nuclides	Analysis of chemical cleaning of reactor tube and fuel in place. Discusses origin of reactor radionuclides.	RW Perkins	HW56242

Time Period	Data	Comments	Reference Author	Document
1960		History and description of reactor effluent water handling practices. Some data and radionuclide sources discussed.	RB Hall PC Jerman	HW63653
1948 to 1963		Tabulation of fuel element failures	WN Koop	HW81300

TABLE A.2. Regional Monitoring Reports

All of these documents included total alpha, total beta measurements on an evaporated sample of reactor effluent water. These documents also included data on release to the atmosphere. Early reports include estimates of iodine-131 in metal charged into dissolvers. Later reports show measured iodine-131 release data, ruthenium release data from 200 Area stacks and measurements of tritium, carbon-64 and sulfur-35 released from reactor stacks.

Time Period	Comments	Reference Author	Document
All of 1945	Weekly reports bound together	CC Gamertsfelder HM Parker	HW7-1115
All of 1946	Annual summary report	LD Turner	HW3-5402
First, 1947		LD Turner	HW-3-5511
Second, 1947		JW Healy	HW-7317
Third, 1947		W Singlevich	HW-8549
Fourth, 1947		W Singlevich	HW-9496
First, 1948		W Singlevich	HW-10242
Second, 1948		W Singlevich	HW-11333
Third, 1948		W Singlevich	HW-12677
Fourth, 1948		W Singlevich, HJ Paas	HW-13743
First, 1949		W Singlevich, HJ Paas	HW-14243
Second, 1949		W Singlevich, HJ Paas	HW-17434
Third, 1949		W Singlevich, HJ Paas	HW-18615
Fourth, 1949	Includes I-131 from "green run"	W Singlevich, HJ Paas	HW-17003
First, 1950		W Singlevich, HJ Paas	HW-18446
Second, 1950		W Singlevich, HJ Paas	HW-19454
Third, 1950		W Singlevich, HJ Paas	HW-20700
Fourth, 1950		HJ Paas	HW-21566
First, 1951		W Singlevich, HJ Paas	HW-21214
Second, 1951		HJ Paas	HW-22313
Third, 1951		HJ Paas	HW-23133
Fourth, 1951		HJ Paas	HW-24203
First, 1952		HJ Paas	HW-25866
Second, 1952		HJ Paas	HW-26493
Third, 1952		HJ Paas	HW-27510
Fourth, 1952		HJ Paas	HW-27641
First, 1953		HJ Paas	HW-28009
Second, 1953		HJ Paas	HW-29514
Third, 1953		HJ Paas	HW-30174
Fourth, 1953		HJ Paas	HW-30744

Time Period	Comments	Author	Document
First, 1954		HJ Paas	HW-31818
Second, 1954		HJ Paas, GE Pilcher	HW-33896
Third, 1954		GE Pilcher, JK Soldat, ZE Carey	HW-36504
Fourth, 1954		JK Soldat, GE Pilcher, DL Reid, ZE Carey	HW-36505
First, 1955		CW Thomas, GE Pilcher, KC Knoll, BV Andersen	HW-36506
Second, 1955		CW Thomas, GE Pilcher, BV Andersen, JK Soldat, DL Reid	HW-38566
Third, 1955		JK Soldat, BV Andersen	HW-39429
Fourth, 1955		JK Soldat, BV Andersen	HW-40871
First, 1956		BV Andersen, JK Soldat	HW-43012
Second, 1956		BV Andersen, JK Soldat	HW-44215
Third, 1956		BV Andersen, JK Soldat NW McConiga	HW-46726
Fourth, 1956		BV Andersen, JK Soldat, MW McConiga	HW-48374
First, 1957		MW McConiga, JK Soldat	HW-51009
Second, 1957		MW McConiga, JK Soldat	HW-52803
Third, 1957		MW McConiga, JK Soldat, JM Selby	HW-54841
Fourth, 1957		MW McConiga, JK Soldat, JM Selby	HW-54842

TABLE A.3. Reactor Effluent Water Analyses

Documents containing results of specific radionuclide analysis on reactor effluent water.

Time Period	Comments	Reference Author	Document
1944	100-B at 100 MW	RI Martens	HW3-1209
1945		RE Kitson	HW3-1678
1945		JM West, JJ O'Connor	HW3-3222
1946		JM West	HW7-3692
1946		JM West	HW7-4063
1946		JM West	HW7-4673
1950-1951		JW Healy	HW23177Del
1951		EE Larkin, RL Watters, ZE Carey, W Singlevich	HW21844
1951		JW Healy	HW24578
1952		RL Watters, EE Larkin	HW24956
1953		ZE Carey	HW25044
1951-1953	Summary document	WY Matsumoto, DL Reid, ZE Carey	HW32141
1955 July, Aug. Sept.		WY Matsumoto, DL Reid	HW41632
1956 Jan. to May		PO Jackson	HW45092
1956 Aug.		DL Reid	HW45747
1956 June, July, Aug.		DM Polinsky	HW46709
1956 Sept.	Revised to include KE data	DM Polinsky	HW47261Rev.
1956 Oct.		DM Polinsky	HW47811
1956 Nov., Dec.		DL Reid	HW48350
1957 Jan.		DL Reid	HW49146
1957 Feb.		DL Reid	HW49588
1957 Jan., Feb., Mar.		HT Norton	HW49843
1957 Mar., April		DL Reid	HW50292
1957 April		HT Norton	HW50769
1957 April, May		DL Reid	HW51383
1957 May		DL Reid	HW51397
1957 June		DL Reid	HW51743
June 1957 to Nov. 1959	Summary document	RB Hall, PC Jerman	HW63653

TABLE A.4 Fuel Failure Data

History of manufacture and irradiation plus radiometallurgical examination data.

Time Period	Comments	Reference Author	Document
1948 to 1951	Irradiation data and metallurgical findings for the first 51 fuel failures and 4 suspects	DP O'Keefe	HW22344
5/48 to 10/51		EC Wood, AE DeMers	HW22687
11/51		EC Wood	HW22984
1951	Bibliography on fuel failures	BJ Borgmier	HW21199
1952		EC Wood	HW23185
		LW Lang	HW24020
		LW Lang	HW24379
		RJ Bartlett, LW Lang	HW24718
		RJ Bartlett, LW Lang	HW24857
		RJ Bartlett, LW Lang	HW25293
		RJ Bartlett, LW Lang	HW25499
		RJ Bartlett, LW Lang	HW25784
		LW Lang, JK Anderson	HW26060
		LW Lang, JK Anderson	HW26385
		LW Lang, JK Anderson	HW26646
1953		LW Lang, JK Anderson	HW26980
		LW Lang, JK Anderson	HW27266
		LW Lang, JK Anderson	HW27616
		LW Lang, JK Anderson	HW28027
		JK Anderson	HW28675
		JK Anderson	HW29629
		JK Anderson	HW30703
1954		JK Anderson	HW31282
		JK Anderson	HW35221
1955		JK Anderson, RJ Bartlett	HW35826
		JK Anderson, RJ Bartlett	HW36188
		JK Anderson, RJ Bartlett	HW36707

Time Period	Comments	Reference Author	Document
1956		JK Anderson, LW Hartse	HW-42367
		JW Sowards	HW-42654
		JW Sowards, LW Hartse	HW-43065
		JW Sowards, LW Hartse	HW-43838
		JW Sowards, LW Hartse	HW-44261
		RR Bloomstrand	HW-45144
		RR Bloomstrand	HW-46119
		RR Bloomstrand	HW46680
		RR Bloomstrand	HW47572
		RR Bloomstrand	HW47940
1957		RR Bloomstrand	HW-48501
		RR Bloomstrand	HW-49575
		RR Bloomstrand	HW50182
		RR Bloomstrand	HW51443
		RR Bloomstrand	HW53482
		RR Bloomstrand	HW53483
		RR Bloomstrand	HW53954
	Definition of terms	RR Bloomstrand	HW54316
		RR Bloomstrand	HW54658
		RR Bloomstrand	HW54659

TABLE A.5. Routine Sampling and Counting Methods

Time Period	Data	Comments	Reference Author	Document
1948		Routine methods for radiochemical analysis	SA Reynolds	HW13622
1949		Standard practices for survey work in 100, 200, 300 Areas	JM Smith, Jr.	HW46104
1950		Sample counting methods	JW Healy LC Schwendiman RC Thorburn	HW18258
1951		Radiochemical analytical procedures	JW Healy RC Thorburn ZE Carey	HW20136
1951		Calculation of conversion factors used in counting room	JH Wolff	HW22682
1952		Alpha counting procedures	JH Wolff	HW23769
1954		Standard practices counting manual	LC Schwendiman	HW30492
1956		Standard practices radiochemical calculation manual	HT Norton PO Jackson DL Reid	HW46436
1957		Regional monitoring program	BV Andersen JK Soldat	HW52038

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