**Cover Sheet for a Hanford
Historical Document
Released for Public Availability**

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DECLASSIFIED

DOCUMENT NO.

DUN-1069

Hanford Code C-65

SERIES AND COPY NO.

DATE _____

May 12, 1966

(CLASSIFICATION)

DOUGLAS/UNITED NUCLEAR, INC.

RICHLAND, WASHINGTON

RESTRICTED DATA

THIS [REDACTED] AS
DEFINED IN THE [REDACTED] ACT OF 1954.
ITS TRANSFER BY ANY MANNER TO AN UNAUTHORIZED
PERSON IS PROHIBITED.

TITLE

RICHLAND ISOTOPE PRODUCTION MATRIX

OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

AUTHOR

L. E. Kusler
R. D. Shimer

THIS DOCUMENT MUST NOT BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS TO IT. WHEN NOT IN USE, IT MUST BE STORED IN AN APPROVED LOCKED REPOSITORY OR AN APPROVED GUARDIAN. WHILE IT IS YOUR RESPONSIBILITY AND UNTIL YOU HAVE OBTAINED A SIGNED RECEIPT FROM THE ISSUING OFFICE, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF THIS PROJECT AND FROM AN UNAUTHORIZED PERSON. IT IS NOT PERMITTED TO, AND STORAGE IN ANY PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE REPRODUCED. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED ISSUING OFFICE. ALL PERSONS READING THIS DOCUMENT ARE REQUESTED TO SIGN IN THE SPACE PROVIDED BELOW.

[illegible]

54-5100-166 (10-65)
AEC-RL00 RICHLAND, WASH.

(CLASSIFICATION)

DECLASSIFIED

DECLASSIFIED

DUN-1069

Hanford Code C-65

This document consists of 10
pages.

RICHLAND ISOTOPE PRODUCTION MATRIX

May 12, 1966

L. E. Kusler
R. D. Shimer

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of D. S. Lewis

CG-NMP-1 8-8-94

By J. E. Savelly 11-15-94

Verified By S. Roberts 12-20-94

NOT UCN

DISTRIBUTION

AEC

1-12. DG Williams

BATTELLE-NORTHWEST

13. EA Eschbach
14. GA Last
15. CA Rohrmann

GENERAL ELECTRIC

16. RR Bloomstrand
17. RL Dickeman
18. WJ Dowis
19. WJ Ferguson
20. MC Leverett
21. J Milne
22. JW Riches
23. RD Shimer

ISOCEM

24. RA Connell
25. OF Hill
26. JN Judy
27. CG Lewis
28. AJ Scott
29. AE Smith
30. WG Smith
31. RE Tomlinson
32. JH Warren

DOUGLAS UNITED NUCLEAR

33. TW Ambrose	48. RH Meichle
34. DH Bangerter	49. R Nilson
35. RS Bell	50. GF Owsley
36. WA Blanton	51. RS Peterson
37. RW Bown	52. RW Reid
38. PA Carlson	53. KL Robertson
39. RO Gumprecht	54. OC Schroeder
40. CD Harrington	55. HC Spencer
41. HW Heacock	56. JR Spink
42. RD Jensen	57. JT Stringer
43. RT Jessen	58. GR Vance
44. S Koepcke	59. WK Woods
45. CW Kuhlman	60. DUN Record
46. LE Kusler	61. DUN File
47. WM Mathis	62-65. Extra

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

This document contains Restricted Data as defined in the Atomic Energy Act of 1954, and the disclosure of its contents in any manner to an unauthorized person is prohibited by law.

DECLASSIFIED

RICHLAND ISOTOPE PRODUCTION MATRIXINTRODUCTION

Isotope production calculations have been prepared in the past to indicate present and potential reactor capability; however, the cases evaluated generally considered production of only one or possibly two isotopes. With the wide variety and potential demand for numerous isotopes, the question arises as to what the production capability would be if several isotopes were being produced at the same time. To study this problem in more detail and determine which of several alternates may be used in meeting production requirements, the Case Generator and Evaluator System has been developed. This document presents a production matrix and reviews the assumptions used to derive the matrix. This matrix should be useful in planning future CAGE isotope cases.

DECLASSIFIEDSUMMARY

Reactor isotope production capability of the six Richland production reactors has been calculated for T₂, Co-60, U-233, Po-210, Pu-238 and Pu-239. The total annual production of each isotope has been divided into six equal portions. These subdivisions may be combined to illustrate the various product mixes that can be produced in the Richland reactors. Quantities of each isotope are listed in Tables I, II, III and IV for four time periods--current, within the next 18 months, 1970 and post-1970. Smaller quantities may be calculated by increasing the number of subdivisions. The matrices represent reactor production potential only and cases selected for detailed evaluation will require further review to determine what limitations exist in the separations as well as fuel and target jacketing facilities. Individual reactor production quantities of each isotope are listed on Table V to illustrate the quantities that could be produced with complete reactor loadings.

The isotope production quantities listed are estimated to be accurate within 10 percent and are intended primarily to illustrate the production capabilities that may be incorporated in the CAGE system.

This matrix does not include all the attractive Richland production modes or products but is limited to those isotopes specifically designated for evaluation⁽¹⁾. Other isotopes such as Np-237, Tm-170, Pm-147 and plutonium in excess of 20 percent Pu-240 could each be added at some future date.

DISCUSSION

Isotopic production quantities have been developed for the six production reactors and are presented in matrix form in Tables I, II, III and IV. The matrix form permits the selection of several quantities of isotopes and plutonium for further evaluation with the CAGE system. Quantities have been developed for four specific periods to illustrate the gains that can be achieved as a result of the 5-Year R&D Program. The time periods are (1) current, (2) assured capability, which is available within the next 18 months, (3) 1970 capability, and (4) post-1970 capability in which fully enriched fuel elements may be used as driver elements.

(1) DG Williams. "Supplemental CAGE Assumptions - Isotope Production Cases," HAN-94392. April 12, 1966 (Secret).

The total reactor production of each isotope (T₂, Co-60, U-233, Po-210, Pu-238 and Pu-239) is divided into six equal portions for each period. The quantities in each subdivision may be combined into various product mixes. The number of subdivisions may be increased to provide flexibility for illustrating various product mixes. Slightly enriched uranium is used for driver elements in many of the production modes. Therefore, plutonium production is included in most of the subdivisions.

In using the matrix to study various product mixes, six subdivisions must be selected to include all the available production capability. In the 1970 time period, additional flexibility is available in that subdivisions from preceding time periods may be used in selecting operating modes. Similar flexibility is available when post-1970 values are included, with the exception that for polonium, cobalt and plutonium some natural or low enriched uranium is used, whereas for the other products in this time period, fully enriched uranium and target element loadings are assumed. Combining modes where fully enriched uranium and less than 2 percent enriched uranium drivers are both being used to support the same type of target elements in one reactor is highly questionable. Therefore, Table V has been included which lists individual reactor production capability which may be more convenient for selecting cases for detailed review.

The assured production for the K and small reactors assumed that specific fuel power can be increased to 30 percent to compensate for target materials that are inserted in the reactor and displace fuel. A specific full power increase of 20 percent has been successfully demonstrated in the current U-233 program.

The 1970 capability assumes that the high power density fuel program for the K and small reactors is successful and that the specific power of fuel elements can be increased 100 percent and up to 50 percent of the reactor volume will be available for irradiating target materials with no decrease in reactor power. In the post-1970 period, it is assumed that fully enriched fuel elements could be used and 100 percent of the total production capability could be converted to isotope production. When fully enriched fuel elements are used as driver elements, a small amount of low enriched or natural uranium may be required throughout the reactor to provide a negative fuel temperature coefficient for reactor control purposes. The matrices, however, assume full loading capability of fully enriched fuel. In the event reactor fringe loadings are undesirable because of the low flux in the fringe, it is estimated that only 80 percent of the production capability would be available for other isotopes and 20 percent would be plutonium. Co-60 quantities were calculated in this manner for each time period and represent 100 curies per gram product.

Polonium production quantities for the 1970 and post-1970 period assume that graphite tube blocks will be removed from each of the K and three small reactors to provide additional volume for irradiating bismuth. The number of channels modified in this manner can be varied, depending on polonium

DECLASSIFIED

production requirements. In this case, it was assumed that 360 tube blocks in each of the small reactors and 540 tube blocks in each of the K reactors would be removed. Polonium quantities shown in Tables II, III and IV include production in 68 spare channels in N-Reactor where bismuth can be irradiated without any loss in plutonium production. This polonium production from the 68 spare channels is available for all production modes. In the 1968, 1970 and post-1970 periods, 100 process tubes in N-Reactor are diverted from plutonium to polonium production. All polonium production quantities are at launch and assume that 1.4 grams at reactor discharge are required for each gram at launch.

For Pu-238 production, the quantities of neptunium destroyed are listed because this amount must be replaced and in all instances the availability of neptunium will limit Pu-238 production.

Production quantities listed for U-233 assume that the U-232 requirements would be less than 5 ppm which is consistent with the 5-Year R&D Program objectives.

Plutonium quantities are for 6 percent Pu-240 content; if higher Pu-240 concentrations are desired, a plutonium production decrease of 2 percent may be used for each percent increase in Pu-240 up to 20 percent Pu-240.

For ease in using Tables I, II, III and IV, matrix guidelines are included. These provide a brief outline of the content and how the matrix may be used.

L. E. Kusler

L. E. Kusler, Senior Engineer
Advanced Concepts and Planning

R. D. Shimer

R. D. Shimer, Senior Engineer
Advanced Technology
General Electric Company

DECLASSIFIED

MATRIX GUIDELINES

1. Total production capability equals any six subdivisions for a given time period.
2. Subdivisions from previous time periods may be included in arriving at total production quantities.
3. Number of subdivisions may be increased for greater flexibility.
4. All plutonium quantities: 6 percent Pu-240. For estimating Pu-240 concentrations up to 20 percent, decrease plutonium production 2 percent for each 1 percent increase in Pu-240 content. Only one-fifth of the total plutonium can be converted to Pu-240 contents in the range of 12 to 20 percent.
5. Co-60: 100 curies per gram of cobalt.
6. U-233: less than 5 ppm U-232.
7. Pu-238: 85-90 percent Pu-238 (variation caused by different reactor loadings).

DECLASSIFIED

TABLE I

REACTOR PRODUCTION MATRIX
CURRENT TECHNOLOGY

	Pu kg	T ₂ kg	U-233 kg	Co-60 MCi	Po-210 at Launch, kg	Pu-238 kg
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
1/6	803 Pu .33 T ₂	704 Pu 2.58 T ₂	720 Pu 125 U-233	730 Pu 25 Co-60	765 Pu .50 Po-210	716 Pu 132 Pu-238 165 Np Destroyed
Total	4818 Pu 1.98 T ₂	4224 Pu 15.48 T ₂	4320 Pu 750 U-233	4380 Pu 150 Co-60	4590 Pu 3.0 Po-210	4296 Pu 792 Pu-238 990 Np Destroyed

DECLASSIFIED

TABLE II

REACTOR PRODUCTION MATRIX
ASSURED TECHNOLOGY - 1968

	Pu kg	T ₂ kg	U-233 kg	Co-60 MCi	Po-210 at Launch, kg	Pu-238 kg
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	453 Pu 6.4 T ₂ .11 Po-210	708 Pu 183 U-233 .11 Po-210	732 Pu 35 Co-60 .11 Po-210	760 Pu .86 Po-210	703 Pu 192 Pu-238 242 Np* .11 Po-210
Total	5016 Pu 1.98 T ₂ .67 Po-210	2718 Pu 38.4 T ₂ .67 Po-210	4248 Pu 1098 U-233 .67 Po-210	4392 Pu 210 Co-60 .67 Po-210	4560 Pu 5.16 Po-210	4218 Pu 1152 Pu-238 1452 Np* .67 Po-210

*Destroyed.

DECLASSIFIED

TABLE III

REACTOR PRODUCTION MATRIX - 1970

	Pu kg	T ₂ kg	U-233 kg	Co-60 Mci	Po-210 at Launch, kg	Pu-238 kg
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	376 Pu 7.35 T ₂ .11 Po-210	448 Pu 437 U-233 .11 Po-210	495 Pu 85 Co-60 .11 Po-210	750 Pu 7.86 Po-210	434 Pu 463 Pu-238 580 Np* .11 Po-210
Total	5016 Pu 1.98 T ₂ .67 Po-210	2256 Pu 44.1 T ₂ .67 Po-210	2688 Pu 2622 U-233 .67 Po-210	2970 Pu 510 Co-60 .67 Po-210	4500 Pu 47.16 Po-210	2604 Pu 2778 Pu-238 3480 Np* .67 Po-210

*Destroyed.

DECLASSIFIED

TABLE IV

REACTOR PRODUCTION MATRIX - POST-1970

	Pu kg	T ₂ kg	U-233 kg	Co-60 Mci	Po-210 at Launch, kg	Pu-238 kg
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
1/6	836 Pu .33 T ₂ .11 Po-210	0 11.6 T ₂ .11 Po-210	208 Pu 662 U-233 .11 Po-210	160 Pu 145 Co-60 .11 Po-210	750 Pu 7.86 Po-210	0 877 Pu-238 1100 Np* .11 Po-210
Total	5016 Pu 1.98 T ₂ .67 Po-210	0 69.6 T ₂ .67 Po-210	1245 Pu 3972 U-233 .67 Po-210	960 Pu 870 Co-60 .67 Po 2-10	4500 Pu 47.16 Po-210	0 5262 Pu-238 6600 Np* .67 Po-210

*Destroyed.

DECLASSIFIED

TABLE V

REACTOR PRODUCTION CAPABILITY

Product	Period	Reactors						Total		
		3 Small		2 K		N		Total		
		Pu kg	Product kg	Pu kg	Product kg	Pu kg	Product kg	Pu kg	Product kg	
Plutonium	Current	1410	1.08 T ₂	2360	.90 T ₂	1045	0	4815	1.98 T ₂	
	1968	1410	1.08 T ₂	2360	.90 T ₂	1245	.67 Po-210	5015	1.98 T ₂	.67 Po-210
	1970	1410	1.08 T ₂	2360	.90 T ₂	1245	.67 Po-210	5015	1.98 T ₂	.67 Po-210
	Post-1970	1410	1.08 T ₂	2360	.90 T ₂	1245	.67 Po-210	5015	1.98 T ₂	.67 Po-210
T ₂	Current	1310	4.08	2160	6.1	755	5.3	4225	15.48	
	1968	680	12	1130	20	905	6.3 (*)	2715	38.3	.67 Po-210
	1970	500	14.3	850	23.6	905	6.3 (*)	2255	44.3	.67 Po-210
	Post-1970	0	20.5	0	34	0	15 (*)	0	69.5	.67 Po-210
U-233	Current	1235	280	2040	470	1045	0	4320	750	
	1968	1135	415	1870	685	1245	0 (*)	4250	1100	.67 Po-210
	1970	665	875	780	1750	1245	0 (*)	2690	2625	.67 Po-210
	Post-1970	0	1500	0	2470	1245	0 (*)	1245	3970	.67 Po-210
Co-60	Current	1270	47 MCi	2140	78 MCi	970	25 MCi	4380	150 MCi	
	1968	1215	70 MCi	2020	110 MCi	1155	30 MCi (*)	4390	210 MCi	.67 Po-210
	1970	815	145 MCi	1120	295 MCi	1035	70 MCi (*)	2970	510 MCi	.67 Po-210
	Post-1970	300	250 MCi	465	420 MCi	195	200 MCi (*)	960	870 MCi	.67 Po-210
Po-210	Current	1385	0.80	2160	2.20	1045	0	4590	3.0	
	1968	1355	1.20	1960	3.30	1245	0.67	4560	5.17	
	1970	1260	22.8	2005	23.0	1234	1.35	4499	47.16	
	Post-1970	1260	22.8	2005	23.0	1234	1.35	4499	47.16	
Pu-238	Current	1235	286	2040	480	1020	25	4295	791 ⁽¹⁾	
	1968	1135	425	1870	700	1215	30 (*)	4220	1155 ⁽²⁾	.67 Po-210
	1970	665	895	780	1790	1155	90 (*)	2600	2775 ⁽³⁾	.67 Po-210
	Post-1970	0	1515	0	2530	0	1220 (*)	0	5265 ⁽⁴⁾	.67 Po-210

- (1) 990 neptunium destroyed
 (2) 1452 neptunium destroyed
 (3) 3480 neptunium destroyed
 (4) 6600 neptunium destroyed
 (*) .67 Po-210

DECLASSIFIED