04000672

VOID SHEET

Sep 2 ✓ 118323

TO: License Fee Management Branch

FROM: RI

SUBJECT: VOIDED APPLICATION

Control Number: 118323

Applicant: NUCLEAR METALS, Inc.

Date Voided: 9-21-96

Reason for Void: Responses to NRC letter dated 1/11/94 and TAR dated 4/29/94 were not received. Therefore the NRC has ceased working on the Amendment request. After review. SMB-179/040-00672.

Rebecca J. Brown 9/21/96
Signature Date

Attachment:
Official Record Copy of
Voided Actic

FOR LFMB USE ON

Final Review of VOID Completed:

Refund Authorized and processed

— No Refund Due

Fee Exempt or Fee Not Required

Comments: ______

Log completed

Processed by: BR

9610150032 960921
PDR ADOCK 04000672
B PDR

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d1

SEP 21 1996

Frank Vumbaco
Vice President, Health & Safety
Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742

SUBJECT: TERMINATION OF WORK ON APPLICATION FOR MATERIAL LICENSE AMENDMENT DATED JULY 1. 1993

Dear Mr. Vumbaco:

This letter is to transmit a copy of the Technical Assistance Request (TAR) response dated April 29, 1994. Based on two telephone conversations held on September 12, 1996, NRC has terminated work on the amendment request regarding copper reclamation, Mail Control No. 118323.

If at some time in the future you wish to pursue this issue, please provide the information requested in our letter dated January 11, 1994, and address the issues in the TAR response dated April 29, 1994.

Sincerely,

ORIGINAL SIGNED BY:

Ronald R. Bellamy
Division of Nuclear Materials Safety

License No. SMB-179
Docket No. 040-00672
Control No. 118323

Enclosure:
Letter dated January 11, 1994
TAR response dated April 29, 1994

DOCUMENT NAME: C:\TYPING\DEFLTR\NMICUV.OID
To receive a copy of this document, indicate in the box: "C" = Copy w/o attach/encl "E" = Copy w/ attach/encl "N" = No copy

OFFICE	DNMS/RI	N	DNMS/RI					
NAME	Shaffer		Bellamy					
DATE	09/12/96		09/12/96		09/ /96		09/ /96	

OFFICIAL RECORD COPY **ML 10**

cc:
Betsy Harper, Assistant Attorney General
Commonwealth of Massachusetts
Department of Attorney General
Environmental Protection Division
One Ashburton Place
Boston, Massachusetts 02108

Cynthia Weidner, Environmental Analyst
Commonwealth of Massachusetts
Department of Environmental Protection
10 Commerce Way
Woburn, Massachusetts 01801

Robert Hallisey, Director
Radiation Control Program
Commonwealth of Massachusetts
Department of Health
150 Tremont Street
Boston, Massachusetts 02111

Reference Librarian
Concord Public Free Library
129 Main Street
Concord, Massachusetts 01742

Michael Moore, Executive Director
Concord Board of Health
141 Keyes Road
Concord, Massachusetts 01742

AUG 2 2 1996

Frank Vumbaco
Vice President, Health & Safety
Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742

SUBJECT: APPLICATION FOR MATERIAL LICENSE AMENDMENT DATED JULY 1, 1993, AND OUR REQUEST FOR ADDITIONAL INFORMATION DATED JANUARY 11, 1994

Dear Mr. Vumbaco:

This concerns the subject application for a material license amendment and our letter in which we notified you that the application was deficient and that certain additional information was required.

You are hereby notified that unless within thirty (30) days from the date of this notice we receive the additional information requested, we will consider that you have abandoned your application. This action is without prejudice to the resubmission of an application.

Sincerely,

Original Singed By:
James H. Joyner

Ronald R. Bellamy
Division of Nuclear Materials Safety

License No. SMB-179
Docket No. 040-00672
Control No. 118323

Enclosure:
Letter dated January 11, 1994

DOCUMENT NAME: S:\ABANDON.NMI
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OFFICE	DNMS/RI	N	DNMS/RI	N				
NAME	Shaffer		Bellamy					
DATE	08/21/96		08/21/96		08/ /96		08/ /96	

OFFICIAL RECORD COPY

ML 10

TELEPHONE CONVERSATION LOG

PERSON CALLED:	ORGANIZATION:	TELEPHONE NUMBER:
Eric Andersen	NMI, Inc.	508-369-5410
LICENSE NUMBER: SMB-179	DOCKET NUMBER: 040-00672	MAIL CONTROL NUMBER: 118323

PERSON CALLING:

Steve W. Shaffer — (610) 337-5256
USNRC Region I — FAX Numbers
475 Allendale Road — (610) 337-5269 or
King of Prussia, PA 19406 — (610) 337-5393

SUBJECT: TAR response dated January 21, 1994

SUMMARY:

Ron Bellamy, Marie Miller and myself were present during the phone conference with Eric. Frank Vumbaco was unable to participate in the call.

We discussed the response and what concerns headquarters had with the release of the contaminated copper. It was generally agreed that pursuing the amendment would be an extremely taxing and lengthy process. I agreed to fax a copy of the response to Eric after the call. He stated that he would discuss this with Mr. Vumbaco and get back to us.

ACTION REQUIRED/TAKEN: None

SIGNATURE: Steve W. Shaffer

DATE: September 12, 1996

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AUG 2 2 1996

Frank Vumbaco
Vice President, Health & Safety
Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742

SUBJECT: APPLICATION FOR MATERIAL LICENSE AMENDMENT DATED JULY 1, 1993, AND OUR REQUEST FOR ADDITIONAL INFORMATION DATED JANUARY 11, 1994

Dear Mr. Vumbaco:

This concerns the subject application for a material license amendment and our letter in which we notified you that the application was deficient and that certain additional information was required.

You are hereby notified that unless within thirty (30) days from the date of this notice we receive the additional information requested, we will consider that you have abandoned your application. This action is without prejudice to the resubmission of an application.

Sincerely,

Original Singed By:
James H. Joyner

for Ronald R. Bellamy
Division of Nuclear Materials Safety

License No. SMB-179
Docket No. 040-00672
Control No. 118323

Enclosure:
Letter dated January 11, 1994

DOCUMENT NAME: S:\ABANDON.NMI
To receive a copy of this document, indicate in the box: "C" = Copy w/o attach/encl "E" = Copy w/ attach/encl "N" = No copy

OFFICE	DNMS/RI	N	DNMS/RI	N				
NAME	Shaffer		Bellamy					
DATE	08/21/96		08/21/96		08/ /96		08/ /96	

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ML 10

cc:
Betsy Harper, Assistant Attorney General
Commonwealth of Massachusetts
Department of Attorney General
Environmental Protection Division
One Ashburton Place
Boston, Massachusetts 02108

Cynthia Weidner, Environmental Analyst
Commonwealth of Massachusetts
Department of Environmental Protection
10 Commerce Way
Woburn, Massachusetts 01801

Robert Hallisey, Director
Radiation Control Program
Commonwealth of Massachusetts
Department of Health
150 Tremont Street
Boston, Massachusetts 02111

Reference Librarian
Concord Public Free Library
129 Main Street
Concord, Massachusetts 01742

Michael Moore, Executive Director
Concord Board of Health
141 Keyes Road
Concord, Massachusetts 01742

bcc:
Region I Docket Room (w/concurrences)

NUCLEAR METALS, INC.

Ms 16
Q-4

04 August 1994

United States Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406-1415

Attention: Mr. Duncan White
Facilities Radiological Safety
and Safeguards Branch
Division of Radiation Safety
and Safeguards

Reference: License No. SMB-179
Docket No. 040-00672
Control No. 118323

Subject: NRC letter dated 11 January 1994, Unrestricted Disposition of Copper Plates Containing Depleted Uranium

Dear Mr. White:

In the NRC's letter referenced above, comments and questions in response to NMI's request of 1 July 1993 were broken down into ten sections. In general, these questions requested additional and specific data pertaining to the derivation, makeup, expected use and radiological consequences of the copper electrowon (recovered) from the pickling /etching liquor used to remove copper sheathing from extruded DU rods.

As discussed in our telephone conversation of 03 Aug. 94, this mailing is intended to provide theoretical data characterizing the potential radiological consequences of the proposed operations (unrestricted disposition of copper with residual DU), in response to the relevant requests for information in the letter referenced above.

NMI commissioned a technical evaluation of the external radiation exposure potential for 'generic' copper sheets/slabs contaminated with DU at the proposed limit of 100 ppm. George E. Chabot, Ph.D, CHP, a recognized expert in the field of dosimetry and shielding calculations, prepared the enclosed report for NMI titled "DOSE RATE EVALUATIONS FOR EXPOSURE TO COPPER METAL CONTAMINATED WITH

118323

AUG 10 1994

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2229 Main Street, Concord, Massachusetts 01742 (508) 369-5410

DEPLETED URANIUM", dated July 30, 1994.

Although the complete technical report occupies 63 single-sided pages, the majority of this is taken up with output results from the codes used, as listed below.

Appendix A: "Output Results from EGS4 Monte Carlo Simulations"
Appendix B: "Output Results from VARSKIN-MOD2"
Appendix C: "Output Results from MICROSHIELD 3.12"

The first seven pages of text describe the calculational models and methodolgies used, and summarize the resultant data. As stated in the summary, the maximum possible annual dose equivalents have been evaluated as about 250 mrem shallow, and 6 mrem penetrating. The foundation assumptions regarding slab dimensions, distances to receptor, etc. are detailed later in the report.

Obviously, the assumptions used were grossly conservative, compared to any potential 'real-world' scenarios; it is unlikely that any person would spend all day, 365 days per year, in contact with the approximately-infinite copper slab postulated. These calculations have effectively shown that potential doses to members of the public resulting from free release of this material are extremely small.

Because of the small magnitude or these values, NMI hopes that it will not be necessary to construct more complex scenarios for end-use of the copper product, as relates to potential dose assessment. As a business, NMI would also like to keep open any option for re-use or sale of the material, and would therefore prefer to avoid construction of these potentially-limiting scenarios.

As specified in the original application, (and in the interim response letter provided to you earlier this year, dated 06 May 94) NMI's approach to release of the electrowon copper product would be to implement control procedures to assure that average average lot concentrations do not exceed 100 ppm, and average batch (the collective output from each electrowinning 'run') concentrations do not exceed 300 ppm.

Sincerely,

Eric B. Andersen
Staff Health Physicist

cc: F. J. Vumbaco
Vice-President, Health and Safety

NMI

NUCLEAR METALS, INC.
2229 Main Street, Concord, MA 01742-3813
Telephone (508) 369-5410

Dose Rate Evaluations For Exposure To Copper Metal Contaminated With Depleted Uranium

DOSE RATE EVALUATIONS FOR EXPOSURE TO COPPER METAL CONTAMINATED WITH DEPLETED URANIUM

Prepared for: Eric Andersen
Nuclear Metals, Inc.
2229 Main St.
Concord, MA 10742

Submitted by: George E. Chabot
2 Eugley Park East
North Reading, MA 01864

Date: July 30, 1994

Summary

Calculations have been carried out to evaluate the shallow (7 mg cm-2) and penetrating (1000 mg cm-2) dose rates to individuals in close proximity to slabs of copper metal comtaminated uniformly at a level of 100 ppm, by weight, with depleted uranium. Slabs ranging in areal dimensions from 4 feet by 4 feet to infinite dimensions and with thicknesses from 0.25 inches (0.635 cm) to 10 cm (essentially infinitely thick for calculational purposes). The maximum possible annual shallow dose equivalent has been evaluated as about 250 mrem, and the maximum possible annual penetratinmg dose has been evaluated as about 6 mrem. Various calculational approaches have been taken, and agreement among them was good. Details of the methods used and the results obtained are contained in the following pages.

Source Assumptions

The source material was assumed to consist of copper metal contaminated to the extent of 100 ppm, by weight, of ^{238}U. In all cases it was assumed that the relatively short-lived progeny of ^{238}U, namely ^{234}Th, ^{234m}Pa, and ^{234}Pa, were in secular equilibrium with the parent ^{238}U; branching fractions were accounted for (i.e., ^{234m}Pa decays 99.84% of the time by beta minus decay to ^{234}U, and 0.16% of the time it undergoes isomeric transition to ground state ^{234}Pa). In general, decay scheme data were taken from Kocher[1]. We have done calculations for single slabs of assumed dimensions 4"x4"x0.25" thick and for larger area slabs, 0.25" thick or greater. In some cases cylindrical slab geometries were assumed to ease the mathematical integrations (e.g., a 68.8 cm radius slab was used to simulate the 4foot by 4 foot slab); the geometry substitutions had minimal effects on the results.

Calculational Methods

Calculations were done to evaluate the soft tissue dose rates at depths of 7 mg cm^{-2} and at 1000 mg cm^{-2} both at contact or near contact with the slab surface and at one foot in air from the respective slab surface. The dose point, or 1 cm^2 dose averaging area, was situated opposite the geometric center of the respective finite-sized slab. Dose rates have been evaluated for all significant radiations of concern, including beta particles, gamma radiation, and bremsstrahlung. Conversion electron dose rate were also assessed, although these were minimal. Various methods were used to evaluate the required dose rates.

Monte Carlo simulations were carried out using the EGS-4[2] computer code; these allowed evaluation of doses from all the radiations of interest for selected cases. The source material was modeled as copper, and the planar receptor volume was defined

as water lying between depths of 6.5 and 7.5 mg cm^{-2}, for estimation of the 7 mg cm^{-2} dose rate, and 999.5 and 1000.5 mg cm^{-2} for determination of the 1000 mg cm^{-2} dose rate.. Calculations were performed for between 10^5 and 10^7 case histories per batch, and 10 to 30 batches were run per case. Because of restrictions on computer run time, source thicknesses were limited to one inch for the Monte Carlo calculations. Multiple batch runs allowed good estimations of the errors associated with the dose estimates. For many of the cases, gamma dose estimations were run separately after it was decided to enter all the photon emission data for ^{234}Pa.

Beta dose rate calculations were also performed using the Varskin-Mod2[3] computer code and techniques developed by Chabot[4]. Additionally, gamma dose rates were evaluated using the Microshield[5] code. The Microshield library radionuclides of interest were used along with the stored photon energy data; Taylor's form of the buildup factor was selected.

Additional details of some of the calculations are included in the following section.

Results and Discussion

As expected, the dose rates at shallow depths are weighted heavily by the beta radiation, particularly that from ^{234m}Pa. At the 1000 mg cm^{-2} depth the delivered dose is essentially all from penetrating radiation, with gamma rays and bremsstrahlung often contributing comparable amounts. The results for beta dose rates evaluated by all the techniques are remarkably similar. The gamma dose rates estimated from Microshield tend to exceed somewhat those obtained from the Monte Carlo simulations. This is likely the result of the energy selection/weighting process used in establishing the Microshield library and of the use of infinite volume buildup factors for secondary photons.

Table 1 provides a summary of the results obtained from the Monte Carlo simulations. The data output sheets are included as Appendix A. It should be noted that the simulations are each for a specified number of ^{238}U disintegrations occurring in the source. In order to convert the dose outputs, in rads, to dose rate, in rads hr^{-1}, from the 100 ppm copper slab, the respective dose was multiplied by 4.0067E4 t/n, where t is the source thickness, in cm, and n is the number of disintegrations per batch for the respective case. This factor results in part from the source geometry used in the simulations. A geometry reciprocity relationship was used in which the source is pictured as a small isotropic source embedded in the copper matrix (the source has an effective volume of 1 cm^2 times the slab thickness), and the receptor is a thin slab extending laterally to the dimensions of the source slab. The receptor volume is backed by at least 20 cm water-equivalent material in the simulation. The factor 4.0067E4 t/n is the product of the effective source volume and the ^{238}U activity concentration in disintegrations per hour per cm^3 per unit slab volume divided by the number of ^{238}U disintegrations used in the simulation.

The beta dose from the Monte Carlo simulations includes contributions from bremsstrahlung photons; this contribution is also listed separately in Table 1 for many of the cases. Beta particle spectral shapes were generated as described by Murthy[6] for the radionuclides of concern. These are shown as Figures 1 through 3 of Appendix A. Figure 4 shows the combined distributions. These combined data were used to generate a cumulative probability distribution function which was sampled in an appropriate fashion to select the energy of each beta particle emitted in the simulation.

Table 2 includes results of beta dose rate calculations obtained using Varskin-Mod2 and Chabot's techniques. The calculations used cylindrical source geometries for convenience. Varskin

dose rates were averaged over 1 cm^2. Chabot's calculations were done for point receptors; for the source dimensions used (1 meter diameter and greater) the theoretical dose rates to a point and to the 1 cm^2 area are the same. Appendix B contains the output sheets from the Varskin-Mod2 runs. The Varskin calculations were done for a source strength and exposure time that would yield 1E5 disintegrations of ^{238}U for comparison of the dose data directly with the EGS-4 results. The dose rates for the material of interest were obtained by multiplying the calculated dose rates by the ratio of the actual ^{238}U activity concentration in the source material (3.008E-4 $\mu Ci\ cm^{-3}$) to the assumed concentration (7.0937E-2 $\mu Ci\ cm^{-3}$).

Within the uncertainties of the analyses (errors are given for the Monte Carlo simulations in Table 1 and in the data output sheets, and estimated minimum errors of 10% apply for Varskin-Mod2 and Chabot's method), the results of all three methods agree well with each other, with the 7 mg cm^{-2} dose rate being about 2.7E-5 rads hr^{-1} at contact with a large slab of the source material and about 2E-5 rads hr^{-1} at one foot in air from the surface of such a slab.

The results of the Microshield gamma dose rate estimation are summarized in Table 3. The code output sheets are in Appendix C. The calculated exposure rates were converted to tissue (water) dose rates by converting exposure to dose in air and multiplying by the effective values of the mass energy absorption coefficient ratios for water compared to air (calculated by weighting coefficient values at specified energies by the energy fluence rates calculated in Microshield).

For the infinite slab case, Microshield determined a gamma dose rate at the body surface of about 5.5E-7 rads hr^{-1} for the 10 cm thick slab (essentially infinitely thick for the case of interest). Comparisons of similar geometries show that, in

general, Microshield tends to yield gamma dose rates near the surface of the body that exceed the Monte Carlo dose rates at the 7 mg cm^{-2} depth by about 15 to 25%. This is not significant considering the low magnitudes of the dose rates. The gamma dose rate from a single 4'x4'x0.25" thick slab (or for a cylinder 68.8 cm in diameter by 0.25"thick) is about 40% of the infinite slab (10 cm thick) dose rate. The 1000 mg cm^{-2} penetrating dose rates are typically about 75 to 85% of the surface or 7 mg cm^{-2} dose rates.

Conclusions and Comments

The maximum evaluated (contact) 7 mg cm^{-2} dose rate from a thick infinite slab of copper contaminated to the extent of 100 ppm with ^{238}U, with short-lived progeny in equilibrium, is about 2.9E-5 rads hr^{-1}. The comparable 1000 mg cm^{-2} dose rate is about 7.0E-7 rads hr^{-1}. The latter value was obtained by multiplying the 1000 mg cm^{-2} dose rate from the Monte Carlo simulation for the 4'x4'x1" thick slab (contact: 5.44E-7 rads hr^{-1}) by the ratio of the thick infinite slab dose rate (5.46E-7 rads hr^{-1})to the 4'x4'x1" thick slab dose rate (4.28E-7 rads hr^{-1}) from the Microshield calculation. At 1 foot in air from the infinite slab surface the 7 mg cm^{-2} dose rate would reduced to about 2.1E-5 rads hr^{-1}; the 1000 mg cm^{-2} dose rate does not change significantly at one foot compared to contact. For a single 4"x4"x0.25" thick slab the contact dose rates at 7 mg cm^{-2} and 1000 mg cm^{-2} are approximately 2.9E-5 rads hr^{-1} and 3.3E-7 rads hr^{-1}, respectively; the analogous dose rates at one foot in air from the single slab are 1.7E-5 rads hr^{-1} and 9.8E-8 rads hr^{-1}, respectively.

For the infinite, thick slab the penetrating (1000 mg cm^{-2}) dose rate to an individual exposed continuously for one year would be about 6 mrem, well below the 10CFR20 regulatory limit of 100 mrem for members of the public. In reality, accounting for realistic

occupancy in proximity to the material and the finite dimensions of products fabricated from the copper stock, the actual annual dose would likely be well below 1 mrem. The annual skin dose to an individual in close and continuous contact with the copper stock would be about 250 mrem, virtually all of which would be from beta radiation. Given realistic assumptions as to proximity to the source, the presence of any attenuating materials, and reduced exposure times, the actual annual dose would likely be a small fraction of this value. While 10CFR20 does not give explicit limits for skin dose to members of the public, a conservative value (particularly considering the occupational limit is intended to prevent deterministic effects) consistent with the whole body limit of 100 mrem (compared to the 5000 mrem occupational limit) would be 1000 mrem (i.e., (100 mrem/5000 mrem)x50,000 mrem), recognizing that 50,000 mrem is the occupational annual skin dose limit. The ICRP in Report 60 (para. 194, p.46) has recommended applying a reduction factor of 10 to the occupational skin dose limit such that the limit for the public would be 50 mSv (5000 mrem).

Given the small projected doses, relative to reasonable limits, that are associated with the use of copper metal contaminated to the extent of 100 ppm with depleted uranium, I believe that the unrestricted use of this material is acceptable. Naturally, such use requires approval by concerned regulatory agencies.

References

1. Kocher, D.C.. Radioactive Decay Data Tables - A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments, DOE-TIC-11026, Technical Information Center, 1981.

2. Nelson, W.R., Hirayama, H., Rogers, D.W.O., The EGS4 Code System, SLAC report 265, Stanford Linear Accelerator Center, Stanford, 1985.

3. Durham, J.S., VARSKIN MOD2 and SADDE MOD2: Computer Codes for Assessing Skin Dose from Skin Contamination, NUREG/CR-5873, Pacific Northwest Laboratory, prepared for U.S. Nuclear Regulatory Commission, Dec. 1992.

4. Chabot, G.E., Skrable, K.W., French, C.S., "When Hot Particles are not on the Skin", Radiation Protection Management, 5(6), 31-42, 1988.

Chabot, G.E., Khalifeh,A., Chao, M., French, C.S., Skrable, K.W., "A Technique to Correct for Self Absorption in Beta Radiat on Sources and for Attenuation in other Media", Radiation Protection Management, 9(4), 50-62, 1992.

5. Microshield 3.12, Grove Engineering, 1988.

6. Murthy, M.S.S., "Shape and Average Energy of Beta-Particle Spectra", Int. J. Applied Rad. & Isotopes, 22, 111-123, 1971.

Table 1

Dose Rates (mrads/hr soft tissue) from EGS-4 Monte Carlo Simulations

Geometry	Depth (mg/cm^2)	Beta	Conversion Electrons	Bremsstrahlung	Gamma	Total *
Inf. slab; 0.25" thick; contact	7	2.82E-5	4.72E-9		1.94E-7	2.84E-5 (0.88%)
	1000	1.62E-7	0.0		1.53E-7	3.15E-7 (7.45%)
Inf. slab; 0.25" thick; 1 foot air	7	2.07E-5	0.0		1.95E-7	2.09E-5 (1.14%)
	1000	1.55E-7	0.0		1.46E-7	3.00E-7 (8.30%)
4'x4'x0.25"; contact	7	2.84E-5	1.02E-8	2.34E-7	1.94E-7	2.86E-5 (1.48%)
	1000	1.74E-7	0.0	1.74E-7	1.56E-7	3.30E-7 (10.1%)
4'x4'x0.25"; 1 foot air	7	1.72E-5	0.0	1.10E-7	1.55E-7	1.74E-5 (1.23%)
	1000	3.00E-8	0.0	3.00E-8	6.79E-8	9.79E-8 (11.8%)
4"x4"x1"; contact	7	2.87E-5	0.0	4.04E-7	3.88E-7	2.93E-5 (2.10%)
	1000	2.28E-7	0.0	2.28E-7	3.17E-7	5.44E-7 (11.2%)
4'x4'x1"; 1 foot air	7	1.69E-5	0.0	2.48E-7	2.56E-7	1.72E-5 (2.30%)
	1000	1.48E-7	0.0	1.48E-7	1.78E-7	3.24E-7 (16.1%)

* Value in parentheses below each total is the percent standard deviation in the total dose rate.

Table 2

Beta Radiation Dose Rates (rads/hr soft tissue) at 7 mg/cm² Depth from Varskin-Mod 2 and Chabot

Geometry	Varskin-Mod2	Chabot
Cylinder, 1 m diameter; 0.25" thick; contact	2.71E-5	2.69E-5
Cylinder, 1 m diameter; 0.25" thick; 1 foot air	1.19E-5	1.30E-5
Cylinder, 10 m diameter; 0.25" thick; 1 foot air	1.90E-5	2.16E-5
Cylinder, 100 m diameter; 0.25" thick; 1 foot air	1.92E-5	2.16E-5

Table 3

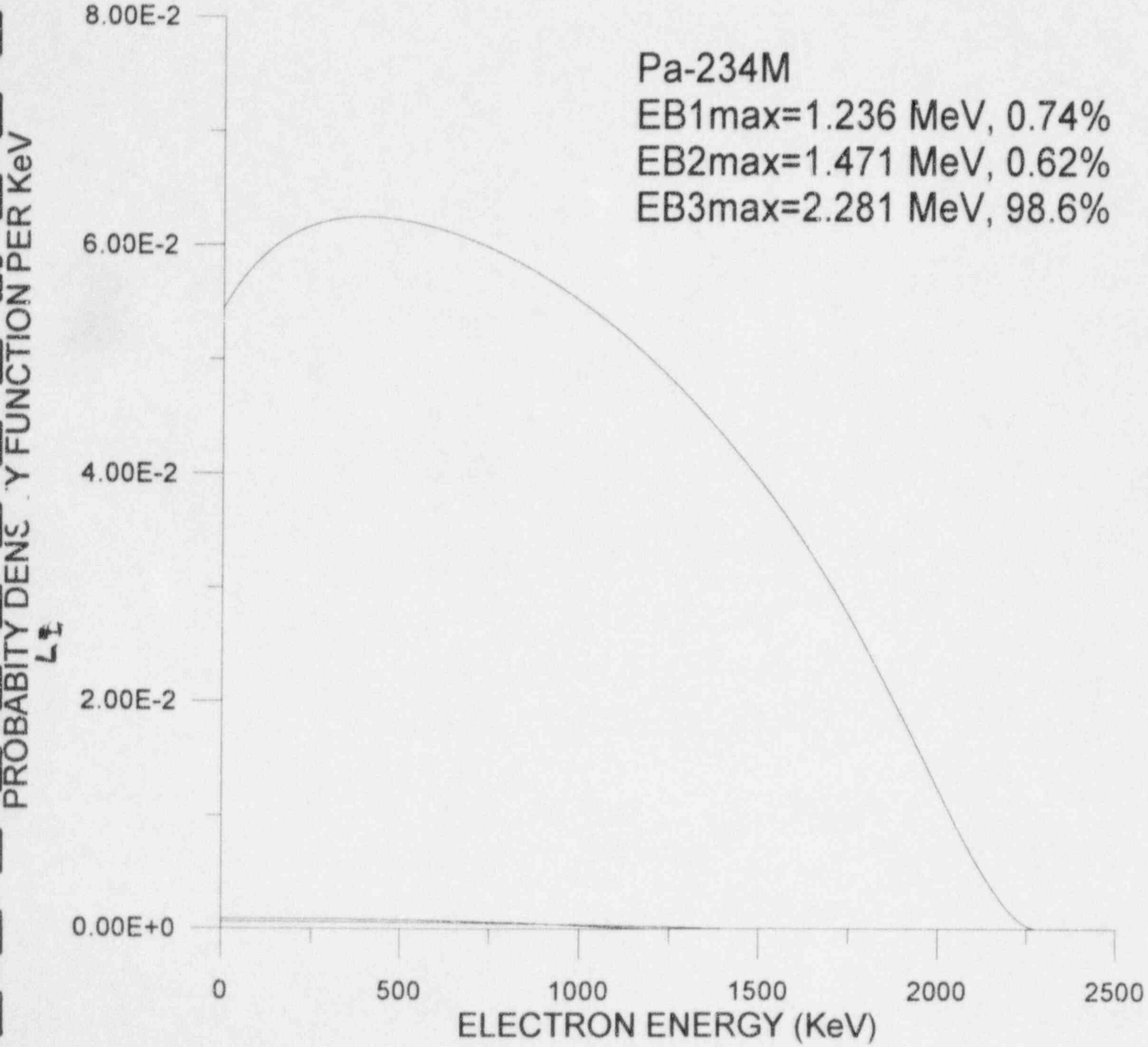
Gamma Radiation Dose Rates from Microshield

Geometry	File Name	File Ref.	Exp. Rate (R/hr)	Tissue Dose Rate (rads/hr)
Inf. slab; 10 cm thick; 1 cm air	NMIINF	NMI-1	5.62E-7	5.46E-7
Cylinder; 68.8 cm rad.; 0.635 cm thick	NMICYL	NMI-2	2.27E-7	2.21E-7
Cylinder; 68.8 cm rad.; 0.635 cm thick; 1 foot air	NMICYLAI	NMI-3	8.04E-8	7.83E-8
Cylinder; 68.8 cm rad.; 10 cm thick; 0.001 cm air	NMICYL2	NMI-4	5.47E-7	5.32E-7
Inf. slab; 10 cm thick; 1 cm air; 1 cm water	NMIINFCM	NMI-5	4.79E-7	4.66E-7
Inf. slab; 2.54 cm thick; 1 cm air	NMI1IN	NMI-6	4.65E-7	4.52E-7
Rect. slab; 4'x4'x10 cm; 1 cm air	NMIRECT	NMI-7	5.32E-7	5.17E-7
Inf. slab; 10 cm thick; 1 foot air	NMIINFFT	NMI-8	5.57E-7	5.42E-7
Inf. slab; 0.635 cm thick; 0.001 cm air	NMIINF25	NMI-9	2.42E-7	2.35E-7
Rect. slab; 4'x4'x1"; 1 cm air	NMIRECIN	NMI-10	4.41E-7	4.28E-7

APPENDIX A

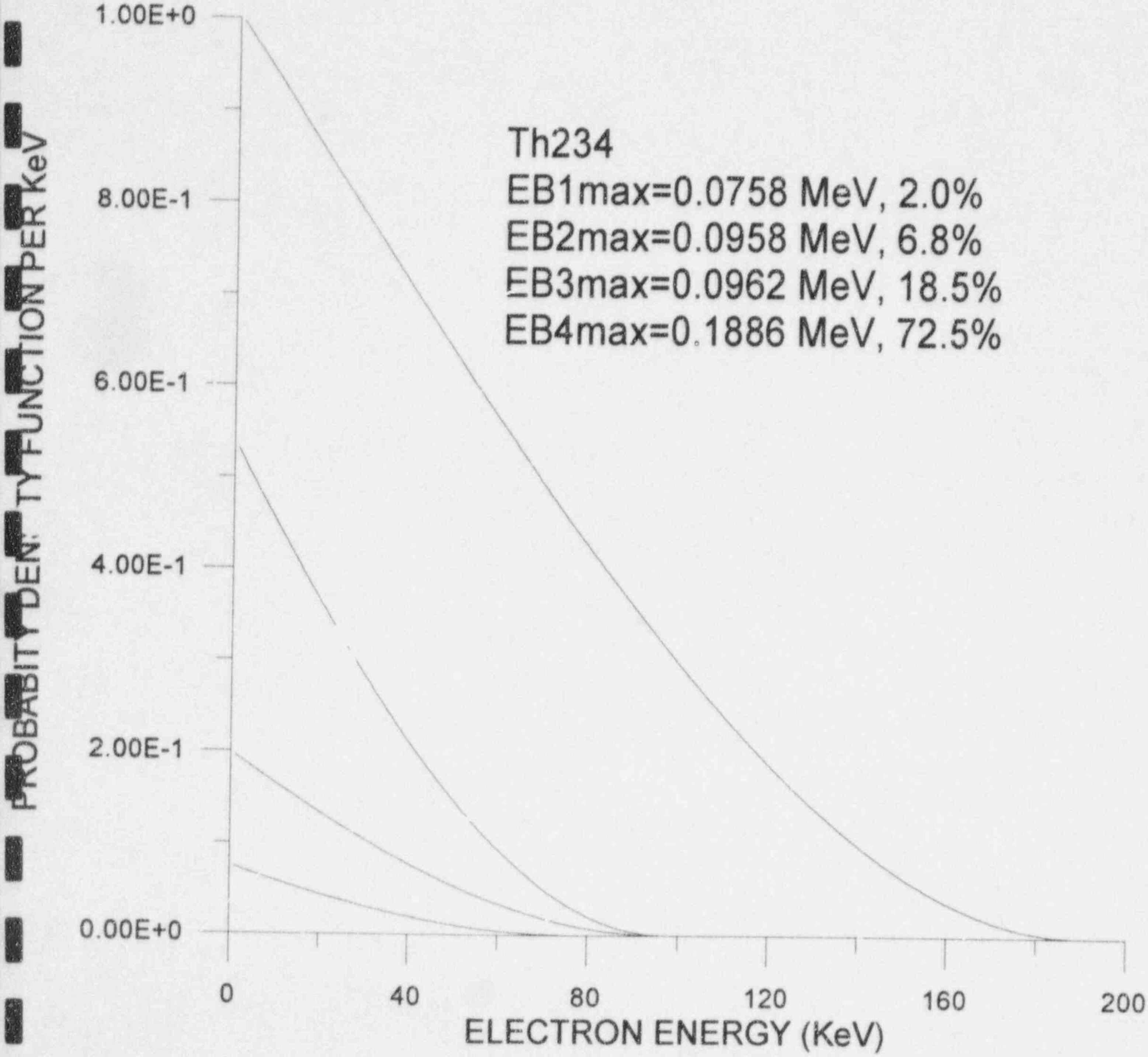
OUTPUT RESULTS FROM EGS4 MONTE CARLO SIMULATIONS

Figure 1



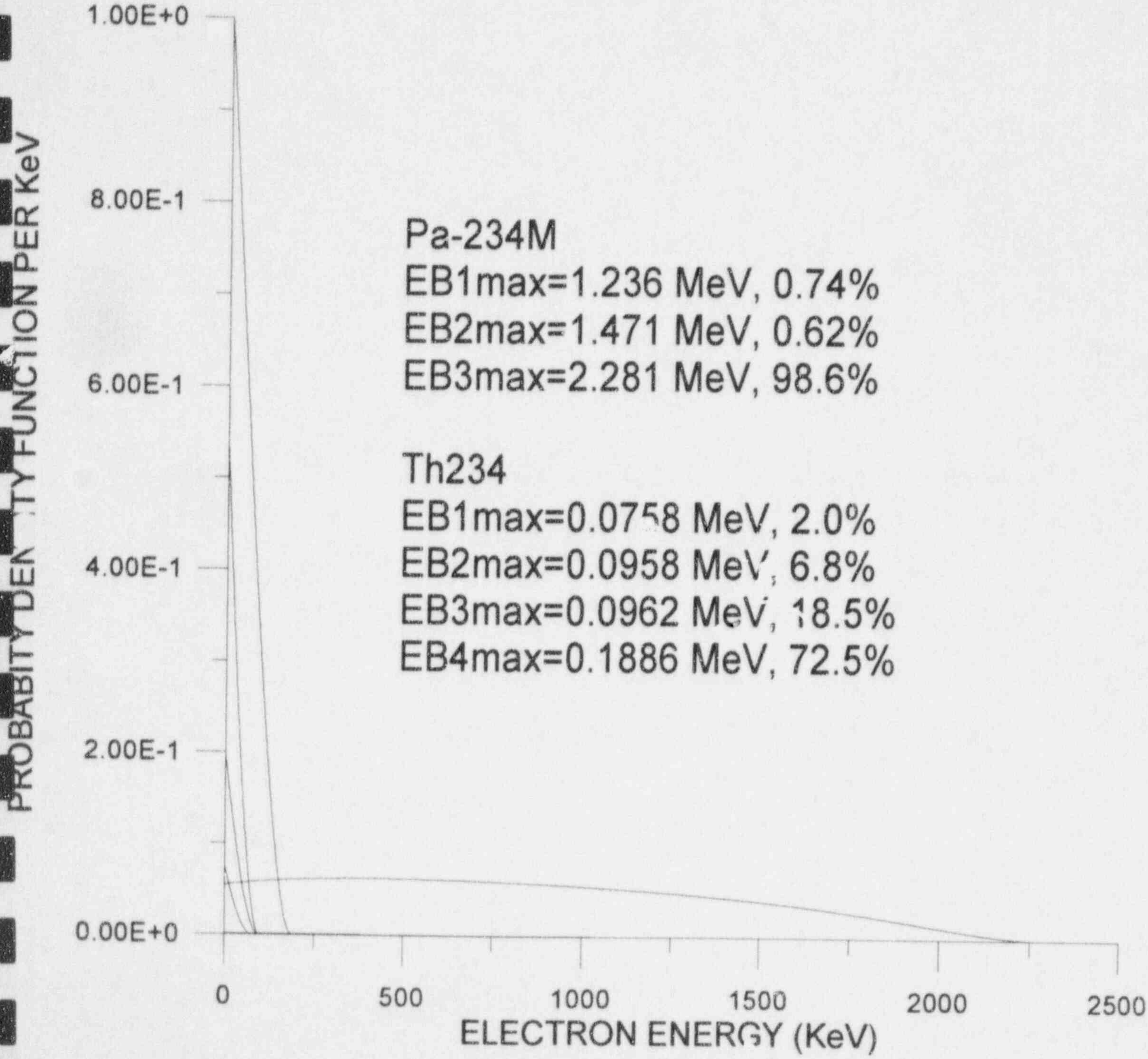
Pa-234M
EB1max=1.236 MeV, 0.74%
EB2max=1.471 MeV, 0.62%
EB3max=2.281 MeV, 98.6%
PROBABITY DENS Y FUNCTION PER KeV
8.00E-2
6.00E-2
4.00E-2
2.00E-2
0.00E+0
0
500
1000
1500
2000
2500
ELECTRON ENERGY (KeV)

Figure 2



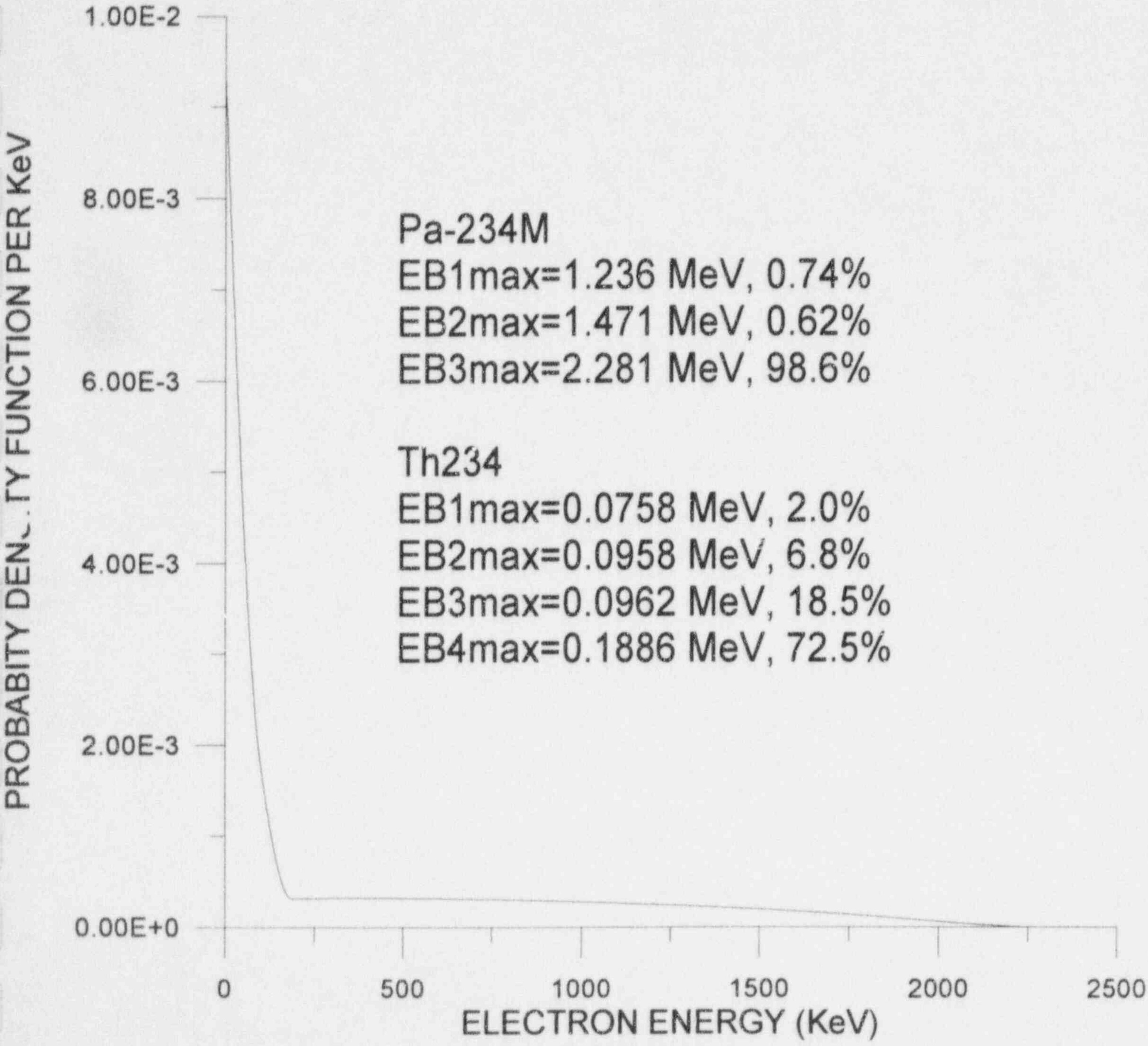
Th234
EB1max=0.0758 MeV, 2.0%
EB2max=0.0958 MeV, 6.8%
EB3max=0.0962 MeV, 18.5%
EB4max=0.1886 MeV, 72.5%
1.00E+0
8.00E-1
6.00E-1
4.00E-1
2.00E-1
0.00E+0
PROBABITY DENSITY FUNCTION PER KeV
0
40
80
120
160
200
ELECTRON ENERGY (KeV)

Figure 3



PROBABITY DEN TY FUNCTION PER KeV
1.00E+0
8.00E-1
6.00E-1
4.00E-1
2.00E-1
0.00E+0
Pa-234M
EB1max=1.236 MeV, 0.74%
EB2max=1.471 MeV, 0.62%
EB3max=2.281 MeV, 98.6%
Th234
EB1max=0.0758 MeV, 2.0%
EB2max=0.0958 MeV, 6.8%
EB3max=0.0962 MeV, 18.5%
EB4max=0.1886 MeV, 72.5%
0
500
1000
1500
2000
2500
ELECTRON ENERGY (KeV)

Figure 4



PROBABITY DEN.. TY FUNCTION PER KeV
1.00E-2
8.00E-3
6.00E-3
4.00E-3
2.00E-3
0.00E+0
0
500
1000
1500
2000
2500
ELECTRON ENERGY (KeV)
Pa-234M
EB1max=1.236 MeV, 0.74%
EB2max=1.471 MeV, 0.62%
EB3max=2.281 MeV, 98.6%
Th234
EB1max=0.0758 MeV, 2.0%
EB2max=0.0958 MeV, 6.8%
EB3max=0.0962 MeV, 18.5%
EB4max=0.1886 MeV, 72.5%

Summary Sheet of Output Doses (rads) Adjusted to 10^5 Disintegrations

7 mg/cm^2					
geometry	Beta Dose	Conv. Electron	Gamma other than by Pa-234	Pa-234 Gamma only	Total Dose
Infinte, 1/4" thick, contact	1.108E-4 ± 0.88%	1.855E-8 ± 69.22%	5.211E-7 ± 3.89%	2.404E-7 ± 8.47%	1.116E-4 ± 0.88%
Infinite, 1/4" thick, 1 foot of air	8.14E-5 ± 1.15%	0.0	5.982E-7 ± 10.50%	1.679E-7 ± 15.46%	8.217E-5 ± 1.14%
4' x 4' 1/4" thick, contact	1.115E-4 ± 1.49%	4.008E-8 ± 55.14%	5.139E-7 ± 2.73%	2.468E-7 ± 3.62%	1.123E-4 ± 1.48%
4'x4' 1/4" thick, 1 foot of air	6.769E-5 ± 1.24%	0.0	4.414E-7 ± 12.79%	1.675E-7 ± 14.55%	6.830E-5 ± 1.23%
4' x 4' 1" thick, contact	1.137E-4 ± 2.1%	0.0	1.067E-6 ± 8.11%	4.578E-7 ± 15.95%	1.152E-4 ± 2.075%
4'x4' 1" thick, 1 foot of air	6.640E-5 ± 2.28%	0.0	7.220E-7 ± 24.43%	2.850E-7 ± 3.9%	6.744E-5 ± 2.26%

1000 mg/cm^2					
geometry	Beta Dose	Conv. Electron	Gamma other than by Pa-234	Pa-234 Gamma only	Total Dose
Infinte, 1/4" thick, contact	6.379E-7 ± 13.78%	0.0	4.178E-7 ± 5.47%	1.850E-7 ± 9.21%	1.241E-6 ± 7.45%
Infinite 1/4" thick, 1 foot of air	6.075E-7 ± 14.77%	0.0	4.117E-7 ± 8.26%	1.621E-7 ± 12.06%	1.181E-6 ± 8.29%
4' x 4' 1/4" thick, contact	6.847E-7 ± 18.98%	0.0	4.260E-7 ± 2.45%	1.856E-7 ± 5.71%	1.296E-6 ± 10.09%
4'x4' 1/4" thick, 1 foot of air	1.180E-7 ± 27.36%	0.0	1.964E-7 ± 11.19%	7.067E-8 ± 14.96%	3.851E-7 ± 11.84%
4' x 4' 1" thick, contact	8.944E-7 ± 24.66%	0.0	8.350E-7 ± 9.05%	4.098E-7 ± 12.9%	2.139E-6 ± 11.18%
4'x4' 1" thick, 1 foot of air	5.832E-7 ± 29.81%	0.0	5.076E-7 ± 21.48%	1.813E-7 ± 4.69%	1.272E-6 ± 16.14%

RESULT FOR SKIN at CONTACT (NO AIR GAP)

Infinite large Slab Source of 0.635 cm thick (1/4")

RAYLEIGH DATA AVAILABLE FOR MEDIUM 1 BUT OPTION NOT REQUESTED.

RAYLEIGH DATA AVAILABLE FOR MEDIUM 2 BUT OPTION NOT REQUESTED.

EGS SUCCESSFULLY 'HATCHED' FOR 2 MEDIA.

```
*** PRESTA INPUTS ***
IPLC,IBCA,ILCA,IOLDTM,BLCMIN:
0 0 0 0   0.0000
          0          0          0          0   2.395
```

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm

***** PRESTA INPUTS *****

NEW PRESTA PATH-LENGTH CORRECTION USED
BOUNDARY CROSSING ALGORITHM INVOKED
BLCMIN= 2.395
LATERAL CORRELATION ALGORITHM INVOKED
NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm

***** END OF PRESTA INPUTS *****

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO 0.010 MeV KINETIC ENERGY

BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO 0.001 MeV

RESULTS ARE AVERAGED FROM 30 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN EACH BATCH = 100000

← 1.108E-4 compared to 1.07E-4 from VARSKIN MOD2

DOSE AT 7 mg/cm^2 FROM BATA PATICLES=0.1108E-03 +/- 0.88 % rad
DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.6379E-06 +/- 13.78 % rad

DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.1855E-07 +/- 69.22 % rad
DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad

DOSE AT 7 mg/cm^2 FROM GAMMA RAY=0.3982E-06 +/- 15.00 % rad
DOSE at 1000 mg/cm^2 FROM GAMMA RAY=0.4877E-06 +/- 14.28 % rad

TOTAL DOSE AT 7 mg/cm^2 = 0.1112E-03 +/- 0.88 % rad

TOTAL DOSE AT 1000 mg/cm^2 = 0.1126E-05 +/- 9.96 % rad

SOURCE: Infinite slab source of 1"/4 thick contact with skin

***** PRESTA INPUTS *****

NEW PRESTA PATH-LENGTH CORRECTION USED
BOUNDARY CROSSING ALGORITHM INVOKED
BLCMIN= 2.395
LATERAL CORRELATION ALGORITHM INVOKED
NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm

***** END OF PRESTA INPUTS *****

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO 0.010 MeV KINETIC ENERGY
BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO 0.001 MeV

RESULTS ARE AVERAGED FROM 30 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH = 100000

DOSE AT 7 mg/cm^2 FROM ORIGIN GAMMA=0.5211E-06 +/- 4.13 % rad →
DOSE at 1000 mg/cm^2 FROM ORIGIN GAMMA=0.4178E-06 +/- 5.47 % rad

DOSE AT 7 mg/cm^2 FROM PA234 GAMMA=0.2404E-06 +/- 8.47 % rad
DOSE at 1000 mg/cm^2 FROM PA234 GAMMA=0.1850E-06 +/- 9.21 % rad

TOTAL DOSE AT 7 mg/cm^2 = 0.7614E-06 +/- 3.89 % rad → 1.94x10^-7 rad/…

TOTAL DOSE AT 1000 mg/cm^2 = 0.6028E-06 +/- 4.73 % rad → 1.53x10^-7

```
 START TUTOR1

CALL HATCH TO GET CROSS-SECTION DATA

RAYLEIGH DATA AVAILABLE FOR MEDIUM  1 BUT OPTION NOT REQUESTED.

RAYLEIGH DATA AVAILABLE FOR MEDIUM  2 BUT OPTION NOT REQUESTED.

EGS SUCCESSFULLY 'HATCHED' FOR     3 MEDIA.

*** PRESTA INPUTS ***
IPLC,IBCA,ILCA,IOLDTM,BLCMIN:
0 0 0 0   0.0000
           0           0           0           0   2.395

------------------------------------------------------------------

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

                    MEDIUM NO.          t,prime,min for E=Emax
                        1                    0.141E-02 cm
                        2                    0.140E-03 cm
                        3                     1.21     cm
------------------------------------------------------------------


--------------------------------------------------------------------------------
                  ***** PRESTA INPUTS *****
                        NEW PRESTA PATH-LENGTH CORRECTION USED
                        BOUNDARY CROSSING ALGORITHM INVOKED
                        BLCMIN=    2.395
                        LATERAL CORRELATION ALGORITHM INVOKED
                        NEW TMXS CALCULATION USED


PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                    MEDIUM NO.          t,prime,min for E=Emax
                        1                    0.141E-02 cm
                        2                    0.140E-03 cm
                        3                     1.21     cm

                  ***** END OF PRESTA INPUTS *****
--------------------------------------------------------------------------------


KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                          0.010 MeV KINETIC ENERGY
 BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                          0.001 MeV

 RESULTS ARE AVERAGED FROM  30 BATCHES

 NUMBER OF U-238 DISINTEGRATION IN EACH BATCH =   100000

 THE THICHNESS OF SOURCE = 0.6350 cm

 THE AIR GAP BETWEEN SOURCE AND SKIN = 30.48 cm.

 DOSE AT    7 mg/cm^2 FROM BATA PATICLES=0.8150E-04 +/-   1.15 % rad
 DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.6075E-06 +/-  14.77 % rad
```

1 foot of air Gap

Inf. Slab
p.1

```
DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/-  99.90 % rad
DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/-  99.90 % rad

DOSE AT   7 mg/cm^2 FROM GAMMA RAY=0.5231E-06 +/-  14.73 % rad
DOSE at 1000 mg/cm^2 FROM GAMMA RAY=0.3748E-06 +/-  20.33 % rad

TOTAL DOSE AT    7 mg/cm^2 = 0.8202E-04 +/-   1.15 % rad

TOTAL DOSE AT 1000 mg/cm^2 = 0.9824E-06 +/-  11.98 % rad
```

SOURCE: Infinite large slab of 1/4" thick, 1 ft of air gap.   Gamma

---

***** PRESTA INPUTS *****

NEW PRESTA PATH-LENGTH CORRECTION USED
BOUNDARY CROSSING ALGORITHM INVOKED
BLCMIN=   2.395
LATERAL CORRELATION ALGORITHM INVOKED
NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm
3	1.21 cm

***** END OF PRESTA INPUTS *****

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO 0.010 MeV KINETIC ENERGY

BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO 0.001 MeV

RESULTS ARE AVERAGED FROM 10 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH =   100000

DOSE AT   7 mg/cm^2 FROM ORIGIN GAMMA=0.5982E-06 +/- 10.50 % rad → 1.522×10^{-7} rad/h
DOSE at 1000 mg/cm^2 FROM ORIGIN GAMMA=0.4117E-06 +/-   8.26 % rad → 1.048×10^{-7}

DOSE AT   7 mg/cm^2 FROM PA234 GAMMA=0.1679E-06 +/- 15.46 % rad → 4.272×10^{-8}
DOSE at 1000 mg/cm^2 FROM PA234 GAMMA=0.1621E-06 +/- 12.06 % rad → 4.124×10^{-8}

TOTAL DOSE AT   7 mg/cm^2 = 0.7661E-06 +/-   8.87 % rad

TOTAL DOSE AT 1000 mg/cm^2 = 0.5738E-06 +/-   6.84 % rad

CONTACT BOX

"window" Contact

p.1

```
32-bit Power for Lahey Computer Systems
Phar Lap's 386|DOS-Extender(tm) Version 4.1L
Copyright (C) 1986-92 Phar Lap Software, Inc.
Available Memory = 5228 Kb
```

```
INPUT SOURCE THICKNESS,BATCHES,NCASES FOR EACH BATCH,SEED
 START TUTOR1

CALL HATCH TO GET CROSS-SECTION DATA

RAYLEIGH DATA AVAILABLE FOR MEDIUM  1 BUT OPTION NOT REQUESTED.

RAYLEIGH DATA AVAILABLE FOR MEDIUM  2 BUT OPTION NOT REQUESTED.

EGS SUCCESSFULLY 'HATCHED' FOR      2 MEDIA.

*** PRESTA INPUTS ***
IPLC,IBCA,ILCA,IOLDTM,BLCMIN:
0 0 0 0   0.0000
           0           0           0           0   2.395

-----------------------------------------------------------------

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

                    MEDIUM NO.          t,prime,min for E=Emax
                        1                    0.141E-02 cm
                        2                    0.140E-03 cm
-----------------------------------------------------------------


---------------------------------------------------------------------------------
                  ***** PRESTA INPUTS *****
                           NEW PRESTA PATH-LENGTH CORRECTION USED
                           BOUNDARY CROSSING ALGORITHM INVOKED
                           BLCMIN=    2.395
                           LATERAL CORRELATION ALGORITHM INVOKED
                           NEW TMXS CALCULATION USED


PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                    MEDIUM NO.          t,prime,min for E=Emax
                        1                    0.141E-02 cm
                        2                    0.140E-03 cm

                  ***** END OF PRESTA INPUTS *****
---------------------------------------------------------------------------------


KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                         0.010 MeV KINETIC ENERGY
  BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                         0.001 MeV
    1 NEGATIVE USTEP=-.100098E+03 IR,IRNEW,IROLD=   9   4   9X,Y,Z,R=-0.526E-01

  RESULTS ARE AVERAGED FROM  20 BATCHES
```

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH = 100000

DOSE AT 7 mg/cm^2 FROM BATA PATICLES=0.1115E-03 +/- 1.49 % rad → 2.84x10^-5 rad/h
DOSE AT 7 mg/cm^2 FROM BATA BREM PART=0.9187E-06 +/- 17.01 % rad → 2.34x10^-7
DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.6847E-06 +/- 18.98 % rad → 1.74x10^-7
DOSE AT 1000 mg/cm^2 FROM BATA BREM PART=0.6847E-06 +/- 18.98 % rad → "

DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.4008E-07 +/- 55.14 % rad → 1.02x10^-8 rad/h
DOSE AT 7 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad

DOSE AT 7 mg/cm^2 FROM GAMMA RAY=0.5577E-06 +/- 14.70 % rad → 1.42x10^-7 rad/h
DOSE at 1000 mg/cm^2 FROM GAMMA RAY=0.4302E-06 +/- 33.07 % rad → 1.094x10^-7 "

TOTAL DOSE AT 7 mg/cm^2 = 0.1121E-03 +/- 1.49 % rad → 2.85x10^-5 rad/h

TOTAL DOSE AT 1000 mg/cm^2 = 0.1115E-05 +/- 17.28 % rad → 2.84x10^-7 rad/h

SOURCE: 4'X4'X1/4" SLAB SOURCE GAMMA PORTION CONTACT WITH SKIN
Pa-234 GAMMA INCLUDED

***** PRESTA INPUTS *****

NEW PRESTA PATH-LENGTH CORRECTION USED
BOUNDARY CROSSING ALGORITHM INVOKED
BLCMIN= 2.395
LATERAL CORRELATION ALGORITHM INVOKED
NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm

***** END OF PRESTA INPUTS *****

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
0.010 MeV KINETIC ENERGY
BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
0.001 MeV

RESULTS ARE AVERAGED FROM 10 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH = 10000000

DOSE AT 7 mg/cm^2 FROM ORIGIN GAMMA=0.5139E-04 +/- 2.73 % rad →
DOSE at 1000 mg/cm^2 FROM ORIGIN GAMMA=0.4260E-04 +/- 2.45 % rad

DOSE AT 7 mg/cm^2 FROM PA234 GAMMA=0.2486E-04 +/- 3.62 % rad
DOSE at 1000 mg/cm^2 FROM PA234 GAMMA=0.1856E-04 +/- 5.71 % rad

TOTAL DOSE AT 7 mg/cm^2 = 0.7625E-04 +/- 2.19 % rad → 1.94×10^-7 rads/hr

TOTAL DOSE AT 1000 mg/cm^2 = 0.6116E-04 +/- 2.44 % rad → 1.56×10^-7 rads/hr

air Gap BOX

4' x 4' x 0.25"
+ 1 foot air

p.1

```
32-bit Power for Lahey Computer Systems
Phar Lap's 386|DOS-Extender(tm) Version 4.1L
Copyright (C) 1986-92 Phar Lap Software, Inc.
Available Memory = 5192 Kb
```

```
INPUT SOURCE THICKNESS,BATCHES,NCASES FOR EACH BATCH,SEED
 START TUTOR1

CALL HATCH TO GET CROSS-SECTION DATA

RAYLEIGH DATA AVAILABLE FOR MEDIUM  1 BUT OPTION NOT REQUESTED.

RAYLEIGH DATA AVAILABLE FOR MEDIUM  2 BUT OPTION NOT REQUESTED.

EGS SUCCESSFULLY 'HATCHED' FOR     3 MEDIA.

*** PRESTA INPUTS ***
IPLC,IBCA,ILCA,IOLDTM,BLCMIN:
0 0 0 0   0.0000
           0           0           0           0   2.395

-----------------------------------------------------------------

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

                    MEDIUM NO.         t,prime,min for E=Emax
                        1                   0.141E-02 cm
                        2                   0.140E-03 cm
                        3                    1.21     cm
-----------------------------------------------------------------


-------------------------------------------------------------------------------
                   ***** PRESTA INPUTS *****
                             NEW PRESTA PATH-LENGTH CORRECTION USED
                             BOUNDARY CROSSING ALGORITHM INVOKED
                             BLCMIN=    2.395
                             LATERAL CORRELATION ALGORITHM INVOKED
                             NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                    MEDIUM NO.         t,prime,min for E=Emax
                        1                   0.141E-02 cm
                        2                   0.140E-03 cm
                        3                    1.21     cm

                   ***** END OF PRESTA INPUTS *****
-------------------------------------------------------------------------------

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                          0.010 MeV KINETIC ENERGY
  BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                          0.001 MeV
```

p. 2

RESULTS ARE AVERAGEL FROM 20 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH = 100000

DOSE AT 7 mg/cm^2 FROM BATA PATICLES=0.6769E-04 +/- 1.24 % rad → 1.72x10⁻⁵ rad/h
DOSE AT 7 mg/cm^2 FROM BATA BREM PART=0.4330E-06 +/- 20.87 % rad → 1.10x10⁻⁷
DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.1180E-06 +/- 27.36 % rad → 3.00x10⁻⁸
DOSE AT 1000 mg/cm^2 FROM BATA BREM PART=0.1180E-06 +/- 27.36 % rad

DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad
DOSE AT 7 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad

no 234 Pa
DOSE AT 7 mg/cm^2 FROM GAMMA RAY=0.6201E-06 +/- 20.84 % rad → 1.58x10⁻⁷ rad/h
DOSE at 1000 mg/cm^2 FROM GAMMA RAY=0.2892E-06 +/- 22.47 % rad → 7.36x10⁻⁸

TOTAL DOSE AT 7 mg/cm^2 = 0.6831E-04 +/- 1.24 % rad → 1.74x10⁻⁵ rad/h

TOTAL DOSE AT 1000 mg/cm^2 = 0.4073E-06 +/- 17.82 % rad → 1.04x10⁻⁷ rad/h

SOURCE: 4'X4'X1/4" SLAB SOURCE AT ONE FOOT DISTANCE FROM THE SKIN Gamma

---

```
                  ***** PRESTA INPUTS *****
                            NEW PRESTA PATH-LENGTH CORRECTION USED
                            BOUNDARY CROSSING ALGORITHM INVOKED
                            BLCMIN=     2.395
                            LATERAL CORRELATION ALGORITHM INVOKED
                            NEW TMXS CALCULATION USED


PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                    MEDIUM NO.          t,prime,min for E=Emax
                        1                    0.141E-02 cm
                        2                    0.140E-03 cm
                        3                     1.21     cm

                  ***** END OF PRESTA INPUTS *****
```

```
KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                          0.010 MeV KINETIC ENERGY
  BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                          0.001 MeV

  RESULTS ARE AVERAGED FROM  10 BATCHES

  NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH =   100000
  THICKNESS OF THE BOX SLAB SOURCE IS  0.635 cm

  DOSE AT    7 mg/cm^2 FROM ORGIN GAMMA RAY=0.4414E-06 +/-  12.79 % rad
  DOSE at 1000 mg/cm^2 FROM ORGIN GAMMA RAY=0.1964E-06 +/-  11.19 % rad

  DOSE AT    7 mg/cm^2 FROM PA234 GAMMA RAY=0.1675E-06 +/-  14.55 % rad
  DOSE at 1000 mg/cm^2 FROM PA234 GAMMA RAY=0.7067E-07 +/-  14.96 % rad

  TOTAL GAMMA DOSE AT     7 mg/cm^2 = 0.6089E-06 +/-   10.10 % rad → 1.55x10^-7 rads/h

  TOTAL GAMMA DOSE AT 1000 mg/cm^2 = 0.2670E-06 +/-    9.13 % rad → 6.79x10^-8 rads/h
```

```
SOURCE:4'X4'X1" SLAB SOURCE AT CONTACT WITH SKIN (PA-234 GAMMA NOT INCLUDED)
--------------------------------------------------------------------------------
                 ***** PRESTA INPUTS *****
                          NEW PRESTA PATH-LENGTH CORRECTION USED
                          BOUNDARY CROSSING ALGORITHM INVOKED
                          BLCMIN=     2.395
                          LATERAL CORRELATION ALGORITHM INVOKED
                          NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                   MEDIUM NO.          t,prime,min for E=Emax
                       1                    0.141E-02 cm
                       2                    0.140E-03 cm

                 ***** END OF PRESTA INPUTS *****
--------------------------------------------------------------------------------


KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                          0.010 MeV KINETIC ENERGY
  BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                          0.001 MeV

  RESULTS ARE AVERAGED FROM  10 BATCHES

  NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH =    400000
  THE SOURCE IS 4'X4'X1" SLAB

  DOSE AT   7 mg/cm^2 FROM BATA PATICLES=0.1137E-03 +/-   2.10 % rad
  DOSE AT   7 mg/cm^2 FROM BATA BREM PART=0.1586E-05 +/-  15.15 % rad
  DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.8944E-06 +/-  24.66 % rad
  DOSE AT 1000 mg/cm^2 FROM BATA BREM PART=0.8944E-06 +/-  24.66 % rad

  DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/-  99.90 % rad
  DOSE AT 7 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/-  99.90 % rad
  DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/-  99.90 % rad
  DOSE AT 1000 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/-  99.90 % rad

  DOSE AT   7 mg/cm^2 FROM GAMMA RAY=0.7797E-06 +/-  13.46 % rad
  DOSE at 1000 mg/cm^2 FROM GAMMA RAY=0.8672E-06 +/-  24.72 % rad

  TOTAL DOSE AT    7 mg/cm^2 = 0.1145E-03 +/-   2.09 % rad

  TOTAL DOSE AT 1000 mg/cm^2 = 0.1762E-05 +/-  17.46 % rad
```

SOURCE: 4'X4'X1" SLAB, CONTACT   Gamma

```
-------------------------------------------------------------------------------
                ***** PRESTA INPUTS *****
                         NEW PRESTA PATH-LENGTH CORRECTION USED
                         BOUNDARY CROSSING ALGORITHM INVOKED
                         BLCMIN=     2.395
                         LATERAL CORRELATION ALGORITHM INVOKED
                         NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                    MEDIUM NO.          t,prime,min for E=Emax
                        1                       0.141E-02 cm
                        2                       0.140E-03 cm

                ***** END OF PRESTA INPUTS *****
-------------------------------------------------------------------------------


KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO
                                      0.010 MeV KINETIC ENERGY
  BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO
                                      0.001 MeV
  SOURCE: Infinite large slab source of 2.540 cm thick
        at contact with skin.

  RESULTS ARE AVERAGED FROM  10 BATCHES

  NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH =   200000

  DOSE AT    7 mg/cm^2 FROM ORIGIN GAMMA=0.5334E-06 +/-   8.11 % rad
  DOSE at 1000 mg/cm^2 FROM ORIGIN GAMMA=0.4175E-06 +/-   9.05 % rad

  DOSE AT    7 mg/cm^2 FROM PA234 GAMMA=0.2289E-06 +/-  15.95 % rad
  DOSE at 1000 mg/cm^2 FROM PA234 GAMMA=0.2049E-06 +/-  12.90 % rad

  TOTAL DOSE AT     7 mg/cm^2 = 0.7623E-06 +/-   7.43 % rad  → 3.88×10^-7 rads/h

  TOTAL DOSE AT 1000 mg/cm^2 = 0.6224E-06 +/-   7.41 % rad  → 3.17×10^-7
```

Multiply by 2.

SOURCE:4'X4'X1" SLAB SOURCE WITH 1 FOOT OF AIR AT NTP IN BETWEEN THE SKIN

***** PRESTA INPUTS *****

NEW PRESTA PATH-LENGTH CORRECTION USED
BOUNDARY CROSSING ALGORITHM INVOKED
BLCMIN= 2.395
LATERAL CORRELATION ALGORITHM INVOKED
NEW TMXS CALCULATION USED

PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

MEDIUM NO.	t,prime,min for E=Emax
1	0.141E-02 cm
2	0.140E-03 cm
3	1.21 cm

***** END OF PRESTA INPUTS *****

KNOCK-ON ELECTRONS CAN BE CREATED AND ANY ELECTRON FOLLOWED DOWN TO 0.010 MeV KINETIC ENERGY
BREM PHOTONS CAN BE CREATED AND ANY PHOTON FOLLOWED DOWN TO 0.001 MeV

RESULTS ARE AVERAGED FROM 30 BATCHES

NUMBER OF U-238 DISINTEGRATION IN THIS EVALUATION IN ECAH BATCH = 100000

DOSE AT 7 mg/cm^2 FROM BATA PATICLES=0.1660E-04 +/- 2.28 % rad
DOSE AT 7 mg/cm^2 FROM BATA BREM PART=0.2438E-06 +/- 20.82 % rad
DOSE AT 1000 mg/cm^2 FROM BATA PATICLES=0.1458E-06 +/- 29.81 % rad
DOSE AT 1000 mg/cm^2 FROM BATA BREM PART=0.1458E-06 +/- 29.81 % rad

DOSE AT 7 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad
DOSE AT 7 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM CONV ELECTRON=0.0000E+00 +/- 99.90 % rad
DOSE AT 1000 mg/cm^2 FROM C-ELECTRON BREM=0.0000E+00 +/- 99.90 % rad

DOSE AT 7 mg/cm^2 FROM ORGIN GAMMA RAY=0.1805E-06 +/- 24.43 % rad
DOSE at 1000 mg/cm^2 FROM ORGIN GAMMA RAY=0.1269E-06 +/- 21.48 % rad

DOSE AT 7 mg/cm^2 FROM PA234 GAMMA RAY=0.7125E-07 +/- 3.90 % rad
DOSE at 1000 mg/cm^2 FROM PA234 GAMMA RAY=0.4532E-07 +/- 4.69 % rad

TOTAL DOSE AT 7 mg/cm^2 = 0.1686E-04 +/- 2.26 % rad

TOTAL DOSE AT 1000 mg/cm^2 = 0.3181E-06 +/- 16.14 % rad

All value should multiply by 4 before comparing

(4 times thicker)

APPENDIX B

OUTPUT RESULTS FROM

VARSKIN-MOD2

P. 1

Program VARSKIN-MOD2

Cylindrical Source Geometry

Nuclide :	Th-234	
1.8*X90 Distance :	1.998000E-02	cm
Average Beta Energy :	4.760000E-02	MeV
No gamma dose calculation		
Source Strength :	7.093700E-02	uCi/cm^3
Source Density :	8.940000	g/cm^3
Diameter of Disk :	1000000.000000	um
Thickness of Disk :	6350.000000	um
Skin Depth :	7.000000	mg/cm^2
Thickness of Cover :	0.000000E+00	mm
Air Gap Thickness :	0.000000E+00	mm
Irradiation Time :	1.000000	min

1 m in diameter
1/4" thick

no air gap

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	4.43E-05
.1128	0.00E+00
.1596	0.00E+00
.1954	4.42E-05
.2257	4.42E-05
.2523	0.00E+00
.2764	0.00E+00
.2985	0.00E+00
.3192	0.00E+00
.3385	0.00E+00
.3568	0.00E+00
.3742	0.00E+00
.3909	0.00E+00
.4068	0.00E+00
.4222	0.00E+00
.4370	0.00E+00
.4514	0.00E+00
.4652	0.00E+00
.4787	4.41E-05
.4918	4.42E-05
.5046	4.26E-05
.5171	4.42E-05
.5293	0.00E+00
.5412	0.00E+00
.5528	0.00E+00
.5642	0.00E+00

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 1.14E-05 rad/hr
The total beta dose averaged over 1.0000 square cm = 1.90E-07 rad

Program VARSKIN-MOD2

Cylindrical Source Geometry

Nuclide :	Pa-234
1.8*X90 Distance :	8.622000E-01 cm
Average Beta Energy :	8.297000E-01 MeV
No gamma dose calculation	
Source Strength :	7.093700E-02 uCi/cm^3
Source Density :	8.940000 g/cm^3
Diameter of Disk :	1000000.000000 um
Thickness of Disk :	6350.000000 um
Skin Depth :	7.000000 mg/cm^2
Thickness of Cover :	0.000000E+00 mm
Air Gap Thickness :	0.000000E+00 mm
Irradiation Time :	1.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	6.43E-03
.1128	6.43E-03
.1596	6.43E-03
.1954	6.43E-03
.2257	6.44E-03
.2523	6.43E-03
.2764	6.44E-03
.2985	6.43E-03
.3192	6.43E-03
.3385	6.44E-03
.3568	6.43E-03
.3742	6.42E-03
.3909	6.43E-03
.4068	6.43E-03
.4222	6.44E-03
.4370	6.43E-03
.4514	6.43E-03
.4652	6.43E-03
.4787	6.43E-03
.4918	6.43E-03
.5046	6.43E-03
.5171	6.41E-03
.5293	6.40E-03
.5412	6.44E-03
.5528	6.47E-03
.5642	6.43E-03

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 6.39E-03 rad/hr
The total beta dose averaged over 1.0000 square cm = 1.06E-04 rad

Irradiation time = 1.0E+00 min
The beta dose rate for the 2 radionuclides, averaged over
1 square cm, = 6.40E-03 rad/hr → 2.714 x 10^-5 rad/hr

The total beta dose for the 2 radionuclides, averaged over 1 square cm, = 1.07E-04 rad

Program VARSKIN-MOD2

Cylindrical Source Geometry

Nuclide :	Th-234	
1.8*X90 Distance :	1.998000E-02	cm
Average Beta Energy :	4.760000E-02	MeV
No gamma dose calculation		
Source Strength :	7.093700E-02	uCi/cm^3
Source Density :	8.940000	g/cm^3
Diameter of Disk :	1000000.000000	um
Thickness of Disk :	6350.000000	um
Skin Depth :	7.000000	mg/cm^2
Thickness of Cover :	0.000000E+00	mm
Air Gap Thickness :	304.800000	mm
Irradiation Time :	1.000000	min

1 m in diameter
1/4" thick
1 foot of air gap

The beta dose rate averaged over 1.0000 square cm = 0.00E+00 rad/hr
The total beta dose averaged over 1.0000 square cm = 0.00E+00 rad

Program VARSKIN-MOD2

Cylindrical Source Geometry

Nuclide :	Pa-234	
1.8*X90 Distance :	8.622000E-01	cm
Average Beta Energy :	8.297000E-01	MeV
No gamma dose calculation		
Source Strength :	7.093700E-02	uCi/cm^3
Source Density :	8.940000	g/cm^3
Diameter of Disk :	1000000.000000	um
Thickness of Disk :	6350.000000	um
Skin Depth :	7.000000	mg/cm^2
Thickness of Cover :	0.000000E+00	mm
Air Gap Thickness :	304.800000	mm
Irradiation Time :	1.000000	min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	2.82E-03
.1128	2.82E-03
.1596	2.82E-03
.1954	2.82E-03
.2257	2.82E-03
.2523	2.82E-03
.2764	2.82E-03
.2985	2.82E-03
.3192	2.82E-03
.3385	2.82E-03

.3568	2.82E-03
.3742	2.82E-03
.3909	2.82E-03
.4068	2.82E-03
.4222	2.82E-03
.4370	2.82E-03
.4514	2.82E-03
.4652	2.82E-03
.4787	2.82E-03
.4918	2.82E-03
.5046	2.82E-03
.5171	2.82E-03
.5293	2.82E-03
.5412	2.82E-03
.5528	2.82E-03
.5642	2.82E-03

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 2.80E-03 rad/hr
The total beta dose averaged over 1.0000 square cm = 4.66E-05 rad

Irradiation time = 1.0E+00 min
The beta dose rate for the 2 radionuclides, averaged over
1 square cm, = 2.80E-03 rad/hr → 1.19x10⁻³ rad/hr
The total beta dose for the 2 radionuclides, averaged over
1 square cm, = 4.66E-05 rad

p. 1

Program VARSKIN-MOD2

Cylindrical Source Geometry

```
          Nuclide : Pa-234
 1.8*X90 Distance :    8.622000E-01 cm
Average Beta Energy :  8.297000E-01 MeV
     No gamma dose calculation
  Source Strength :    7.093700E-02 uCi/cm^3
   Source Density :        8.940000 g/cm^3
 Diameter of Disk :    1.000000E+07 um
Thickness of Disk :     6350.000000 um
       Skin Depth :        7.000000 mg/cm^2
Thickness of Cover :   0.000000E+00 mm
 Air Gap Thickness :     304.800000 mm
  Irradiation Time :       1.000000 min
```

10 m in diameter

1/4" thick

1 foot of air gap

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	4.50E-03
.1128	4.50E-03
.1596	4.50E-03
.1954	4.50E-03
.2257	4.50E-03
.2523	4.50E-03
.2764	4.50E-03
.2985	4.50E-03
.3192	4.50E-03
.3385	4.50E-03
.3568	4.50E-03
.3742	4.50E-03
.3909	4.50E-03
.4068	4.50E-03
.4222	4.50E-03
.4370	4.50E-03
.4514	4.50E-03
.4652	4.50E-03
.4787	4.50E-03
.4918	4.50E-03
.5046	4.50E-03
.5171	4.50E-03
.5293	4.50E-03
.5412	4.50E-03
.5528	4.50E-03
.5642	4.50E-03

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 4.47E-03 rad/hr
The total beta dose averaged over 1.0000 square cm = 7.45E-05 rad

Program VARSKIN-MOD2

```
     Cylindrical Source Geometry

               Nuclide : Th-234
      1.8*X90 Distance :     1.998000E-02 cm
   Average Beta Energy :     4.760000E-02 MeV
         No gamma dose calculation
       Source Strength :     7.093700E-02 uCi/cm^3
        Source Density :         8.940000 g/cm^3
      Diameter of Disk :     1.000000E+07 um
     Thickness of Disk :      6350.000000 um
            Skin Depth :         7.000000 mg/cm^2
    Thickness of Cover :     0.000000E+00 mm
     Air Gap Thickness :       304.800000 mm
      Irradiation Time :         1.000000 min

The beta dose rate averaged over     1.0000 square cm =   0.00E+00 rad/hr
The total beta dose averaged over     1.0000 square cm =   0.00E+00 rad

Irradiation time =    1.0E+00 min
The beta dose rate for the 2 radionuclides, averaged over
1 square cm, =   4.47E-03 rad/hr → 1.896x10^-5 rads/hr
The total beta dose for the 2 radionuclides, averaged over
   1 square cm, =   7.45E-05 rad
```

Program VARSKIN-MOD2

Cylindrical Source Geometry

Nuclide : Pa-234
1.8*X90 Distance : 8.622000E-01 cm
Average Beta Energy : 8.297000E-01 MeV
No gamma dose calculation
Source Strength : 7.093700E-02 uCi/cm^3
Source Density : 8.940000 g/cm^3
Diameter of Disk : 1.000000E+08 um — 100 m in diameter
Thickness of Disk : 6350.000000 um — 1/4" thick
Skin Depth : 7.000000 mg/cm^2
Thickness of Cover : 0.000000E+00 mm
Air Gap Thickness : 304.800000 mm — 1 foot of air
Irradiation Time : 1.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	4.56E-03
.1128	4.56E-03
.1596	4.56E-03
.1954	4.56E-03
.2257	4.56E-03
.2523	4.56E-03
.2764	4.56E-03
.2985	4.56E-03
.3192	4.56E-03
.3385	4.56E-03
.3568	4.56E-03
.3742	4.56E-03
.3909	4.56E-03
.4068	4.56E-03
.4222	4.56E-03
.4370	4.56E-03
.4514	4.56E-03
.4652	4.56E-03
.4787	4.56E-03
.4918	4.56E-03
.5046	4.56E-03
.5171	4.56E-03
.5293	4.56E-03
.5412	4.56E-03
.5528	4.56E-03
.5642	4.56E-03

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 4.53E-03 rad/hr
The total beta dose averaged over 1.0000 square cm = 7.54E-05 rad

Program VARSKIN-MOD2

Cylindrical Source Geometry

```
           Nuclide : Th-234
   1.8*X90 Distance :     1.998000E-02 cm
 Average Beta Energy :     4.760000E-02 MeV
        No gamma dose calculation
     Source Strength :     7.093700E-02 uCi/cm^3
      Source Density :         8.940000 g/cm^3
    Diameter of Disk :     1.000000E+08 um
   Thickness of Disk :      6350.000000 um
          Skin Depth :         7.000000 mg/cm^2
  Thickness of Cover :     0.000000E+00 mm
   Air Gap Thickness :       304.800000 mm
    Irradiation Time :         1.000000 min

The beta dose rate averaged over      1.0000 square cm =   0.00E+00 rad/hr
The total beta dose averaged over      1.0000 square cm =   0.00E+00 rad

Irradiation time =     1.0E+00 min
The beta dose rate for the 2 radionuclides, averaged over
1 square cm, =    4.53E-03 rad/hr  → 1.9 x 10^-3
The total beta dose for the 2 radionuclides, averaged over
    1 square cm, =    7.54E-05 rad
```

APPENDIX C

OUTPUT RESULTS FROM

MICROSHIELD 3.12

Microshield 3.12
=================
(University of Lowell - #161)

Page : 1
File : NMIINF.MSH
Run date: July 26, 1994
Run time: 4:40 p.m.

File Ref: NMI-1
Date: 7/26/94
By: DEC
Checked: ________

CASE: nmiinfslab

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector........................	X	11.	cm.
Source slab thickness.......................	T1	10.	"
Microshield inserted air gap.................	air	1.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmiinfslab

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8128e-13	Pa-234m	3.0080e-10	Th-234	3.0080e-10
U-238	3.0080e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.660e-03	6.066e-03	1.044e-05
2	1.2794	1.945e-03	5.020e-03	9.149e-06
3	.9668	1.265e-01	2.296e-01	4.461e-04
4	.7573	3.127e-02	4.008e-02	8.140e-05
5	.5449	4.826e-03	3.887e-03	7.992e-06
6	.3706	1.235e-03	5.668e-04	1.166e-06
7	.2884	1.130e-03	3.460e-04	6.915e-07
8	.2240	3.393e-03	6.622e-04	1.258e-06
9	.1567	1.934e-03	1.869e-04	3.258e-07
10	.1187	4.280e-02	1.816e-03	2.878e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.167e-01	2.882e-01	5.615e-04

Microshield 3.12
=================
(University of Lowell - #161)

Page : 1
File : NMICYL.MSH
Run date: July 26, 1994
Run time: 4:13 p.m.

File Ref: NMC-2
Date: 7/26/94
By: RTC
Checked:

CASE: nmicyl1

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	0.636	cm.
Source cylinder radius......................	R	68.8	"
Source cylinder length......................	T1	0.635	"
Thickness of second shield..................	T2	0.001	"

Source Volume: 9442.79 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmicyl1

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 21
Number of radial segments (Nradius)........... **

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.5448e-09	Pa-234m	2.8404e-06	Th-234	2.8404e-06
U-238	2.8404e-06				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.568e+01	2.119e-03	3.648e-06
2	1.2794	1.837e+01	1.881e-03	3.428e-06
3	.9668	1.194e+03	9.127e-02	1.774e-04
4	.7573	2.953e+02	1.708e-02	3.468e-05
5	.5449	4.557e+01	1.807e-03	3.716e-06
6	.3706	1.166e+01	2.937e-04	6.040e-07
7	.2884	1.067e+01	1.949e-04	3.894e-07
8	.2240	3.204e+01	4.130e-04	7.846e-07
9	.1567	1.827e+01	1.366e-04	2.381e-07
10	.1187	4.042e+02	1.579e-03	2.503e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.046e+03	1.168e-01	2.273e-04

Microshield 3.12
=================

(University of Lowell - #161)

Page : 1	File Ref: NMI-3
File : NMICYLAI.MSH	Date: 7/26/94
Run date: July 26, 1994	By: [illegible]
Run time: 4:20 p.m.	Checked:

CASE: nmicylair

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	31.120	cm.
Source cylinder radius......................	R	68.8	"
Source cylinder length......................	T1	0.635	"
Thickness of second shield..................	T2	30.480	"
Microshield inserted air gap................	air	0.005	"

Source Volume: 9442.79 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Air gap
Air		.001220	.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			
Copper	8.940		

CASE: nmicylair

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 21
Number of radial segments (Nradius)........... **

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.5448e-09	Pa-234m	2.8404e-06	Th-234	2.8404e-06
U-238	2.8404e-06				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.568e+01	7.079e-04	1.219e-06
2	1.2794	1.837e+01	6.439e-04	1.174e-06
3	.9668	1.194e+03	3.187e-02	6.194e-05
4	.7573	2.953e+02	6.146e-03	1.248e-05
5	.5449	4.557e+01	6.776e-04	1.393e-06
6	.3706	1.166e+01	1.163e-04	2.392e-07
7	.2884	1.067e+01	8.079e-05	1.615e-07
8	.2240	3.204e+01	1.816e-04	3.451e-07
9	.1567	1.827e+01	6.626e-05	1.155e-07
10	.1187	4.042e+02	8.616e-04	1.366e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.046e+03	4.136e-02	8.043e-05

Microshield 3.12

(University of Lowell - #161)

Page : 1
File : NMICYL2.MSH
Run date: July 26, 1994
Run time: 4:25 p.m.

File Ref: NMI-4
Date: 7/26/94
By: ACC
Checked:

CASE: nmicyl2

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	10.001	cm.
Source cylinder radius......................	R	68.8	"
Source cylinder length......................	T1	10.	"
Thickness of second shield..................	T2	0.001	"

Source Volume: 148705. cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmicyl2

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 21
Number of radial segments (Nradius)........... **

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	7.1572e-08	Pa-234m	4.4731e-05	Th-234	4.4731e-05
U-238	4.4731e-05				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	2.469e+02	5.908e-03	1.017e-05
2	1.2794	2.893e+02	4.890e-03	8.912e-06
3	.9668	1.881e+04	2.236e-01	4.346e-04
4	.7573	4.650e+03	3.905e-02	7.930e-05
5	.5449	7.177e+02	3.787e-03	7.787e-06
6	.3706	1.837e+02	5.523e-04	1.136e-06
7	.2884	1.680e+02	3.372e-04	6.738e-07
8	.2240	5.046e+02	6.453e-04	1.226e-06
9	.1567	2.877e+02	1.821e-04	3.175e-07
10	.1187	6.365e+03	1.770e-03	2.805e-06
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16				
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19				
20				
	TOTALS:	3.222e+04	2.808e-01	5.469e-04

Microshield 3.12
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(University of Lowell - #161)

Page : 1
File : NMIINFCM.MSH
Run date: July 26, 1994
Run time: 7:47 p.m.

File Ref: NMI-5
Date: 7/26/94
By: ntr
Checked: ________

CASE: nmiinfslab1cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector........................	X	12.	cm.
Source slab thickness.......................	T1	10.	"
Thickness of second shield..................	T2	1.	"
Microshield inserted air gap................	air	1.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Air gap
Air			.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			
Copper	8.940		

CASE. nmiinfslab1cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8128e-13	Pa-234m	3.0080e-10	Th-234	3.0080e-10
U-238	3.0080e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.660e-03	5.310e-03	9.140e-06
2	1.2794	1.945e-03	4.340e-03	7.910e-06
3	.9668	1.265e-01	1.964e-01	3.817e-04
4	.7573	3.127e-02	3.382e-02	6.869e-05
5	.5449	4.826e-03	3.220e-03	6.620e-06
6	.3706	1.235e-03	4.587e-04	9.433e-07
7	.2884	1.130e-03	2.752e-04	5.499e-07
8	.2240	3.393e-03	5.175e-04	9.831e-07
9	.1567	1.934e-03	1.429e-04	2.492e-07
10	.1187	4.280e-02	1.360e-03	2.156e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.167e-01	2.459e-01	4.789e-04

Microshield 3.12
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(University of Lowell - #161)

Page : 1
File : NMI1IN.MSH
Run date: July 26, 1994
Run time: 7:52 p.m.

File Ref: NMI-6
Date: 7/26/94
By: RSC
Checked: ______

CASE: nmiinfslab1in

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.........................	X	3.540	cm.
Source slab thickness........................	T1	2.540	"
Microshield inserted air gap.................	air	1.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmiinfslab1in

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8128e-13	Pa-234m	3.0080e-10	Th-234	3.0080e-10
U-238	3.0080e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.660e-03	4.660e-03	8.022e-06
2	1.2794	1.945e-03	4.003e-03	7.296e-06
3	.9668	1.265e-01	1.890e-01	3.673e-04
4	.7573	3.127e-02	3.410e-02	6.925e-05
5	.5449	4.826e-03	3.435e-03	7.062e-06
6	.3706	1.235e-03	5.218e-04	1.073e-06
7	.2884	1.130e-03	3.268e-04	6.530e-07
8	.2240	3.393e-03	6.411e-04	1.218e-06
9	.1567	1.934e-03	1.853e-04	3.230e-07
10	.1187	4.280e-02	1.815e-03	2.877e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.167e-01	2.387e-01	4.650e-04

Microshield 3.12
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(University of Lowell - #161)

Page : 1
File : NMIRECT.MSH
Run date: July 26, 1994
Run time: 8:23 p.m.

File Ref: NMI-7
Date: 7/26/94
By: REC
Checked:

CASE: nmirectslab

GEOMETRY 11: Rectangular solid source - slab shields

Distance to detector........................	X	11.	cm.
Source width................................	W	121.920	"
Source length...............................	L	121.920	"
Rectangular solid, thickness toward dose pt..	T1	10.	"
Microshield inserted air gap................	air	1.	"

Source Volume: 148645. cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmirectslab

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of lateral angle segments (Ntheta).....	21
Number of azimuthal angle segments (Npsi).....	21
Number of radial segments (Nradius)...........	21

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	7.1543e-08	Pa-234m	4.4712e-05	Th-234	4.4712e-05
U-238	4.4712e-05				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	2.468e+02	5.767e-03	9.927e-06
2	1.2794	2.892e+02	4.763e-03	8.681e-06
3	.9668	1.880e+04	2.171e-01	4.220e-04
4	.7573	4.648e+03	3.787e-02	7.691e-05
5	.5449	7.174e+02	3.672e-03	7.549e-06
6	.3706	1.836e+02	5.368e-04	1.104e-06
7	.2884	1.679e+02	3.304e-04	6.603e-07
8	.2240	5.044e+02	6.437e-04	1.223e-06
9	.1567	2.876e+02	1.930e-04	3.365e-07
10	.1187	6.362e+03	2.321e-03	3.679e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	3.221e+04	2.732e-01	5.320e-04

Microshield 3.12
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(University of Lowell - #161)

Page : 1
File : NMIINFFT.MSH
Run date: July 26, 1994
Run time: 9:08 p.m.

File Ref: NMI-8
Date: 7/26/94
By: nec
Checked:

CASE: nmiinfslab1ftair

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector........................	X	40.480	cm.
Source slab thickness.......................	T1	10.	"
Microshield inserted air gap................	air	30.480	"

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmiinfslab1ftair

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8128e-13	Pa-234m	3.0080e-10	Th-234	3.0080e-10
U-238	3.0080e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.660e-03	6.022e-03	1.037e-05
2	1.2794	1.945e-03	4.980e-03	9.076e-06
3	.9668	1.265e-01	2.276e-01	4.424e-04
4	.7573	3.127e-02	3.971e-02	8.064e-05
5	.5449	4.826e-03	3.847e-03	7.909e-06
6	.3706	1.235e-03	5.602e-04	1.152e-06
7	.2884	1.130e-03	3.416e-04	6.827e-07
8	.2240	3.393e-03	6.531e-04	1.241e-06
9	.1567	1.934e-03	1.841e-04	3.209e-07
10	.1187	4.280e-02	1.787e-03	2.832e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.167e-01	2.857e-01	5.566e-04

Microshield 3.12

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(University of Lowell - #161)

Page : 1
File : NMIINF25.MSH
Run date: July 28, 1994
Run time: 4:18 p.m.

File Ref: MMI-9
Date: 7/28/94
By: [illegible]
Checked: ____

CASE: nmiinfslab25

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector........................	X	0.636	cm.
Source slab thickness.......................	T1	0.635	"
Microshield inserted air gap................	air	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmiinfslab25

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8128e-13	Pa-234m	3.0080e-10	Th-234	3.0080e-10
U-238	3.0080e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.660e-03	2.277e-03	3.920e-06
2	1.2794	1.945e-03	2.010e-03	3.663e-06
3	.9668	1.265e-01	9.713e-02	1.887e-04
4	.7573	3.127e-02	1.810e-02	3.676e-05
5	.5449	4.826e-03	1.907e-03	3.921e-06
6	.3706	1.235e-03	3.084e-04	6.342e-07
7	.2884	1.130e-03	2.039e-04	4.075e-07
8	.2240	3.393e-03	4.304e-04	8.176e-07
9	.1567	1.934e-03	1.415e-04	2.466e-07
10	.1187	4.280e-02	1.627e-03	2.579e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.167e-01	1.241e-01	2.417e-04

Microshield 3.12
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(University of Lowell - #161)

Page : 1
File : NMIRECIN.MSH
Run date: July 28, 1994
Run time: 6:02 p.m.

File Ref: NM1-10
Date: 7/28/94
By: [illegible]
Checked: ________

CASE: nmirectslablin

GEOMETRY 11: Rectangular solid source - slab shields

Distance to detector........................	X	3.540	cm.
Source width................................	W	121.920	"
Source length...............................	L	121.920	"
Rectangular solid, thickness toward dose pt..	T1	2.540	"
Microshield inserted air gap................	air	1.	"

Source Volume: 37755.8 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Copper	8.940	

CASE: nmirectslablin

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of lateral angle segments (Ntheta)..... 31
Number of azimuthal angle segments (Npsi)..... 31
Number of radial segments (Nradius)........... 31

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	1.8172e-08	Pa-234m	1.1357e-05	Th-234	1.1357e-05
U-238	1.1357e-05				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	6.268e+01	4.432e-03	7.629e-06
2	1.2794	7.345e+01	3.803e-03	6.932e-06
3	.9668	4.775e+03	1.794e-01	3.485e-04
4	.7573	1.181e+03	3.229e-02	6.559e-05
5	.5449	1.822e+02	3.243e-03	6.667e-06
6	.3706	4.663e+01	4.899e-04	1.008e-06
7	.2884	4.266e+01	3.051e-04	6.098e-07
8	.2240	1.281e+02	5.937e-04	1.128e-06
9	.1567	7.304e+01	1.686e-04	2.940e-07
10	.1187	1.616e+03	1.621e-03	2.570e-06
11				
12				
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14				
15				
16				
17				
18				
19				
20				
	TOTALS:	8.181e+03	2.263e-01	4.410e-04

118323

NMI
NUCLEAR METALS, INC.

06 May 1994

United States Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406-1415

Attention: Mr. Duncan White
Facilities Radiological Safety
and Safeguards Branch
Division of Radiation Safety
and Safeguards

Reference: License No. SMB-179
Docket No. 040-00672
Control No. 118323

Subject: NRC letter dated 11 January 1994,
Unrestricted Disposition of Copper Plates Containing
Depleted Uranium

Dear Mr. White:

In the NRC's letter referenced above, comments and questions in response to NMI's request of 1 July 1993 were broken down into ten sections. In general, these questions requested additional and specific data pertaining to the derivation, makeup, expected use and radiological consequences of the copper electrowon (recovered) from the pickling /etching liquor used to remove copper sheathing from extruded DU rods.

As discussed in our telephone conversation on the week of 11 Feb. 94 (and recounted Wednesday, 04 May 94), this letter is intended to fulfill your need for an interim response to the relevant requests for information based on data currently available. At present, this data is inadequate for the purpose of conclusive characterization of the external dose rate as a function of residual DU content in the electrowon (recovered) copper.

As discussed several times in subsequent telephone conversations, NMI's initial attempt to empirically validate the results of theoretical external dose rate calculations was incomplete. Due to an experimental setup flaw (the DU concentration in the demonstration copper plates was improperly characterized),

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2229 Main Street, Concord, Massachusetts 01742 (508) 369-5410

MAY 18 1994

quantitative correlation of the observed dosimetry results with expectation values was inconsistent. In order to obtain the additional data required, and to verify/validate the original theoretical dose calculations, an alternative approach is being developed. Due to schedular constraints (and the physical limitations of the approach), it is unlikely that the empirical assessment will be finished until late July 94.

As specified in the original application, NMI's approach to release of the electrowon copper product would be to implement control procedures to assure that:

- average batch concentrations do not exceed 300 ppm.
- average lot concentrations do not exceed 100 ppm.
- any material exceeding these (and any other applicable) criteria does not escape the control of NMI, and is properly dispositioned, retained, or in some way recycled.

The anticipated empirical and theoretical assessments are intended to provide data which would support quantitative assessment of the radiological impact of operations yielding copper contaminated at these levels.

Free release criteria should be based on the concentration in the product, and should not be relevant to the source of the copper product (i.e. how it was produced). It is assumed that any relevant dose or risk-based criterion is directly related to the activity concentration. A product-based licensing criterion is important to NMI because it may be possible to optimize or change the recovery/production process or equipment to yield purer copper, or reduce the cost of the recovery operation. To that end, NMI intends to focus (with your agreement) on the QA/QC, sampling and survey techniques to be applied to ensure that the copper product meets or exceeds (activity concentration lower than) the release criteria, once established and approved.

Note that the scope of this request applies specifically to NMI's Massachusetts licensed facility; any proposed/potential activities at CMI would be addressed separately, through the Agreement State of SC (and any additional regulatory authorities, as applicable).

With respect to the letter referenced above, the following paragraphs recap the remaining requests for information:

Item 2 addresses an alternate source for the copper product. Although the recovery option of basin materials has NOT been selected, it is still considered a viable option. Should the option to recover copper and DU from the basin sludge become economically

or environmentally desirable, NMI would expect that the same criteria for free release would be applied, based on the consideration that the radiological consequences of such an operation would be identical to those of the electrowinning process. As discussed earlier, the release criteria should remain the principle focus (and QA/QC procedural controls to provide assurance that the product meets these criteria), based on dose equivalent (or potential dose equivalent), and the precepts of ALARA. In this framework, the source of the material becomes irrelevant (except where the total quantity or magnitude of the source term poses a significant change in the assessed risk).

Item 3 requests information regarding the derivation or production process for the copper product (such as a process diagram, and descriptions of facilities and equipment to be used), and the resultant waste streams (and how they are handled). While this information can be compiled, NMI is currently focussing on the output end of the process, as discussed in our telephone conversations and outlined in the first sections of this letter. A description of the current production process will be provided with NMI's summary evaluation of the characterization data being obtained.

Item 4 requests information regarding entrapment of DU in the cathode surface, and distribution within the copper plates. At present, there is inadequate data to characterize entrapment/ entrainment as a function of surface formations (whether nodular, smooth, or dendritic). Some literature exists referencing the selective distribution of non-radiological contaminants, but it is expected that survey and sampling techniques, combined with administrative and procedural controls will concentrate on negating the significance of any preferential distribution processes. Whatever the surface appearance or shape, the resultant activity concentration in the product copper dominates any radiological consequence considerations. The experimental data already obtained, and that still to be collected, will also be used in characterizing the variability of the DU concentration in the plates, to allow development of appropriate sampling and survey techniques.

Item 5 also requests information regarding the distribution of DU in the copper product (maximum average concentration per lot, per batch, etc.), and will be addressed with the experimental data collected. Preliminary data (from long-exposure TLDs) shows the distribution within a given plate to vary significantly, but within reasonable bounds.

Item 6 will be addressed by summarizing and presenting the results of the experiment(s), when completed.

Item 7 requests information regarding the sampling and analytical techniques, minimum detection limit (mdl) for the analytical instruments to be used (for each radiation), and for a procedural description of applicable action levels, triggers, and resulting actions. After adequate empirical data has been collected, NMI will be able to set up (and describe) appropriate sampling, analysis, and survey procedures.

Item 8 requests descriptive information regarding the applicable QA department procedure(s), including any independent measurements to be made (validation / verification), and the basis or rational for statistical sampling. Upon collection and evaluation of the empirical data describing the distribution of activity within the plates, NMI will be able to refine the statistical sampling procedure, and determine the appropriate analytical techniques and survey instrumentation required.

Item 9 requests information on the fate of the product, after release from NMI. It is expected that the predominant commercial use for the product will be as partial fill material for smelting, in the production of ingots (which will subsequently be rolled into sheet, extruded into wire, etc.). However, smaller-quantity commercial and/or private uses are also envisioned. NMI's objective is to obtain licensing to implement recovery and procedural release controls that will allow "free release" of the product material. Any beneficial use (or reuse) of the material would be allowed. A discussion of the potential hazards arising from candidate / likely uses (such as smelting) will be presented with the summary evaluation.

It is expected that NMI's summary data will be available by 15 August 94 to provide adequate characterization of the product material, and the potential hazards of its reuse.

Sincerely,

Eric B. Andersen
Staff Health Physicist

* Item 1 (Am-241 broken out separately...) and item 10 (submit application for withholding and an affidavit as per 10 CFR 2.790(b)(1)) have been previously addressed, and are not referenced in this letter.

CC: F. J. Vumbaco
Vice-President, Health and Safety

NMI

MS 20

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

APR 2 9 1994

SMB-179
040-00672

MEMORANDUM FOR: Ronald R. Bellamy, Chief
Nuclear Material Safety and Safeguards Branch
Division of Radiation Safety and Safeguards
Region I

FROM: Frederick C. Combs, Chief
Operations Branch
Division of Industrial and
Medical Nuclear Safety, NMSS

SUBJECT: TECHNICAL ASSISTANCE REQUEST DATED JANUARY 21, 1994
REGARDING THE REQUEST BY NUCLEAR METALS INC TO
RELEASE COPPER SHEET CONTAMINATED WITH DEPLETED
URANIUM FOR UNRESTRICTED USE

This is in response to your Technical Assistance Request (TAR) (enclosed) dated January 21, 1994, regarding the request by Nuclear Metals, Inc. (NMI) to release for unrestricted use copper sheets contaminated with small amounts of depleted uranium (DU). According to the licensee's data, the copper is recovered from a sulphuric acid solution by electroplating on a metal cathode. The acid solution is used to remove a thin surface layer of copper from extruded uranium rods, and the copper, as well as the DU, enter the solution at that point. The uranium contamination is incorporated into the recovered copper during electroplating by entrapment of small uranium-bearing droplets of solution. The recovered copper is produced in the form of 2' square sheets, 1/8" thick, and the licensee's analysis showed that the concentration of DU in the copper from different recovery runs varied over the range of 6 to 281 parts DU per million parts copper by weight (ppm), with an average of about 60 ppm. The licensee also stated that, due to the nature of their smelting operations, the DU incorporated into the copper is initially free of decay products. The licensee requested amendment of their license to permit release of the copper sheet for unrestricted use. The DU concentration per lot to be released would average about 100 ppm, with the maximum concentration in any recovery run being 300 ppm. The quantity of copper to be released is estimated at 52,000 pounds annually. Sheets with removable surface contamination greater than 1000 dpm alpha/100 cm^2 would not be released.

We have reviewed the licensee's request, as well as their radiological impact calculations, and have concluded that the request cannot be approved in its current form. Our analysis shows that the doses from handling the sheet during production and fabrication will be quite small, of the order of 10 mrem/yr skin dose and a much smaller penetrating dose. The low doses result from the low dose rates from the sheet, as well as limited contact time with the copper, assumed in this analysis to be a few hours per week. However, in

118323

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a worst case scenario, the copper sheet would be used to make an ornamental object, such as a bracelet, that would be worn continuously. Such an object would most likely be made of a copper alloy, such as brass, which would contain approximately 70 percent by weight copper. The dose rate in this case would be of the order of 60 μrem/hr to the skin, the corresponding penetrating dose being of the order of a few μrem/hr. The annual dose would be about 530 mrem skin and about 1 mrem penetrating. Other assumptions regarding contact time may be viewed as more reasonable than constant contact. However, in view of the fact that wearing jewelry continuously is not an unusual custom, this assumption appears to be justified when examining a worst case scenario. The calculations assumed an ingrowth to equilibrium of the shorter lived decay products of DU, including thorium-234, protactinium-234m, protactinium-234, and uranium-234. Decay products beyond uranium-234 will not make significant contributions in the time span of interest in this situation. Ingrowth of the significant dose contributors to equilibrium would occur within about four months of isolation of the DU. DU concentrations of 300 ppm were used, and the calculations were performed using the computer code MICROSHIELD for the gamma component of the dose and VARSKIN for the beta component.

In an attempt to put the above doses in perspective relative to current contamination control practices, the criteria for the release for unrestricted use of decontaminated items were used for comparison. The criterion traditionally used for releasing decontaminated equipment for unrestricted use is 5000 dpm/100 cm^2 for uranium contamination. Assuming this contamination to be on the surface of the article, the corresponding skin dose rate assuming constant contact is about 1500 mrem/yr. However, this release criterion does not assume constant contact, and the dose rate that would result from unrestricted use of such items would be expected to be substantially lower than that value. The calculated skin dose of 530 mrem/yr is therefore high when compared to this release criterion, and may be considered unacceptable. You should therefore discuss with the licensee the possibility of controlling their electrowinning process to ensure much lower maximum DU concentrations than 300 ppm, which may serve as a more acceptable basis for granting the licensee's request. Alternatively, the licensee may be permitted to release the copper sheet containing the higher DU concentrations of up to 300 ppm, but only for uses that would preclude direct contact with the public.

You should therefore consider this response as a denial of the amendment request pending review with the licensee of the possible options discussed above, or others of a similar nature. The results of these discussions, as well as any additional information that the licensee may provide on this matter, should be resubmitted to us for review. We would also like to alert you to the fact that there is precedent for denial of a similar request by the Commission several years ago. The denial was based not only on dose considerations, but also on concern with the possibility of contaminating the general metal supply, thereby creating possible problems for industries that require clean materials for their products, such as the photographic industry and manufacturers of high sensitivity radiation measuring devices and microelectronic components. An additional concern identified in connection with this case was that smelting of DU-contaminated copper tends to concentrate the DU in the slag, and handling and disposal of this slag may also need special attention. In view of these considerations, reaching a

decision in this matter following discussions with the licensee may take a long time, and the licensee should be informed of a probable long delay in arriving at a decision regarding their amendment request.

Regarding your intent to prepare an Environmental Assessment (EA) for renewal 2of the license, your TAR and attached documentation did not provide the reasons for taking this action. We therefore request that, in parallel with negotiations with the licensee regarding our response to this TAR, you provide us with some detail regarding this matter.

Should you need further information regarding this matter, please contact Sami Sherbini of my staff at (301) 504-3680.

Frederick C. Combs, Chief
Operations Branch
Division of Industrial and
Medical Nuclear Safety, NMSS

Enclosure: As stated

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
475 ALLENDALE ROAD
KING OF PRUSSIA, PENNSYLVANIA 19406-1415

January 21, 1994

License No. SMB-179
Docket No. 040-00672
Control No. 118323

MEMORANDUM FOR: Carl J. Paperiello, Director
Division of Industrial and Medical Nuclear Safety, NMSS

FROM: Charles W. Hehl, Director
Division of Radiation Safety and Safeguards, RI

SUBJECT: TECHNICAL ASSISTANCE REQUEST: REVIEW OF NUCLEAR METALS INC. REQUEST FOR UNRESTRICTED DISPOSITION OF COPPER

In an application dated July 1, 1993, Nuclear Metals, Inc (NMI) requests approval under 10 CFR 20.302(a) for the unrestricted disposition of copper containing up to 100 parts per million (ppm) by weight of depleted uranium (DU) on the average in each lot and up to 300 ppm maximum DU on average in any particular recovery batch of copper. These values correspond to about 30 and 90 picocuries of DU per gram of copper, respectively. The copper is extracted from an acid pickling solution as copper plates using an electrowinning process. The extraction is part of the recycling process for this pickling solution. The licensee has about 10,000 kilograms (22,000 pounds) of copper in inventory at this time and expects to generate between 12,700 and 23,600 kilograms (28,000 to 52,000 pounds) per year, as a result of normal operations. The licensee calculated the radiation dose from the residual DU in the copper using VARSKIN and MICROSHIELD methodologies and concluded that the dose to members of the general public from the released copper will meet applicable limits. Copies of the licensee's application and our first letter to the licensee regarding the application are enclosed.

While not specifically mentioned in the July 1, 1993 request, the submission of the proposal to release copper containing DU which is generated during normal operations is an important milestone towards the remediation of the holding basin at the licensee's facility. The holding basin containing DU and copper is the reason the site is listed in the Site Decommissioning Management Plan (SDMP). The licensee has indicated in separate correspondence (June 30, 1993 letter, copy enclosed) it intends to pursue recycling DU and copper removed from the holding basin instead of the commercial burial of these materials as radioactive waste. While the licensee's present proposal to release the copper does not provide sufficient information to allow approval, a decision on the request is important both to the continued operation of the NMI plant and to our efforts to motivate the licensee to develop and implement a remediation plan for the holding basin. The effect on the holding basin remediation arises from the fact that our action on this request will likely have a significant effect on a future

request for authorization to release copper recycled from the holding basin, whether that request is made to the NRC or the State of South Carolina. Therefore, we would appreciate your prompt review of and comments on the application and our letter to the licensee.

Also, we need guidance on whether an Environmental Assessment (EA), a Commission Paper and/or a Federal Register Notice will be necessary. While we believe the categorical exclusions in 10 CFR 51.22(c)(xiii) and (xv) might apply, it is not clear that they were intended to cover such a situation. Also, we have previously notified the licensee that we intend to prepare an EA for the renewal of its licenses, notwithstanding these categorical exclusions. Our rationale for the EA is described in our letter to NMI dated October 6, 1992 (copy enclosed). We will shortly provide you the licensee's Environmental Report and request assistance in preparing that EA.

Charles W. Hehl, Director
Division of Radiation Safety
and Safeguards

Enclosures:
1. Letter and Application from NMI, dated July 1, 1993
2. Letter from Region I to NMI, dated January 11, 1994
3. Letter from NMI to Region I, dated June 30, 1993
4. Letter from Region I to NMI, dated October 6, 1992

TELEPHONE CONVERSATON RECORD	Date: 2/22/94	Time: 9:00 am
Mail Control No.: 118323	**License :** SMB-179	**Docket No.:** 040-00672
Person Called: Eric Anderson	**Organization:** Nuclear Metals	**Telephone Number:** (508) 369-5410

Person Calling: Duncan White

Subject: Licensing Actions

Summary: The following licensing actions were dicsussed:

1. The licensee will add interim waste storage to their license through the renewal process.
2. Region I will require a letter to extent the deadline for responding to the deficiency letter for the renewal.
3. Region I will issue the amendment for adding the Am-241 to the license within the next two weeks.
4. Copper recycling status:
   a. NMI is working with Dr. French at Lowell to evaluate the copper plate data and the TLD data.
   b. The data presented to date by NMI is based on 2 plates out of a batch of 44 plates. According to Mr. Anderson, the basis for this sampling size is not clear.
   c. The copper sold by the licensee would have to be melted down to be used.
   d. Uranium progeny concentrates in the slag. The licensee did not know if the uranium also concentrated in the slag.
   e. The licensee could not provide a clear answer, at this time, concerning the distribution of the DU in the copper.

Action Required/Taken: none, additional information

Signature: Duncan White DW	**Date:** March 7, 1994

OFFICIAL RECORD COPY ML 10

TELEPHONE CONVERSATON RECORD	Date: 2/10/94	Time: 11:00 AM
Mail Control No.: 118323	**License :** SMB-179	**Docket No.:** 040-00672
Person Called: Eric Anderson	**Organization:** Nuclear Metals	**Telephone Number:** (617) 369-5410
Person Calling: Duncan White		
Subject: Status of Copper Recycling Response		

Summary: The following items were discussed. Mr. Anderson will call next week to detail which items in the deficiency letter that NMI will respond to in the short term and which items will require an extension.

1. There has been problems with the experiments with the TLDs and the plates. The TLDs were not placed at the highest concentration of DU on the copper plates. The TLDs were placed in areas with lower DU activity and non representative of the DU distribution. This will probably require the experiment to be redone.
2. I stated that the NRC is not evaluating the amendment request in terms of distinguishing the source of the DU/copper mix (i.e. holding basin versus operational materials). NRC is concerned that the copper will be released to minimize dose the public.
3. The licensee asked what type of worst case should they consider in order to respond to question #9. I stated that the exposure scenario should be credible but conservative. Mr. Anderson stated that the distribution of DU in the copper plates is uniform. He also indicated that uranium progeny concentrates in the slag during copper smelting processes. The fate of the uranium was not known.
4. The licensee asked about the licensing aspects of the amendment since some of the process for the recycling will be done at Carolina Metals in South Carolina, an Agreement State. I stated that it was NMI responsibility to make any necessary changes to their SC license regarding this process. In response to the licensee's question about coordination, I indicated that the NRC and the States have cooperated in the past if the Agreement State asks.

Action Required/Taken: none at this time, more conversations to follow

Signature: Duncan White	**Date:** February 11, 1994

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
475 ALLENDALE ROAD
KING OF PRUSSIA, PENNSYLVANIA 19406-1415

January 21, 1994

License No. SMB-179
Docket No. 040-00672
Control No. 118323

MEMORANDUM FOR: Carl J. Paperiello, Director
Division of Industrial and Medical Nuclear Safety, NMSS

FROM: Charles W. Hehl, Director
Division of Radiation Safety and Safeguards, RI

SUBJECT: TECHNICAL ASSISTANCE REQUEST: REVIEW OF NUCLEAR METALS INC. REQUEST FOR UNRESTRICTED DISPOSITION OF COPPER

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January 21, 1994

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Division of Industrial and Medical Nuclear Safety, NMSS

FROM: Charles W. Hehl, Director
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Charles W. Hehl, Director
Division of Radiation Safety
and Safeguards

Enclosures:
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JAN 1 1 1994

License No. SMB-179
Docket No. 040-00672
Control No. 118323

Nuclear Metals Inc.
ATTN: Frank J. Vumbaco
Vice President, Health and Safety
2229 Main Street
Concord, Massachusetts 01742

Dear Mr. Vumbaco:

SUBJECT: Unrestricted Disposition of Copper Plates Containing Depleted Uranium

This letter is in reference your letter and application dated July 1, 1993. In order for us to complete our review of this report, we need the following information:

1. The review of your request for the unrestricted deposition of copper will take some time to complete. We will separate your request for Americium-241 (Am-241) in reference standards from the copper recycling request and process them as separate amendment actions.

2. Your request for the unrestricted disposition of copper plates containing depleted uranium (DU) appears to apply only to material currently being processed. In your June 30, 1993 letter to the NRC, you state that Nuclear Metals, Inc. (NMI) has selected the recovery option for remediation of the holding basin. This letter also states that holding basin recycling equipment will be installed at Carolina Metals, Inc. (CMI). Please state whether the process for the generation and disposition of copper described in this amendment request is also intended for the recovery of uranium and copper in the holding basin and whether you intend to use the same limits for unrestricted disposition of copper in that process. If you intend to make a separate application to the State of North Carolina for the unrestricted release of copper generated from the remediation of the holding basin, please make a statement to that effect.

3. Please provide a more detailed description of the process used to separate the copper. Your response should include, at a minimum, a description of the facilities and equipment to be used, a diagram of the process, the types of waste streams that are generated and how they are handled, and the control of non-radiological hazardous materials that could effect the safe handling of licensed material. If you intend this application to apply to material from the holding basin, your discussion of the process should begin at the holding basin and indicate which steps take place at NMI and at CMI.

4. Your application states that the uranium bearing electrolyte is mechanically entrapped because of the irregular, nodular, character of the cathode surface. It is not clear from your application if the distribution of the uranium in the copper is uniform or is biased to particular areas of the copper plate due the deposition process. Please provide a description of the size and weight, including variations, of each plate and the pattern of uranium deposition in the copper plate.

5. Your application requests approval for the unrestricted disposition of reclaimed copper containing DU in concentrations up to 100 parts per million (ppm) by weight on average in each lot and up to 300 ppm maximum on average in any particular recovery batch. It appears from our review that this maximum average concentration will allow localized concentrations greater than 300 ppm DU in individual plates. Please revise your proposed release criteria to 1) specify what constitutes a recovery batch and a lot; 2, incorporate a maximum DU concentration in copper for any measurement that can not be exceeded; and 3) describe your methodology for determining if a recovery batch and lot meet the proposed release criteria.

6. In section 5.4, your application indicates that you are making additional measurements to verify the radiation levels from copper containing uranium. Please provide the results for this evaluation. Your response should include a description of the measurements made, the instrumentation utilized and the calibration of the instruments.

7. In Section 3.4 of your application, you indicate that the surfaces of the copper plates will be surveyed for removable surface contamination prior to release for unrestricted use. In Section 3.3 of your application, you indicate that two plates from each run will be sampled and analyzed for uranium concentration. Please describe your sampling and analytical procedures for both of these surveys. Your response should include the survey of all plates, instrumentation and its minimum detection limits for each radiation present, survey procedures, trigger levels, and actions taken if the DU concentrations in a copper plate or batch exceeds criteria for unrestricted release.

8. In Section 3.3 of your application, you indicate that the Quality Assurance Department will make the measurements to verify that the copper meets the proposed release criteria using a written procedure. We assume these are instruments in addition to those made to release the copper for unrestricted use, to assure the accuracy of the original measurements. Please clearly describe your procedures for releasing the plates, including your quality assurance program. The quality assurance program should include, at a minimum, 1) independent measurements to verify the uranium concentration in the copper plates; 2) confirmation of the uranium deposition pattern in the copper plate; and 3) a statistical basis for number of copper plates to be examined for quality assurance purposes.

9. The dosimetry described in Section 5 of your application appears to assume that the uranium concentration in the copper remains the same as when released by NMI. Since Section 4 of your application states that the sale to a copper smelter is likely, what evidence do you have that this is the worst case? Will smelting result in more or less uniform distribution or will the uranium separate from the copper into the slag or dross?

10. Your letters dated June 30, 1993 and July 1, 1993 states that the process description of the reclamation of the copper and the amount reclaimed is considered competition sensitive and requests that the NRC treat this information as company Proprietary. In order for us to consider withholding this information from public disclosure, you must submit an application for withholding and an affidavit as described in 10 CFR 2.790(b)(1).

Please respond in duplicate to my attention at the Region I office. Refer to Mail Control No. 118323 in your response. We request that you submit this information within thirty days of the date of this letter.

If you have any questions regarding this request, please contact me at (610) 337-5042. Thank you for your cooperation in this matter.

Sincerely,

Original Signed By:
Duncan White

Duncan White
Facilities Radiological Safety
and Safeguards Branch
Division of Radiation Safety
and Safeguards

cc:
Commonwealth of Massachusetts
Department of the Attorney General
ATTN: Betsy Harper
Assistant Attorney General
Environmental Protection Division
One Ashburton Place
Boston, Massachusetts 02108

Commonwealth of Massachusetts
Department of Environmental Protection
ATTN: Rodene A. DeRice
Environmental Analyst
10 Commerce Way
Woburn, Massachusetts 01801

Commonwealth of Massachusetts
Department of Health
ATTN: Robert Hallisey
Director
Radiation Protection Program
150 Tremont Street
Boston, Massachusetts 02111

Concord Free Public Library
ATTN: Ray Gerke
129 Main Street
Concord, Massachusetts 01742

bcc:
Region I Docket Room (w/enclosures)
J. Kinneman, RI
D. White, RI

RI:DRSS	RI:DRSS
White/cmm	Kinneman
01/6/94	01/6/94

NUCLEAR METALS, INC.

1 July 1993

United States Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406

040-00672

Attn: Mr. John Kinneman, Chief
Research, Development and Decommissioning Section

Re: Materials License SMB-179 (Docket 040-00672)

Dear Mr. Kinneman:

Please find the enclosed two copies of our NRC Form 313 application for amendment to Materials License SMB-179 (Docket 040-00672). The requested amendment includes:

(1) Per 10 CFR 20.302 (a), NMI requests authorization for unrestricted disposition of electrowon copper produced at NMI. This amendment request is explained in more detail in the enclosed License Amendment Application for Disposition of Electrowon Copper. NMI requests that the process description of reclamation of the copper and the amount reclaimed be withheld from public disclosure per 10 CFR 9.17 (a) (4) because this information is held in commercial confidence by NMI.

119160

(2) NMI requests authorization to receive Am-241 contained in air filters as part of an ongoing series of Air Filter Intercomparison Studies conducted by the US Environmental Protection Agency. Each filter contains less than 600 picocuries of total activity (a combination of Am-241, Cs-137 and Sr-90), three filters are provided per study and two studies are conducted per year.

Also enclosed is the appropriate amendment application fee of four hundred eighty dollars ($480) per 10 CFR 170.31 for a Category 2C Materials License.

Thank you for your attention to this letter. If there are any questions regarding the enclosed, please contact Frank J. Vumbaco at (508) 369-5410 x385.

Sincerely,

Tony Carpenito

Tony Carpenito
Supervisor, Health Physics

9408290385 930701
PDR ADOCK 04000672
C PDR

TC/ltr/usnrc.071

Enclosures

cc: F. J. Vumbaco, Manager, Health/Safety, RSO
Henry Morton, Morton Associates, Potomac MD

118323

JUL 06 1993

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OFFICIAL RECORD COPY ML 10

2229 Main Street, Concord, Massachusetts 01742 (508) 369-5410

License Fee Information
on Appl dtd 7/1/93

NRC FORM 313 (3-92) 10 CFR 30, 32, 33, 34, 35 and 40

U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB: NO. 3150-0120
EXPIRES 6-30-93

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 3.25 HOURS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0120), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

APPLICATION FOR MATERIAL LICENSE

INSTRUCTIONS: SEE THE APPROPRIATE LICENSE APPLICATION GUIDE FOR DETAILED INSTRUCTIONS FOR COMPLETING APPLICATION. SEND TWO COPIES OF THE ENTIRE COMPLETED APPLICATION TO THE NRC OFFICE SPECIFIED BELOW.

APPLICATION FOR DISTRIBUTION OF EXEMPT PRODUCTS FILE APPLICATIONS WITH:

DIVISION OF INDUSTRIAL AND MEDICAL NUCLEAR SAFETY
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555

ALL OTHER PERSONS FILE APPLICATIONS AS FOLLOWS:

IF YOU ARE LOCATED IN:

CONNECTICUT, DELAWARE, DISTRICT OF COLUMBIA, MAINE, MARYLAND, MASSACHUSETTS, NEW HAMPSHIRE, NEW JERSEY, NEW YORK, PENNSYLVANIA, RHODE ISLAND, OR VERMONT, SEND APPLICATIONS TO:

LICENSING ASSISTANT SECTION
NUCLEAR MATERIALS SAFETY BRANCH
U.S. NUCLEAR REGULATORY COMMISSION, REGION I
475 ALLENDALE ROAD
KING OF PRUSSIA, PA 19406-1415

ALABAMA, FLORIDA, GEORGIA, KENTUCKY, MISSISSIPPI, NORTH CAROLINA, PUERTO RICO, SOUTH CAROLINA, TENNESSEE, VIRGINIA, VIRGIN ISLANDS, OR WEST VIRGINIA, SEND APPLICATIONS TO:

NUCLEAR MATERIALS SAFETY SECTION
U.S. NUCLEAR REGULATORY COMMISSION, REGION II
101 MARIETTA STREET, NW, SUITE 2900
ATLANTA, GA 30323

IF YOU ARE LOCATED IN:

ILLINOIS, INDIANA, IOWA, MICHIGAN, MINNESOTA, MISSOURI, OHIO, OR WISCONSIN, SEND APPLICATIONS TO:

MATERIALS LICENSING SECTION
U.S. NUCLEAR REGULATORY COMMISSION, REGION III
799 ROOSEVELT ROAD
GLEN ELLYN, IL 60137

ARKANSAS, COLORADO, IDAHO, KANSAS, LOUISIANA, MONTANA, NEBRASKA, NEW MEXICO, NORTH DAKOTA, OKLAHOMA, SOUTH DAKOTA, TEXAS, UTAH, OR WYOMING, SEND APPLICATIONS TO:

MATERIAL RADIATION PROTECTION SECTION
U.S. NUCLEAR REGULATORY COMMISSION, REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TX 76011-8064

ALASKA, ARIZONA, CALIFORNIA, HAWAII, NEVEDA, OREGON, WASHINGTON, AND U.S. TERRITORIES AND POSSESSIONS IN THE PACIFIC, SEND APPLICATIONS TO:

NUCLEAR MATERIALS SAFETY SECTION
U.S. NUCLEAR REGULATORY COMMISSION, REGION V
1450 MARIA LANE
WALNUT CREEK, CA 94596-5368

040-00672

PERSONS LOCATED IN AGREEMENT STATES SEND APPLICATIONS TO THE U.S. NUCLEAR REGULATORY COMMISSION ONLY IF THEY WISH TO POSSESS AND USE LICENSED MATERIAL IN STATES SUBJECT TO U.S. NUCLEAR REGULATORY COMMISSION JURISDICTIONS.

1. THIS IS AN APPLICATION FOR (Check appropriate item)
- A. NEW LICENSE
- X B. AMENDMENT TO LICENSE NUMBER SMB-179
- C. RENEWAL OF LICENSE NUMBER

2. NAME AND MAILING ADDRESS OF APPLICANT (Include Zip Code)

Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742

3. ADDRESS(ES) WHERE LICENSED MATERIAL WILL BE USED OR POSSESSED

2229 Main Street
Concord, Massachusetts 01742

4. NAME OF PERSON TO BE CONTACTED ABOUT THIS APPLICATION: Frank J. Vumbaco, Manager, Health/Safety

TELEPHONE NUMBER: (508) 369-5410 x385

SUBMIT ITEMS 5 THROUGH 11 ON 8½ x 11" PAPER. THE TYPE AND SCOPE OF INFORMATION TO BE PROVIDED IS DESCRIBED IN THE LICENSE APPLICATION GUIDE.

5. RADIOACTIVE MATERIAL
a. Element and mass number; b. chemical and/or physical form; and c. maximum amount which will be possessed at any one time.

6. PURPOSE(S) FOR WHICH LICENSED MATERIAL WILL BE USED.

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING AND EXPERIENCE.

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTRED AREAS.

9. FACILITIES AND EQUIPMENT.

10. RADIATION SAFETY PROGRAM.

11. WASTE MANAGEMENT.

12. LICENSEE FEES (See 10 CFR 170 and Section 170.31)
FEE CATEGORY 2C — AMOUNT ENCLOSED $ 480.00

13. CERTIFICATION. (Must be completed by applicant) THE APPLICANT UNDERSTANDS THAT ALL STATEMENTS AND REPRESENTATIONS MADE IN THIS APPLICATION ARE BINDING UPON THE APPLICANT.

THE APPLICANT AND ANY OFFICIAL EXECUTING THIS CERTIFICATION ON BEHALF OF THE APPLICANT, NAMED IN ITEM 2, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH TITLE 10, CODE OF FEDERAL REGULATIONS, PARTS 30, 32, 33, 34, 35, AND 40 AND THAT ALL INFORMATION CONTAINED HEREIN, IS TRUE AND CORRECT TO THE BEST OF THEIR KNOWLEDGE AND BELIEF.

WARNING: 18 U.S.C. SECTION 1001 ACT OF JUNE 25, 1948, 62 STAT. 749 MAKES IT A CRIMINAL OFFICE TO MAKE A WILLFULLY FALSE STATEMENT OR REPRESENTATION TO ANY DEPARTMENT OR AGENCY OF THE UNITED STATES AS TO ANY MATTER WITHIN ITS JURISDICTION.

SIGNATURE - CERTIFYING OFFICER	TYPED/PRINTED NAME	TITLE	DATE
Frank J Vumbaco	Frank J. Vumbaco	Manager, Health/Safety	7/1/93

FOR NRC USE ONLY

TYPE OF FEE	FEE LOG	FEE CATEGORY	COMMENTS
Amd	Sep 2 I	2C (3P)	Adding 3P increased scope changing app fee

AMOUNT RECEIVED	CHECK NUMBER
$480 + / 860	91091 / 23982

APPROVED BY: [signature]

DATE: 11/5/93

NRC FORM 313 (3-92)

OFFICIAL RECORD COPY ML 10 118323 JUL 06 1993

Postmarked 7/2/93

LICENSE AMENDMENT APPLICATION FOR DISPOSITION OF ELECTROWON COPPER

1. Introduction

1.1 Summary Of What Is Sought

Nuclear Metals Inc.) is extracting copper from a process pickling solution in order to regenerate the solution for reuse ("closed loop" process) and to recover the copper as a valuable resource. NMI requests approval pursuant to 10 CFR Part 20.302(a) to disposition, without restriction, the reclaimed copper metal containing up to 100 parts depleted uranium per million parts copper by weight (ppm) on average in each lot of copper released and up to 300 ppm maximum on average in any particular recovery batch (copper plates generated by one electrowinning run). This application provides information requested in 10 CFR Part 20.302(a).

2. Description of Material

2.1 Physical Properties

Metallic copper sheet, about 2 feet square and about 1/8 inch thick is formed by electrowinning the copper from a process solution.

2.2 Chemical Properties

Chemical Composition. Metallic copper containing a trace of uranium. Analysis of representative samples showed an average copper content of about 99.77%. The principal contaminants are oxygen (about 0.18%) and silica. Other trace constituents detected (Ca, Ag, Fe, Mg, Pb, and S) were at levels consistent with their expected presence in copper from other commercial sources. The copper metal is considered a recovered resource, not a waste. If it were to be discarded, however, it would not be a hazardous waste according to definitions or criteria of the US EPA.

2.3 Radionuclides

Process solution from which the copper is extracted also contains a trace of depleted uranium dissolved in it. Radionuclide decay products in the uranium decay series are

absent from the process stream because they report to the residual slag and foundry skulls generated by an earlier melting and casting process step and do not have time to grow significantly into the uranium in process. No other radioactive material is processed by NMI.

Expected Range. The depleted uranium content observed in copper recovered during the past year ranged from 6 to 281 ppm as tabulated in Table 1. Uranium concentrations in Table 1 are representative of the range expected.

Concentration. The concentration observed in the recovered copper averaged 61.5 ppm.

Maximum Concentration. Uranium concentration in copper is not expected to exceed 300 ppm. A recovery batch containing more than 300 ppm U will not be released.

3. Operational Factors

3.1 Processing, Handling, etc.

Acidic solution, comprised of H_2SO_4 and H_2O_2, is used by NMI to remove a thin surface layer of copper from extruded, depleted uranium (DU) machining stock rods. The copper and uranium concentrations are monitored by sampling and analyzing the solution periodically. When a process control concentration limit of 40 grams per liter of copper is reached, the spent solution is withdrawn from the pickling operation and is stored in holding tanks (batch filled). From the holding tank, the solution is continuously pumped into a pair of electrowinning cells where the copper is electroplated onto the cathodes. The spent solution is subsequently diverted to a separate tank where the excess uranium is precipitated to maintain a DU concentration of about 5 grams per liter in the process pickling solution.

After the copper concentration is reduced to about 15 grams per liter, electrowinning is stopped and the metallic copper sheets are removed and rinsed to clean their surfaces. The electrowinning process proper recovers the copper in an extremely high state of purity. Because of the irregular, nodular, character of the depositional (cathode) surface, however, some minute droplets of uranium-bearing electrolyte are mechanically entrapped in the interdendritic spaces. The microscopic

				ELECTROWINNING-NEW PROCESS				3/1/92			
					URANIUM-CONTENT						
		TANK#1						TANK#2			
DATE	RUN#	PLATE#	SIDE	PPM	WEIGHT (#)		RUN#	PLATE#	SIDE	PPM	WEIGHT (#)
3/19/92	133	A	-	7			-	-	-	-	
3/19/92	133	B	-	6	931		-	-	-	-	
3/30/92	-	-	-	-			132	A	-	69	
3/30/92	-	-	-	-			132	B	-	64	733
4/6/92	134	A	-	33			-	-	-	-	
4/6/92	134	B	-	33	950		-	-	-	-	
4/10/92	-	-	-	-			133	21	A	227	
4/10/92	-	-	-	-			133	14	B	281	702
4/21/92	135	16	B	126			-	-	-	-	
4/21/92	135	3	B	95	633		-	-	-	-	
4/24/92	-	-	-	-			134	9	A	34	
4/24/92	-	-	-	-			134	21	B	61	712
5/1/92	136	12	A	31			-	-	-	-	
5/1/92	136	18	B	39	725		-	-	-	-	
5/9/92	-	-	-	-			135	10	A	30	
5/9/92	-	-	-	-			135	3	B	36	794
5/18/92	137	2	B	26			-	-	-	-	
5/18/92	137	14	B	37	732		-	-	-	-	
6/18/92	138	5	A	60			-	-	-	-	
6/18/92	138	15	A	16	1215		-	-	-	-	
5/22/92	-	-	-	-			136	7	B	25	
5/22/92	-	-	-	-			136	19	A	12	693
7/1/92	-	-	-	-			137	4	A	10	
7/1/92	-	-	-	-			137	11	A	10	1287
8/31/92	139	13	B	20							
8/31/92	139	18	A	24	1758						
9/16/92	-	-	-	-			138	14	B	94	
9/16/92	-	-	-	-			138	19	A	104	1203
12/31/92	140	10	B	55			-	-	-	-	
12/31/92	140	18	A	26	1305		-	-	-	-	
1/14/93	-	-	-	-			139	4	A	38	
1/14/93	-	-	-	-			139	20	B	164	932
2/13/93	141	13	A	82			-	-	-	-	
2/13/93	141	20	B	111	1553		-	-	-	-	
2/27/93	-	-	-	-			140	8	B	38	
2/27/93	-	-	-	-			140	17	B	90	1337

				ELECTROWINNING-NEW PROCESS				3/1/92			
						URANIUM-CONTENT					
		TANK#1						TANK#2			
DATE	RUN#	PLATE#	SIDE	PPM	WEIGHT (#)		RUN#	PLATE#	SIDE	PPM	WEIGHT (#)
		AVERAGE		45.9			AVERAGE			77.1	
		MAX		126			MAX			281	
		MIN		6			MIN			10	
		MEDIAN		33			MEDIAN			49.5	
		STD DEV		35.4			STD DEV			75.9	
		N SAMPLES		18			N SAMPLES			18	
						BOTH TANKS					
								PPM			
				AVERAGE				61.5			
				MAX				281			
				MIN				6			
				MEDIAN				37.5			
				STD DEV				60.482			
				N SAMPLES				36			

inclusions are the source of the trace DU contamination in the electrowon copper plates.

3.2 Production Rate

The production of electrowon copper plate during the fiscal year, from October 1991 through September 1992 totaled about 28,000 pounds. At plant operating capacity, copper production would be estimated to be about 52,000 pounds per year.

3.3 Quality Assurance

Measurement of uranium in the copper metal is governed by written procedure and is the responsibility of the Quality Assurance Department. Copper plates from each plating batch are identified and held; two plates from each run are sampled and analyzed for uranium concentration. Only after analytical results demonstrate uranium to be less than the regulatory limit for release may the batch be added to a lot for eventual release.

3.4 Surface Contamination

Before unrestricted release, NMI will survey the copper surface for removable radioactive contamination. It will not be released if its surface is contaminated in excess of 1000 dpm alpha/100 cm^2.[1]

4. Disposition of the Copper

NMI anticipates sale to a copper smelter is likely; however, NMI requests that no restrictions be imposed on the disposition of the copper. NMI will assure the specified uranium concentration limits are met before releasing each lot of copper. At the specified limits, potential radiation dose is a small fraction of regulatory limits and a small fraction of the dose a person receives from the natural environment.

5. Radiological Impact Evaluation

5.1 Potential Exposure

A worst case exposure scenario was postulated for the exposure pathways analysis. Radiation from the copper surface

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1 USNRC Regulatory Guide 1.86, Table 1, June 1974.

and determination of the potential dose rate at the surface of a thick copper slab were estimated by calculation. Estimated alpha, beta, and gamma radiation were then compared with radiation protection standards.

5.2 Method(s) of Analysis

Analyses of potential exposure from alpha, beta, and gamma radiation from a 10 cm thick copper slab are described in the attached Evaluation of Exposure to Copper Containing 100 ppm Uranium.

5.3 Analysis of Radiation Doses

5.3.1 Dose To The People Most Exposed Via Each Pathway

The calculation indicates alpha radioactivity would be about 1 dpm/100 cm^2, which is 0.001 of the unrestricted release limit for removable alpha specified in Regulatory Guide 1.86.[2] After aging to radioactive equilibrium, beta radiation from the uranium progeny would be the same fraction of its implied limit as would its parent uranium alpha when compared to the limit for alpha.

The calculated beta radiation dose rate to skin at the surface of copper would be 180 to 240 mrem/yr, with and without clothing. If a person were exposed as much as 0.1 of the time, his annual skin dose would be only about 18 to 24 mrem. There is no regulatory limit on dose rate to the skin of a member of the public. But if the pattern of limiting dose to members of the public to 0.1 of occupational dose limits were applied to skin, a skin dose limit to members of the public would be about 750 mrem/qtr, or 3000 mrem/yr by current regulation[3] or 5000 mrem/yr by pending regulation.[4] An annual skin dose of 18 to 24 mrem would be only about 0.04 to 0.08 of a likely standard, if there were one.

The calculated deep dose rate from gamma radiation would be about 3.4 mrem/yr, which is but 0.034 of the 100 mrem/yr limit

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2 Because of its short range, only alpha radiation emitted at the surface of copper may escape the metal.

3 Occupational dose limit to skin of whole body is 7½ rem per calendar quarter, stated in 10 CFR Part 20.102

4 The occupational shallow dose equivalent limit to the skin or to any extremity is 50 rem, stated in 10 CFR Part 50.1201(a)(2)(ii).

for members of the public according to pending regulation.[5] This is also only 0.07 of the 50 mrem/yr level from external radiation for demonstrating compliance with the 100 mrem/yr limit.[6]

Thus according to these calculations, 100 ppm U238 + decay products in copper presents only a small fraction of limits for unrestricted release or public exposure.

5.4 Measurements

NMI is performing measurements to verify that radiation levels from the reclaimed copper are very low, although such low level measurements will be uncertain and may be inconclusive. Results of the measurements will be made available when completed.

6. ENVIRONMENTAL IMPACT ASSESSMENT

6.1 Need and Justification of Proposed Disposition

Nuclear Metals Inc. (NMI) is extracting copper from a process solution, which removes it from an eventual waste stream and recovers the copper as a valuable resource. The aim of this request is authorization to allow the reclaimed copper to be used in a safe and reasonable way.

6.2 Identification and Discussion of Alternatives and Their Impacts

There is no impact on existing processes.

No other waste stream is created.

6.3 Evaluation Of Proposal And Alternatives

Environmental impact is diminished by removing copper from the process solution and by avoiding the necessity to mine and refine an equivalent amount of copper from ore.

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5 10 CFR Part 20.1301.

6 10 CFR Part 20.1302(b)(2)(ii)

7. License Amendment Information

7.1 License Condition Requiring Amendment

NMI requests that Source Material License SMB-179 be amended to authorize the unrestricted disposition of electrowon copper plates as discussed above. The following specific change requested relates to the Application for Renewal submitted to Region 1, USNRC on 28 April, 1989: Supplement No. 7, Item No. 11B Waste Management - Disposal Procedures, A. Closed loop pickling - Process Description, (p. S-7-3).

7.2 License Change Requested

After the second sentence of the second paragraph, ending "... solution is treated to remove the dissolved copper via electrowinning and returned to the pickle tanks for re-use," add the following sentences: "Cathode copper plates from each electrowinning run are sampled and analyzed to determine their trace uranium concentration. Lots of copper plates whose average uranium concentration does not exceed 100 parts depleted uranium per million parts copper by weight (ppm), and that do not include plates from any individual run which exceeds 300 ppm DU, are released for sale or other beneficial use."

7.3 Basis of Change

Dose calculations described in the attached *Evaluation of Exposure to Copper Containing 100 ppm Uranium* and discussed in Paragraph 5 of this request demonstrate that realistic potential doses to members of the public resulting from the requested license amendment would only constitute a small fraction of the established or anticipated exposure limit. These calculations are being validated by measurements on actual representative copper plates from the electrowinning process as discussed in Paragraph 5.4. Approval of the requested amendment will facilitate the beneficial use of a significant quantity of high purity copper, will avoid the energy expenditure and other adverse environmental impacts involved with mining and refining an equivalent quantity of new copper metal, and will preclude the allocation of limited disposal capacity that would otherwise be required if the recovered plates were dispositioned as low-level radioactive waste.

EVALUATION OF EXPOSURE TO COPPER CONTAINING 100 PPM URANIUM

Introduction

The radiation at the surface of copper metal containing a trace of uranium-238 has been estimated by calculation. Alpha, beta, and gamma radiation are compared with radiation protection standards.

Source Description

For this evaluation copper metal is assumed to contain 100 parts depleted uranium per 10^6 parts copper by mass. The density of copper metal is 8.94 g/cm^3.

For the purpose of estimating potential exposure and dose-equivalent rates in the future, uranium series decay products that would have grown into the copper metal 100 years hence were calculated. Appendix A lists the amounts relative to a unit activity of uranium-238 after 100 years.

- Alpha exposure will be estimated on the basis of U^{238} alpha alone. There will not be significant growth of another alpha-emitting nuclide within 100 years.
- Calculated dose rate from beta radiation will account for beta radiation emitted by Th^{234}, Pa^{234m}, and Pa^{234}.
- Gamma dose rate calculation will account for gamma radiation from U^{238}, Th^{234}, Pa^{234m}, and Pa^{234}.

Alpha Radioactivity

Alpha radioactivity at the surface of copper is one item of radiological interest. The concentration by mass is converted to radioactivity concentration and the alpha radiation that might escape the surface of the copper is estimated. First, derive the U-to-Cu atom ratio.

$$\text{Mass} \times \frac{\text{Av}}{\text{g atomic wt}} = \text{No. atoms}$$

$$10^2 \text{ g } U^{238} \times \frac{\text{Av atoms}}{238 \text{ g U}} = 0.42 \cdot \text{Av atoms } U^{238}$$

$$10^6 \text{ g } Cu^{63} \times \frac{\text{Av atoms}}{63 \text{ g Cu}} = 1.59 \times 10^4 \cdot \text{Av atoms Cu}$$

$$\frac{U^{238}}{Cu} \text{ atomic ratio} = \frac{0.42 \cdot \text{Av}}{1.59 \times 10^4 \cdot \text{Av}} = 2.65 \times 10^{-5}$$

where:

Av = Avagadro's number = 6.0225×10^{23} atoms/g mole

Uranium-238 alpha radioactivity might escape the metal only if it is emitted within the range of the alpha in copper. The range is 5.8 mg/cm^2 in copper, as calculated in Appendix B. Thus, the next step is to calculate the alpha radioactivity concentration at the surface of copper metal.

The alpha radioactivity concentration within 5.8 mg/cm^2 of the surface is:

$$\text{Conc} = \frac{5.8 \text{ mg Cu}}{\text{cm}^2} \times \frac{6.0225 \times 10^{23} \text{ atoms}}{63 \text{ g Cu}} \times \frac{1 \text{ g}}{10^3 \text{mg}} \times \frac{2.6 \times 10^{-5}\ U^{238} \text{ atom}}{\text{Cu atom}}$$

$$\text{Conc} = 1.4 \times 10^{15} \text{ atoms U/cm}^3$$

The uranium alpha radioactivity is:

$U\alpha$ activity = $\lambda \cdot N$

where: λ = radioactive decay constant (sec^{-1})

N = number of radioactive atoms

$U\alpha$ activity = $(4.88 \times 10^{-18}/\text{sec})(1.4 \times 10^{15} \text{ atoms/cm}^2)(100 \text{ cm}^2)$

$U\alpha$ activity = 0.7 α disintegrations/(sec·100 cm^2)

This is far below the unrestricted release limits for fixed and removable uranium alpha radiation, which are:[1]

- average 5000 dpm α/100 cm^2;
- maximum 15,000 dpm α/100 cm^2; and
- removable 1000 dpm α/100 cm^2.

Beta Radioactivity

After aging 100 years, Th^{234}, Pa^{234m}, and Pa^{234} will be the significant beta-emitting products of U^{238} decay. The low decay rate of U^{234} prevents significant growth of it and following radionuclides in the series. Interpretation of beta radiation contamination limits for unrestricted release of material contaminated by uranium varies. One interpretation is that as long as uranium alpha radiation does not exceed its limit, then beta radiation from associated decay products will not exceed an implied limit. Thus, beta radiation may be interpreted to be the same fraction of an implied release limit as is alpha radiation in the case of interest. Thus, beta as well as alpha radiation may be interpreted to be only about 0.001 of the unrestricted release limit.

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1 USNRC. 1974. *Termination of Operating Licenses for Nuclear Reactors*. Reg. Guide 1.86. June 1974.

The shallow dose equivalent[2] caused by Th^{234}, Pa^{234m}, and Pa^{234} progeny of U^{238} in the copper was computed with the aid of VARSKIN.[3,4] In the first calculation skin was assumed to be in continuous contact with copper metal containing 100 ppm U^{238}, aged 100 years. Input data and the computed shallow dose equivalent rate are reported in Appendix C. However, the radionuclide concentration and the reported dose must be reduced by a factor of 1000 to represent the problem of interest.[5]

The shallow dose equivalent rate corresponding to the problem of interest is 2.7×10^{-5} rad/hr, or 2.7×10^{-3} mrem/hr. That would equal 238 mrem/yr if skin were constantly in contact with the copper metal.

In a second calculation, a layer of clothing was assumed to be between the copper and the skin. The cloth was assumed to be 0.7 mm thick and 0.4 g/cm^3 in density, about the same as cloth in coveralls. The calculated shallow dose equivalent rate dropped slightly to 2.05×10^{-5} rad/hr, or 2.05×10^{-2} mrem/hr as recorded in Appendix D. If the clothed skin were in constant contact with the copper metal for a year, the shallow dose equivalent rate would be 180 mrem/yr.

It would seem most unlikely for a person to be in contact with a copper object more than six hours a day, perhaps while sitting in one place. Assuming exposure ¼ of the time, the calculated annual dose to skin would be 45 mrem if clothed or 60 mrem if bare. There is no prescribed limit on dose to the skin of a member of the public in either 10 CFR Part 20.105 or 10 CFR Part 20.1501. Even if the radiation levels in 10 CFR Part 20.105(b) were misapplied, the computed skin dose rate would be less than 0.05 of the limit, 100 mrem in 7 days.

Validation Check

To check the validity of the VARSKIN code for the uranium series beta radiation of interest, a benchmark case was calculated. Beta radiation is reported to produce about 240 mrem/hr at the surface of aged uranium metal. Th^{234}, Pa^{234m}, and Pa^{234} in radioactive equilibrium with U^{238} metal were described in VARSKIN input, and the dose rate was computed by VARSKIN. The record of calculation, listed as *Depl. Uranium Metal* in Appendix E, reports a maximum dose rate of 0.270 rad/hr, or 270 mrem/hr. For this case VARSKIN overestimated the actual dose rate by about 10 percent.[6]

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2 Shallow dose equivalent is the dose equivalent at depth of 0.007 cm in human tissue averaged over an area of 1 cm^2, or 7 mg/cm^2, resulting from external exposure.

3 J.S. Durham. 1992. *VARSKIN MOD2 and SADDE MOD2: Computer Codes for Assessing Skin Dose from Skin Contamination*. NUREG/CR-5873. Dec. 1992.

4 VARSKIN is a computer code designed to calculate the radiation dose to skin from beta-emitting radionuclides. Its development was sponsored by the USNRC.

5 VARSKIN would not allow an activity concentration as low as the one of interest to be entered directly; thus, values 1000 times higher were entered.

6 Further examination may uncover an explanation of the difference between reported and calculated values. Gamma radiation may be included in one value but not in the other.

Gamma Radiation

The exposure rate (mR/hr) and deep dose-equivalent rate (mrem/hr) were calculated for the following conditions.

- A copper slab 10 cm thick and infinite in other dimensions.
- Assume a 1 cm air gap between the surface of the copper and a point where exposure is calculated.
- Copper density is 8.94 g/cm ^{3}.
- The copper contains 100 ppm U ^{238}.
- The radionuclide concentration in the copper is:

Nuclide	Concentration (Ci/cm^3)
U^{238}	3.0×10^{-10}
Th^{234}	3.0×10^{-10}
Pa^{234m}	3.0×10^{-10}
Pa^{234}	4.8×10^{-13}

The geometry and materials are also described in Appendix F.

The gamma radiation exposure rate was computed with the program MICROSHIELD.[7]

The exposure rate was converted to dose equivalent rate with the program MSREM.[8] Using the energy flux at the exposure point as a function of energy group, MSREM derives the deep dose equivalent rate assuming the radiation flux is either isotropic or planar. The conversion is based on data in ICRU Report 43.[9]

Appendix F summarizes computed results. The calculated exposure rate, 5.65×10^{-4} mR/hr, equals 4.9 mrem/yr, assuming continuous exposure.

The corresponding dose equivalent rate, assuming exposure to a planar flux of gamma rays from a copper slab is 3.9×10^{-7} rem/hr. That equals 3.4 mrem/year, which is only 0.034 of the NRC radiation protection standard for members of the public.[10]

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7 Grove Engineering, Inc. 1987. *MICROSHIELD*. v. 3.

8 Grove Engineering, Inc. *MSREM*.

9 International Commission on Radiation Units and Measurements. 1988. *Determination of Dose Equivalents From External Sources - Part 2*. ICRU Report 42. Dec. 15, 1988.

10 10 CFR Part 20.1301.

APPENDIX A

Result of decaying 1 curies of U-238
Combining the same daughters resulting from different decay paths.
for 100 years = 36,525.00 days

NUCLIDE	FRACTION	ACTIVITY (ci)
U-238	1.00000e+000	1.00000e+000
Th-234	1.00000e+000	1.00000e+000
Pa-234m	1.00000e+000	1.00000e+000
Pa-234	1.60000e-003	1.60000e-003
U-234	2.83186e-004	2.83186e-004
Th-230	1.27307e-007	1.27307e-007
Ra-226	1.81712e-009	1.81712e-009
Rn-222	1.81630e-009	1.81630e-009
Po-218	1.81630e-009	1.81630e-009
Pb-214	1.81593e-009	1.81593e-009
Bi-214	1.81593e-009	1.81593e-009
Po-214	1.81555e-009	1.81555e-009
Pb-210	8.45827e-010	8.45827e-010
Bi-210	8.45229e-010	8.45229e-010
Po-210	8.28954e-010	8.28954e-010

APPENDIX B

Range of Uranium-238 Alpha Radiation in Copper

To calculate the range of Uranium-238 alpha radiation in copper metal, first calculate its range in air

The range of alpha radiation in air is calculated by the equation:

$$r_{air} = 0.56 \cdot T \quad \text{when } T < 4 \text{ Mev}$$
$$r_{air} = 1.24 \cdot T - 2.62 \quad \text{when } 4 < T < 8 \text{ Mev}$$

Where: r_{air} = α range in air (cm)
T = α kinetic energy (Mev)

For U^{238} α, $T = 4.2$ Mev

$$\therefore \quad r_{air} = 1.24 \cdot T - 2.62$$
$$r_{air} = 1.24(4.2) - 2.62$$
$$r_{air} = 2.59 \text{ cm in air}$$

In other materials, the alpha range, within 15%, is calculated by:

$$R_{med} = 0.56 \, A^{1/3} \cdot r_{air}$$

where: R_{med} = α range in medium (mg/cm²)
A = atomic mass of medium

The range of U^{238} α in copper is:

$$R_{cu} = 0.56 \cdot (64)^{1/3} \cdot 2.59$$
$$R_{cu} = 5.8 \text{ mg/cm}^2$$

Alternatively, alpha range in a medium may be calculated by relative mass stopping power. The expression for relative mass stopping power, S_m, is:

$$S_m = \frac{R_{air}}{R_{med}} = \frac{\alpha \text{ range in air}}{\alpha \text{ range in medium}}$$

or

$$R_m = \frac{R_{air}}{S_m} = \frac{r_{air} \cdot \rho_{air}}{S_m}$$

where: ρ_{air} = air density = 1.29 mg/cm³ at std. conditions
S_m = 0.58 for air/copper

The range of U^{238} α in copper is:

$$R_{cu} = \frac{(2.59 \text{ cm})(1.29 \text{ mg/cm}^3)}{0.58}$$
$$R_{cu} = 5.76 \frac{\text{mg}}{\text{cm}^2}$$

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ref: Fitzgerald, Brownell, and Mahoney, Math[illegible] [illegible] of Radiation [illegible], pp 77-86, pub. [illegible]

APPENDIX C

Program VARSKIN-MOD2

100 ppm U in Copper

Cylindrical Source Geometry

Nuclide :	Th-234	
1.8*X90 Distance :	1.998000E-02	cm
Average Beta Energy :	4.760000E-02	MeV
No gamma dose calculation		
Source Strength :	3.000000E-01	uCi/cm^3
Source Density :	8.940000	g/cm^3
Diameter of Disk :	14260.000000	um
Thickness of Disk :	964.000000	um
Skin Depth :	7.000000	mg/cm^2
Thickness of Cover :	0.000000E+00	mm
Air Gap Thickness :	1.000000E-01	mm
Irradiation Time :	60.000000	min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	1.86E-04
.1128	1.86E-04
.1596	1.86E-04
.1954	1.86E-04
.2257	1.86E-04
.2523	1.86E-04
.2764	1.86E-04
.2985	1.86E-04
.3192	1.86E-04
.3385	1.86E-04
.3568	1.86E-04
.3742	1.86E-04
.3909	1.86E-04
.4068	1.86E-04
.4222	1.86E-04
.4370	1.86E-04
.4514	1.86E-04
.4652	1.86E-04
.4787	1.86E-04
.4918	1.87E-04
.5046	1.86E-04
.5171	1.86E-04
.5293	1.86E-04
.5412	1.86E-04
.5528	1.86E-04
.5642	1.86E-04

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 1.85E-04 rad/hr
The total beta dose averaged over 1.0000 square cm = 1.85E-04 rad

Program VARSKIN-MOD2

100 ppm U in Copper

Cylindrical Source Geometry

Nuclide	:	Pa234m
1.8*X90 Distance	:	8.622000E-01 cm
Average Beta Energy	:	8.297000E-01 MeV
No gamma dose calculation		
Source Strength	:	3.000000E-01 uCi/cm^3
Source Density	:	8.940000 g/cm^3
Diameter of Disk	:	14260.000000 um
Thickness of Disk	:	964.000000 um
Skin Depth	:	7.000000 mg/cm^2
Thickness of Cover	:	0.000000E+00 mm
Air Gap Thickness	:	1.000000E-01 mm
Irradiation Time	:	60.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	2.71E-02
.1128	2.71E-02
.1596	2.71E-02
.1954	2.71E-02
.2257	2.71E-02
.2523	2.71E-02
.2764	2.71E-02
.2985	2.71E-02
.3192	2.71E-02
.3385	2.70E-02
.3568	2.70E-02
.3742	2.70E-02
.3909	2.70E-02
.4068	2.70E-02
.4222	2.69E-02
.4370	2.69E-02
.4514	2.69E-02
.4652	2.68E-02
.4787	2.68E-02
.4918	2.68E-02

.5046	2.67E-02
.5171	2.67E-02
.5293	2.67E-02
.5412	2.66E-02
.5528	2.65E-02
.5642	2.64E-02

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 2.67E-02 rad/hr
The total beta dose averaged over 1.0000 square cm = 2.67E-02 rad

Program VARSKIN-MOD2

100 ppm U in Copper

Cylindrical Source Geometry

Nuclide : Pa-234
1.8*X90 Distance : 2.705400E-01 cm
Average Beta Energy : 2.055000E-01 MeV
No gamma dose calculation
Source Strength : 4.800000E-04 uCi/cm^3
Source Density : 8.940000 g/cm^3
Diameter of Disk : 14260.000000 um
Thickness of Disk : 964.000000 um
Skin Depth : 7.000000 mg/cm^2
Thickness of Cover : 0.000000E+00 mm
Air Gap Thickness : 1.000000E-01 mm
Irradiation Time : 60.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	1.47E-05
.1128	1.47E-05
.1596	1.47E-05
.1954	1.47E-05
.2257	1.47E-05
.2523	1.47E-05
.2764	1.47E-05
.2985	1.47E-05
.3192	1.47E-05
.3385	1.47E-05
.3568	1.47E-05
.3742	1.47E-05
.3909	1.47E-05

.4068	1.47E-05
.4222	1.47E-05
.4370	1.47E-05
.4514	1.47E-05
.4652	1.47E-05
.4787	1.46E-05
.4918	1.47E-05
.5046	1.49E-05
.5171	1.46E-05
.5293	1.47E-05
.5412	1.46E-05
.5528	1.46E-05
.5642	1.46E-05

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 1.46E-05 rad/hr
The total beta dose averaged over 1.0000 square cm = 1.46E-05 rad

Irradiation time = 6.0E+01 min
The beta dose rate for the 3 radionuclides, averaged over 1 square cm, = 2.69E-02 rad/hr
The total beta dose for the 3 radionuclides, averaged over 1 square cm, = 2.69E-02 rad

APPENDIX D

Program VARSKIN-MOD2

100ppm U:Cu|clothing

Cylindrical Source Geometry

```
            Nuclide : Th-234
   1.8*X90 Distance :    1.998000E-02 cm
Average Beta Energy :    4.760000E-02 MeV
    No gamma dose calculation
    Source Strength :    3.000000E-01 uCi/cm^3
     Source Density :        8.940000 g/cm^3
   Diameter of Disk :    14260.000000 um
  Thickness of Disk :      964.000000 um
         Skin Depth :        7.000000 mg/cm^2
 Thickness of Cover :    7.000000E-01 mm
      Cover Density :    4.000000E-01 g/cm^3
  Air Gap Thickness :    1.000000E-01 mm
   Irradiation Time :       60.000000 min
```

The beta dose rate averaged over 1.00 square cm = 0.00E+00 rad/hr
The total beta dose averaged over 1.00 square cm = 0.00E+00 rad

```
             Nuclide : Pa234m
     1.8*X90 Distance :     8.622000E-01 cm
  Average Beta Energy :     8.297000E-01 MeV
        No gamma dose calculation
      Source Strength :     3.000000E-01 uCi/cm^3
       Source Density :        8.94^)00 g/cm^3
     Diameter of Disk :    14260.000000 um
    Thickness of Disk :      964.000000 um
           Skin Depth :        7.000000 mg/cm^2
   Thickness of Cover :     7.000000E-01 mm
        Cover Density :     4.000000E-01 g/cm^3
    Air Gap Thickness :     1.000000E-01 mm
     Irradiation Time :       60.000000 min
```

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	2.05E-02
.1128	2.05E-02
.1596	2.04E-02
.1954	2.04E-02
.2257	2.04E-02
.2523	2.03E-02
.2764	2.02E-02
.2985	2.02E-02
.3192	2.01E-02
.3385	2.01E-02
.3568	2.00E-02
.3742	1.99E-02
.3909	1.98E-02
.4068	1.97E-02
.4222	1.96E-02
.4370	1.95E-02
.4514	1.94E-02
.4652	1.95E-02
.4787	1.91E-02
.4918	1.90E-02
.5046	1.88E-02
.5171	1.86E-02
.5293	1.84E-02
.5412	1.82E-02
.5528	1.79E-02
.5642	1.76E-02

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.00 square cm = 1.94E-02 rad/hr
The total beta dose averaged over 1.0000 square cm = 1.94E-02 rad

Nuclide : Pa-234
1.8*X90 Distance : 2.705400E-01 cm
Average Beta Energy : 2.055000E-01 MeV
No gamma dose calculation
Source Strength : 4.800000E-04 uCi/cm^3
Source Density : 8.940000 g/cm^3
Diameter of Disk : 14260.000000 um
Thickness of Disk : 964.000000 um
Skin Depth : 7.000000 mg/cm^2
Thickness of Cover : 7.000000E-01 mm
Cover Density : 4.000000E-01 g/cm^3
Air Gap Thickness : 1.000000E-01 mm
Irradiation Time : 60.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	5.77E-06
.1128	5.77E-06
.1596	5.77E-06
.1954	5.77E-06
.2257	5.77E-06
.2523	5.77E-06
.2764	5.76E-06
.2985	5.76E-06
.3192	5.76E-06
.3385	5.75E-06
.3568	5.75E-06
.3742	5.74E-06
.3909	5.73E-06
.4068	5.72E-06
.4222	5.71E-06
.4370	5.70E-06
.4514	5.69E-06
.4652	5.67E-06
.4787	5.65E-06
.4918	5.63E-06
.5046	5.60E-06
.5171	5.58E-06
.5293	5.54E-06
.5412	5.50E-06
.5528	5.45E-06
.5642	5.40E-06

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.00 square cm = 5.65E-06 rad/hr
The total beta dose averaged over 1.0000 square cm = 5.65E-06 rad

Irradiation time = 6.0E+01 min
The beta dose rate for the 3 radionuclides, averaged over
1 square cm, = 1.95E-02 rad/hr
The total beta dose for the 3 radionuclides, averaged over
1 square cm, = 1.95E-02 rad

APPENDIX E

Program VARSKIN-MOD2

Depl. Uranium Metal

Cylindrical Source Geometry

Nuclide :	Th-234	
1.8*X90 Distance :	1.998000E-02	cm
Average Beta Energy :	4.760000E-02	MeV
No gamma dose calculation		
Source Strength :	6.350000	uCi/cm^3
Source Density :	19.000000	g/cm^3
Diameter of Disk :	14260.000000	um
Thickness of Disk :	454.000000	um
Skin Depth :	7.000000	mg/cm^2
Thickness of Cover :	0.000000E+00	mm
Air Gap Thickness :	1.000000E-01	mm
Irradiation Time :	60.000000	min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	1.85E-03
.1128	1.85E-03
.1596	1.86E-03
.1954	1.72E-03
.2257	1.72E-03
.2523	1.86E-03
.2764	1.86E-03
.2985	1.86E-03
.3192	1.86E-03
.3385	1.86E-03
.3568	1.86E-03
.3742	1.85E-03
.3909	1.86E-03
.4068	1.86E-03
.4222	1.86E-03
.4370	1.86E-03
.4514	1.86E-03
.4652	1.86E-03
.4787	1.86E-03
.4918	1.85E-03
.5046	1.85E-03
.5171	1.86E-03
.5293	1.86E-03
.5412	1.86E-03
.5528	1.86E-03
.5642	1.85E-03

The area of irradiation is larger than   1.0000 square cm

The beta dose rate averaged over   1.0000 square cm = 1.83E-03 rad/hr

The total beta dose averaged over   1.0000 square cm = 1.83E-03 rad

Program VARSKIN-MOD2

Depl. Uranium Metal

Cylindrical Source Geometry

Nuclide :	Pa234m
1.8*X90 Distance :	8.622000E-01 cm
Average Beta Energy :	8.297000E-01 MeV
No gamma dose calculation	
Source Strength :	6.350000 uCi/cm^3
Source Density :	19.000000 g/cm^3
Diameter of Disk :	14260.000000 um
Thickness of Disk :	454.000000 um
Skin Depth :	7.000000 mg/cm^2
Thickness of Cover :	0.000000E+00 mm
Air Gap Thickness :	1.000000E-01 mm
Irradiation Time :	60.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	2.70E-01
.1128	2.70E-01
.1596	2.70E-01
.1954	2.70E-01
.2257	2.70E-01
.2523	2.70E-01
.2764	2.70E-01
.2985	2.70E-01
.3192	2.70E-01
.3385	2.69E-01
.3568	2.69E-01
.3742	2.69E-01
.3909	2.69E-01
.4068	2.69E-01
.4222	2.69E-01
.4370	2.68E-01
.4514	2.68E-01
.4652	2.68E-01
.4787	2.67E-01
.4918	2.67E-01

.5046	2.67E-01
.5171	2.66E-01
.5293	2.66E-01
.5412	2.65E-01
.5528	2.65E-01
.5642	2.64E-01

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 2.67E-01 rad/hr
The total beta dose averaged over 1.0000 square cm = 2.67E-01 rad

Program VARSKIN-MOD2

Depl. Uranium Metal

Cylindrical Source Geometry

Nuclide : Pa-234
1.8*X90 Distance : 2.705400E-01 cm
Average Beta Energy : 2.055000E-01 MeV
No gamma dose calculation
Source Strength : 1.020000E-02 uCi/cm^3
Source Density : 19.000000 g/cm^3
Diameter of Disk : 14260.000000 um
Thickness of Disk : 454.000000 um
Skin Depth : 7.000000 mg/cm^2
Thickness of Cover : 0.000000E+00 mm
Air Gap Thickness : 1.000000E-01 mm
Irradiation Time : 60.000000 min

Calculated Results:

Radial Distance (cm)	Dose Rate (rad/hr)
.0000	1.47E-04
.1128	1.47E-04
.1596	1.47E-04
.1954	1.47E-04
.2257	1.47E-04
.2523	1.47E-04
.2764	1.47E-04
.2985	1.47E-04
.3192	1.47E-04
.3385	1.47E-04
.3568	1.43E-04
.3742	1.47E-04
.3909	1.47E-04

.4068	1.47E-04
.4222	1.47E-04
.4370	1.47E-04
.4514	1.47E-04
.4652	1.47E-04
.4787	1.46E-04
.4918	1.46E-04
.5046	1.46E-04
.5171	1.46E-04
.5293	1.46E-04
.5412	1.45E-04
.5528	1.46E-04
.5642	1.46E-04

The area of irradiation is larger than 1.0000 square cm

The beta dose rate averaged over 1.0000 square cm = 1.45E-04 rad/hr

The total beta dose averaged over 1.0000 square cm = 1.45E-04 rad

Irradiation time = 6.0E+01 min

The beta dose rate for the 3 radionuclides, averaged over 1 square cm, = 2.69E-01 rad/hr

The total beta dose for the 3 radionuclides, averaged over 1 square cm, = 2.69E-01 rad

APPENDIX F

Microshield 3.12
================
(Henry Morton - #098)

```
Page     : 1                                        File Ref: ___________
File     : CU-U_A.MSH                                   Date: ___/___/___
Run date: February 21, 1993                               By: ___________
Run time: 2:36 p.m.                                  Checked: ___________
```

CASE: 100 ppm U-238 Aged 100 Years in a 10 cm Copper Slab

GEOMETRY 14: Infinite slab source - slab shields

```
Distance to detector......................... X        11.        cm.
Source slab thickness........................ T1       10.        "
Microshield inserted air gap................. air       1.        "
```

MATERIAL DENSITIES (g/cc):

Material	Source	Air gap
Air		.001220
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		
Cu-U100		
Copper	8.940	

CASE: 100 ppm U-238 Aged 100 Years in a 10 cm Copper Slab

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Pa-234	4.8000e-13	Pa-234m	3.0000e-10	Th-234	3.0000e-10
U-238	3.0000e-10				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.6486	1.656e-03	6.050e-03	1.041e-05
2	1.2794	1.940e-03	5.006e-03	9.125e-06
3	.9668	1.261e-01	2.290e-01	4.450e-04
4	.7573	3.119e-02	3.997e-02	8.118e-05
5	.5449	4.813e-03	3.877e-03	7.971e-06
6	.3706	1.232e-03	5.653e-04	1.163e-06
7	.2884	1.127e-03	3.451e-04	6.897e-07
8	.2240	3.384e-03	6.604e-04	1.255e-06
9	.1567	1.929e-03	1.864e-04	3.249e-07
10	.1187	4.269e-02	1.811e-03	2.871e-06
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	TOTALS:	2.161e-01	2.874e-01	5.600e-04

Microshield

=================

(Henry Morton - #098)

Page	: 1	File Ref:	________
File	: CU-U_A.MSH	Date:	___/___/___
Run date:	February 21, 1993	By:	________
Run time:	2:42 p.m.	Checked:	________

CASE: 100 ppm U-238 Aged 100 Years in a 10 cm Copper Slab

RESULTS:

Group	Energy (MeV)	Flux (MeV/ sec/sq cm)	Exposure (mr/hr)	Isotropic Model (REM/hr)	Planar Model (REM/hr)
1	1.649	6.050e-03	1.041e-05	6.883e-09	7.617e-09
2	1.279	5.006e-03	9.125e-06	5.618e-09	6.458e-09
3	.967	2.290e-01	4.450e-04	2.569e-07	3.128e-07
4	.757	3.997e-02	8.118e-05	4.563e-08	5.474e-08
5	.545	3.877e-03	7.971e-06	4.357e-09	5.334e-09
6	.371	5.653e-04	1.163e-06	6.171e-10	7.688e-10
7	.288	3.451e-04	6.897e-07	3.719e-10	4.587e-10
8	.224	6.604e-04	1.255e-06	6.672e-10	8.549e-10
9	.157	1.864e-04	3.249e-07	1.594e-10	2.337e-10
10	.119	1.811e-03	2.871e-06	1.669e-09	2.321e-09
TOTALS		2.874e-01	5.600e-04	3.229e-07	3.916e-07

October 6, 1993

Nuclear Metals, Inc.
ATTN: Frank J. Vumbaco
Manager, Health/Safety
2229 Main Street
Concord, Massachusetts 01742

Gentlemen:

This refers to your application dated July 1, 1993, for an amendment to Materials Li ense SMB-179.

We received your check for $480. Your request, however, is subject to an application fee of $540 as specified in fee Category 3P and Footnote 1(d)(2) of §170.31, 10 CFR 170. Enclosed is a copy of the July 23, 1992, **Federal Register** notice containing the Commission's revised fee regulations which went into effect July 23, 1992. Footnote 1(d)(2) states that "An application for amendment to a materials license or approval that would place the license or approval in a higher fee category or add a new fee category must be accompanied by the prescribed application fee for the new category." Your request for authorization to possess Americium 241 will increase the scope of your licensed program to include fee Category 3P. Payment of the additional $60 should be made to the following address:

U.S. Nuclear Regulatory Commission
ATTN: Brenda Brown
License Fee and Debt Collection Branch, DAF/OC
Mail Stop MNBB 4503
Washington, D.C. 20555

Your application will be processed by the Region I Licensing staff located at 475 Allendale Road, King of Prussia, PA 19406. The additional fee, however, is required prior to issuance of the amendment. When submitting the fee, please refer to CONTROL NUMBER 118323.

We direct your attention to the Federal Register notice dated July 20, 1993, regarding revisions to the Commission's fee regulations (10 CFR 170 and CFR `71), which went into effect August 19, 1993. Applications for licensing actions postmarked on or after the effective date will be subject to the revised fees in 10 CFR 170.

If we do not receive a reply from you within 30 calendar days from the date of this letter, we shall assume that you do not wish to pursue your application and will void this action.

Sincerely,

/S/

Brenda Brown
License Fee and Debt Collection Branch
Division of Accounting and Finance
Office of the Controller

Enclosures:
1. July 23, 19.2 **Federal Register** notice
2. July 20, 1993 **Federal Register** notice

cc: Region I

DISTRIBUTION:
Pending Fee File
OC/DAF/R/F
LFDCB R/F (2)

OFFICE:	LFDCB	LFDCB
NAME:	BBrown	SKimberley
DATE:	10/4/93	10/6/93

RCJ3/A:\NUCMETIN.FEE

: (FOR LFMS USE)
: INFORMATION FROM LTS
BETWEEN: : ---------------------
:
LICENSE FEE MANAGEMENT BRANCH, ARM : PROGRAM CODE: 11300
AND : STATUS CODE: 2
REGIONAL LICENSING SECTIONS : FEE CATEGORY: 2C
: EXP. DATE: 19890531
: FEE COMMENTS: ____________________
: DECOM FIN ASSUR REQD: Y
::

LICENSE FEE TRANSMITTAL

A. REGION

1. APPLICATION ATTACHED
   APPLICANT/LICENSEE: NUCLEAR METALS, INC.
   RECEIVED DATE: 930706
   DOCKET NO: 4000672
   CONTROL NO.: 118323
   LICENSE NO.: SMB-179
   ACTION TYPE: AMENDMENT

2. FEE ATTACHED
   AMOUNT: $480.00
   CHECK NO.: 910191

3. COMMENTS

SIGNED Rebecca J. Brown
DATE 7/14/93

B. LICENSE FEE MANAGEMENT BRANCH (CHECK WHEN MILESTONE 03 IS ENTERED /✓/)

1. FEE CATEGORY AND AMOUNT: 2C (3P) Adding 3P $540

2. CORRECT FEE PAID. ✓ APPLICATION MAY BE PROCESSED FOR:
   AMENDMENT ____________
   RENEWAL ____________
   LICENSE ____________

3. OTHER ______________________________
   ____

Renewal pending 110636

SIGNED B
DATE 11/5/93