



0 ✓

BNWL-236 SUPP 2

Supplement 2

UC-34 5-



A REVISED
PHOTON PROBABILITY LIBRARY
FOR USE WITH ISOSHL-III

APRIL 1969



AEC RESEARCH & DEVELOPMENT REPORT

ROUTE TO	P. O. NO.	EXTENSION	DATE
Albuquerque	6008	703	AUG 25 1969
J. K. Smith	30914	P.S.	8-27-69
K. L. Smith	30914	P.S.	

BNWL-236
 SUPPLEMENT 2

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

3 3679 00060 2450

BNWL-236
Supplement 2
UC-34, Physics

A REVISED
PHOTON PROBABILITY LIBRARY
FOR USE WITH ISOSHLD-III

By

C. A. Mansius

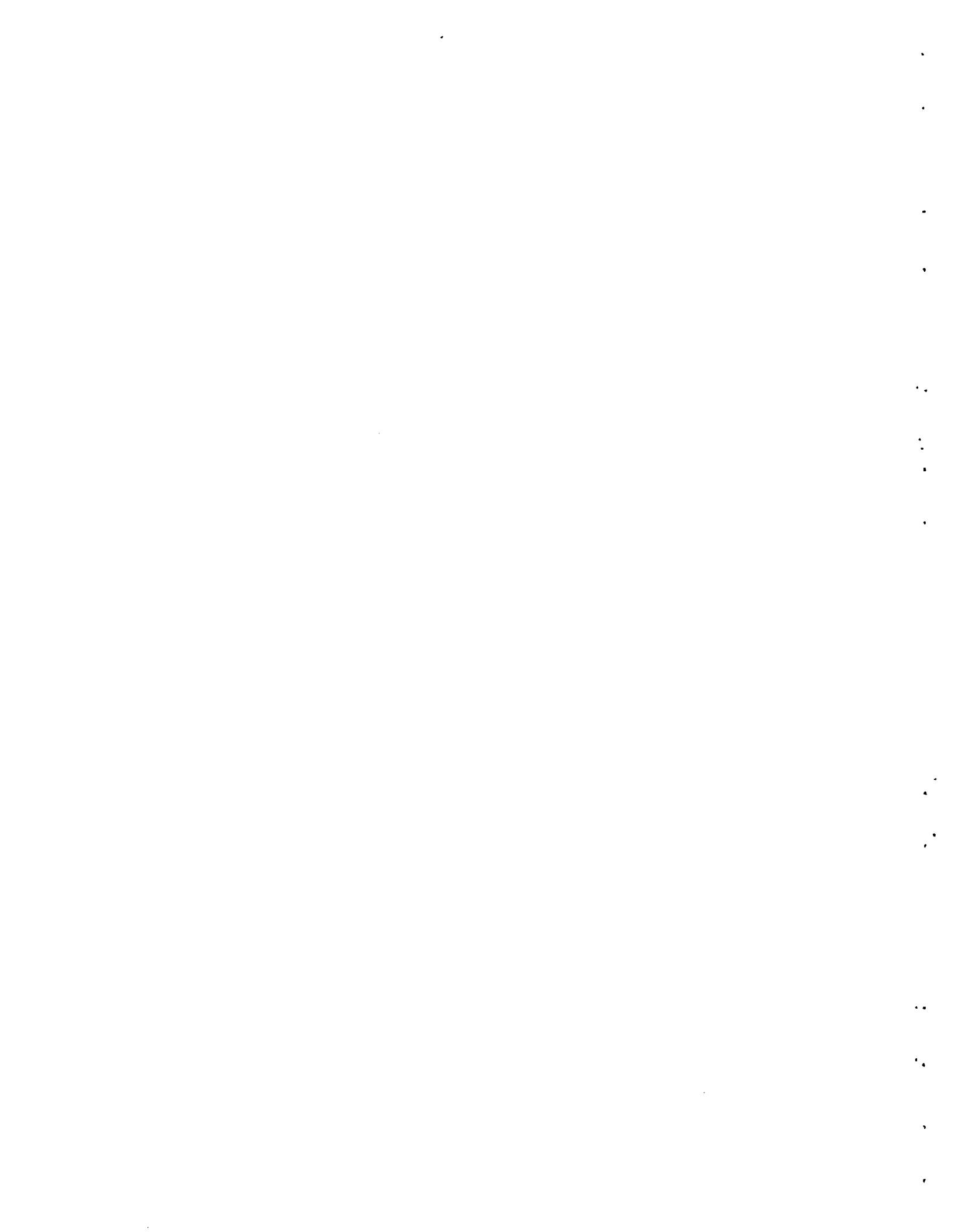
Reactor Physics and Operation Department
FFTF Project

April 1969

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON 99352

CONTENTS

I.	INTRODUCTION	1
II.	SUMMARY AND CONCLUSIONS	2
III.	DISCUSSION	3
	A. Library Structure	3
	B. Library Use	4
	C. Data Evaluation	4
IV.	ISOSHLD CALCULATIONS USING PHOTON LIBRARY	7
V.	ISOSHLD-III CODE CHANGES	9
VI.	ACKNOWLEDGEMENT	10
	REFERENCES	10
	APPENDIX A - Photon Production Library.	11
	APPENDIX B - Photon Production by Group and Isotope for Specified Decay Time	23
	DISTRIBUTION	27



A REVISED PHOTON PROBABILITY LIBRARY
FOR USE WITH ISOSHL D-III

C. A. Mansius

I. INTRODUCTION

The computer code ISOSHL D^{1, 2} was designed to fill the need of performing fixed geometry shield calculations in a convenient manner with a minimum amount of input data. The photon probability library is one of several libraries included in the code. The data contained in the photon library are used to calculate the photon source group structure produced by any mixture of radioactive isotopes. A number of obvious errors were found in the initial photon library. In addition, it was believed that collapsing complex gamma spectra into just six groups would not necessarily give an adequate source for attenuation calculations. This revision of the library was made for these reasons, and to include the latest available data. The first printing of BNWL-236 was released in June, 1966, with Supplement 1² being printed in March, 1967.

II. SUMMARY AND CONCLUSIONS

An updated photon probability library was assembled for use with the computer code ISOSHLD. A listing of the library is presented in Appendix 1. Each of the listed isotopes was tagged with one of the following letters: (1) S - stable isotope, no gamma emission; (2) K - decay data known; (3) U - decay data uncertain, and (4) N - no decay data available. The data given for the K-tagged isotopes were taken from References 3 and 4. References 3, 4, and 5 were used to estimate the gamma emission probability for the U-tagged isotopes. In addition to the library update, ISOSHLD was changed as follows: (1) any number of data pairs (photon energy and emission probability) can be used for any isotope in the photon library, (2) total gamma source energy is conserved in the 16 energy group gamma source table rather than total number of photons, (3) print out data were added to give the number of photons by isotope for each of the 16 gamma energy groups, and (4) a second RIBD library was added for the calculation of fission product inventories for fast reactors fueled with ^{239}Pu and ^{238}U .

The accuracy of ISOSHLD calculations is not expected to be limited significantly by the data in the photon library if Mode 1 is used. This conclusion is based on the results of a number of Mode 1 calculations for fission products associated with fuel irradiated from one to several hundred days. For decay times greater than about eight hours, K-tagged isotopes were found to establish the gamma intensity and the shield requirements. For decay times less than about eight hours, calculated results are low because of the presence of N-tagged isotopes. The error, which is largest at zero decay time, is estimated to be less than 25% based on the curie inventory associated with all fission products. This estimate assumes that the number and spectral distribution of the photons emitted by an average N-tagged isotope is the same as that for an average K-tagged isotope. Approximately 20% of the radioactive fission product isotopes in the library are tagged N.

When Mode 2 calculations are made, in which the curie content of individual isotopes is specified, reliable results can be achieved only if K-tagged isotopes are selected.

III. DISCUSSIONA. Library Structure

The photon probability library contains data for each of the 450 isotopes in the RIBD library followed by 49 selected radioisotopes. The photon decay probabilities and decay energies in MeV for each of the 499 isotopes are presented in Appendix A. Library data are compiled from References 3, 4, 5 and 6. The library format for each isotope is as follows:

CARD No. 1

<u>Column</u>	<u>Format</u>	<u>Variable</u>
1-3	I3	Atomic mass number
4-5	I2	Atomic number
6-8	A3	Isotope Name
9-10	I2	Total number of decay energies for isotope
11-15	F5.0	First photon probability
16-20	F5.0	First photon decay energy, MeV
21-70	F5.0	Second through sixth photon probability and decay
77-79	I3	Isotope identification number
80	AI	Data evaluation symbol

CARD No. 2

<u>Column</u>	<u>Format</u>	<u>Variable</u>
1-5	F5.0	Seventh photon probability
6-10	F5.0	Seventh photon decay energy MeV
11-70	F5.0	Eighth to 13th photon probabilities and decay energies
77-79	I3	Isotope identification number

Cards 3 through M are used in the same format as Card No. 2, as required to tabulate all photon probabilities and energies. The maximum number of data pairs is six on Card 1, and seven on each subsequent card.

B. LIBRARY USE

The photon probability library can be used in either of two ways. The first (Mode 1) is linked to the RIBD subroutine used to calculate in-reactor fission product inventories. The end product of a RIBD calculation is a curie inventory listing of 450 isotopes as a function of specified decay times. Utilizing the gamma decay schemes for each isotope in the probability library and the curie data from RIBD, the code generates a multigroup gamma energy table in which the number of photons in each energy group is tabulated starting with the lowest energy group. Using the data in this form, attenuation calculations can be performed for any of the 10 geometry options incorporated in ISOSHL D.

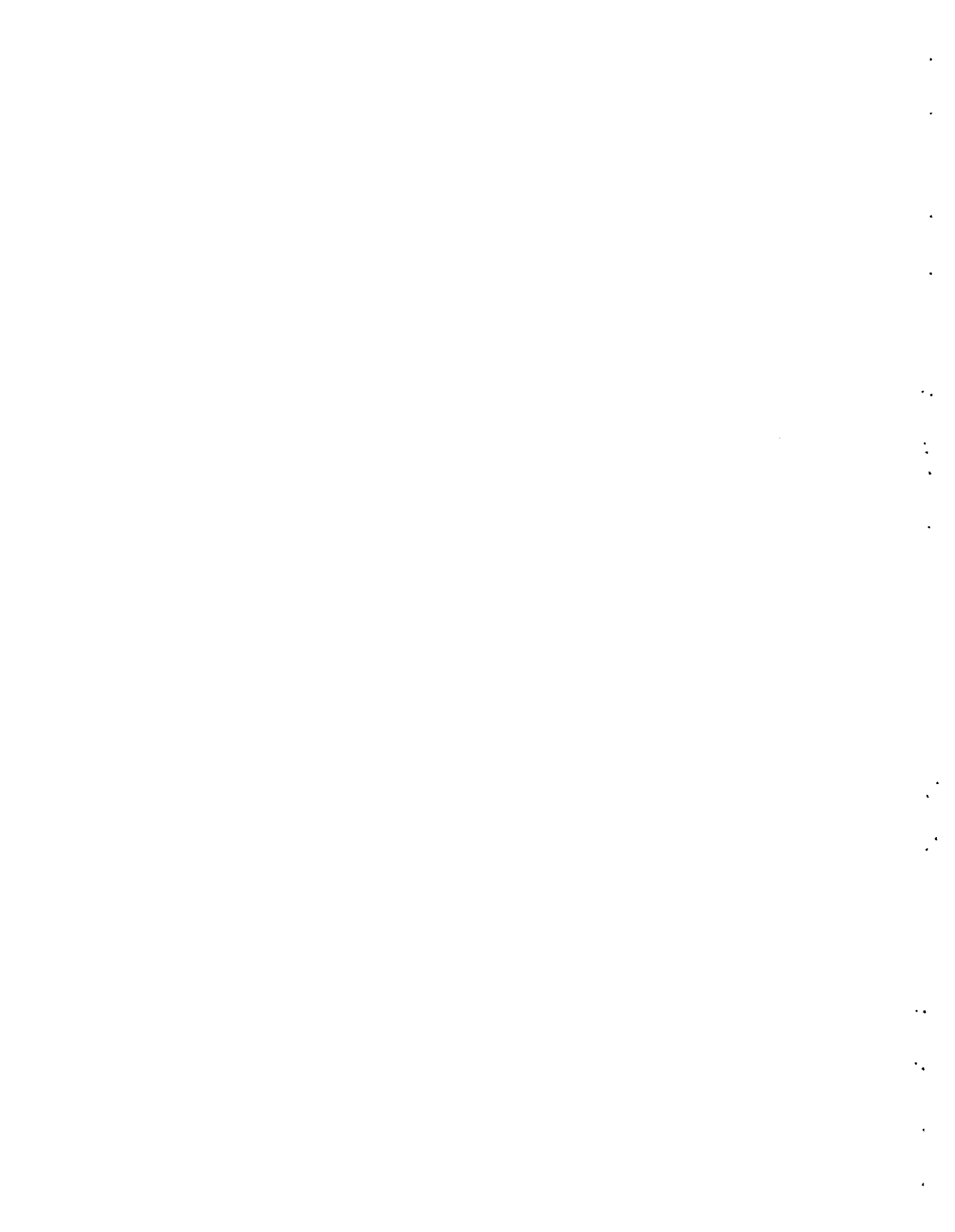
The second way (Mode 2) in which the photon probability library data can be used is to specify as input the number of curies of as many isotopes as desired. The group gamma energy table is then structured using only these specified isotopes. The attenuation calculations are made as in Mode 1 for the desired geometry.

C. DATA EVALUATION

Gamma decay schemes have not been measured for all of the isotopes included in the library. To make future updating of the library less difficult, each isotope was tagged in column 80 of each data card with one of the four letters S, K, U, or N. The four tag letters have the following meanings:

- S - the isotope is stable, no gamma decay,
- K - the gamma decay scheme, both probability and energy, has been documented for the specific isotope and the values are considered to be well established,
- U - gamma energies have been measured, but the emission probability associated with each has not been established,
- N - neither gamma energies nor emission probabilities were reported in the literature reviewed. ^{3, 4, 5, 6}

About 25% of the 499 isotopes included in the library are in the U and N categories, with about an equal number in each category. An estimate was made of the gamma decay scheme for those isotopes tagged U based on the available data. No method was available for generating gamma decay schemes for those isotopes for which no experimental data were found. For this reason, no data were included for these in the photon probability library.



IV. ISOSHL D CALCULATIONS USING PHOTON LIBRARY

The user of ISOSHL D has three choices for gamma source input: (1) internally calculated gamma fission product inventory using the RIBD subrouting, (2) selection of specific isotopes from the photon probability library, and (3) direct specification of the number of photons with given energies. The third choice is of no concern here, because it does not involve use of the photon probability library. By choice of input options, the gamma sources generated from subroutine RIBD will contain either (a) the decay gamma radiation from all of the radioactive fission isotopes, or (b) the decay gamma radiation from one of the following groups: (1) noble gases only, (2) halogens only, (3) volatile solids only, or (4) all fission isotopes except noble gases, volatile solids, and halogens.

In performing shielding calculations in which either all of the fission products or any of the specified groups of fission products are involved, the accuracy of the calculation is not limited significantly by the photon library even though the decay schemes associated with about 25% of the isotopes are not well known. This conclusion is based on dose rate calculations from fission product decay made with ISOSHL D using ^{239}Pu as the fissile fuel and irradiations times from one to several hundred days. Air and lead were selected as the shielding materials, with lead thicknesses up to 20 cm.

The results show that after eight hours of decay, essentially all of the calculated gamma dose rates are associated with K-tagged fission products. The U- and N-tagged isotopes have decayed to the extent they do not contribute; therefore, it is not essential that their decay schemes be known accurately for these conditions.

The greatest error in fission product dose rate calculations occurs at zero decay when omission of data for N-tagged isotopes might underestimate the rate by up to 25%. In estimating the error it was assumed that the gamma energy distribution and the number of gammas emitted per decay would be about the same for the N-tagged isotopes as for the

K-tagged. Of the approximately 335 radioactive isotopes in the fission product portion of the photon probability library, about 20% are N-tagged.

When specific isotopes are selected from the library for use in performing shielding calculations, only K-tagged isotopes should be used. The selection of U-tagged isotopes on an individual basis should be avoided because of the uncertainty of the listed values. The N-tagged isotopes cannot be used because no gamma decay data exist in the library. Gamma radiation is probably associated with most of the N-tagged radioactive isotopes; however, no method of generating gamma spectra was available.

V. ISOSHLD-III CODE CHANGES

Several changes were made in the ISOSHLD code to accommodate the new library, to generate additional output, and to calculate fission product inventories for fast or thermal reactors based on data for two different RIBD libraries. In the original code¹ the RIBD library contains data necessary to calculate the fission product inventory for thermal reactors fueled with ^{235}U and ^{238}U . In ISOSHLD-III a second library has been added which contains data necessary for a fission product inventory calculation in a fast reactor fueled with ^{239}Pu and ^{238}U . In this version of the code, thermal and fast reactor libraries are named TLIBE/Feb. 69 and FLIBE/Feb. 69, respectively.

Except for updating half-life values, TLIBE/Feb. 69 contains the same data as described in Reference 1, whereas FLIBE contains data developed by O'Dell and Bunch.⁷ The ISOSHLD-III photon probability library is used with each of the above libraries to generate the photon data for the group gamma energy table.

The input variable, DEL, required on Card 1b of the RIBD input is now defined by the ratio b/a where b and a refer to the initial fission rates of ^{238}U and ^{235}U for a thermal reactor calculation (TLIBE/Feb. 69) or ^{238}U and ^{239}Pu for a fast reactor calculation (FLIBE/Feb. 69).

A second code change allows any number of gamma energy and probability pairs for each isotope in the photon probability library instead of the 6-pair limitation in the original code. Another code change conserves total source energy within each group. Because the energy range of each group is relatively small, the effect of this change is small. However, gamma energy flux is usually a more important parameter than gamma number flux.

A fourth change was made to provide additional output. The added printed data contain the number of photons by isotope for each of the gamma energy groups. From this printout, the important isotopes for shielding considerations can be easily identified. An example of the added output is shown in Appendix B.

VI. ACKNOWLEDGEMENT

The author wishes to thank M. G. Zimmerman for his assistance in assembling data for the photon production library, and D. R. Marr for his help in making the required coding changes in ISOSHL D.

REFERENCES

1. R. L. Engel et al. ISOSHL D - A Computer Code for General Purpose Shielding Analysis, BNWL-236. Battelle-Northwest, Richland, Washington, June 1966.
2. G. L. Simmons et al. ISOSHL D-II: Code Revision to Include Calculation of Dose Rate from Shielded Bremsstrahlung Sources, BNWL-236 Supplement 1. Battelle-Northwest, Richland, Washington, March 1967.
3. C. M. Lederer, J. M. Hollander, and I. Perlman. Table of Isotopes. John Wiley and Sons, N. Y., 1967.
4. Nuclear Data, Nuclear Data Group, Katherine Way, Editor, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Through vol. 2, no. 5, March 1968.
5. W. B. Cottrell and A. W. Savolainen. U. S. Reactor Containment Technology, A Compilation of Current Practice in Analysis, Design, Construction, Test and Operation, ORNL-NSIC-5, vol. I. Oak Ridge National Laboratory, Oak Ridge, Tennessee, August 1965.
6. Nuclear Science Abstracts through July 1968.
7. L. D. O'Dell and W. L. Bunch. Revised Fast Reactor Library for Use with RIBD, BNWL-962. Battelle-Northwest, Richland, Washington, February 1969.

APPENDIX A
PHOTON PRODUCTION LIBRARY



556499	ISOSHIELD PHOTON PRODUCTION LIBRARY, CA MANSIUS 2-13-69													
7230ZN2 3	.08	.015	.90	.145	.10	.192								001K
7231GA210	.08	.601	.27	.630	.96	.835	.10	.894	.07	1.05	.035	1.47		002K
.20 2.5	.05	1.86	.26	2.20	.05	1.6								002
7232GE2 0														003S
7330ZN2 0														004N
7331GA2 3	.94	.295	.06	.74	.01	1.04								005K
7332GE2 1	.09	.054												006K
7431GA213	.11	.50	1.0	.6	.09	.87	.05	1.11	.08	1.2	.05	1.33		007K
.45 2.35	.08	1.46	.07	1.76	.06	1.93	.08	3.23	.03	2.55	.03	2.73		007
7432GE2 0														008S
7531GA2 2	.01	.36	.03	.58										009K
7532GE1 1	.34	.139												010K
7532GE2 6	.003	.066	.014	.199	.11	.265	.003	.427	.003	.477	.001	.628		011K
7533AS2 0														012S
7631GA2 3	.50	.563	.50	.96	.50	1.12								013U
7632GE2 0														014S
7633AS2 6	.43	.559	.06	.657	.05	1.22	.007	1.44	.04	1.79	.009	2.1		015K
7634SE2 0														016S
7732GE1 2	.26	.215	.12	.159										017K
7732GE213	.61	.21	.45	.263	.15	.368	.25	.417	.18	.563	.11	.632		018U
.14 .73	.06	.80	.05	.93	.06	1.09	.022	2.3	.055	1.7	.09	1.2		018
7733AS2 3	.001	.086	.025	.239	.008	.522								019K
7734SE1 1	.50	.161												020K
7734SE2 0														021S
7832GE2 2	.94	.277	.06	.294										022K
7833AS2 6	.56	.614	.21	.70	.08	.83	.11	1.31	.05	1.6	.02	1.94		023U
7834SE2 0														024S
7933AS2 5	.02	.36	.02	.43	.005	.54	.005	.73	.01	.89				025K
7934SE1 1	1.0	.096												026K
7934SE2 0														027K
7935BR2 0														028S
8033AS2 6	.42	.666	.014	.8	.04	1.22	.04	1.64	.017	1.8	.004	2.35		029K
8034SE2 0														030S
8035BR1 3	.07	.62	.01	.67	.001	1.26								031K
8035BR2 1	.36	.037												032K
8036KR2 0														033S
8133AS2 0														034K
8134SE1 1	.08	.10												035K
8134SE2 3	.036	.28	.013	.56	.01	.83								036K
8135BR2 0														037K
8136KR2 0														038N
8234SE2 0														039S
8235BR210	.66	.554	.41	.619	.27	.698	.83	.777	.25	.828	.31	1.04		040K
.26 1.32	.19	1.48	.17	1.9	.035	.27								040
8236KR2 0														041K
8334SE1 5	.16	.35	.13	.65	.40	1.01	.11	2.02	.02	1.66				042K
8334SE2 9	.44	.22	.69	.36	.59	.52	.25	.71	.41	.83	.16	1.06		043K
.25 1.31	.16	1.88	.17	2.29										043
8335BR2 1	.014	.53												044K

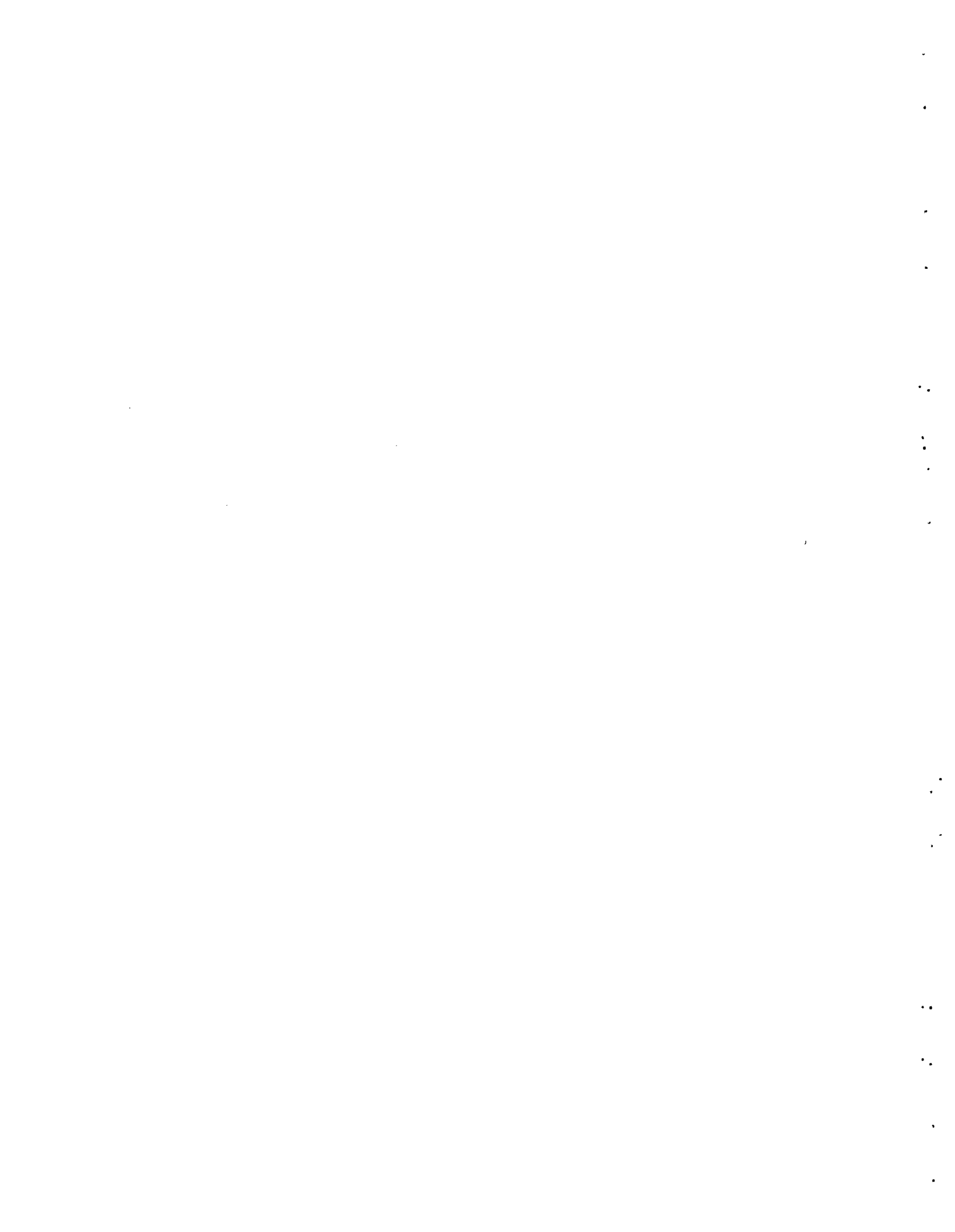
9138SR2	5	.30	1.03	.03	.93	.27	.75	.15	.645	.05	1.40	089K
9139Y	1	1	.95	.55								090K
9139Y	2	1	.003	1.21								091K
9140ZR2	0											092S
9236KR2	0											093N
9237RB2	0											094N
9238SR2	3	.90	1.37	.04	.44	.03	.23					095K
9239 Y2	5	.004	1.83	.047	1.40	.14	.934	.026	.56	.023	.448	096K
9240ZR2	0											097S
9336KR2	0											098N
9337RB2	0											099N
9338SR2	3	.65	1.1	.25	1.4	.10	1.8					100U
9339Y	211	.033	2.18	.018	1.9	.007	1.42	.023	.94	.007	.67 .06 .267	101K
.0007	2.14	.0007	1.62	.0035	1.2	.003	.49	.0005	2.48			101
9340ZR2	0											102K
9341NB1	1	1.0	.029									103U
9341NB2	0											104S
9436KR2	0											105N
9437RB2	0											106N
9438SR2	1	1.0	1.42									107K
9439Y	210	.011	3.53	.013	3.06	.015	2.57	.024	2.13	.016	1.90 .024 1.65	108K
.05	1.13	.43	.92	.06	.56	.007	2.84					108
9440ZR2	0											109S
9441NB1	1	.002	.87									110K
9441NB2	2	1.0	.871	1.0	.702							111K
9442M02	0											112S
9536KR2	0											113N
9537RB2	0											114N
9538SR2	0											115N
9539Y	2	2	.10	1.3	.10	1.8						116U
9540ZR2	2	.49	.756	.49	.724							117K
9541NB1	1	1.0	.235									118U
9541NB2	1	1.0	.765									119K
9542M02	0											120S
9639Y	2	3.33	1.5	.40	1.0	1.0	.7					121U
9640ZR2	0											122S
9641NB2	9	.21	1.2	.49	1.09	.22	.85	.14	.81	.97	.78 .59 .57	123K
.28	.46	.10	.24	.07	.216							123
9642M02	0											124S
9736KR2	0											125N
9737RB2	0											126N
9738SR2	0											127N
9739Y	2	0										128N
9740ZR2	6	.03	1.35	.013	.69	.017	.60	.017	1.84	.015	1.75 .03 1.15	129U
9741NB1	1	.98	.747									130K
9741NB2	2	.98	.665	.02	1.0							131K
9742M02	0											132S
9840ZR2	0											133N
9841NB1	0											134N
9841NB2	12	.08	1.93	.04	1.88	.10	1.68	.04	1.52	.10	1.44 .30 1.16	135U
1.0	.787	.75	.72	.09	.33	.05	2.7	.05	2.44	.05	2.24	135
9842M02	0											136S

.13	.434	.18	.345	.16	.314	.31	.273	.07	.089	.025	1.71	.04	1.14	230		
11749IN1	2	.31	.314	.14	.158									231K		
11749IN2	2	1.0	.565	.87	.158									232K		
11750SN1	1	.87	.158											233K		
11750SN2	0													234S		
11846CD2	0													235K		
11849IN2	1	.15	1.23											236K		
11850SN2	0													237S		
11946CD1	0													238N		
11946CD2	1	.21	.8											239U		
11949IN1	3	.05	.30	.05	.91	.9	.024							240U		
11949IN2	2	.95	.82	.05	.73									241K		
11950SN1	1	.16	.024											242K		
11950SN2	0													243S		
12049IN2	13	.06	2.01	.07	1.87	.06	1.47	.14	1.28	1.0	1.17	.61	1.02	244K		
		.12	.94	.34	.86	.12	.71	.09	.198	.12	.09	.02	2.63	.04	2.22	244
12050SN2	0														245S	
12146CD2	0														246N	
12149IN1	0														247N	
12149IN2	1	1.0	.94												248U	
12150SN1	1	1.0	.037												249U	
12150SN2	0														250K	
12151SB2	0														251S	
12249IN2	3	.40	.99	.40	1.14	.72	1.16								252U	
12250SN2	0														253S	
12251SB1	2	.50	.061	.17	.075										254K	
12251SB2	4	.007	1.26	.007	1.14	.034	.686	.66	.564						255K	
12252TE2	0														256S	
12349IN2	1	1.0	1.1												257U	
12350SN1	1	.02	1.08												258U	
12350SN2	1	.84	.160												259K	
12351SB2	0														260S	
12352TE1	1	.84	.159												261K	
12352TE2	0														262S	
12450SN2	0														263S	
12451SB1	3	.20	.644	.20	.603	.20	.505								264K	
12451SB2	10	.07	2.09	.50	1.69	.02	1.45	.05	1.37	.03	1.31	.024	1.05		265K	
		.024	.967	.14	.72	.07	.644	.97	.603						265	
12452TE2	0														266S	
12550SN1	6	.97	.325	.001	1.94	.0022	1.61	.005	1.47	.002	1.07	.01	.64		267K	
12550SN2	9	.0005	2.23	.006	1.97	.0014	1.41	.0014	1.17	.04	1.07	.014	.904		268K	
		.015	.811	.004	.468	.003	.342								268	
12551SB2	5	.14	.63	.24	.60	.10	.463	.31	.427	.06	.176				269K	
12552TE1	2	.003	.11	.07	.035										270K	
12552TE2	0														271S	
12650SN2	3	.35	.06	.35	.067	.35	.092								272U	
12651SB1	2	.10	.41	.15	.67										273U	
12651SB2	3	1.0	.41	1.00	.69	1.0	.66								274U	
12652TE2	0														275S	
12750SN2	6	.50	.27	.50	.49	.50	.99	.20	1.65	.10	2.32	.10	2.74		276U	
12751SB2	5	.24	.77	.54	.46	.06	.31	.14	.25	.04	.06				277U	
12752TE1	2	.0008	.789	.0019	.059										278K	



APPENDIX B
PHOTON PRODUCTION BY GROUP
AND ISOTOPE FOR SPECIFIED DECAY TIME

GROUP	NUMBER OF PHOTONS BY GROUP, ISOTOPE FOR DECAY TIME= 10.0 DAYS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
GE	77	0.0	5.9+06	1.3+06	2.5+06	3.5+05	6.7+05	5.3+05	0.0	3.3+05	0.0	0.0	1.3+05	0.0	0.0	0.0
AS	77	2.3+08	9.4+09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR*	80	0.0	0.0	0.0	1.2-11	0.0	0.0	1.6-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR	80	1.4-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR	82	0.0	1.5+09	0.0	4.8+10	4.0+10	1.3+10	1.1+10	7.4+09	0.0	6.6+09	0.0	0.0	0.0	0.0	0.0
BR	83	0.0	0.0	0.0	3.7-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR*	85	7.4-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR*	85	3.0-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR	85	0.0	0.0	0.0	5.1+12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RB	86	0.0	0.0	0.0	0.0	0.0	1.7+12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR*	87	0.0	0.0	0.0	2.0-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR	88	2.3-11	0.0	0.0	2.2-12	0.0	1.0-11	0.0	6.2-12	0.0	8.0-12	0.0	1.4-11	0.0	0.0	0.0
RB	88	0.0	0.0	0.0	0.0	0.0	0.0	5.6-12	0.0	0.0	9.8-12	0.0	0.0	1.1-12	0.0	0.0
Y*	89	0.0	0.0	0.0	0.0	0.0	2.0+13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y*	90	0.0	9.9-14	0.0	1.2-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y	90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR	91	0.0	0.0	0.0	0.0	2.2+07	3.7+07	5.0+07	7.1+06	1.4+10	0.0	0.0	0.0	0.0	0.0	0.0
Y*	91	0.0	0.0	0.0	0.0	8.1+07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y	91	0.0	0.0	0.0	0.0	0.0	0.0	1.1+13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR	92	0.0	1.8-14	0.0	2.5-14	0.0	0.0	0.0	5.6-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y	92	0.0	0.0	0.0	3.3-06	0.0	2.0-05	0.0	6.8-06	0.0	5.9-07	0.0	0.0	0.0	0.0	0.0
Y	93	0.0	2.3+07	0.0	0.0	2.6+06	7.8+06	0.0	2.4+06	0.0	6.5+06	1.1+06	0.0	0.0	0.0	0.0
NB*	41	93	5.8+07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB	41	94	0.0	0.0	0.0	1.5+02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR	40	95	0.0	0.0	0.0	3.7+15	3.0+15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB*	41	95	0.0	1.3+14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB	41	95	0.0	0.0	0.0	0.0	6.6+15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR	40	96	0.0	0.0	0.0	6.6+09	1.3+10	3.1+10	1.3+10	5.0+09	0.0	0.0	0.0	0.0	0.0	0.0
NB*	41	97	0.0	0.0	0.0	0.0	0.0	0.0	2.4+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB	41	97	0.0	0.0	0.0	4.7+11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MO	42	99	6.5+13	0.0	0.0	4.7+11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TC*	43	99	6.0+14	0.0	0.0	9.8+13	2.7+13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	44	103	0.0	0.0	0.0	6.9+15	4.2+14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	45	103	7.8+13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	45	105	0.0	1.8-02	2.9-02	7.3-02	2.0-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	45	105	5.2-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	45	106	0.0	0.0	1.9+13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RH*	45	106	0.0	6.7-22	0.0	3.1-21	1.5-21	1.1-21	8.0-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AG*	47	108	1.3+02	0.0	0.0	6.7+14	3.1+14	4.7+13	6.2+12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AG	47	108	0.0	0.0	0.0	4.1+03	9.4+03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PD	46	109	1.6+07	0.0	0.0	5.6+00	9.2+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AG*	47	109	4.2+08	0.0	0.0	1.3+06	1.2+06	5.4+06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



DISTRIBUTION

No. of
Copies
OFFSITE

1	<u>AEC Chicago Patent Group</u> G. H. Lee
32	<u>AEC Division of Reactor Development Technology</u> M. Shaw, Director, RDT Asst Dir for Nuclear Safety Analysis & Evaluation Br, RDT:NS Environmental & Sanitary Engrg Br, RDT:NS Research & Development Br, RDT:NS Asst Dir for Plant Engrg, RDT Facilities Br, RDT:PE Components Br, RDT:PE Instrumentation & Control Br, RDT:PE Liquid Metal Systems Br, RDT:PE Asst Dir for Program Analysis, RDT Asst Dir for Project Mgmt, RDT Liquid Metals Projects Br, RDT:PM FFTF Project Manager, RDT: PM (3) Asst Dir for Reactor Engrg, RDT Control Mechanisms Br, RDT:RE Core Design Br, RDT:RE (3) D. R. Emon (1) Fuel Engineering Br, RDT:RE Fuel Handling Br, RDT:RE Reactor Vessels Br, RDT:RE Asst Dir for Reactor Tech, RDT Coolant Chemistry Br, RDT:RT Fuel Recycle Br, RDT:RT Fuels & Materials Br, RDT:RT Reactor Physics Br, RDT:RT (2) P. B. Hemmig (1) Special Technology Br, RDT:RT Asst Dir for Engrg Standards, RDT
263	<u>AEC Division of Technical Information Extension</u>
1	<u>AEC Idaho Operations Office</u> <u>Nuclear Technology Division</u> C. W. Bills, Director
1	<u>AEC San Francisco Operations Office</u> <u>Director, Reactor Division</u>

No. of
Copies

4	<u>AEC Site Representatives</u> Argonne National Laboratory Atomics International Atomic Power Development Assoc. General Electric Co.
6	<u>Argonne National Laboratory, Argonne</u> R. A. Jaross LMFBR Program Office A. E. McCarthy N. J. Swanson <u>Idaho Falls</u> R. K. Ferguson J. W. Rizzie
2	<u>Atomic Power Development Assoc.</u> Document Librarian R. J. Beaudry
8	<u>Atomics International</u> D. J. Cockeram (5) A. W. Thiele <u>Liquid Metal Information Center</u> J. J. Droher (2)
2	<u>Babcock & Wilcox Co.</u> Atomic Energy Division S. H. Esleeck G. B. Garton
1	<u>BNW Representative</u> N. A. Hill (ZPR-III)
5	<u>Bechtel Corporation</u> J. J. Teachnor, Project Administrator, FFTF
1	<u>Combustion Engineering</u> 1000 MWe Follow-On Study W. P. Staker, Project Manager
6	<u>General Electric Co.</u> Advanced Products Operation Karl Cohen (3) Bertram Wolfe M. L. Weiss <u>Nuclear Systems Programs</u> D. H. Ahmann

No. of
Copies

2 Gulf General Atomic Inc.
General Atomic Div
D. Coburn

1 Idaho Nuclear Corporation
D. R. deBoisblanc

4 Oak Ridge National Laboratory
C. E. Clifford
H. C. Claiborne
D. K. Trnbey
W. O. Harms

1 Stanford University
Nuclear Division
Division of Mechanical Engrg
R. Sher

1 United Nuclear Corporation
Research and Engineering Center
R. F. DeAngelis

11 Westinghouse Electric Corporation
Atomic Power Division
Advanced Reactor Systems
J. C. R. Kelly (10)
P. S. Bland

ONSITE-HANFORD

1 AEC Chicago Patent Group
R. K. Sharp (Richland)

4 AEC RDT Site Representative
P. G. Holsted

5 AEC Richland Operations Office
D. R. Elle
W. E. Lotz
J. M. Shivley (3)

18 Atlantic Richfield Hanford Company
C. E. Backman B. J. McMurray
J. S. Cochran H. A. Moulthrop
J. B. Fecht N. P. Nisick
W. M. Harty G. H. Sahler
R. W. Harvey H. P. Shaw
J. R. Houston R. E. Tomlinson
W. P. Ingalls D. T. Vladimiroff
C. W. Malody J. H. Warren
T. R. McKenzie ARHCO File

No. of
Copies

3	<u>Battelle Memorial Institute</u>
1	<u>Bechtel Corporation</u> D. H. Weiss (Richland)
1	<u>Computer Sciences Corporation</u> Z. E. Carey
2	<u>Donald W. Douglas Laboratories</u> J. Greenborg M. L. Smith
20	<u>Douglas United Nuclear Incorporated</u> T. W. Ambrose W. M. Mathis E. C. Bennett N. R. Miller J. R. Bolliger W. S. Nechodom C. D. Corbit F. E. Owen T. E. Dabrowski R. W. Reid G. C. Fullmer J. W. Riches R. O. Gumprecht R. V. Skinner R. T. Jessen J. T. Stringer H. R. Kosmata P. J. Zimmerman C. W. Kulhman DUN File
3	<u>Vitro-Hanford Engineering Services</u> L. B. Ufkes D. E. Sebade G. Kligfield
1	<u>Westinghouse Electric Corporation</u> R. Strzelecki (Richland)
77	<u>Battelle-Northwest</u> S. O. Arneson E. R. Astley R. A. Bennett E. T. Boulette W. O. Bunch (5) J. J. Cadwell W. E. Cawley J. C. Cochran D. L. Condotta R. R. Cone J. H. Cox G. M. Dalen F. G. Dawson D. R. de Halas E. A. Evans L. G. Faust L. M. Finch

Battelle-Northwest (contd)

J. P. Hale
J. E. Hanson
R. E. Heineman
J. W. Helm
M. M. Hendrickson
R. J. Hennig
P. L. Hofmann
C. W. Lindernmeier
W. W. Little
B. Mann
C. A. Mansius (5)
D. R. Marr
W. B. McDonald
C. E. Newton
J. N. Paglieri
H. M. Parker
R. E. Peterson
H. G. Powers
W. C. Roesch
F. H. Shadel
D. W. Shannon (2)
G. L. Simmons
D. E. Simpson
C. R. F. Smith
W. G. Spear
R. J. Squires
D. Streng
D. D. Stepnewski
H. H. Van Tuyl
N. G. Wittenbrock
M. R. Wood
F. W. Woodfield
J. R. Worden
Technical Publications (2)
Technical Information (5)
FFTF Files (10)
FFTF Technical Reports Office

