71-6771

SAFETY ANALYSIS REPORT

INSERT FOR SN-1 RADWASTE SHIPPING CONTAINER

SUBMITTED BY GPU-NUCLEAR CORPORATION

DECEMBER 1981

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1. General Information

1.1 Introduction

The purpose of this report is to present the safety analysis of the proposed shielding and structural insert to be used in the model SN-1 radioactive waste shipping container. This report will address item number 6 in the Certificate of Compliance, Number 6771, Revision 3, issued for the licensing of the model SN-1 shipping container on July 31, 1981.

The model SN-1 shipping container is currently licensed for type "B" shipments and in the proposed use will transport 50 ft^3 liners of radioactive waste. The contents of this report includes the analysis of the structural shoring and shielding provided by the secondary container (concrete-carbon steel insert) in the SN-1 interior.

The design of the insert involves the 50 ft^3 liner being surrounded by a carbon steel cylinder with a bottom plate of carbon steel. The space between the carbon steel walls and the SN-1 wall is filled with concrete. A concrete plug-type head with a carbon steel bottom is then placed on top of the liner with a rubber mat being placed on top of the plug. This design will completely enclose the interior space between the liner and the SN-1 interior walls. This insert is designed to meet all NRC and DOT regulations pertaining to the shipping of large quantities of radioactive material.

1.2 Package Description

1.2.1 Packaging

The SN-1 package description is found in the SAR, part 1.2, accompanying the Certificate of Conformance 6771, Rev. 3, and will not be repeated here. The insert consists of a carbon steel cylinder 50 inches O.D. and 57 inches high, with the top being open. The 50 ft^3 liner is placed within this cylinder. This carbon steel cylinder is enclosed by a concrete cyliner 75½ inches high, 1 inch thick, with an O.D. of 72 inches. The top 18½ inches of this concrete cylinder are tapered to allow easier placement of the concrete plug-type head onto the liner top. The concrete plug is 18½ inches thick with an O.D. of 58 inches on top tapered to an O.D. of 56 inches on the bottom. The plug is also equipped with lifting lugs to provide quick removal and placement. The liner itself is also provided with lifting lugs. This insert was designed to meet all regulations associated with normal transportation and accident conditions found in the NRC and DOT radioactive waste shipping regulations.

The design details and dimensions are found on the drawings in Appendix 1.3. The principal design parameters for the insert are shown below. The parameters for the model SN-1 shipping cask are given in the SAR of the SN-1 licensing package in Section 1.2, Package Description.

Carbon Steel Cylinder:	57 inches high, 50 inches O.D. Side walls .25 inches thick. Cylinder bottom 51½ inches O.D. 3 inches thick. Weight - 2357 lbs.
Concrete Cylinder:	75½ inches high, 72 inches O.D. (Top 18 inches tapered), 11 inches thick. Weight - 9221 lbs.

Concrete Plug:	18 inches thick, 58 inches O.D. on top, 56 inches O.D. on bottom. Bottom plate - .5 inch thick carbon steel. Weight - 3094 lbs.
Total Weight of Insert:	14,672 lbs.

1.2.2 Operational Features

Not Applicable.

1.2.3 Contents of Package

The SN-1 shipping container with insert will be used to transport EPICOR II prefilter liners which were used to treat intermediate level activity water. The liner is a five feet high right circular cylinder, four feet in diameter containing approximately 30 ft^3 of ion exchange media. The walls and top are ¼" thick with the bottom ½" to 5/8" thick made of A-36 carbon steel and of welded construction. The interior of the liners are coated with Phenoline 368 to retard corrosion. A cross-sectional view of the liner is shown in Appendix 1.3.

There are a total of 49 liners now stored on site at TMI. Of the 49 liners, number 1 through 11 contain organic resin material only, while numbers 12 through 50 contain both inorganic and organic resin material. The organic resin consists of anion, cation and mixed bed media. The vessels have all been dewatered to a bounding limit of 2.0% (volume) free standing water.

Liner number 16 has been extensively tested at Battelle Columbus Laboratories and it is believed to be representative of the remaining 49 liners. The liners are loaded to under 5000 curies, keeping within the limit established in section 1.2.3 of the SAR for the licensing package.

The liners will be vented, sampled and purged with an inerting atmosphere by means of a tool developed by EG&G Idaho prior to shipment. This will insure that the gas mixture in the liner is known and understood and that the contents will remain within known conditions during the time of shipment.

1.3 Appendix

1.3.1 Loading Configuration

The basic loading configuration is represented by the concrete-carbon steel insert loaded into the SN-1 cask, with the 50 ft^3 liner loaded into the insert and then having the concrete plug-type head being placed on the insert. A rubber mat is then placed on top of the concrete plug-type head. The purpose of this mat is to completely fill the void between the concrete head and the lid of the SN-1. The SN-1 cask lid is then secured in place along with the impact limiters. When the top impact limiter is in place, sheet metal of the same diameter as the top of the impact limiter will be placed on the impact limiter and bolted to it. The SN-1 loading parameters are given in section 1.3, Appendix, of the original SAR for the model SN-1. The total weight of the entire package is shown below:

Weight of insert	-	14,672 lbs.
Weight of 50 ft^3 liner	-	3,050 lbs.

Weight of SN-1	-	36,700 lbs.
TOTAL WEIGHT	-	54,422 lbs.

This weight is under the 60,000 lbs. limit maintained in the original SAR for the model SN-1 licensing package found in section 1.3, Appendix. This is also under the 23,300 lbs. maximum weight of contents allowed in the SN-1 under this same section of the original SAR.

The major radioactive constituents and their activities are as follows:

Isotope	Half Life	Activity (curies)
Sr^{90}	29 years	43.66
Cs^{134}	2.06 years	189.47
Cs^{137}	30.17 years	991.67
Ru^{106}		126.27

The majority of gamma activity is from Cs^{134} and Cs^{137} and is concentrated into the top 3 to 6 inches of the resin bed.

Radioactive constituents consist of activated corrosion products and fission products in transport groups I, II, III, and IV. The liner will contain less than 15 grams of TRU and will therefore be fissle exempt. The decay heat generated is minimal, amounting to only a few watts and not exceeding 100 watts.

The Battelle Columbus Laboratory also performed a gas analysis on the void space between the resin layer and the top of the liner with the following results listed in Table 1:

TABLE 1

Gas Analysis of liner PF-16 by Battelle Columbus Laboratory

	PF-16 Light Fraction Sample 1	PF-16 Light Fraction Sample 2[a]	PF-16 Heavy Fraction
	Volume Percent		
Carbon Dioxide	5.52 ± 0.06	5.27 ± 0.06	0.30 ± 0.03
Argon	0.96 ± 0.05	0.96 ± 0.05	0.94 ± 0.05
Oxygen	0.20 ± 0.02	0.30 ± 0.05	20.2 ± 0.2
Nitrogen	80.6 ± 0.4	81.2[b] ± 0.5	78.0 ± 0.4
Carbon Monoxide	0.2 ± 0.02	------	0.004 ± 0.001
Hydrogen	12.4 ± 0.2	12.2 ± 0.02	0.5 ± 0.05
	Parts per Million by Volume		
Methane	500. ± 2.5		45. ± 5.
Ethylene & Acetylene	0.7 ± 0.1		0.1
Ehane	42. ± 4		4. ± 1.
Propylene	0.1		0.1
Propane	6. ± 1		1. ± 0.2
Iso-butane	0.6 ± 1		0.4 ± 0.1
n-Butane	0.1		0.1
Hydrogen Sulfide	20		20
Carbonyl Sulfide	10		10
Suflur Dioxide	10		10
Unknown Components	20		20

a. Not subjected to detailed analysis.

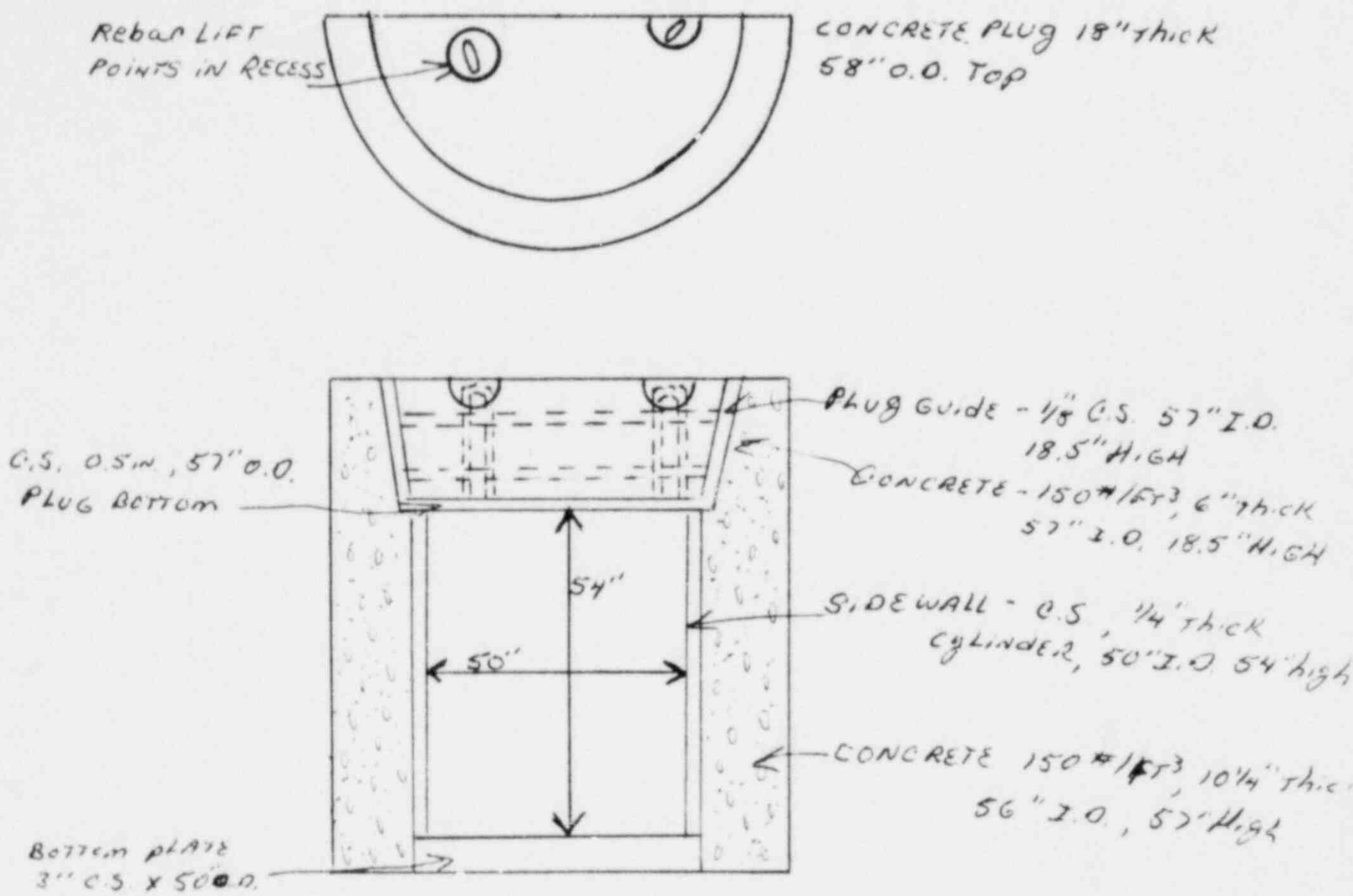
b. Includes CO.

2. Structural Analysis

2.1 Description

The SN-1 radwaste shipping container is to be used for shipping the 4x4 prefilters used by the EPICOR II system. Although these prefilters are within the total curie content specified for the SN-1 cask, the radiation concentrations cause local high radiation at the containment boundary. For this reason additional concrete shielding is being added around the liner between the SN-1 containment. This concrete, combined with steel forming, provides both cribing and shielding for the 4x4 EPICOR prefilters. The bottom of the shielding consists of a flat plate 3" thick, the sidewalls being a ¼" thick, carbon steel cylinder used as a form to place 10 3/4" of 3000 psi concrete around the sides. The top plug is a ½" thick carbon steel plate with 18" of reinforced concrete cast in place and removable. The concrete top and the steel sidewall cylinder are tapered and coated with a concrete release agent to facilitate removal when the cask is returned to normal service.

2.2 Weight Distribution



MATERIALS AND WEIGHTS

Bottom Plate				
CS	3.48 ft^3 at 495#/ft^3			1722#
Sidewall				
CS	1.23 ft^3 at 495#/ft^3	=	608	
Grout	68.23 ft^3 at 150#/ft^3	=	10,234	10,843
Plug Guide				
CS	.25 ft^3 at 495#/ft^3	=	125	
Grout	16.22 ft^3 at 150#/ft^3	=	2,440.5	2,565
Plug				
CS	.74 ft^3 at 495#/ft^3	=	365	
Concrete	26.6 ft^3 at 150#/ft^3	=	3,987	4,352
				19,482

Liner 3,050 + shield 19,482 + SN-1 36,700 + 59,232

2.3 Free Drop Design Envelope

The SN-1 cask was designed for a free drop of 30 feet. Since deceleration loads from a one foot drop (18.94g) were considerably less than the design allowable, maximum stresses would not exceed the allowable due to a one foot drop.

The SN-1 design conditions for a 30 foot drop are as follows:

	Load	Deceleration	Design Conditions
1.	End Drop	G = 45g	Maximum pressure internal 258 psi References 2.7.1.1
2.	Side Drop	G = 90g	Maximum internal load 27,592 #/inch as line load References 2.7.1.2
3.	Corner Drop	G = 30g	Maximum internal load 23,000 # uniformly distributed 50% head, 50% side
4.	Top Impact	G = 45g	Maximum pressure internal 258 psi Reference 2.7.1.4

The following evaluation assumes that the concrete density is 150#/ft.[3] for those cases where loading on the SN-1 cask exceeds the design, a lower density concrete is specified to assure reduction of loads to be within the SN-1 design envelope.

2.4 End Drop Internal Pressure

The internal pressures developed

a) From liner and steel form and plug.

1) Force - F_1

$$F_1 = \frac{W}{g} a$$

W =	weight of liner	3050
	+ weight of bottom	1722
	+ weight of CS side	608
	+ weight of plug	4477
	W =	9857

$$\therefore F_1 = \frac{9857}{g} 45g = \underline{443,600\#}$$

2) Pressure - P_1

$$P_1 = \frac{F_1}{\pi(25)^2} = 221 \text{ psi}$$

b) From Concrete Side Wall

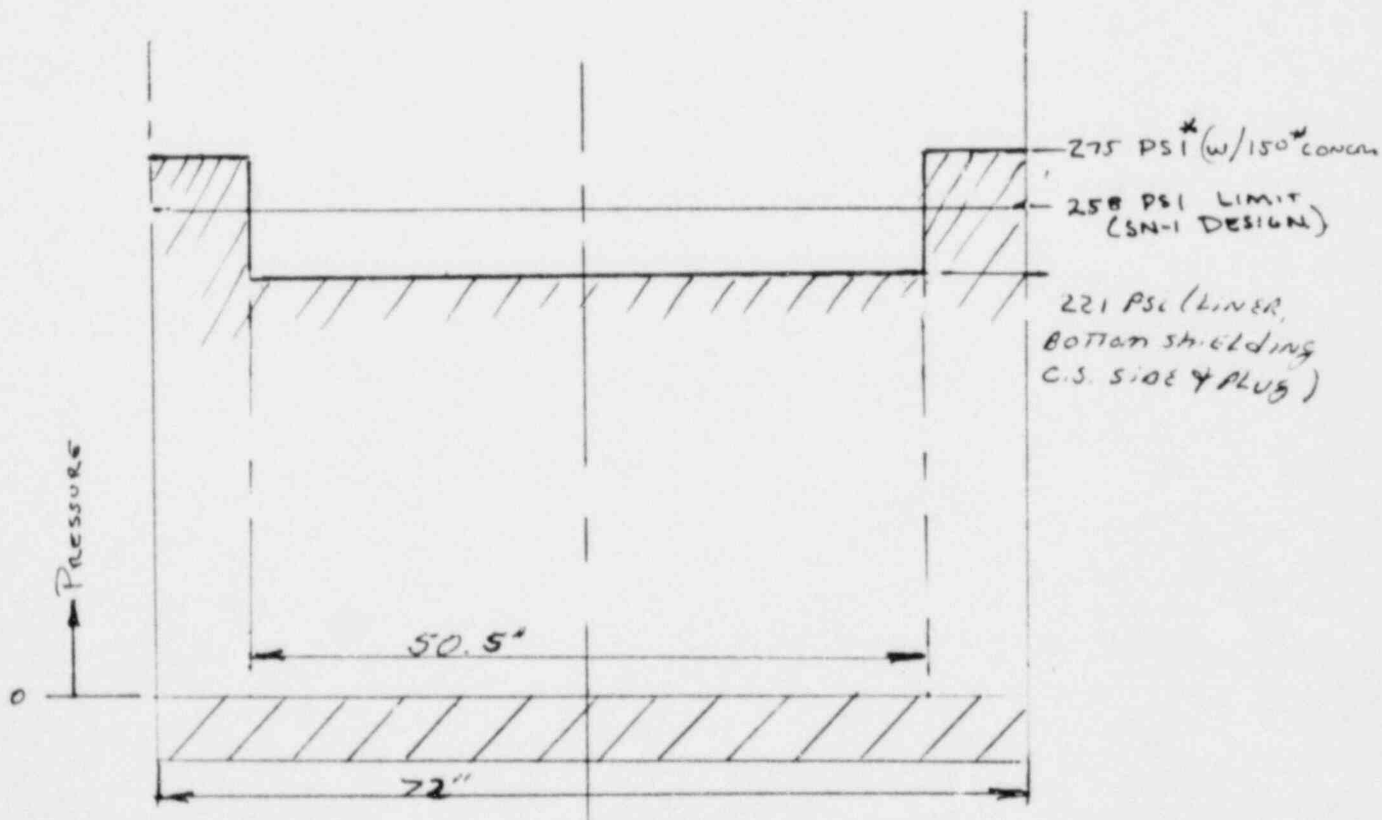
1) Force

$$F_2 = \frac{(10{,}234 + 2404)}{g} 45g = 568{,}710\#$$

2) $$P_2 = \frac{568{,}710}{\frac{\pi}{4}(72^2 - 50.5^2)} = 275 \text{ psi}$$

*Concrete density for acceptability = $\frac{258}{275} \times 150 = 140\ \#/ft^3$

c) Load Distribution on Bottom of SN-1 Cask



SN-1 CASK BOTTOM PRESSURE DISTRIBUTION

2.5 Side Drop Internal Pressure

a) Weight distribution on shell from bottom plate in line load

$$F_1 = \frac{W}{D}g = \frac{1722 \cdot 90}{(10.75+3)} = 11{,}271 \text{ \#/in}$$

b) Weight distribution on shell from shielding and cylinder

$$F_2 = \frac{(608 + 3050 + 10{,}234)90}{(54 + 3)} = 21{,}935 \text{ \#/in.}$$

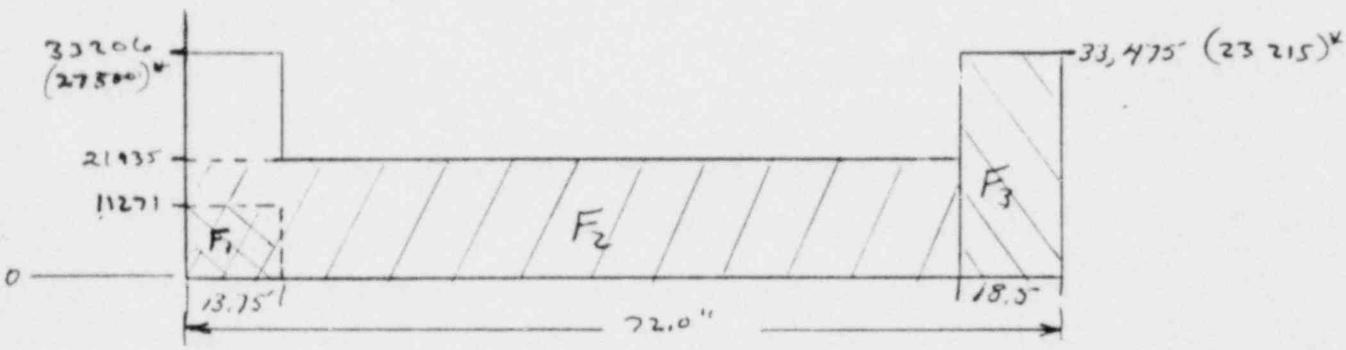
(16,500)*

c) Weight distribution from plug and plug guide

$$F_3 = \frac{((365 + 3987) + (125 + 2404))90}{18.5} = 33{,}475.14 \text{ \#/in.}$$

(27,256)*

d) Load Summary

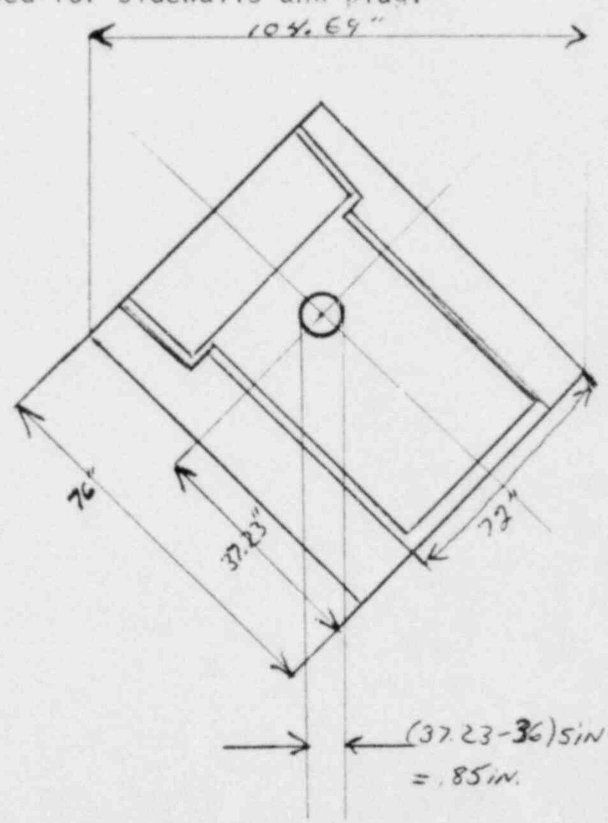


*Providing 100 #/ft^3 concrete is used for sidewalls and plug.

2.6 Corner Drop Internal Pressure

Determine C.G. of liner and Shielding

Item	Weight	X into CG
Liner	3050#	30"
Bottom	1722	1.5"
Cylinder C.S.	608#	30"
Cyliner Grout	10234#	28.5"
Plug C.S.	365#	57.25"
Plug Concrete	3987#	66.50"
Plug Guide C.S.	125#	66.25"
Plug Guide Conc.	2440#	66.25"



$$CG = \frac{\Sigma WX}{\Sigma W} = \frac{859955}{22531} = \underline{38.17} \text{ inches}$$

<u>Distribution of Load on Bottom and Side</u>

$$\text{Sides} = \frac{(52.35 + .12)}{104.69} = 50.1\% \text{ or } (.501)(22531) = 11288.$$

$$\text{Bottom} = \frac{52.35 - .12}{104.69} = 49.9\% \text{ or } (.499)(22531) = 11243.$$

2.7 Top Impact

The internal Pressure developed

a) From Plug and Steel Form and Liner

1) $F_1 = \frac{W}{g} a$

W = Weight of liner	3050
+ Weight of Bottom Plate	1722
+ Weight of C.S. Side	608
+ Weight of Plug	4352
+ Weight of Side Concrete*	2715
	12447

$^*\frac{\pi}{4}(57^2 - 50.2^2)57/12^3 = 18.10 \text{ ft}^3$

$$F_1 = \frac{12447}{g} 45g = 560{,}115\#$$

2) Pressure

$$P_1 = \frac{F_1}{\frac{\pi}{4}(57)^2} = 220 \text{ psi}$$

b) From Concrete Sidewall

1) Force - F_2

$$\text{Weight} = (\tfrac{\pi}{4}(72^2 - 57^2)76/12^3)150$$

$$= (66.84)(150) = 10026$$

$$F_2 = \frac{10026}{g} 45g = \underline{451{,}170\#}$$

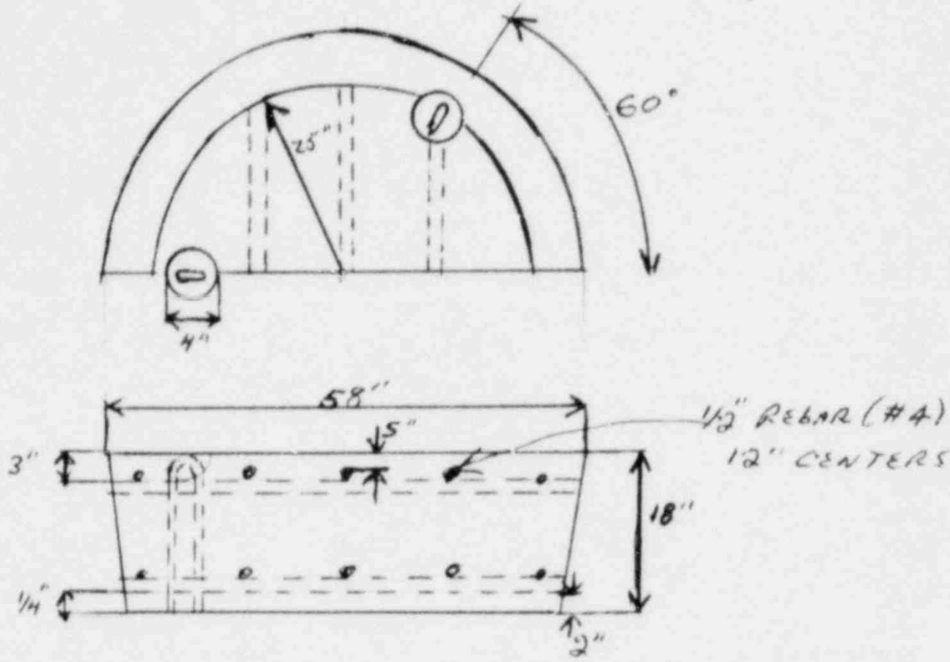
2) Pressure

$$p\ \frac{451{,}170}{\frac{\pi}{4}(72^2 - 57^2)} = 296 \text{ psi}$$

*Providing 130#/cu. ft. concrete is used for sidewalls.

2.8 Plug Detail for SN-1 Cask Shielding

Deformed Bar Placement



*Actual Dimension Determined By Layout.

1. Reinforcement to concrete ratio = .00185

   Grade 60 deformed bar required (ACI Chapter 7.12) for shrinkage and temperature reinforcement.

2. Lift weight 5000# ∴ Stress on lift bar with D.F. = 2.0 all on one log.

$$= \frac{5000 \times 2.0}{.20 in.^2} = 50,000 \text{ psi (allowable 60, ksi)}$$

$$DM = \frac{60}{50} = 1.2$$

2.9 Summary

The addition of shielding-cribing inside the SN-1 cask, to accomodate the concentrated radiation conditions of the EPICOR II prefilter liners, was found to be within the cask design envelope for a 30 foot drop test. The design conditions used to qualify the unmodified SN-1 cask for the 30 foot drop test, converted the assumed cask contents into several loading cases. The shielding-cribing and liner contents of the SN-1 modification were used to determine loading distributions for each of these conditions. These loading distributions were found to be within the design envelope of the SN-1 cask analysis. Limitations required to assure restriction of loads within this envelope are that the concrete density of the sidewall shielding-cribing remains less then 100 pounds per cubic foot. With this SN-1 modification designed for the 30' drop conditions, all other design considerations such as one foot drop or shipping loads are considered inconsequential.

3. Thermal Evaluation

3.1 Discussion

The thermal evaluation presented in Section 3.0 of the SAR for the Certificate of Conformance 6771, Rev. 0, of the model SN-1 licensing package is to be referenced for this section of the present report. The original SAR presented very conservative upper bound limits used in thermal analysis and these would not be changed by the proposed insert.

The following analysis is concerned only with the effects of temperature on the concrete insert. To be more specific the following analysis addresses only the maximum temperature during normal transport conditions and the hypothetical fire conditions. The reasons for this selectiveness is that the concrete insert would not be adversely affected by the minimum temperature of -40^{o}F in still air and shade as presented in the original SAR for the licensing of the SN-1. Furthermore, because the thermal expansion rate of the concrete (.60E-5) is less than that of the steel (.65E-5) used for the cask, there is no internal pressure due to heating expected.

The analysis will show that the concrete insert temperature at the maximum temperature during normal shipping conditions will be maintained at 190^{o}F and during the half hour fire conditon the concrete temperature will be maintained at 197^{o}F. Thus the concrete insert will experience no significant degradation during these high temperature conditions.

3.2 Summary of Thermal Properties of Materials (taken from the original SAR for the SN-1 License)

3.2.1 O-Ring

The O-ring has an operating range of -70^{o}F to 700^{o}F for ½ hour, with no loss of service.

3.2.2 Insulation

The insulation is Johns Manville H. T. Banroc; for specifications see Appendix 3.o

Description of Thermal Protection System

The exposure of a bare steel SN-1 cask to the fire accident could result in excessive internal pressure due to vaporization of any liquids in the package.

Accordingly, the SN-1 cask is equipped with an insulating thermal protection system which is designed to limit the rise in containment temperature and pressure in the event of the fire accident. The elements of the thermal protection system are as follows (See Drawing B-08001 in Section II):

- Urethan Foam

  The cask top and bottom corners are protected from the fire by the presence of the shock absorbers. The shock absorbers are completely clad with 24 gauge 304 stainless steel and are held in place by means of support brackets which are designed to withstand the "g" loads of impact in the 30 ft. drop test. The shock absorber material is Upjohn Isonate System CPR 13 fire retardent urethane foam.

- Jacketed Insulation

  All exposed surfaces of the SN-1 cask with the exception of tie down and lifting lugs are covered with 1" thick Johns Manville Banroc block insulation.

  This insulation is canned in a 24 gauge 304 stainless steel jacket. The jacketed insulation is held to the shell by means of 304 stainless steel straps. Top and bottom segments consist of circular plates held to the cask by means of bolts and washers. The ends of the Banroc insulation are recessed under the urethane foam shock absorbers.

  The purpose of the thermal protection system is to control, not necessarily eliminate, heat input to the cask from the fire accident such that containment temperature and pressure do not exceed design values. Portions of the cask such as tie down and lifting lugs will be exposed to the fire. Also, local heating of the cask could occur at joints in the jacketed insulation and at local areas in the thermal protection system which may be damaged during the puncture tests. These effects are considered and discussed in Sections 3.4 and 3.5.

3.2.3 Impact Limiters

The impact limiters are filled with Upjohn CPR 13; for specifications see Appendix 3.6.

3.3 Technical Specifications of Components

See appendix 3.6.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Maximum Temperature - $130^{o}F$ in still air.

3.4.1a Effects of Solar Heating

The incident solar energy on clear days at latitude $42^{o}N$ is given in Figure 5.3 of reference 1. Because of the cyclic nature of the solar heat load and the large thermal capacity of the SN-1 cask, an average value of solar heat load over 24 hours is used in the analysis.

Integrating the curve denoted as normal in Figure 5.3 of reference 1 gives an average solar heat load of 144 BTU/hr-ft^2.

The Total Solar Heat Load is:

qs = 144 BTU/hr-ft^2 x 6.6 ft x 7.0 ft.

= 6650 BTU/hr.

The Decay Heat Load is:

qd = 6 watts = 20 BTU/hr.

Total Heat Load to be rejected from Cask Surfaces is:

qt = qs + qd = 6650 + 20 = 6670 BTU/hr.

Basic equation describing convection and radiation from a cask surface is:

$$qt = hcAC(Ts-Ta) + 0.173\ F_{12}\ Ar((\frac{Ts + 460}{100})^4) - (\frac{Ta + 460}{100})^4$$

qt = Total heat transferred, BTU/hr.

hc = Convective heat transfer Coefficient, BTU/hr-ft^2-$^{+}$F.

Ac = Effective convective surface area, ft^2.

Ar = Effective radiative surface area, ft^2.

Ts = Cask Surface Temperature, F.

Ta = Ambient Temperature, ^{o}F.

F12 = The Gray Body Shape Factor.

Because external surface of cask is unpinned, the effective surface areas for convection and radiation are the same and thus Ac - Ar = A, where A is ½ the total vertical surface of the cask:

$$A = \frac{\pi \times 6.66 \times 7.0}{2} = 73\ ft^2.$$

The convective heat transfer coefficient hc is:

$hc = 0.19(Ts - Ta)^{1/3}$ (from equation 5.4 of reference 1).

As discussed on page 136 of reference 1, the gray body shape factor, F_{12}, may be approximated by E, the emissivity of the cask surface, if the surroundings are large compared to the cask. The emissivity for brightly polished 304 stainless steel can be estimated from Table A-23 of reference 2, as 0.5. Thus the basic convection and radiation equation becomes:

$$\frac{6670}{73ft^2}\ BTU/hr. = 0.19(Ts - 130)^{4/3} + 0.086\ \left(\left(\frac{Ts + 460}{100}\right)^4 - \left(\frac{130 + 460}{100}\right)^4\right)$$

Trail and Error Solution Yields Ts = 189^{0}F.

The temperature of the cask contents under normal conditions of transport is calculated by considering the decay heat flow through the concrete insert, cask wall and insulation jacket as shown below:

Assuming all decay heat is transferred from the vertical jacketed surface, the decay heat flux is:

$$\frac{Qd}{A} = \frac{20}{\pi \times 6' \times 4'} \text{ BTU/hr.} = 0.27 \text{ BTU/hr-ft}^2$$

The heat flow through the Banroc insulation is given by:

$$\frac{Qd}{A} = \frac{K}{X}(T_4 - 189^oF) \text{ BTU/hr-ft}^2$$

Where $K = 0.36$ BTU/in/ft^2-'F-hr

$X = 1$ inch

$$\therefore T_4 = (0.27 \text{ BTU/hr-ft}^2)(\frac{1}{.36}) + 189 = 189.8^oF$$

The heat flow through the steel shell is given by:

$$\frac{Qd}{A} = \frac{K}{X}(T_3 - 189.8)$$

Where $K = 25$ BTU/hr-ft-^oF

$X = 4$ in. $= .33$ ft.

$$\therefore T_3 = 189.8 + \frac{.27}{25/.33} = 189.9^oF$$

The heat flow through the concrete insert is as follows:

$$\frac{Qd}{A} = \frac{K}{X}(T_2 - 1898) \text{ BTU/hr-ft}^2$$

Where $K = 1.05$ BTU/hr-ft-^oF

$X = 11$ inches $= 0.92$ ft.

$$\therefore T_2 = 189.9 + \frac{.27}{1.05/.92} = 190^oF$$

The heat flow through the inside air film is:

$$\frac{Qd}{A} = 0.19(T_1 - 190)^{4/3}$$

$$\therefore T_1 = (\frac{.27}{0.19})^{3/4} + 190 = 191.3^oF$$

Thus the cask internal temperature will be less than 191.3^oF under normal transport conditions.

3.5 Hypothetical Thermal Accident Conditions (Taken from the original SAR for the SN-1 License)

Cask Response to Fire Accident

The SN-1 cask structure and closure head seal is protected from the ½ hour fire accident by the thermal protection system described in Section 1.1. The main shell is protected by the 1" Banroc insulation. The top and bottom corners and closure head seal are protected by the insulating properties of the urethane foam shock absorbers. All components of the thermal protection system are designed to be retained under impact conditions and are canned in 24 gauge stainless steel for retention of form and insulating properties under direct exposure to fire.

Upon exposure to the 1475°F ambient it is expected that the insulation jacket will heat up rapidly due to the low heat capacity of the thermal protection system. The thermal energy transferred to the cask shell and internals during the ½ hour fire must be less than that given by a steady state calculation in which the outside surface temperature of the insulation is assumed to be equal to the 1475°F ambient and the inside surface temperature of the insulation is assumed to remain at the pre-fire steady state value. It is further assumed that all of the heat transferred through the thermal protection system plus all heat transferred through penetrations in the thermal protection system during the ½ hour fire is stored in the cask metal structure. The predicted cask shell temperature using this approach represent an upper limit for the post fire equilibrium condition.

3.5.1 Thermal Model

The model used to calculate maximum heat input to the cask and maximum post fire equilibrium temperature is shown in Figure 3-1. A half cylindrical segment shown cross hatched in Figure 3-1 is assumed to be available to absorb heat input from the fire. Heat is transferred to the cask metal by the following means:

1. Conduction through the Banroc insulation. Insulation outside surface temperature is assumed to be equal to the 1475^{o}F fire ambient. Insulation inside surface temperature is assumed to be constant at 189.8^{o}F.

2. Conduction through the urethane foam shock absorber. Credit has been taken for only a 6 inch thickness of urethane foam. The actual effective thickness will be much greater since only local compression will occur under corner and side impact. Under end impact the effective thickness is greater than 6 inches.

3. Radiation from the fire ambient to local openings in the thermal protection system. Local openings considered are:

• Cask tie down lugs (one half of the heat from one set of two lugs is considered)	1 ft^2
• Two shock absorber tie downs	0.28 ft^2
• Two lid lifting lugs	0.14 ft^2
• Local 6" diameter puncture of thermal protection system	0.20 ft^2
TOTAL	1.62 ft^2

Insulation surface areas and cask metal heat capacity

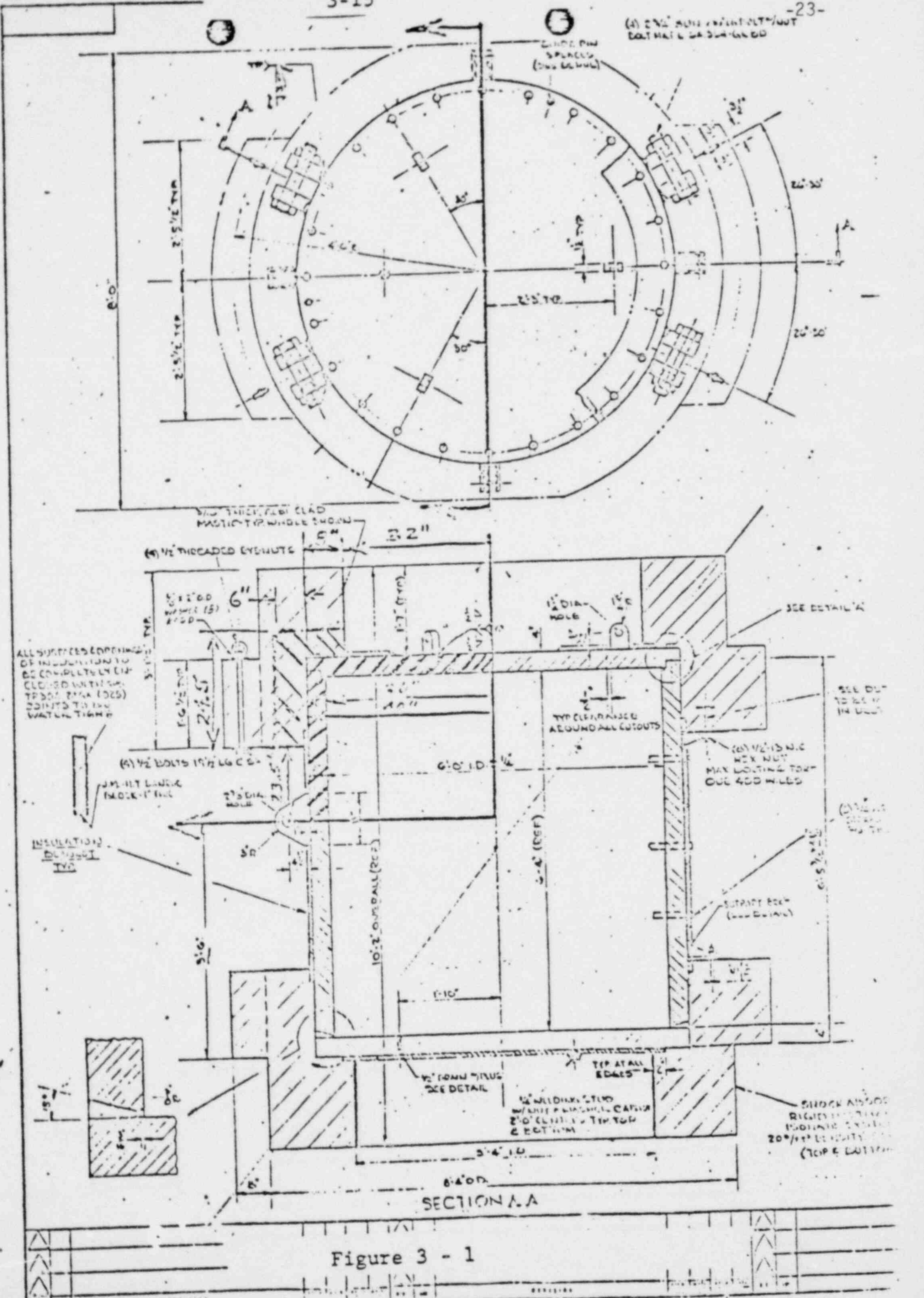


Figure 3 - 1

pertinent to this analysis are calculated below:

Banroc Insulation:

Top Area $= \frac{1}{2} \times \pi \times 32 \qquad = 1610 \text{ in}^2$

Side Area $= \frac{1}{2} \times 2\pi \times 41 \times 23.5 \qquad = \underline{3130 \text{ in}^2}$

$4740 \text{ in}^2 = 32.2 \text{ ft}^2$

Urethane Shock Absorbers:

Top Area $= \frac{1}{2} \times \pi((46)^2 - (32)^2)) \qquad = 1720 \text{ in}^2$

Side Area $= \frac{1}{2} \times 2\pi \times 46 \times 24.5 \qquad = \underline{3540 \text{ in}^2}$

$5260 \text{ in}^2 = 36.5 \text{ ft}^2$

Cask Metal Heat Capacity

Top: $\frac{1}{2} \times \pi \times 40^2 \times 4 \times 0{,}29 \text{ \#/in}^3 \times 0.11 \frac{BTU}{\#^oF} = 320 \text{ BTU/}^oF$

Shell: $\frac{1}{2} \times \pi(40^2 - 36^2)\ 38 \times 0.29 \times 0.11 \qquad = \underline{579 \text{ BTU/}^oF}$

899 BTU/^oF

3.5.2 Package Conditions and Environment

See 3.5.1.

3.5.3 Package Temperatures

The thermal energy absorbed by the cask metal during the ½ hour fire .s as follows:

Banroc Insulation:

$Q = \frac{k}{x} \times A \times \Delta T \times \frac{1}{2} \text{ hour} \qquad \text{BTU}$

where x = insulation thickness = 1 inc

A = heat transfer survace area = 32.2 ft^2

$\Delta T = 1475 - 189.8 = 1285.2^oF$

k = thermal conductivity = $0.625 \frac{BTU \text{ in}}{ft^2 \text{ hr } ^oF}$

$Q = \frac{0.625}{1.0} \quad 32.9 \times 1285.2 \times \frac{1}{2} = 13{,}214 \text{ BTU}$

Urethane Shock Absorber:

$Q = \frac{k}{x} \times A \times \Delta T \times \frac{1}{2} \text{ hour} \qquad \text{BTU}$

$$Q = \frac{0.41}{6.0} \times 36.5 \times 1285.2 \times ½ \quad = \quad 1603 \text{ BTU}$$

Thermal Protection System Penetrations:

The net heat interchange between the fire and the cask exposed metal surface is given by:

$q/A = h_r(T_f - T_s)$

Where

T_f = Temperature of radiation environment = 1475^oF

T_s = Surface temperature of cask = 189.8^oF

$h_r = 0.173 \times 10^{-8} F_{12} ((T_f = 460)^2 + (T_s + 460)^2)$

$((T_f + 460) + (T_s + 460))$ BTU/hr ft^2 ^oF

During the fire, F_{12} is equal to the effective emissivity, ε_r, of the cask surface which is given by:

$$F_{12} = \varepsilon_r = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = \frac{1}{\frac{1}{0.8} + \frac{1}{0.9} - 1} = 0.735$$

$h_r = 0.173 \times 10^{-8} \times 0.735\ (1935^2 + 649.8^2)(1935 + 649.8)$

h_r = 13.69 BTU/hr ft^2 ^oF

The thermal energy picked up by the cask metal through openings in the thermal protection system is:

$Q - h_r A (T_f - T_s) \times ½$ hour

$Q = 13.69 \times 1.62 \times 1285.2 \times ½ = 14{,}252$

Total Energy Absorbed by Cask Metal = 13,214 + 1603 + 14,252

= 29,069 BTU

Maximum possible post fire temperature rise of the cask metal is:

$$\Delta T_{max} = \frac{\text{Total Energy Absorbed}}{\text{Cask Metal Heat Capacity}} = \frac{29{,}069 \text{ BTU}}{890 \text{ BTU}/^oF} = 32.7^oF$$

The maximum possible post fire temperature of the cask metal is:

$T_{max} = 189.8 + 32.7 = 223^{o}F.$

Using this temperature the energy absorbed by the concrete insert is:

$$\frac{Q}{A} = \frac{K}{X}(T_3 - T_2)$$

where: $K = 1.05$ BTU/hr-ft-^{o}F

$X = .92$ ft.

$T_3 = 223^{o}F$

$T_2 = 190^{o}F$

$A = 2\pi 3(3 + 6.29) = 175\ ft^2$

$$Q = 175 \times \frac{1.05}{.92} \times (223 - 190) = 6591\ BTU$$

The temperature rise of the concrete insert is:

$$\Delta T = \frac{\text{Total Energy Absorbed}}{\text{Concrete Heat Capacity}}$$

Where the concrete heat capacity

$$= 0.156\ \frac{BTU}{lb\ ^{o}F} \times 120\ \frac{lb}{ft^3} \times 50.3\ ft^3 = 942\ BTU/^{o}F$$

Thus $\Delta T = \frac{6591}{942}\ \frac{BTU}{BTU/^{o}F} = 7.0^{o}F$

The maximum temperature of the concrete insert is $190 + 7.0 = 197^{o}F$

REFERENCES

1. Cask Designer Guide - ORNL-NSIC-68
   - L.B. Shoppert.
2. Heat Transmission - W. H. McAdams
   - 3rd Edition - McGraw-Hill.
3. SAR for Licensing of Model SN-1 Radwaste Shipping Container.

4. Containment

4.1 Containment Boundary

4.1.1 Containment Vessel

The model SN-1 is the containment vessel and is defined in section 4.0 of the original SAR and is referenced for this section. The concrete-carbon steel insert is considered the secondary containment shielding. The insert is a 10" thick, 75½" high concrete cylinder poured in place. A carbon-steel cylinder (50" inside diameter, 57" high with ¼" thick walls) is used as an inner form. The bottom of this cylinder is carbon steel 51½" in diameter and 3" thick which will provide shielding for the underside. The 50 ft^3 vessel will sit inside this carbon steel liner with a tapered plug-type head then fitting into the top of the concrete cylinder. This tapered plug is also cast into place and keyed into position to provide nominal interference with fit during removal and replacement.

4.1.2 Containment Penetrations

Not applicable.

4.1.3 Seals and Welds

Not applicable.

4.1.4 Closure

The concrete plug-type head with a ½" carbon steel bottom plate weighs 3126 lbs. and fits into the top of the concrete liner and rests over the 50 ft^3 radwaste vessel. The top of the SN-1 then seals this entire insert.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Release of Radioactive Material

The SN-1 containment vessel and closure head maintain their integrity under the conditions specified in 10CRF71, Appendix A. Reference section 2, Structural Analysis, of the original SAR for the model SN-1 cask. The concrete carbon steel insert also maintains its integrity inside the SN-1 under these same conditions of 10CFR71, Appendix A. See section 2, Structural Analysis, of this report.

4.2.2 Pressurization of Containment Vessel

The 50 ft^3 liners of radioactive waste will be vented, sampled and purged with an inerting atmosphere prior to shipment which will insure that the gas mixture in the liner is known and understood.

4.2.3 Coolant Containment

Not applicable.

4.2.4 Coolant Loss

Not applicable.

4.3 Containment Requirements for the Hypothetical Accident Conditions

4.3.1 Fission Gas Products

Not applicable.

4.3.2 Release of Contents

For the model SN-1 cask, reference section 4.3.2 of the original SAR. The concrete-carbon steel insert completely encloses the 50 ft^3 liner and will not allow a release of liner contents into the interior of the SN-1 shipping cask under accident conditions. See section 2, Structural Analysis, of this report.

5. Shielding Evaluation

5.1 Discussion and Results

The purpose of this section is to provide the results of the shielding analysis on the concrete-carbon steel insert. The shielding evaluation for the SN-1 shipping cask is found in the original SAR of the licensing package. The present analysis shows that by using this insert, the radiation dose limits of 200 mr/hr on contact or 10 mr/hr at 2 meters for normal shipping conditions and 1.0 r/hr at 3 feet under accident conditions will be met. The structural analysis of the insert under accident conditions is found in section 2 of this report and may be referenced.

The radiation source was considered to be 1) concentrated in the top 3 inches of the ion exchange resin in the 50 ft^3 liner and 2) distrubuted evenly throughout the liner volume. The geometry of the 50 ft^3 liner is shown in Figure 5.1 and the insert and SN-1 package in Figure 5.2. To ensure conservatism, the radiation source for the accident condition was assumed to be concentrated in the top 3 inches of resin. The radiation source used in the calculation was as follows:

Cs-134	187.463 Curies	2.15×10^{-3} Curies/cm^3
Cs-137	991.673 Curies	1.14×10^{-2} Curies/cm^3
Ba-137m	912.339 Curies	1.05×10^{-2} Curies/cm^3

For the normal shipping conditions, the shielding analysis showed the following results:

Location	Dose Rate (mrem/hr)	
	Source in Top 3 Inches of Resin	Source Distributed Evenly
Side contact	69.13	22.16
Contact at 2 meters	5.494	4.8
Top contact	26.71	4.368
Contact at 2 meters	6.874	1.109
Bot contact	0.4893	18.16

For accident conditions it is assumed that the concrete carbon steel insert would develop cracks allowing the radioactive source to flow into various void spaces. Six different scenarios were considered and are shown below (the total volume of radioactive source in top 3 inches would be $8.71 \times 10^4 cm^3$):

1. The 2" x 4" x 2" lift handle voids.
2. The 2" x 7" x 10' liner hook void.
3. The gap between the sides of the prog and the wall of the insert is interference fit with a minimum gap of 1/16".
4. The space between the top of the plug and the SN-1 lid is fit with a rubber mat and it is assumed that this mat will completely fill the void.

The various source locations are shown in Figures 5.3 to 5.5.

The resulting dosages are shown below:

1. 2" x 4" x 2" lift handle voids:

Total source -	Cs-134	0.44 Curies
	Cs-137	2.35 Curies
	Ba-137m	2.16 Curies

   This source would occupy the void completely as shown in Figure 5.3, and is shielded by 4 inches of steel. The resultant dose rate is as follows:

Contact = 96.76 mRem/hr

At 3 ft = 14.09 mRem/hr

At 6 ft = 5.342 mRem/hr

At 2 m = 4.646 mRem/hr

2. 2" x 7" x 10" liner hook void:

Total Source -	Cs-134	4.23 Curies
	Cs-137	22.42 Curies
	Ba-137m	20.7 Curies

This source would occupy the void carefully as shown in Figure 5.4, and is shielded by 12" of concrete (100#/ft^3) and 4" of steel. The resultant dose rate is as follows:

Contact = 14.87 mRem/hr

At 3 ft = 3.007 mRem/hr

At 6 ft = 1.243 mRem/hr

At 2 m = 1.091 mRem/hr

3. Gap between plug sides and insert wall (1/16' x 18" x 18")

Total Source -	Cs-134	2.85 Curies
	Cs-137	15.13 Curies
	Ba-137m	13.93 Curies

The plug and insert are to be interference fit with a maximum gap of 1/16" possible after accident conditions. The source is assumed to enter this crack and fill it completely as shown in Figure 5.5 and is shielded by 4" of steel. The resultant dose rate is as follows:

Contact = 63 mRem/hr

At 3 ft = 9 mRem/hr

At 6 ft = 3.8 mRem/hr

At 2 m = 2.91 mRem/hr.

5.2 Appendix

This appendix contains the technical manual of the computer program used to obtain the shielding evaluation, and the various diagrams referenced in this section.

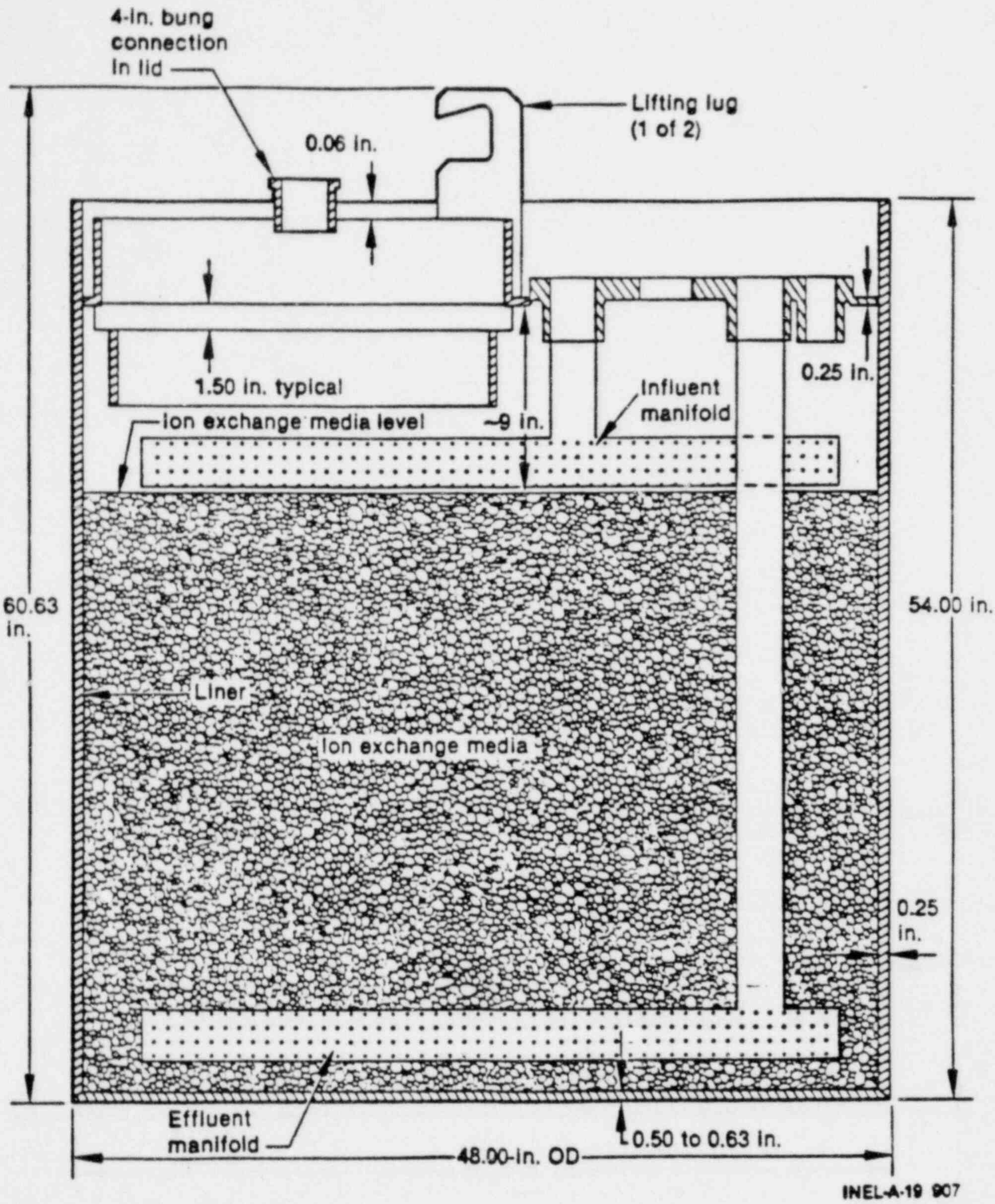


FIGURE 5.1 Cross-sectional view of a typical EPICOR-II liner.

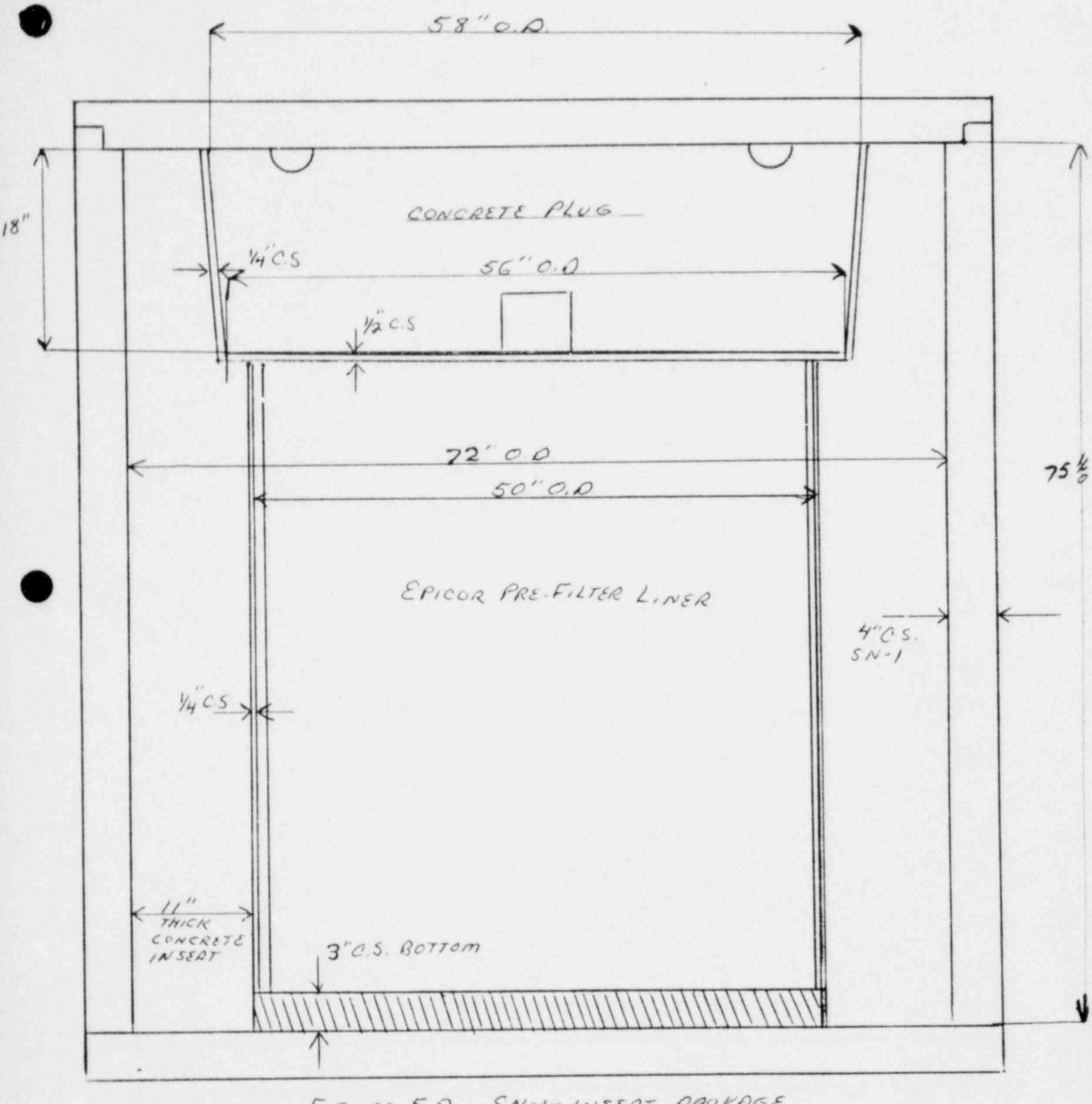


FIGURE 5.2 SN-1- INSERT PACKAGE

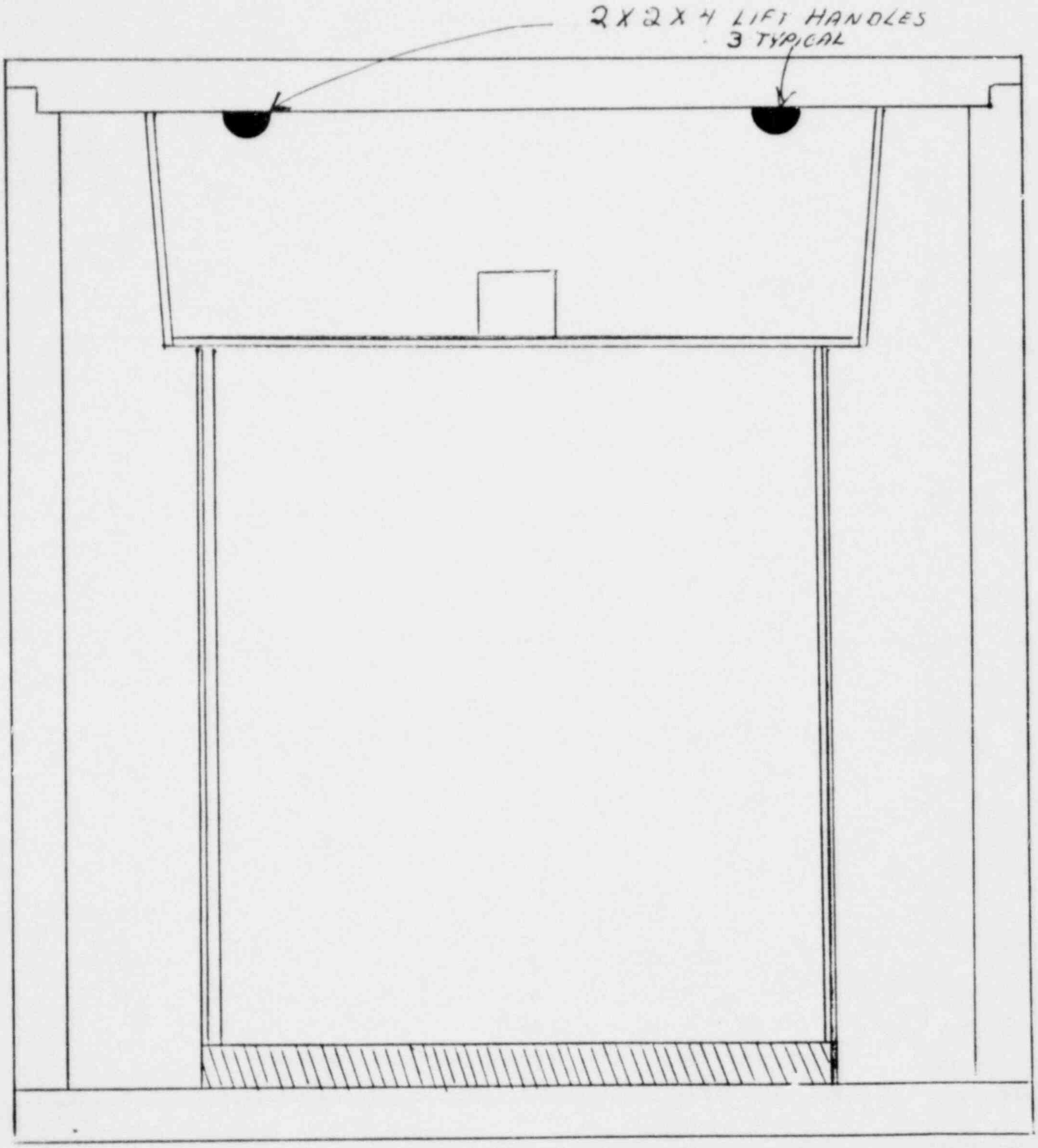


FIGURE 5.3 SOURCE LOCATION IN LIFT HANDLE VOIDS

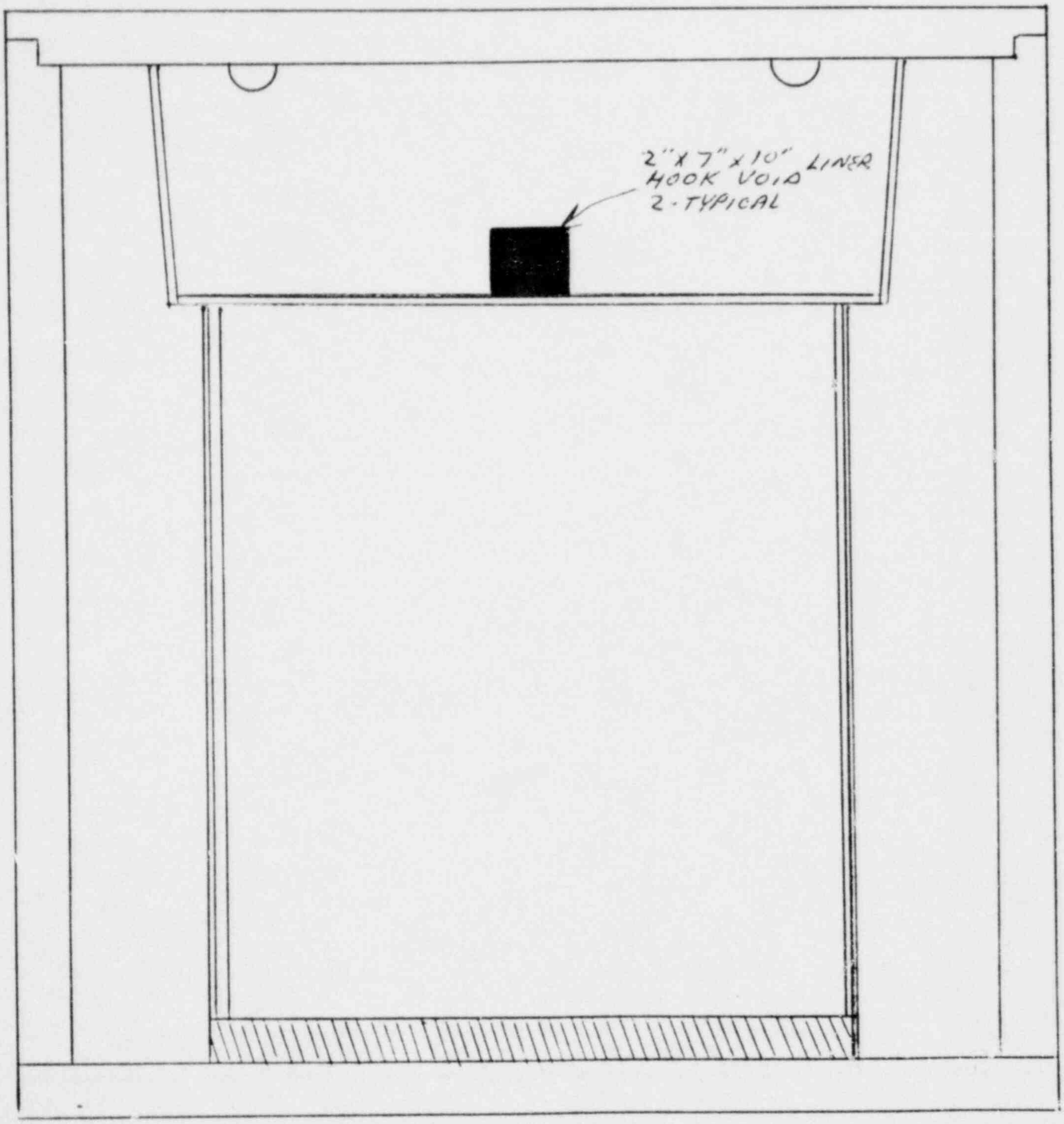


FIGURE 5.4 SOURCE LOCATION
2"x7"x10" LINER HOOK VOID

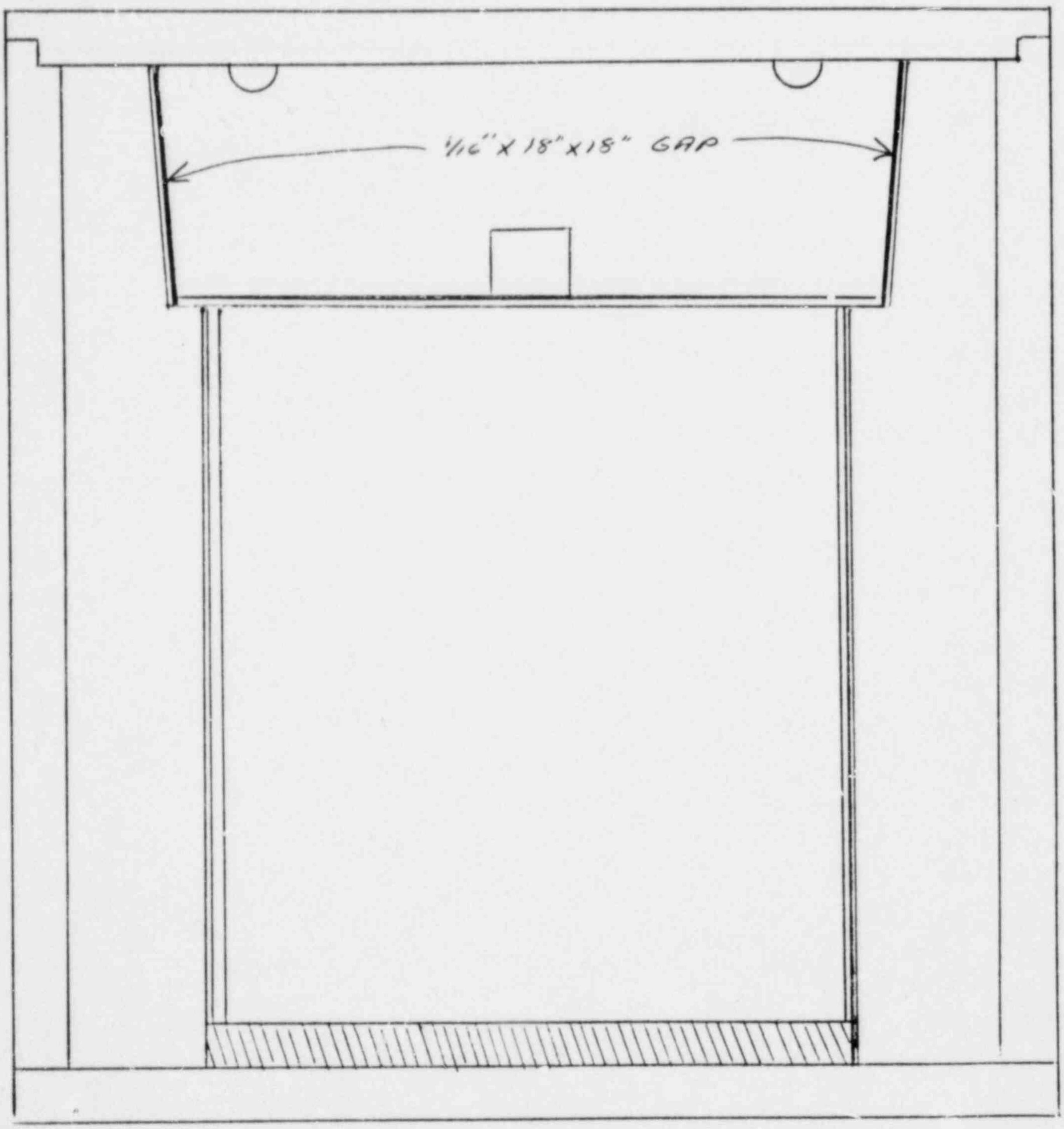


FIGURE 5.5 SOURCE LOCATION
1/16" X 18" X 18" GAP BETWEEN SIDE
WALLS AND PLUG SIDES

BNWL-236

AEC RESEARCH AND DEVELOPMENT REPORT

ISOSHLD - A COMPUTER CODE FOR GENERAL PURPOSE ISOTOPE SHIELDING ANALYSIS

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JUNE, 1966

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ABSTRACT

ISOSHLD is a computer code to perform gamma ray shielding calculations for isotope sources in a wide variety of source and shield configurations. Attenuation calculations are performed by point kernel integration; for most geometries by Simpson's rule numerical integration. Source strength in uniform or exponential distribution (where applicable) may be calculated by the linked fission product inventory code RIBD or by other options as desired. Buildup factors are calculated by the code based on the number of mean free paths of material between the source and detector points, the effective atomic number of a particular shield region (the last unless otherwise chosen), and the point isotropic NDA buildup data available as Taylor coefficients in the effective atomic number range of 4 to 82. Other data needed to solve most isotope shielding problems of practical interest are linked to ISOSHLD in various libraries.

TABLE OF CONTENTS

ISOSHLD - A COMPUTER CODE FOR GENERAL PURPOSE ISOTOPE SHIELDING ANALYSIS

INTRODUCTION

Shielding calculations associated with design and operation of atomic energy installations have traditionally been hand calculations which are time consuming and very approximate. This computer program, ISOSHLD (pronounced Isoshield), attempts to fill the need for a convenient semirigorous calculational method to handle the majority of these problems.

The program was also designed to include most basic data required for these calculations. Thus, considerable effort has been expended in compiling isotopic decay, material attenuation, buildup factor, and other required basic data for these types of shielding calculations. These data were placed in libraries chained to the code so that for most calculations all basic data are supplied.

For most problems the user need only supply:

- The geometry and material composition of the source
- The geometry and materials of the shields.

Optional modes of data entry are available for solving special problems.

The method used in the attenuation calculation is point kernel integration, i.e., the dose at the exposure point is the contribution from a large number of individual point sources. A numerical integration is carried out over the source volume to obtain the total dose.

The code obtains solutions for any combination of the variables listed below:

Shield and Source Geometry

1. Point
2. Line
3. Sphere
4. Sphere with slab shields
5. Truncated cone
6. Disc
7. Cylinder
8. Cylinder with slab shields
9. Cylinder end
10. Rectangular solid
11. Infinite slab and plane
12. Exponential source distribution where applicable

Isotope Selection from Calculated Fission Products

1. Noble gases
2. Halogens
3. Volatile solids
4. All except the above 3
5. All fission products
6. Individual isotopes by individual specification.

Source Type

1. Calculated source strength from known fuel irradiation exposure (See Note.)
2. Specify curies of isotopes in library--both fission products and activation products
3. Source strength in photons of specific energies for source volume.

Note: If Source Type 1 is specified, the irradiation history of the fuel must be described by supplying:

1. Initial conversion ratio
2. Fuel exposure time
3. Fast fission in U-238 per thermal fission
4. Reactor power history
5. Cooling time
6. Proper choice of above variables also approximates fuel irradiation in a fast reactor.

Shield Region Geometry and Materials

1. Number of regions - up to 5
2. Material in each region-choice of 18 (maximum of 20) materials in library
3. Material density in each region - 5 materials allowed in a region
4. Region and material for which buildup is most important.

THEORY

Point Kernel Integration

Figure 1 illustrates a point source, S_o (in this example within a large cylindrical volume, S_v), of gamma ray photons which emits with equal intensity in all directions.

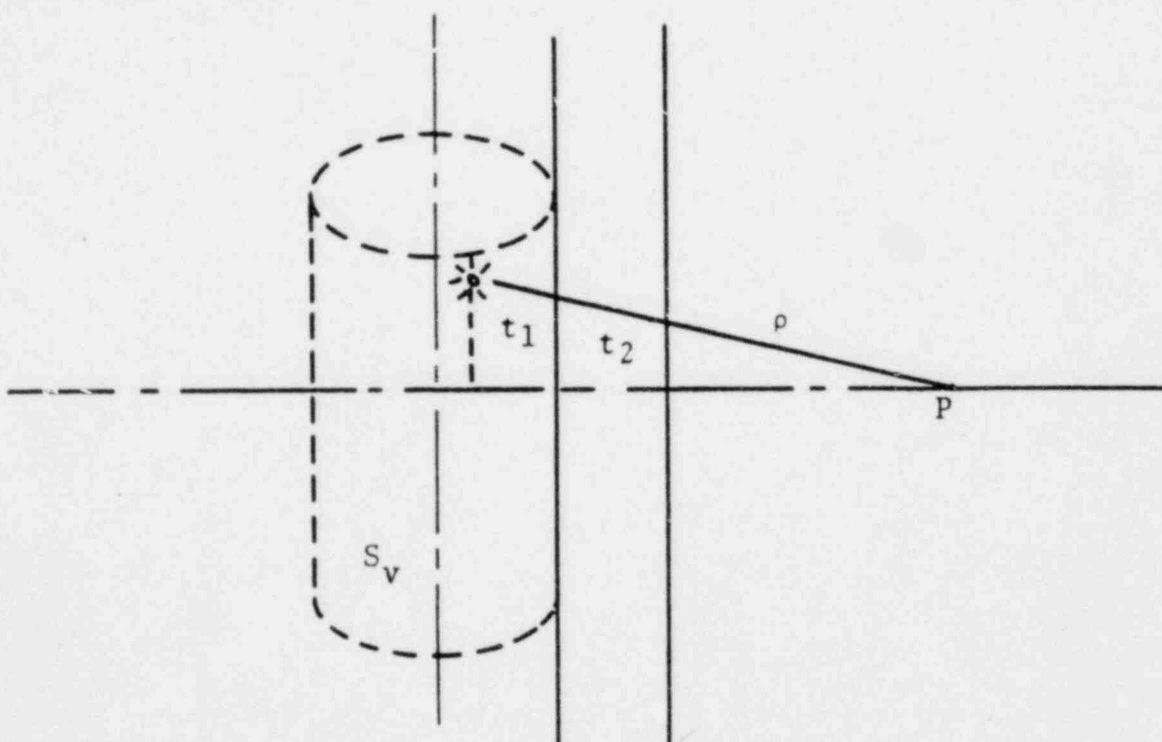


FIGURE 1. Point Source Within a Finite Volume

The dose rate at point P from photons originating at S_o is given by:

$$D = \frac{S_o B\ e^{-b_1}}{K 4 \pi \rho^2} \quad (1)$$

where:

$$b_1 = \sum_{i=1}^{N} \mu_i t_i$$

D = dose rate, R/hr

S_o = emission rate of gamma rays, photons/sec

B = buildup factor, dimensionless

μ_i = linear absorption coefficient of the i th shield, cm^{-1}

t_i = slant distance through the i th shield, cm

K = conversion of gamma ray flux to dose rate

ρ = distance from source to dose point, cm

N = number of shields.

The dose rate at point P from photons of all initial energies originating at all points within the source volume, S_V, is given by

$$D_{tot} = \int_E \int_V \frac{S_o(E,V)\ B(E,b_1)\ e^{-b_1}}{K(E) 4\pi\rho^2(V)}\ dV\ dE \qquad (2)$$

Equation 2 may be analytically integrated for a few simple geometries, and this technique is used to obtain some of the extended source dose formulas given in the shielding handbooks.[1,2,3] Equation 2 may be numerically integrated for virtually any source geometry; however, only regular geometric shapes are normally considered suitable for computer integration. Complex geometric shapes are generally constructed by synthesis of simple shapes.

This numerical integration technique (commonly referred to as point kernel integration) consists of dividing the source volume into a number of differential volumes. The source energy is divided into a number of energy groups narrow enough to consider the buildup factors, attenuation coefficients, and dose conversion factors constant over the energy range of the group. Each monoenergetic differential volume source is then treated as a point source and the dose from each of these point sources [Equation (1)] is calculated. For each point source, new values of B, μ_i, t_i, ρ, S_o, b_1 and K are needed and are calculated using trigonometric relationships and basic data appropriate to the system geometry, source photon energies, and materials. Integration over source volume and source energy is then obtained by summing the dose contributions from all differential source volumes over all source energies. The overall calculation is handled as described above; however, it is necessary to describe in greater detail portions of these calculations.

Calculation of the Volumetric Source Strength

ISOSHLD allows three methods (modes) of evaluating source strength and source distribution.

Method 1

If the source consists of fission nuclides and other decay and neutron activation products in fuel irradiated under known conditions, the subroutine RIBD[(4)] may be used. RIBD is a fission product inventory code that calculates the quantity of all radioisotopes in a fuel sample at various times after exposure. A choice can be made of one, any, several groupings, or all of these isotopes; and a factor representing a recovery efficiency may be applied.

The library of RIBD at the time of this publication contains 450 isotopes. A gamma photon abundance library is also chained to the code which contains these 450 fission products plus 48 activation products. This library contains the energy yield and abundance of all principal gamma rays emitted by each isotope during decay. At the completion of the

RIBD calculation, ISOSHLD calculates the photon yield from each isotope using the RIBD results (in curies) and the data from the photon library. During the process of calculating photon yield, photon energies are examined; and photon yields (photons/sec) are summed into 16 energy groups. The group structure is indicated in Table I.

TABLE I. Energy Structure Used in Mode 1 and 2 Source Strength Calculations.

Group No.	Group Upper Energy Limit, MeV	Group Average Energy, MeV
1	0.2	0.15
2	0.3	0.25
3	0.4	0.35
4	0.55	0.475
5	0.75	0.65
6	0.9	0.825
7	1.1	1.0
8	1.35	1.225
9	1.6	1.475
10	1.8	1.7
11	2.0	1.9
12	2.2	2.1
13	2.4	2.3
14	2.6	2.5
15	2.8	2.7
16	∞	3.0

The attenuation calculations are based on energy flux, the product of flux and photon energy. The result is that the source energy and flux are effectively corrected to the average group energy (the energy used for flux to dose conversion, buildup factors, attenuation coefficients, etc.). Error can develop in Groups 1 and/or 16 if there are source photons significantly less than 0.15 MeV or greater than 3.0 MeV.

Method 2

If a source consists of a known quantity (in curies) of some isotopes contained in the photon abundance library, the code may be operated to specify the isotopes (by library number) and the curies of each. The code will then evaluate the photon abundance per energy group.

Method 3

If only photon generation rates and photon energies are known, then these are read in. In this type of operation ISOSHLD does the attenuation calculations at the specified photon energies. Attenuation coefficients, buildup factors, etc., are interpolated from the 16 group point data in the material and buildup factor libraries.

For the truncated cone (including slab), disc, cylinder on end, and line source, an exponential source distribution may be specified. The formula is:

$$S(x) = Ce^{ax} \tag{3}$$

where a is a positive or negative number specified as input variable SSV1. If SSV1 is not specified, ISOSHLD assumes a zero value; hence, a uniform source distribution is created. The constant C is evaluated by ISOSHLD using the value of "a" and the total source strength.

Mixed Mass Attenuation Coefficients

Linked to ISOSHLD is a library of mass attenuation coefficients in 16 energy groups for 18 common materials. The materials are water, tissue, air, hydrogen, lithium, carbon, aluminum, titanium, iron, zirconium, tin, tungsten, lead, uranium, and ordinary, magnetite, and ferrophosphorous concretes. The attenuation coefficients are listed for materials of unit density. For each source and shield region the code input requires the library material number and the material density. Up to five materials per region are allowed. Thus ISOSHLD calculates region mixed mass attenuation coefficients, μ_i, for each region, i, by

$$\mu_i = \sum_{j=1} d_j \mu_j \tag{4}$$

where j is the index of materials specified to be in region i. If a combination of the 18 materials above will not adequately describe a desired shield material, the code user may add additional materials to this library.

The Buildup Factor

Linked to ISOSHLD is a buildup factor library which contains, for 16 photon energies, the coefficients A, α_1, and α_2 of Taylor's equation[1]

$$B = A\, e^{-\alpha_1 b_1} + (1-A)\, e^{-\alpha_2 b_1}, \tag{5}$$

for dose buildup from a point isotropic source in five materials: water, aluminum, tin, tungstem, and lead. This material range covers the effective atomic numbers (EAN) from 4 to 82. The data in this library were taken from Goldstein[5], page 376.

In the process of kernel integration, the buildup factor for each differential source volume is calculated for all of the materials between source point and dose point. Values of t_i, the source point to dose point line of sight distance through the source and shield regions are calculated for each new source point by trigonometric relationships. Values of μ_i for each shield region are obtained from Equation (4). ISOSHLD then calculates b_1 for the line of sight from the source point to dose point and b_1 is used in Equation (5) to obtain the correct buildup, B.

There are several considerations to be discussed in regard to how A, α_1, α_2 (from the buildup factor library) are used. The method of selection is by effective atomic number. The effective atomic number (EAN) has been defined in a number of ways (discussed in Reference 6); however, within ISOSHLD it is defined as

$$EAN = \frac{\sum_j \frac{d_j Z_j}{A_j}}{\sum_j \frac{d_j}{A_j}}$$

where

Z_j = atomic number of species j in the shield

A_j = atomic weight of species j in the shield

d_j = density of species j in the shield.

A particular shield region should be chosen whose characteristics will be used in calculating buildup through all shields in the system. This region is usually the last shield region, provided the region is thick compared to the sum thickness of the other regions. If no buildup region choice is made, the code will use the last defined region. The EAN is then calculated for the chosen region. ISOSHLD brackets this effective atomic number in the buildup factor table, calculates the buildup factors for both effective atomic numbers available in the library and then interpolates between these to obtain the final buildup factor for use in the numerical integration.

Since the atomic weight for each material in the library is required for use in evaluating EAN, an effective atomic weight (EAW) was defined for the mixed elemental materials given in the library. These were calculated by:

$$EAW = \frac{\sum_k N_k A_k}{\sum_k N_k}$$

where

N_k = atomic density of species k in the mix

A_k = atomic weight of species k in the mix.

In summary, the buildup treatment in ISOSHLD includes all mean free paths in material between the source point and dose point and has the buildup characteristics of the last (or a particular specified shield region). Treatment of buildup for multiregion shields has been discussed in the literature(5,7) and a number of approaches are suggested for various shield configurations. The approach used by ISOSHLD is believed to be the most general and gives a good approximation for most shield configurations.

ISOSHLD PROGRAM AND SUBROUTINES

The following is a brief description of the ISOSHLD program and its subroutines. The reader is referred to Appendix A for Input Instructions; Appendix B for definitions of geometry and variables and for equations solved by ISOSHLD; and to Appendix C for a FORTRAN IV listing.

ISOSHLD Main Program

The main program is a control which calls in the links of ISOSHLD. To fit a 32 k memory computer, it was necessary to link the subroutine RIBD to the rest of ISOSHLD. The main program calls RIBD if necessary and then enters subroutine CONTRL, the main routine, to calculate attenuation.

Subroutine RIBD

Radio-Isotope Buildup and Decay (RIBD) is the name given to Hanford-developed computer program which has been linked to ISOSHLD for the calculation of in-reactor fission product inventories.

RIBD is a general purpose, multiple path, multiple chain, grid processor. When used for fission product calculations, RIBD includes a library containing pertinent nuclear data for 450 nuclides including both ground states and isomeric states where they are known to exist, whether formed directly from fissions of U^{235}, U^{238}, and Pu^{239} or subsequent to fission as a result of neutron capture and/or chain decay.

RIBD organizes the various members described by the library into a grid with the various linkages established from the chain branching data, yield data and neutron capture cross sections with their branching ratios. Chain decay includes not only the simple member-to-member cascade but also the more complex form where branching may partially or completely skip one or two intervening members.

A sample of a portion of the grid is shown in Figure 2. Upper boxes of a pair, where they exist, refer to isomeric states, lower boxes refer to ground states. Y235 and Y239 refer to variable direct yield rates from U^{235} and Pu^{239} respectively. Horizontal transitions between boxes are by neutron capture; vertical transitions are by beta decay and/or isomeric transition. Ground states are allowed to have up to seven source paths, isomeric states up to five source paths. Since time factors and neutron flux levels exert competing influences on each other, inventories of nuclides are affected to varying degrees by the reactor mode of operation. Consequently, RIBD was designed to follow the operating history of the fuel in detail as closely as the user desires through the entire residence period including power level changes, shutdowns, and outages.

RIBD was modified for inclusion in ISOSHLD to calculate only the amount (in curies) of final products at up to five different times after irradiation is complete; however, the original program calculates activity levels (expressed in curies), concentrations (expressed in gram-atoms), heat generation rates (both beta and gamma), and integrated energy releases between time points for any set of times (up to 90) following shutdown.

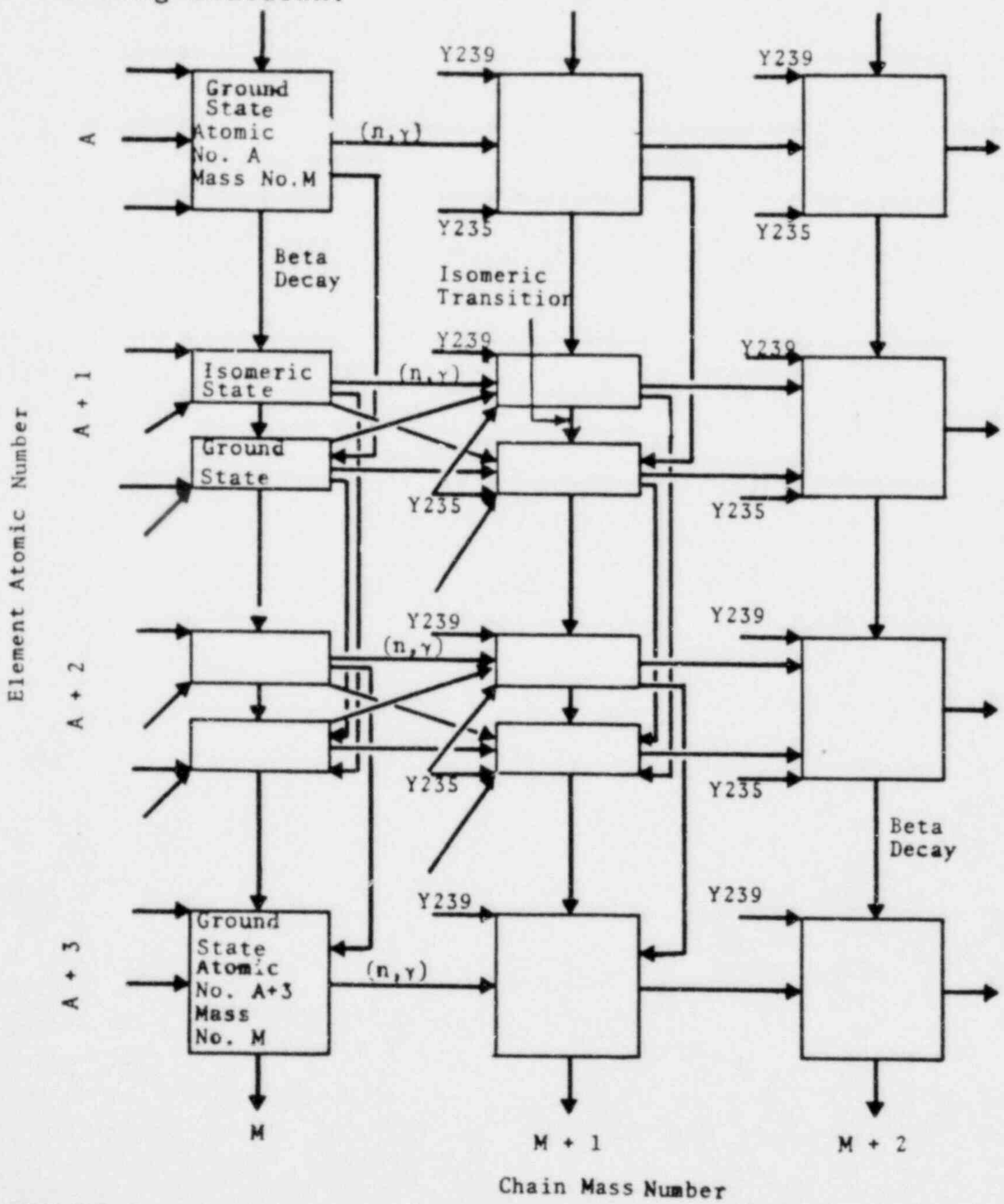


FIGURE 2. Sample Reaction Grid Used in RIBD

Subroutine CONTRL

Subroutine CONTRL is the main program to calculate gamma attenuation for various source and shield configurations. CONTRL programs the following functions in the approximate order shown:

1. Reads in all library data other than the RIBD data.
2. Reads all problem data other than data used for RIBD calculation.
3. Builds a source isotope selection table based on input.
4. Calculates mixed mass attenuation coefficients for all regions and the effective atomic number for the characteristic buildup region.
5. Builds source strength table in 16 groups for MODE 1 or 2 operation and up to 16 groups for MODE 3 operation.
6. Extracts 2 sets of Taylor's coefficients from the buildup library in 16 energy groups based on effective atomic number of the characteristic region.
7. Calls the appropriate subroutine (based on input information) to perform kernel integration in the given source geometry.
8. Converts flux to dose and writes the problem report, i.e., the results.

Subroutine ADJUST

ADJUST is called by various geometry routines to reduce the thickness of the last shield or add an additional air shield as necessary to make the total shield thickness equal the specified source point to dose point distance.

Subroutine BFUNC

BFUNC is called by all attenuation routines to interpolate (on effective atomic number) the buildup factors as calculated from data in the library.

The Attenuation Routines

The attenuation routines evaluate the equations given in Appendix B. Table II indicates the relation between these subroutines and the equations of Appendix B. The reader should examine the portion of Appendix B applicable to a particular subroutine of interest.

TABLE II. Source Attenuation Geometry Subroutine Index

Subroutine (or Function)	Geometry Called for	Appendix B Reference
CYL	Cylindrical source (slab & cyl. shields)	Sect. 6 a, b
DSIC	Disc source	Sect. 5
DSCSRC	Disc source	Sect. 5
ENDCYL	Cylindrical source (end shields)	Sect. 7
E1(ARG)	Truncated cone and infinite slab	Sect. 4
E1(ARG)	Truncated cone and infinite slab	Sect. 4
F1(T,A)	Truncated cone and infinite slab	Sect. 4
LINE	Line source	Sect. 2
POINT	Point source	Sect. 1
RECT	Rectangular source	Sect. 8
SPHERE	Spherical source (slab & spher. shields)	Sect. 3 a,b
SPHSRC	Spherical source (slab & spher. shields)	Sect. 3 a,b
TCONE	Truncated cone and infinite slab and plane	Sect. 4
SIMPS	Generalized Simpsons Integration Used in DSIC, Line, and SPHERE	
TERP	Generalized Interpolation Routine Used in CONTRL	

RECOMMENDATIONS

1. ISOSHLD may be used for routine solution of radiation problems associated with isotopes handling, production, and use. Only those isotopes (or isotope mixtures) which are pure beta emitters or yield a significant quantity of neutrons via spontaneous fission, (γ,n), or (α,n) reactions may not be treated adequately by ISOSHLD. A radionuclide which yields a significant fraction of photons of energy higher than 3 MeV will also require special consideration.
2. The capability of performing bremsstrahlung calculation (source spectra, source strength, and dose rate) should be added to ISOSHLD. This modification requires the addition of a new energy group structure, 0.01 to 2 MeV, suitable for low energy "beta only" decay. A bremsstrahlung source generator would be linked to the code either in the form of a calculational scheme or a table of resolved spectra. Additional library data would be added to handle the wider range of problems within the code capability. At the time of publication of this report, this work has been started.
3. The capabilities of the code should be further extended by the addition of a neutron attentuation routine.

ACKNOWLEDGEMENT

The authors are indebted to R. O. Gumprecht for use of his unpublished RIBD code and data library. Also appreciated are the many discussions with Mr. Gumprecht regarding the use of this code and interpretation of the input and output. The authors are also indebted to R. L. Junkins, Manager, Nuclear Safeguards and Engineering, Battelle Northwest. Work on this code commenced under the sponsorship of General Electric and Mr. Junkins' organization before Hanford's diversification under several contractors. Since diversification, the code has been completed as a joint effort.

APPENDIX A

INPUT PREPARATION

APPENDIX A

INPUT PREPARATION

USE OF THE CODE

The user has the option of choosing one of three types of source specifications and one of 10 source geometries. Up to five shields (the source is always the first shield), composed of up to 18 materials each may be used. The code adds a sixth air shield if the user requests a calculation at some distance beyond the fifth shield.

The amount and kind of input data required by the code depends upon which of the three source specification options is chosen. The source geometry and shield composition are not affected by the way one wishes to specify the source strength. The selection of source type is described below:

Source Type

The Isoshield code has three source input options. The selection of these options is controlled by the input variable MODE. If MODE = 1, a fission product inventory is calculated internally. With this option numerous input parameters are required which specify the burnup and decay history of the fuel. The required parameters include the conversion ratio, reactor power, exposure time, flux time, the U^{235} absorption cross section, the ratio of fast fissions in U^{238} to thermal fissions in fuel, and the fuel cooling times after shutdown at which one desires the dose calculations to be made. Four cooling times after shutdown are allowed. The code always includes an additional calculation at zero time after shutdown.

If MODE = 2, the user arbitrarily specifies the source strength (in curies) of a given isotope or isotopes. A source of any mixture of isotopes is permitted. If MODE = 3, the user specifies the source in terms of the photon abundance and photon energy.

Any geometry option may be used with any of the three source input options.

Choice of Source Type

Typical problems the code would handle are given in Examples 1 and 2.

Example 1. Gamma Radiation Dose in Tissue at Some Distance from a Cloud of Fission Gases.

The following options are available:

- Request the code to calculate the fission product inventory, and by using the weighting factor GROUP, adjust the inventory of fission products in the cloud to account for various removal factors such as retention in the fuel, plateout in the confiner, removal by fog sprays, etc.
- If the fission product inventory is available, specify the number of curies of each isotope contained in the cloud.
- The source may also be described in terms of the number of photons emitted per second from the cloud at given energies.

In all of the above cases it would be necessary to specify the geometry of the cloud, the density of air in the cloud, and the density in air intervening between the cloud and the point at which the dose was to be calculated. If, in addition, it is desired that the dose be calculated in tissue, an additional shield of tissue would be specified and the dose calculated at some depth in this shield.

Example 2. Gamma Radiation Dose in Tissue Some Distance from a Co^{60} Cylindrical Source Enclosed in a Lead Shielded Cask with a Steel Inner and Outer Liner

Specify the source (in curies) of Co^{60} contained. (MODE = 2, WEIGHT (472) = curies of Co^{60})

Shield region 1 is the source itself, and appropriate materials are specified to describe this region. The second shield is the steel inner liner, the third the lead shielding, and the fourth the steel outer liner. The fifth shield is the air between the tissue and the cask, and the sixth shield the tissue in which the dose is to be calculated. In this example the number of shields exceeds the amount allowable, which is five, thus the steel inner liner and source must be lumped together and considered as one shield, or the thickness of the steel inner liner must be added to the outer to reduce the number of shields.

DATA SEQUENCE

The number of data cards required is variable depending on the source mode and whether multiple cases are desired.

The card sequence is given in Table A-I. All isotope data except the source strength is contained in the Isoshld library and input on tape unit A5.

A description of each data card and the required card sequence follow. (Several tape handling cards are required in addition to cards listed below. These, however, are dependent on the computer system used. Hanford Code users will be supplied with this information as necessary upon contacting any of the authors.)

TABLE A-I. Data Card Sequence

Card Number	Use
1	MODE Card specifies the type of source.
1a, 1b, 1c	RIBD parameter cards - Used only when MODE = 1.
2	Title Card - the title is printed out at the top of each output page
3...N	Namelist Cards - as many may be used as are required. Usually 3 will suffice.
N+1...N+20	Up to 20 cards describing the density of up to 20 materials in the 5 allowable shields. One card is used for each material if it is present in any or all of the 5 shields.

DATA CARD DESCRIPTIONS

Card 1 - MODE Card

Card 1 is the MODE Card and determines the manner in which the source will be specified.

MODE = 1: an internally calculated fission product inventory based on a specified quantity of fuel and input parameters describing the burn-up history of the uranium fuel.

MODE = 2: arbitrary specification of the source strength in curies of a given isotope. A source of mixed isotopes is permitted.

MODE = 3: arbitrary specification of the source in terms of the photon abundance and photon energy.

Card 1

Column	Format
11	I1

Cards 1a, 1b, 1c

RIBD Cards

These cards are used only if MODE = 1 on Card 1.

Card 1a

Column	Format	Variable	Use
1-36	6A6	CASER	Title on RIBD pages
41-50	E10.4	CON	Conversion ratio of fuel, grams of plutonium produced per megawatt day at beginning of cycle.

Card 1b

Column	Format	Variable	Use
1-10	E10.4	PO	Power, megawatts
11-20	E10.4	TIME	Irradiation time, days
21-30	E10.4	T	Exposure = $\phi\sigma_a t$; ϕ = neutron flux, neutrons/(cm^2)(sec); σ_a = U^{235} absorption cross section, cm^2; t = fuel irradiation time, sec
31-40	E10.4	SIGA25	U^{235} absorption cross section in barns (absolutely necessary that flux be correctly related to power, PO)
41-50	E10.4	DEL	$\Delta = \frac{\text{fast fissions in } U^{238}}{\text{thermal fission in fuel}}$

Card 1c

Column	Format	Variable	Use
1-8	E8.3	DT(1)	Cooling times, sec
9-16	E8.3	DT(2)	Cooling times, sec
17-24	E8.3	DT(3)	Cooling times, sec
25-32	E8.3	DT(4)	Cooling times, sec

Card 2 - Title Card

Column	Format	Variable	Use
1-72	12A6	TITLE	Words entered here are reprinted as a title at the head of a case. Each case requires a title card or blank card.

Cards 3 to N - Namelist Cards
(one or more namelist cards)

The data for each attenuation calculation consists of one title card (Card 2) and one or more cards using the Namelist format (Cards 3 to N). The first Namelist card (Card 3) must be blank in column 1, $INPUT in column 2-7, followed by at least one blank, followed by data items. Additional cards must have a blank in column 1. The data items are separated by a comma, and the last data item must be followed by a $. Data items must have one of the three following forms:

1. Variable name = constant, where variable name may be either subscripted or not.

2. Array name = set of constants (separated by commas). The number of constants must be equal to the number of elements in the array. The constants must be in the same order as the array is in storage, i.e., the first subscript changes most rapidly. Example: If A is dimensioned 2x2, the constants must be in the following order: A(1), A(2,1), A(1,2), A(2,2).

3. Subscripted variable = set of constants (separated by commas). This form results in the set of constants being placed in consecutive array elements, starting with the element designated by the subscripted variable. The number of constants cannot exceed the

number of elements in the array between the given element in the array and the last element in the array.

The principal advantage of the namelist format is that all values that are not changed do not need to be specified for subsequent attenuation calculations. The variables that may be input in the namelist are given in Table A-II.

TABLE A-II. Table of Namelist Variables

Variable	Array Size	Use	Value Units	Values
NEXT		Program Control - Next Case Options		
GROUP (I)	(5)	Selects isotope group and weight factor	MODE 1 - none MODE 2 - not used MODE 3 - not used	any constant
WEIGHT (J)	(500)	Selects isotopes and weight factor or quantity	MODE 1 - none MODE 2 - curies MODE 3 - not used	any any
SOURCE (L,M)	(3,16)	Selects photon strength	MODE 1,2 - not used MODE 3	
		L = 1, value specifies number of photons		any
		L = 2, value specifies photon energy	MeV	any
IGEOM		Program Control - Selects geometry	None	1 to 10
NSHLD		Specifies number of shields in problem		1 to 5
JBUF		Specifies the shield for which buildup is characteristic		1 to 5
T(K)		Thickeness of shields 1 to 5, K = shield number	cm	any
SLTH	Geometry variables: For use see <u>Geometry Selection</u>		cm	any
X			cm	any
Y			cm	any
ANG1			degrees	0° to 180°
ANG2			degrees	0° to 180°
ANG3			degrees	0° to 180°
NTHETA	Numerical Integration Control variables: For use see <u>Integration Control</u>			
NPSI				
DELR				
SSV1		Exponent for exponential source distribution	none	$-10 \leq SSV1 \leq 10$

NEXT

NEXT is a variable controlling attenuation calculations that instructs the program what to do after reading a set of data. It controls isotope selection and material in shields, not shielding geometry. There are 6 options corresponding to NEXT = 1,2,3,...,6.

NEXT = 1 New isotope selection and new shield material compositions will be made; geometry may be changed.

NEXT = 2 New isotope selection; geometry may be changed.

NEXT = 3 New shield material compositions; geometry may be changed.

NEXT = 4 Geometry change only may be made.

NEXT = 5 Reinitialize all namelist input variables. In this case no calculation is made. A new set of namelist variable values must be specified in the following case.

NEXT = 6 End of run. In this case no attenuation calculation is performed. NEXT may be set equal to 6 to accomplish a normal exit on the IBM 7090.

When NEXT = 1, 2, 3 or 4 any variables describing the geometry and dimensions may be changed. NEXT must be specified as 1 in the first case. In succeeding cases WEIGHT and GROUP are not initialized unless NEXT = 5. When NEXT = 1, shield materials are initialized and added isotopes are allowed, but the previous isotopes are carried over to the new case. They may be set to zero by setting their WEIGHT value equal to zero.

WEIGHT, GROUP, AND SOURCE

Any combination of the isotopes contained in the photon library may be selected for a particular case, using the two arrays GROUP and WEIGHT. GROUP has a dimension of 5 and WEIGHT has a dimension of 500. The subscript in the WEIGHT array corresponds to the location of the desired isotope in the photon library, i.e., WEIGHT (100) corresponds to the 100th isotope in the library. The weight array is used to select individual isotopes and the group array is used to specify all isotopes, or a group of isotopes, contained in the library.

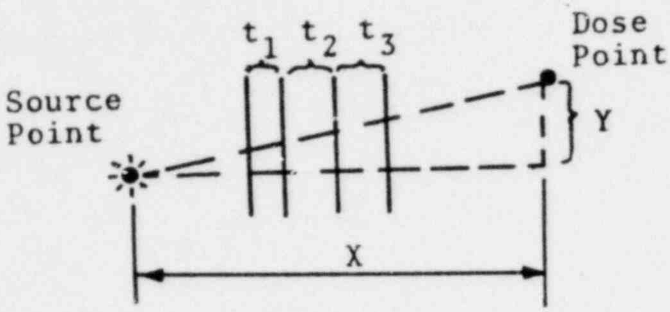
GROUP (1) Noble gases (Xe, Kr)
GROUP (2) Halogens (I, Br)
GROUP (3) Volatile Solids (Se, Te, Cs)
GROUP (4) All elements not included in first 3 groups
GROUP (5) All isotopes in the library

The value specified by the GROUP and WEIGHT arrays has a different meaning, depending on the value of program variable MODE. If MODE = 1, a value specified by group or weight is a weighting factor. The source activity (in curies) calculated by RIBD for a given isotope is in this case multiplied by the weighting factor specified for that isotope. When MODE = 2, the value specified by WEIGHT represents the total curies for a given isotope to be distributed throughout the source. When MODE = 3, WEIGHT and GROUP are replaced by SOURCE to define the total source strength.

Geometry Selections

The various geometries handled by Isoshield are described here along with the input parameters required for each geometry.

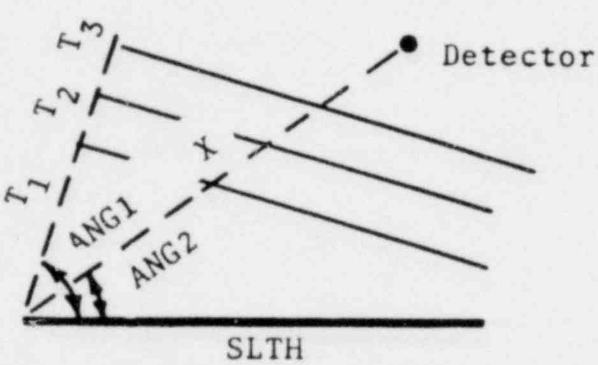
Point Source - Slab Shields



INPUT VARIABLES

IGEOM = 1
X
Y

Line Source - Slab Shields

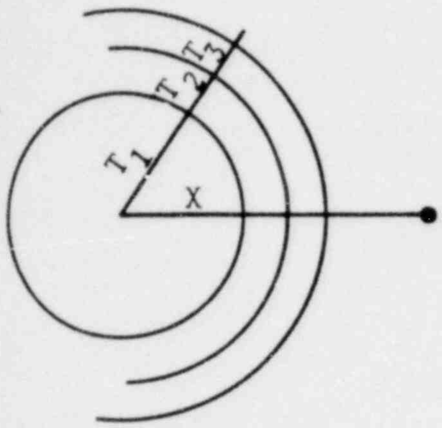


INPUT VARIABLES

IGEOM = 2
X = Dist to detector
ANG1 = Shield normal angle
ANG2 = Detector angle
SLTH = Source length
SSV1 = Exponent for exponential source strength distribution

NOTE: If the source is not completely contained in the first shield region, the thickness of the first shield region will be increased so the complete source is in the first shield region.

Spherical Source and Shields



INPUT VARIABLES

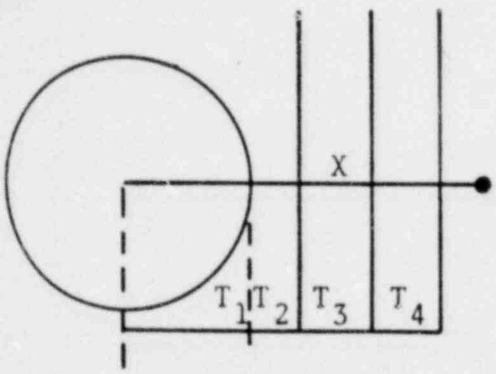
IGEOM = 3

X = Dist from center to detector

T(1) = Source radius

NOTE: Constant source strength distribution only for spherical source

Spherical Source - Slab Shields



INPUT VARIABLES

IGEOM = 4

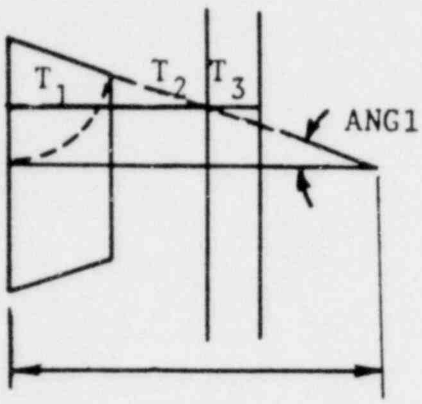
X = Dist from center to detector

T(1) = Source radius

NOTE: Constant source strength distribution only for spherical source

NOTE: Shield region 2 surrounds the source

Truncated Cone Source - Slab Shields



INPUT VARIABLES

IGEOM = 5

ANG1 = Cone angle

T(1) = Source Thickness

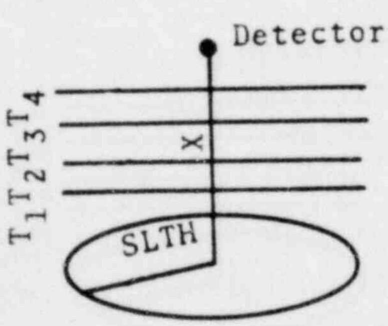
X = Dist to detector from opposite face of source

SSVI = Exponent for exponential source strength distribution

NOTES: If ANG1 = 90.0° (Infinite slab source], then the source strength is input in curies per cm^3.

If T(1) = 0 and ANG1 = 90.0° (Infinite plane source), then the source strength is input in curies per cm^2.

Disc Source - Detector on Center Line - Slab Shields



INPUT VARIABLES

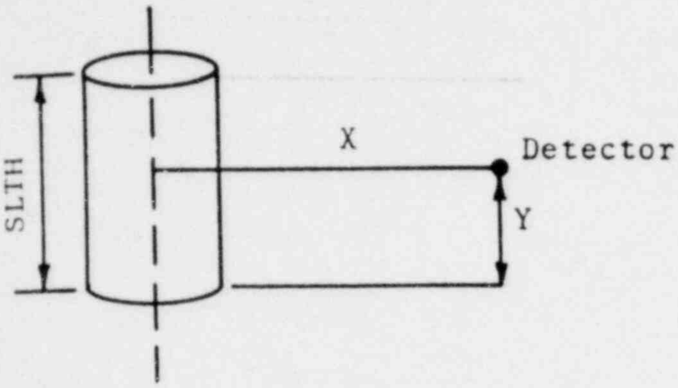
IGEOM = 6

SLTH = Dis radius

X = Dist from center to detector

SSVI = Exponent for radial exponential source strength distribution

Cylindrical Source



INPUT VARIABLE

IGEOM = 7 for cylindrical shields

IGEOM = 8 for slab shields

T(1) = Radius of source

SLTH = Length of source

X = Radial distance to detector from center line of source

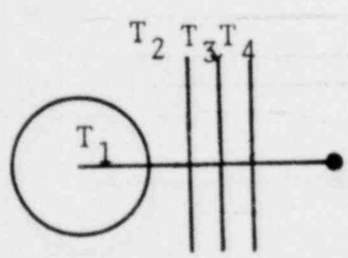
Y = Vertical distance from end of source to detector

NTHETA = Number of horizontal angle intervals for numerical integration

NPSI = Number of vertical angle intervals for numerical integration

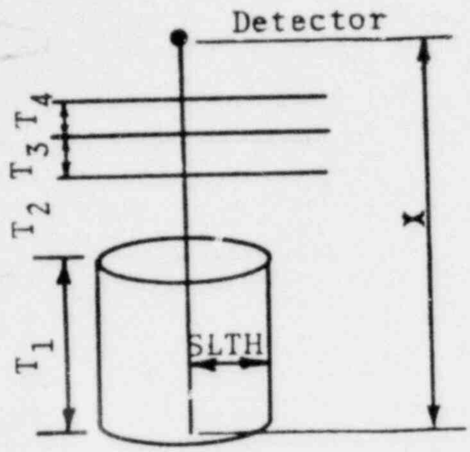
DELR = Length of radial intervals for numerical integration (in cm)

End View of Slab Shields



NOTE: With slab shield, the second shield region surrounds the source

Cylinder With Detector at End on Center Line - Slab Shields



INPUT VARIABLES

IGEOM = 9

SLTH = Radius

T(1) = Cylinder length

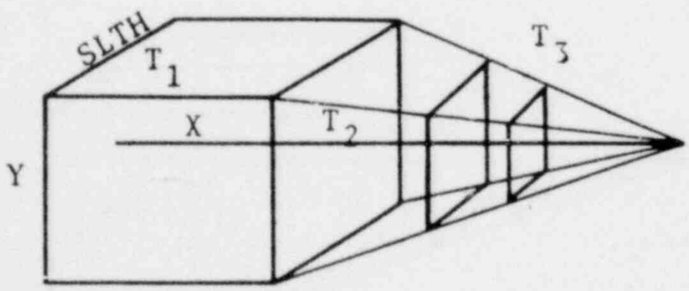
NTHETA = Number of angle intervals for numerical integration

DELR = Length of radial interval for numerical integration

X = Distance to detector from opposite end

SSV1 = Exponent for radial exponential source strength distribution

Rectangular Solid With Detector on Center Line - Slab Shield



INPUT VARIABLES

IGEOM = 10

X = Distance to detector from opposite face of source

Y = Height of source

SLTH = Length of source

T(1) = Thickness of source

NTHETA = Number of horizontal angle intervals for numerical integration

NPSI = Number of vertical Angle intervals for numerical integration

DELR = Length of radial interval for numerical integration

NOTE: Constant source strength distribution only for rectangular solid source

Cards N + 1 to N + 18 - Shield Materials Cards

Each card specifies the density of one material in each of the five allowable shields. The materials which may be used (18 in the library) and the appropriate number designating the material (1 to 18) are listed in Appendix D.

Column	Format	Variable	Use
9-10	I2	MN	Material number corresponding to library material number (Material numbers from 1 to 20)
11-20	E10.4	ρ	Density of this material (if any) in shield 1
21-30	E10.4	ρ	Density of this material (if any) in shield 2
31-40	E10.4	ρ	Density of this material (if any) in shield 3
41-50	E10.4	ρ	Density of this material (if any) in shield 4
51-60	E10.4	ρ	Density of this material (if any) in shield 5
72	I1		= 1 for last material card. Left blank on all preceding cards.

Cards N + 19, etc. - Additional cases

Additional cases may be run by using as few as two additional cards.

Card 1 (following last Material card above) - Title card for second case.

This card signals that additional cases are to be run and changes from the previous case will be described on cards to follow, N+20, etc.

Card 2 - First Namelist card for second case.

Card 3, etc. Additional cards as needed to describe the next case.

Cards..........New material specification if desired. See use of variable NEXT, the program control which determines whether new material specification cards are expected.

APPENDIX B

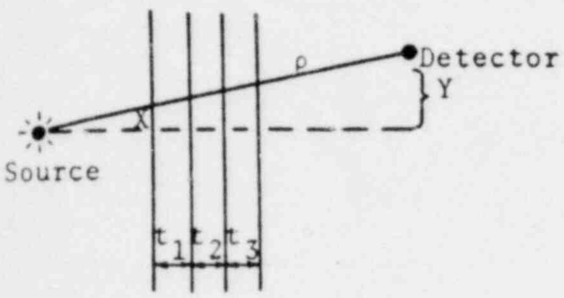
ISOSHLD ATTENUATION EQUATIONS

APPENDIX B

ISOSLD ATTENUATION EQUATIONS

The kernel integration equations for specific geometries are stated below.

1. POINT SOURCE - SLAB SHIELDS



$$\phi = \frac{BSe^{-b_1 \sec\theta}}{4\pi\rho^2}$$

where B = buildup factor

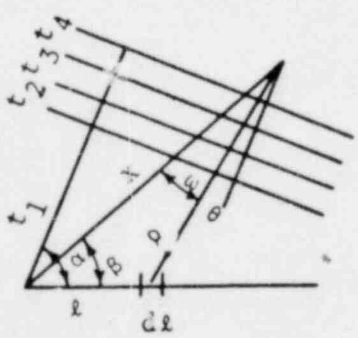
S = source strength

$\theta = \tan^{-1}(Y/X)$

$b_1 = \sum_{i=1}^{N} \mu_i t_i$

N = number of shields

2. LINE SOURCE SLAB SHIELDS



$$\phi = \int_0^{SLTH} \frac{S_L B e^{-b}}{4\pi\rho^2}\, d\ell$$

where $\rho^2 = \ell^2 + x^2 - 2\ell x \cos\beta$

$\sin\omega = \frac{\ell \sin\beta}{\rho}$

$\cos\omega = \frac{x^2 + \rho^2 - \ell^2}{2x\rho}$

$\omega = \tan^{-1}(\sin\omega/\cos\omega)$

$\theta = |\alpha - \beta - \omega|$

$\omega + \theta = \frac{\pi}{2} - (\frac{\pi}{2} - \alpha + \beta)$

$= \alpha + \beta$

$b = \mu_1(\rho - \sec\theta \sum_{i=2}^{N} t_i) +$

$\sec\theta \sum_{i=2}^{N} \mu_i t_i$

N = number of shield regions

B = build up factor

S_L = Source strength energy per unit length

NOTE: If SSV1 ≠ 0, indicating exponential source strength distribution,

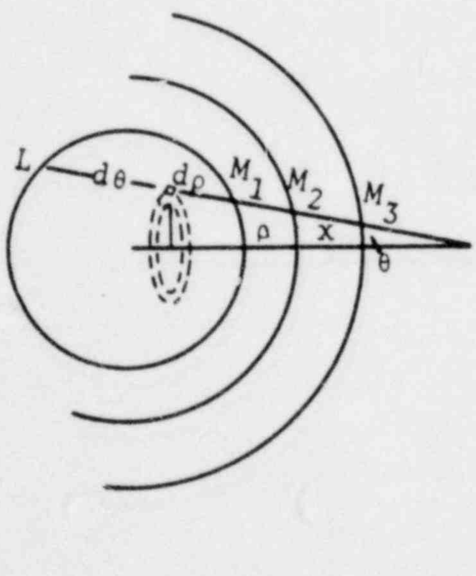
$$S_L = [C][e^{(\ell)(SSV1)}]$$

$$\text{where } SSV2 = \frac{(S)(SSVL)}{(e^{SSV1 \cdot SLTH} - 1)}$$

where S = total source strength

3. SPHERICAL SOURCE

a. Spherical Shields



$$dv = 2\pi\rho\sin\Theta\rho d\rho d\theta$$

$$\phi dv = \frac{BS_\nu e^{-b} dv}{4\pi\rho^2}$$

$$\phi = \int \frac{BS_\nu \sin\theta e^{-b} dv}{2} =$$

$$\frac{1}{2}\int_0^{\theta_2} \sin\theta d\theta \int_{M_1}^{L} BS_\nu e^{-b} d\rho$$

where $\theta_2 = \tan^{-1}(R/\sqrt{x^2 - R^2})$

$L = x\cos\theta + \sqrt{R^2 - (x\sin\theta)^2}$

R = t_1 = Radius of source

$M_1 = x\cos\theta - \sqrt{R^2 - (x\sin\theta)^2}$

$M_2 = x\cos\theta - \sqrt{(R + t_2)^2 - (x\sin\theta)^2}$

⋮

$M_N = x\cos\theta - \sqrt{(R + \sum_{i=2}^{N} t_i)^2 - (x\sin\theta)^2}$

N = number of shield regions

$B = A_1 e^{-\alpha_1 b} + A_2 e^{-\alpha_2 b}$

$b = (\rho - M_1)\mu_1 + \sum_{i=2}^{N} (M_{i-1} - M_i)\mu_i$

S_ν = volumetric source strength

$$\phi = \frac{S_\nu}{2}\int_0^{\theta_2} \sin\theta d\theta \int_{M_1}^{L} (A_1 e^{-b(1 + \alpha_1)} + A_2 e^{-b(1 + \alpha_2)}) d\rho$$

$$\phi = \frac{S_\nu}{2}\int_0^{\theta_2} \sin\theta \Big[A_i e^{(1 + \alpha_1)(M_1\mu_1 - \sum_{i=2}^{N}(M_{i-1} - M_i)\mu_i)} \int_{M_1}^{L} e^{-(1 + \alpha_1)\rho\mu_1} d\rho$$

$$+ A_2 e^{(1 + \alpha_2)[M_1\mu_1 - \sum_{i=2}^{N}(M_{i-1} - M_i)\mu_i]} \int_{M_1}^{L} e^{-(1 + \alpha_2)\rho\mu_1} d\rho\Big] d\theta$$

$$\phi = \frac{S_\nu}{2}\int_0^{\theta_2} \sin\theta \Bigg(A_1 e^{(1 + \alpha_1)c}\left\{\frac{-1}{\mu_1(1 + \alpha_1)}\Big[e^{-(1 + \alpha_1)L\mu_1}\right.$$

$$\left. - e^{-(1 + \alpha_1)M_1\mu_1}\Big]\right\} + A_2 e^{(1 + \alpha_2)c}\left\{\frac{-1}{\mu_1(1 + \alpha_2)}\Big[e^{-(1 + \alpha_2)L\mu_1}\right.$$

$$\left. - e^{-(1 + \alpha_2)M_1\mu_1}\Big]\right\}\Bigg) d\theta$$

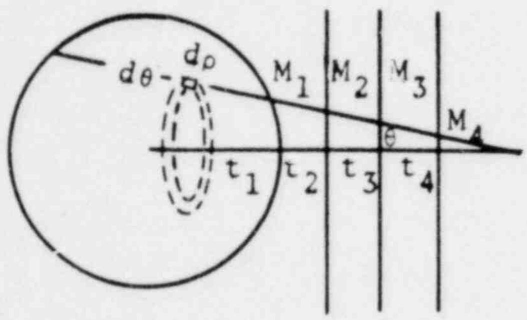
where $C = M_1\mu_1 - \sum_{i=2}^{N}(M_{i-1} - M_i)\mu_i$, function of θ only.

$$\phi = \frac{S_\nu}{2}\int_0^{\theta_2} \sin\theta \left\{\frac{-A_1}{\mu_1(1 + \alpha_1)}\Big[e^{(1 + \alpha_1)(c - L\mu_1)} -\right.$$

$$e^{(1 + \alpha_1)(c - M_1\mu_1}\Big] - \frac{A_2}{\mu_1(1 + \alpha_2)}\Big[e^{(1 + \alpha_2)(c - L_2\mu_1)}$$

$$- e^{(1 + \alpha_2)(c - M_1\mu_1} \Big] \Big\} d\theta$$

b. Slab Shields



R = radius

$$L = x\cos\theta + \sqrt{R^2 - (x\sin\theta)^2}$$

$$M_1 = x\cos\theta - \sqrt{R^2 - (x\sin\theta)^2}$$

$$M_n = \sec\theta \sum_{i=n+1}^{N} t_i$$

for $n = 2, 3, \ldots, N-1$

N = Number of shield regions

$$M_N = (x - \sum_{i=1}^{N} t_i)\sec\theta$$

$$\theta_2 = \tan^{-1}\left(R/\sqrt{x^2 - R^2}\right)$$

S_ν = volumetric source strength

$$\phi = \int \frac{BS_\nu \sin\theta e^{-b} dv}{2}$$

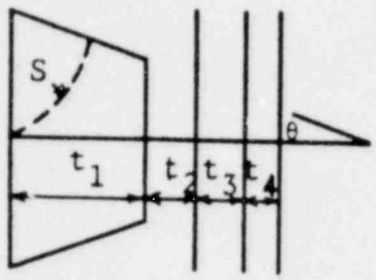
where $b = (\rho - M_1)\mu_1 + (M_1 - \sum_{i=3}^{N} t_i \sec\theta)\mu_2 + \sum_{i=3}^{N} \mu_i t_i \sec\theta$

$$\phi = \frac{S_\nu}{2} \int_0^{\theta_2} \sin\theta \left\{ \frac{-A_1}{\mu(1 + \alpha_1)} \Big[e^{(1 + \alpha_1)(c - L\mu_1)} - e^{(1 + \alpha_1)(c - M_1\mu_1)} \Big] \right.$$

$$\left. - \frac{-A_2}{\mu_1(1 + \alpha_2)} \Big[e^{(1 + \alpha_2)(c - L_2\mu_1)} - e^{(1 + \alpha_2)(c - M_1\mu_1} \Big] \right\} d\theta$$

where $c = M_1\mu_1 - \sec\theta \sum_{i=3}^{N} \mu_i t_i - (M_1 - \sec\theta \sum_{i=3}^{N} t_i)\mu_2$

4. TRUNCATED CONE SOURCE - SLAB SHIELD



See Reference 8

If SSV1 = 0, indicating constant source strength distribution

$$\phi = \frac{S_\nu}{2\mu_1}\sum_{i=1}^{2}\frac{A_i}{1+\alpha_i}\left[E_2(b_{1i}) - E_2(b_{2i}) - \frac{E_2(b_{1i}\sec\theta)}{\sec\theta} + \frac{E_2(b_2\sec\theta)}{\sec\theta}\right]$$

where $S_\nu = \dfrac{\text{total source strength}}{\text{source volume}}$

$b_{1i} = (1+\alpha_i)\sum_{j=2}^{N}\mu_j t_j$, N = Number of shield regions

$b_{2i} = (1+\alpha_i)\sum_{j=1}^{N}\mu_j t_j$

$$E_2(y) = y\int_y^\infty t^{-2}e^{-t}dt$$

If SSV1 ≠ 0, indicating exponential source strength distribution

$$\phi = \frac{S_\nu(0)}{2\mu_1}\,e^{\left(\frac{SSV1}{\mu_1}\sum_{i=1}^{N}\mu_i t_i\right)}\sum_{j=1}^{2}\frac{A_j}{1+\alpha_j}\left[F_1(b_{2j},\alpha_j) - F_1(b_{1j},\alpha_j) - \frac{F_1(b_{2j}\sec\theta,\alpha_j)}{\sec\theta} + \frac{F_1(b_{1j}\sec\theta,\alpha_j)}{\sec\theta}\right]$$

$$\text{where } F_1(y,\alpha) = \int_0^y e^{\alpha b} E_1(b)\,db$$

$$E_1(b) = \int_b^\infty \frac{e^{-t}}{t}\,dt$$

$$S_v(0) = S \Big/ \left\{ \pi \tan^2\theta \left[\frac{D^2 e^{CT}}{C} - \frac{D^2}{C} - \frac{2De^{CT}(CT-1)}{C^2} - \frac{2D}{C^2} + \frac{T^2 e^{CT}}{C} - \frac{2e^{CT}(CT-1)}{C^3} - \frac{2}{C^3} \right] \right\}$$

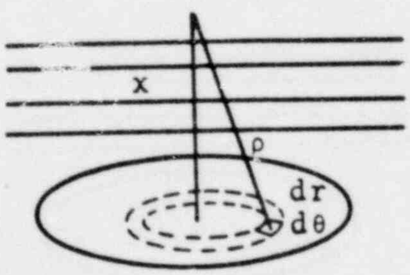
where S = Total source strength

D = Distance to detector from opposite side of source

C = SSV1

T = Source thickness

5. DISC SOURCE (DETECTOR ON CENTER LINE) SLAB SHIELDS



$$dA = r\,dr\,d\theta$$

$$\phi = \int_0^R \int_0^{2\pi} \frac{BS_A e^{-b} r\,d\theta\,dr}{4\pi\rho^2}$$

$$\phi = \int_0^R \frac{BS_A e^{-b} r\,dr}{2(x^2 + r^2)}$$

R = radius

B = Buildup factor

$b = \sum_{i=1}^{N} \mu_i t_i$, N = number of shield regions

S_A = source strength per unit area

if SSV1 = 0, indicating constant source strength

$$S_A = \frac{S}{Area},$$

where S = total source strength

if SSV1 ≠ 0, indicating exponential source strength distribution

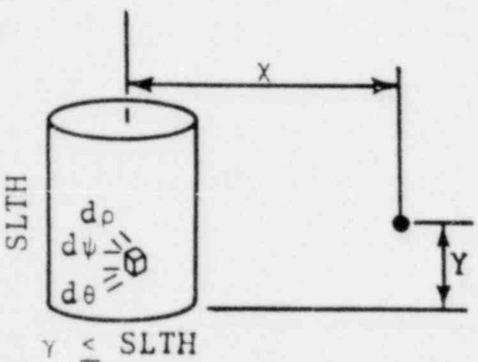
$$S_A = Ce^{(SSV1)(r))}$$

$$\text{where } C = \frac{(S)(C^2)}{2\pi(e^{CR}(CR - 1) + 1)}$$

C = SSV1

R = radius

6. CYLINDRICAL SOURCE



$$dv = \rho^2 d\theta d\psi d\rho$$

$$\phi = \int_v \frac{BS_v e^{-b_1}}{4\pi\rho^2} dv$$

$$b_1 = \sum_{i=1}^{N} \mu_i t_i$$

θ = horizontal angle
ψ = vertical angle
R = radius of cylinder = t_1

$$\phi = \frac{2}{4\pi}\int_0^{\theta_2} d\theta \left[2\int_0^{\psi_1} d\psi \int_{R_1}^{R_2} B(b\sec\psi) S_v e^{-b\sec\psi} d\rho\right.$$

$$+ \int_{\psi_1}^{\psi_2} d\psi \int_{R_1}^{R_3} B(b\sec\psi) S_v e^{-b\sec\psi} d\rho$$

B = Buildup factor

S_v = Volumetric source strength

$$L_1 = x\cos\theta - \sqrt{R^2 - (x\sin\theta)^2}$$

$$L_2 = x\cos\theta + \sqrt{R^2 - (x\sin\theta)^2}$$

$$R_1 = L_1\sec\psi$$

$$R_2 = \min(L_2\sec\psi,\ \min(Y, SLTH - Y)\csc\psi)$$

$$R_3 = \min(L_2\sec\psi,\ \max(Y, SLTH - Y)\csc\psi)$$

$$\psi_1 = \tan^{-1}\left[\frac{\min(Y,\ SLTH - Y)}{L_1}\right]$$

$$\psi_2 = \tan^{-1}\left[\frac{\max(Y,\ SLTH - Y)}{L_1}\right]$$

$$\theta_2 = \tan^{-1}(R/\sqrt{x^2 - R^2})$$

a. Cylindrical Shields

$$b = (\rho\cos\psi - L_1)\mu_1 + \sum_{i=1}^{N-1}(m_i - m_{i+1})\mu_{i+1}$$

where $m_1 = L_1$

$$m_2 = x\cos\theta - \sqrt{(t_1 + t_2)^2 - (x\sin\theta)^2}$$

$$\vdots$$

$$m_N = x\cos\theta - \sqrt{\left(\sum_{i=1}^{N} t_i\right)^2 - (x\sin\theta)^2}$$

N = Number of shield regions

c. Slab Shields

$$b = (\rho\cos\psi - L_1)\mu_1 + (L_1 - \sec\theta\sum_{i=3}^{N} t_i)\mu_2 + \sum_{i=3}^{N}\mu_i t_i \sec\theta$$

NOTE: The view of the cylinder from the end is the same as the sphere

If SSV1 = 0, specifiying constant source strength distribution,

S_v = S/volume,

S = Total source strength

If SSV1 ≠ 0, specifying exponential source strength distribution,

$S_v = be^{SSV1(r)}$,

where $r = \sqrt{x^2 - 2x\rho\cos\theta\cos\psi + \rho^2\cos^2\psi}$

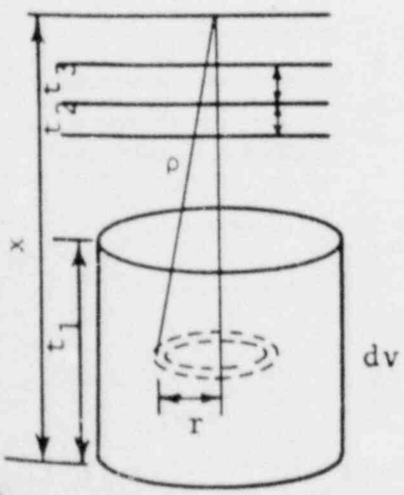
and $$b = \frac{(S)(C^2)}{2\pi he^{CR}(CR - 1) + 2\pi h}$$

where h = cylinder length,

C = SSV1,

R = radius

7. CYLINDER WITH DETECTOR AT END ON CENTER LINE - SLAB SHIELDS



r = radius

$$dv = 2\pi r\rho d\theta d\rho = 2\pi\rho^2 \sin\theta d\theta d\rho$$

$$\phi = \int \frac{BS_v e^{-b}}{4\pi\rho^2} dv$$

$$\phi = 1/2\int_0^{\theta_2} d\theta \int_{R_1}^{R_2} BS_v e^{-b} \sin\theta d\theta d\rho$$

where

B = Buildup

S_v = volumetric energy source strength rate (same as previous cylinder cases)

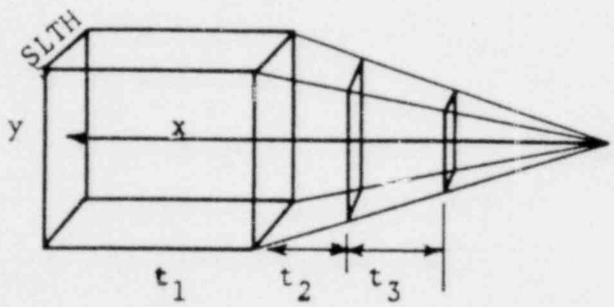
$$b = (\rho - \sec\theta\sum_{i=2}^{N} t_i)\mu_1 + \sum_{i=2}^{N} \mu_i t_i \sec\theta$$

$$\theta_2 = \tan^{-1}\left(\frac{R}{x-t_1}\right)$$

$$R_1 = \sec\theta \sum_{i=2}^{N} t_i$$

$$R_2 = \min(x\sec\theta,\ R\csc\theta)$$

8. RECTANGULAR SOLID - SLAB SHIELDS



$$dv = ds\,dy\,dx$$

$$\phi = \int \frac{BS_v e^{-b}}{4\pi\rho^2} dv$$

$$\phi = \frac{1}{\pi}\int_0^{\frac{SLTH}{2}} ds \int_0^{\frac{V}{2}} dy \int_0^{\frac{t_1}{2}} \frac{BS_v e^{-b}}{\rho_2}\, dt$$

where

B = Buildup

S_v = volumetric source strength rate = $\frac{S}{\text{volume}}$,

S = total source strength

$$\rho^2 = \left(t + \sum_{i=2}^{N} t_i\right)^2 + s^2 + y^2$$

$$\sec\theta = \rho/\left(t + \sum_{i=2}^{N} t_i\right)$$

$$b = \left(\rho - \sec\theta \sum_{i=2}^{N} t_i\right)\mu_1 + \sum_{i=2}^{N} \mu_i t_i \sec\theta$$

APPENDIX C

CODE LISTING

```
C         MAIN PROGRAM - CALLS IN OTHER LINKS
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR ,VOLUME
      DIMENSION FZ(7)
      CALL SETDAR (5,0,FZ)
      CALL SETIO(2,1)
      CALL SETIO(3,2)
      READ (2,10) MODE
   10 FORMAT ( 10XI1)
      GO TO (11,13,13 ),MODE
   11 CALL RIBD
      GO TO 15
C         READ PAST RIBD LIBE
   13 READ (5,20) NCD
      DO 14 I=1,NCD
      READ(5,20) J
   14 CONTINUE
   15 CALL CONTRL(MODE)
   20 FORMAT(I3)
      RETURN
      END
```

```
      SUBROUTINE RIBD
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,    SLTH,TOTAL(4),TT(6),NSHLD,X,YY,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      DIMENSION ISO(450), LISTM(10,96), LISTA(25,40), NRM(96), NRA(40),
     1             DT(5), DATA1(10,450)
      DIMENSION Y(5), TERM(13), SUM2(13), SUM3(13), FX(15), TM(15),
     1     WL(15),WM(15), FM(13), FR(13), TF(14), TX(14), FXT(14),FLM(6),
     2     SEMLT(9), EMLT(9,9), PAR2(14,10,2), PAR3(13,10,2), FEED3(450),
     3     FEED4(450), FEED5(450), FEED6(450), FEED7(450), FEED8(450),
     4     FEED9(450), FEED10(450), DG1(6), DG2(6), FLAM(9), PDN(6)
      DATA KA,KM,MP,NAT/4*0/
      DATA DG1/2.046E-4,1.3578E-3,1.2152E-3,2.449E-3,7.13E-4,2.604E-4/       01402
      DATA DG2/7.0E-5,5.96E-4,4.22E-4,6.52E-4,1.72E-4,8.8E-5/                01403
      DATA FLM/1.075E+3,2.635E+3,9.626E+3,2.603E+4,9.816E+4,2.603E+5/        01404
      LOGICAL L6                                                             01501
 1001 FORMAT(6A6,4X,2E10.4,2I1,10X/2E10.4,I1)                                03001
 1010 FORMAT(1H16A6,2X,1P2E11.3,2X,  I1,19H EXTRA DECAY LISTS,,5H TYPEI2     03101
     1,7H OPTION/1H 1P5E15.4,  I5)
 1050 FORMAT(1H+102X,4HSTEPI3)                                               03301
 1060 FORMAT(1H A3,I3,2X,1P11E10.3,I2)                                       03401
 1070 FORMAT(2E10.4,30X,I1)                                                  03501
 1080 FORMAT(1H 1P2E15.4,45X,  I5)
 1090 FORMAT(9E8.3)                                                          03701
 1091 FORMAT(1H 1P9E10.3,23H DECAY POINTS - SECONDS)                         03801
 1000 FORMAT(I3,I2,    4E9.3,4F5.3,7X,A3,I1)                                 03901
 1002 FORMAT(1H1,3X,24HLIBRARY OUT OF ORDER AT A3,I4/(28X,A3,I4))            04001
 1021 FORMAT(I3)                                                             05701
```



```
      A=1.E-3?
      DO 1111 I=1,5                                                          06971
 1111 A=I*1.E-5                                                              06981
      READ  (5,1021)NCD                                                      06991
      READ  (5,1000)(ML(J),LA(J),FEED3(J),FEED4(J),FEED5(J)
```

```
      X=1.E-37
      DO 1111 I=1,5
 1111 A=X*1.E-5
      READ  (5,1021)NCD
      READ  (5,1000)(ML(J),LA(J),FEED3(J),FEED4(J),FEED5(J),   FEED6(J),
     1FEED7(J),FEED8(J),FEED9(J),FEED10(J),REC(J),ISO(J),J=1,  NCD)
      LOWA=LA(1)-1
      DO 4 J=1,10
      DO 4 K=1,450
    4 DATA1(J,K) = 0.
      DO520 I=1,96
  520 NRM(I) = 0
      DO521 I=1,40
  521 NRA(I) = 0
      DO522 I=1,NCD
  522 DATA1(1,I) = 0.
      U9I = 0.
      PNI = 0.
      DO 23 I=1,6
   23 PDN(I) = 0.
      DO 3 J=1,NCD
      FEED3(J)=.693/FEED3(J)
      FEED9(J)=FEED9(J)*5.9274E-9
      FEED10(J)=FEED10(J)*5.9274E-9
      IF(MP-ML(J))5,1,6
    5 MP=ML(J)
      KM=KM+1
    1 KA=LA(J)-LOWA
      IF(KA)6,6,2
    6 WRITE (3,1002) REC(J-1),ML(J-1),REC(J),ML(J),REC(J+1),ML(J+1)
      CALL EXIT
    2 NRM(KM)=NRM(KM)+1
      NRA(KA)=NRA(KA)+1
      JM=NRM(KM)
      JA=NRA(KA)
      LISTM(JM,KM)=J
      LISTA(JA,KA)=J
```

```
      NAT=MAX0(NAT,KA)
    3 CONTINUE
      NMA=KM
    9 READ  (2,1001)CASER,CON,BIGL,NEDL,KEY,PO,TIME,T,SIGA25,   DEL,NSIG
      FLUX=T/(SIGA25*TIME)
      THETA=TIME
      XBAR=EXP(-T)
      PXBAR=XBAR
      P=PO*8.436E+5
      TFISS=P*TIME
      X=FLUX*SIGA25
      RATIO=FLUX/PO
      NSTEP=1
      TET=TIME
      FMWD=PO*TIME
      P25=P/(1.0+DEL)
      WRITE (3,1010)CASER,CON,BIGL,NEDL,KEY,PO,TIME,T,SIGA25, DEL,NSIG
      BIGL=BIGL*86400.0
      IF(NSIG)31,31,32
   31 JS1=2
      GO TO 33
   32 WRITE (3,1050)NSTEP
      JS1=1
   33 FX(1)=-X
      ADD=1.0
      TM(1)=THETA
      WL(1)=THETA
      SSUM=THETA
      DO 8 L=2,15
      ADD=ADD+1.0
      TM(L)=TM(L-1)*THETA/ADD
      FX(L)=-FX(L-1)*X
      WL(L)=-T/ADD*WL(L-1)
    8 SSUM=SSUM+WL(L)
      TX(1)=SSUM
      DO 11 L=2,14
      ADD=L
```

```
      SSUM=0.0
```

```
      SSUM=0.0
      DO 12 I=1,15
      WL(I)=WL(I)*THETA/ADD
      ADD=ADD+1.0
   12 SSUM=SSUM+WL(I)
   11 TX(L)=SSUM
      IO=1
      IN=2
      DO 290 K=1,NMA
      RET=0.0
   13 N1=0
      N2=0
      N3=0
      JM=NRM(K)
      DO 2900 J=1,JM
      Y(1)=0.0
      Y(2)=0.0
      Y(3)=0.0
      Y(4)=0.0
      Y(5)=0.0
      KI=LISTM(J,K)
      IS=ISO(KI)
      AT=LA(KI)
      KA=LA(KI)-LOWA
      LM=NRA(KA)
      F=FLUX*FEED6(KI)+FEED3(KI)
      I1=KI
      I2=KI
      I3=KI
      I4=KI
      I5=KI
      MP=ML(KI)-1
      PAR2(14,J,IN)=AT
      DO 10 L=1,LM
      NP=LISTA(L,KA)
      IF(ML(NP)-MP)10,100,170
   10 CONTINUE
```

```
100 I4=NP
    I5=14+1
    DO 101 L=1,10
    L4=L
    IF(PAR2(14,L,IO)-AT)101,102,101
101 CONTINUE
102 L5=L4+1
    IF(IS.GT.1) GO TO 140
110 IF(ISO(NP)-2)120,130,130
120 Y(4)=FLUX*FEED6(I4)*FEED7(I4)
    GO TO 135
130 I5=NP
    L5=L4
135 Y(5)=FLUX*FEED6(I5)*FEED7(I5)
    GO TO 170
140 IF(ISO(NP)-2)150,160,160
150 Y(4)=FLUX*FEED6(I4)*(1.0-FEED7(I4))
    GO TO 165
160 I5=NP
    L5=L4
165 Y(5)=FLUX*FEED6(I5)*(1.0-FEED7(I5))
170 IF(N1-1)240,180,210
180 I1=KI-1
    L1=J-1
    Y(1)=FEED3(I1)*(1.0-FEED8(I1))
    IF(N2-1)240,185,190
185 WRITE (3,1002)REC(KI),ML(KI)
    GO TO 240
190 I2=I1-1
    L2=L1-1
    Y(2)=FEED3(I2)*(1.0-FEED8(I2))
    IF(N3-1)240,200,240
200 I3=I2-1
    L3=L2-1
    Y(3)=FEED3(I3)*FEED8(I3)
    GO TO 240
210 I2=KI-1
```



```
    L2=J-1
    IF(IS.GT.1) GO TO 230
```

```
      L2=J-1
      IF(IS.GT.1) GO TO 230
  220 Y(2)=FEED3(I2)*FEED8(I2)
      GO TO 240
  230 Y(2)=FEED3(I2)*(1.0-FEED8(I2))
      IF(N2-1)240,200,240
  240 N3=N2
      N2=N1
      N1=IS
      A=P*FEED5(KI)/100.0
      B=P25*(FEED4(KI)-FEED5(KI))/100.0
      DO 241 L=1,13
      SUM2(L)=Y(1)*PAR2(L,L1,IN)+
     1        Y(2)*PAR2(L,L2,IN)+
     2        Y(3)*PAR2(L,L3,IN)+
     3        Y(4)*PAR2(L,L4,IO)+
     4        Y(5)*PAR2(L,L5,IO)
  241 SUM3(L)=Y(1)*PAR3(L,L1,IN)+
     1        Y(2)*PAR3(L,L2,IN)+
     2        Y(3)*PAR3(L,L3,IN)+
     3        Y(4)*PAR3(L,L4,IO)+
     4        Y(5)*PAR3(L,L5,IO)
      F1=A/F
      F2=B/(F-X)
      F3=F2*XBAR
      F4=DATA1(1,KI)-F1-F2
      ARG=F*THETA
      SUM=0.0
      FM(1)=1.0
      FR(1)=1.0/F
      DO 242 L=2,13
      FM(L)=-FM(L-1)*F
      FR(L)=-FR(L-1)/F
  242 TERM(L)=0.0
      IF(ARG-79.0)260,243,243
  243 NT=1
      DO 244 L=1,10
```

```
      TERM(L)=SUM2(L)*FR(L)
      SUM=SUM+TERM(L)
      IF(.0001-ABS(TERM(L)/SUM))244,245,245
  244 CONTINUE
  245 DATA2(1,KI)=F1+F3+SUM
      PAR2(1,J,IN)=DATA2(1,KI)
      EMFT=0.0
      DO 247 L=2,13
      SSUM=0.0
      PT=ABS(FR(1)*SUM2(L))
      N=0
      DO 246 I=L,13
      N=N+1
      ADD=FR(N)*SUM2(I)
      TEST=ABS(ADD)
      IF(TEST.GT.PT) GO TO 247
      PT=TEST
  246 SSUM=SSUM+ADD
  247 PAR2(L,J,IN)=F3*FX(L-1)+SSUM
  249 FMULT=(1.0-EMFT)/F
      SSUM=SUM
      DO 250 L=1,13
      SSUM=(SUM3(L)-SSUM)/F
      FA=TM(L)
      PAR3(L,J,IN)=FMULT*F4+FA*F1+F2*TX(L)+SSUM
  250 FMULT=(FA-FMULT)/F
      GO TO 300
  260 EFT=EXP(ARG)
      EMFT=1.0/EFT
      F5=F4*EMFT
      IF(ARG-1.0)261,261,291
  261 NT=2
  267 DO 265 L=1,10
      TERM(L)=SUM3(L)*FM(L)
      SUM=SUM+TERM(L)
      IF(.0001-ABS(TERM(L)/SUM))265,266,266
  265 CONTINUE
```



```
  266 SS2=THETA
```

```
266 SS2=THETA
    SSUM=THETA
    Q=THETA
    WL(1)=THETA
    ADD=1.0
    WM(1)=THETA
    DO 262 L=2,15
    ADD=ADD+1.0
    Q=-T/ADD*Q
    WL(L)=-ARG/ADD*WL(L-1)+Q
    SSUM=SSUM+WL(L)
    WM(L)=-ARG/ADD*WM(L-1)
262 SS2=SS2+WM(L)
    FXT(1)=SSUM
    TF(1)=SS2
    DO 264 L=2,14
    SSUM=0.0
    SS2=0.0
    ADD=L
    DO 263 I=1,15
    WL(I)=WL(I)*THETA/ADD
    WM(I)=WM(I)*THETA/ADD
    ADD=ADD+1.0
    SSUM=SSUM+WL(I)
263 SS2=SS2+WM(I)
    FXT(L)=SSUM
264 TF(L)=SS2
    DATA2(1,KI)=DATA1(1,KI)*EMFT+A*TF(1)+B*FXT(1)+SUM
    PAR2(1,J,IN)=DATA2(1,KI)
269 DO 272 L=2,13
    SSUM=0.0
    DO 270 I=2,L
    N=L-I+1
270 SSUM=SSUM+FM(I-1)*SUM2(N)
    DO 271 I=L,13
    N=I-L+1
271 SSUM=SSUM+FM(I)*SUM3(N)
```

```
272 PAR2(L,J,IN)=FM(L)*F5+F3*FX(L-1)+SSUM
    DO 281 L=1,13
    LIM=13-L
    IF(LIM)281,281,282
282 SSUM=0.0
    DO 280 I=1,LIM
    N=I+L
280 SSUM=SSUM+FM(I)*SUM3(N)
281 PAR3(L,J,IN)=DATA1(1,KI)*TF(L)+A*TF(L+1)+B*FXT(L+1)+SSUM
    GO TO 300
291 FA=1.0
    ADD=1.0
    NT=3
    FNUM=EFT-1.0
    SS2=0.0
    WL(1)=1.0
    DO 294 L=1,13
    TF(L)=FNUM/EFT
    FA=FA/ADD*ARG
    FNUM=FNUM-FA
    WL(L+1)=WL(L)+FA
    SS2=-F*SS2+WL(L)*SUM2(L)
    WM(L)=EMFT*SS2
294 ADD=ADD+1.0
    DO 292 L=1,10
    TERM(L)=FR(L)*TF(L)*SUM2(L)
    SUM=SUM+TERM(L)
292 CONTINUE
    IF(.00001.GT.ABS(TERM(L)/SUM)) GO TO 293
293 IF(ABS(TERM(10)/SUM)-.001)298,298,296
296 IF(ARG-2.0)297,297,298
297 NT=4
    SUM=0.0
    DO 299 L=1,10
299 TERM(L)=0.0
    GO TO 267
298 DATA2(1,KI)=DATA1(1,KI)*EMFT+F1*(1.0-EMFT)+F2*(XBAR-EMFT)+SUM
```



```
    PAR2(1,J,IN)=DATA2(1,KI)
```

```
      PAR2(1,J,IN)=DATA2(1,KI)
      DO 295 L=2,13
      SSUM=0.0
      PT=ABS(FR(1)*SUM2(L)*TF(L))
      N=0
      DO 2950 I=L,13
      N=N+1
      ADD=FR(N)*SUM2(I)*TF(I)
      TEST=ABS(ADD)
      IF(TEST.GT.PT) GO TO 295
      PT=TEST
 2950 SSUM=SSUM+ADD
  295 PAR2(L,J,IN)=FM(L)*F5+F3*FX(L-1)+WM(L-1)+SSUM
      GO TO 249
  300 IF(DATA2(1,KI))302,302,301
  301 IF(ABS(TERM(10)/DATA2(1,KI))-.001)305,305,302
  302 IF(RET)303,303,304
  303 RET=1.0
      GO TO 13
  304 WRITE (3,1060)REC(KI),ML(KI),(TERM(I),I=1,10),         DATA2(1,KI)
     1,NT
  305 FLAM(J)=FEED3(KI)
      SSUM=0.0
      LIM=J-1
      IF(LIM)403,403,400
  400 DO 402 L=1,LIM
  401 DATA1(L+1,KI)=(Y(1)*DATA1(L+1,I1)+Y(2)*DATA1(L+1,I2)+Y(3)*
     1DATA1(L+1,I3))/(FLAM(J)-FLAM(L))
  402 SSUM=SSUM+DATA1(L+1,KI)
  403 DATA1(J+1,KI)=DATA2(1,KI)-SSUM
 2900 CONTINUE
      ISAV=IO
      IO=IN
      IN=ISAV
  290 CONTINUE
      ARG=42.4647*THETA
      EMFT=EXP(-ARG)
```

```
      EMNPT=EXP(-.29489*THETA)
      A=3.169*CON*P
      B=.02216*CON*P-1.007*U9I
      C=A+B
      U9I=U9I*EMFT+.022006*CON*P*(1.0-EMFT)
      PNI=PNI*EMNPT+A+B*EMFT-C*EMNPT
      DO 2901 IX=1,NCD
 2901 DATA1(1,IX)=DATA2(1,IX)
      P25=P25/8.436E+5
      DO 2902 I=1,6
      EMFT=EXP(-THETA*FLM(I))
 2902 PDN(I)=PDN(I)*EMFT+(DG1(I)-DG2(I))*P25*(XBAR-EMFT)+DG2(I)*PO*
     X(1.-EMFT)
  599 IF(JS1.GT.1) GO TO 700
  600 NSTEP=NSTEP+1
      READ  (2,1070)PO,TIME,NSIG
      WRITE (3,1080)PO,TIME,NSIG
      WRITE (3,1050)NSTEP
      TET=TET+TIME
      IF(PO)650,650,610
  610 FLUX=RATIO*PO
      FMWD=FMWD+PO*TIME
      X=FLUX*SIGA25
      T=X*TIME
      P=PO*8.436E+5
      TFISS=TFISS+P*TIME
      P25=PXBAR*P/(1.0+DEL)
      XBAR=EXP(-T)
      PXBAR=PXBAR*XBAR
      THETA=TIME
      IF(NSIG)33,33,620
  620 JS1=2
      GO TO 33
  650 DO 670 K=1,NMA
      JM=NRM(K)
      DO 670 J=1,JM
      KI=LISTM(J,K)
      FLAM(J)=FEED3(KI)
      ARG=TIME*FEED3(KI)
      IF(79.0-ARG)651,651,652
```

```
      FLAM(J)=FEED3(KI)
      ARG=TIME*FEED3(KI)
      IF(79.0-ARG)651,651,652
  651 SEMLT(J)=0.0
      GO TO 655
  652 IF(ARG)653,653,654
  653 SEMLT(J)=1.0
      GO TO 655
  654 SEMLT(J)=EXP(-ARG)
  655 SSUM=0.0
      LIM=J-1
      SS2=0.0
      DO 660 I=1,LIM
      TEST=(FLAM(J)-FLAM(I))*TIME
      IF(ABS(TEST)-.0001)660,1660,1660
 1660 TEST=1.0
      SS2=SS2+DATA1(I+1,KI)
  660 SSUM=SSUM+SEMLT(I)*DATA1(I+1,KI)*TEST
      SSUM=SSUM+SEMLT(J)*(DATA1(1,KI)-SS2)
  670 DATA1(1,KI)=SSUM
      EMFT=EXP(-42.4647*TIME)
      EMNPT=EXP(-.29489*TIME)
      PNI=(PNI+1.007*U9I)*EMNPT-1.007*U9I*EMFT
      U9I=U9I*EMFT
      DO 6700 I=1,6
 6700 PUN(I)=PDN(I)*EXP(-TIME*FLM(I))
      GO TO 600
  700 READ  (2,1090)DT
      WRITE (3,1091)DT
      NDT = 1
      DO 701 L=1,4
      IF(DT(L) .GT.0.) NDT = L+1
  701 DT(L) = DT(L)/86400.
      DO 410 K=1,NMA
      JM=NRM(K)
      DO 410 J=1,JM
      KI=LISTM(J,K)
```

```
      FLAM(J)=FEED3(KI)
      DO 406 L=1,4
      ARG=DT(L)*FEED3(KI)
      IF(79.0-ARG)404,404,405
  404 EMLT(J,L)=0.0
      GO TO 406
  405 IF(ARG)409,409,411
  409 EMLT(J,L)=1.0
      GO TO 406
  411 EMLT(J.L)=EXP(-ARG)
  406 CONTINUE
      DO 408 L=1,4
      SSUM=0.0
      LIM=J-1
      SS2=0.0
      DO 407 I=1,LIM
      TEST=(FLAM(J)-FLAM(I))*DT(L)
      IF(ABS(TEST)-.0001)407,1407,1407
 1407 TEST=1.0
      SS2=SS2 DATA1(I+1,KI)
  407 SSUM=SSUM+EMLT(I,L)*DATA1(I+1,KI)*TEST
      SSUM=SSUM+EMLT(J,L)*(DATA1(1,KI)-SS2)
  408 DATA2(L+1,KI) = SSUM * FEED3(KI)
  410 DATA2(1,KI) = DATA1(1,KI) * FEED3(KI)
      DO 421 J=1,NCD
      WRITE(3,425) REC(J),ML(J),(DATA2(K,J),K=1,5)
  421 CONTINUE
  425 FORMAT (2H  A3,I3,2X,1P10E11.3)
  430 CONTINUE
      DO 440 I=1,4
      J = 5-I
  440 DT(J+1) = DT(J)*86400.
      DT(1) = 0.
      DO 22 L=1,5
      TRY=DT(L)/100.0
      IF(TRY-1.0)14,14,15
   14 TLN(L)=DT(L)
```



```
      DATA QOOOHL/6H SEC. /
      TLH(L)=QOOOHL
      GO TO 22
   15 TRY=DT(L)/3600.0
```

```
      DATA Q000HL/6H SEC. /
      TLH(L)=Q000HL
      GO TO 22
   15 TRY=DT(L)/3600.0
      IF(TRY-1.0)16,16,17
   16 TLN(L)=TRY*60.0
      DATA Q001HL/6H MIN. /
      TLH(L)=Q001HL
      GO TO 22
   17 TRY=TRY/24.0
      IF(TRY-1.0)18,19,19
   18 TLN(L)=TRY*24.0
      DATA Q002HL/6H  HR. /
      TLH(L)=Q002HL
      GO TO 22
   19 TRY=TRY/365.0
      IF(TRY-1.0)20,21,21
   20 TLN(L)=TRY*365.0
      DATA Q003HL/6H DAYS /
      TLH(L)=Q003HL
      GO TO 22
   21 TLN(L)=TRY
      DATA Q004HL/6H YRS. /
      TLH(L)=Q004HL
   22 DT(L)=DT(L)/86400.0
      RETURN
      END
```

```
      SUBROUTINE CONTRL(MODE)
C         MAIN PROGRAM TO CALCULATE GAMMA ATTENUATION FOR VARIOUS
C         SOURCE AND SHIELD CONFIGURATIONS
C
C      IN THE FOLLOWING GLOSSARY
C      C IDICATES THE VARIABLE IS CALCULATED INTERNALLY
C      I INDICATES THE VARIABLE  IS INPUT IN NAMELIST INPUT
C      L INDICATES THE VARIABLE IS INPUT FROM THE LIBRARIES
C      O INDICATES OTHER INPUT
C
C     I   ANG1 = CONE ANGLE FOR TR. CONE SOURCE, SHIELD NORMAL ANGLE FOR
C                LINE SOURCE
C     I   ANG2 = DETECTOR ANGLE FOR LINE SOURCE
C     L   BAN(8)  = EFFECTIVE ATOMIC NUMBER FOR BUILD UP LIBE
C     L   BLIB (I,J,K) = BUILDUP FACTOR LIBRARY
C                I= ENERGY GROUP, J= 1 FOR A1, 2 FOR ALFA1, 3 FOR ALFA2
C                K= MATERIAL
C     L   COEF (I,J,K) = ENERGY DEPENDANT SHIELD MATERIAL COEF
C                 I DETERMINES ENERGY
C                 J = 1 SPECIFIES MASS ABSORBTION COEF - MU
C                 J = 2 SPECIFIES ENERGY ABSORBTION COEF - MUE
C                 K DETERMINES MATERIAL
C     C   DATA2 - CURIES CALCULATED IN RIBD
C     I   DELR = LENGTH OF RADIAL INTERVALS FOR NUMERICAL INTEGRATION
C     C   DSRATE - GAMMA DOSE RATE DUE TO ENERGY FLUX RATE OF 1 MEV/SCM
C     L   EAN(20) = EFFECTIVE ATOMIC NUMBER FOR SHIELD LIBE
C     L   EAW(20) = EFFECTIVE ATOMIC WEIGHT FOR SHIELD LIBE
C     C   ENERGY(16) - PHOTON ENERGY IN MEV FOR 16 GROUPS
C     I   GROUP - 5 ISOTOPE SELECTION GROUPS.  INPUT VALUE SPECIFIES A
C               WEIGHTING FACTOR IF MODE = 1, AND CURIES IF MODE = 2.
C               (1)  NOBLE GASES (XE,KR), (2)  HALOGENS (I,BR),
C               (3)  VOLATILE SOLIDS (SE,TE,CS),  (4)  ALL ISOTOPES
C               EXCEPT FIRST 3 GROUPS, (5)  ALL ISOTOPES IN LIBRARY
C     I   GEOM - VARIABLE TO SPECIFY SOURCE AND SHIELD GEOMETRIES
```

```
C              EXCEPT FIRST 3 GROUPS, [illegible]  ALL ISOTOPES IN LIBRARY
C      I   IGEOM = VARIABLE TO SPECIFY SOURCE AND SHIELD GEOMETRIES
C                1= POINT SOURCE - SLAB SHIELDS
C                2= LINE  SOURCE - SLAB SHIELDS
C                3= SPHERICAL SOURCE AND SHIELDS
C                4= SPHERICAL SOURCE - SLAB SHIELDS
C                5= TRUNCATED CONE SOURCE AND SHIELDS- DETECTOR AT APEX
C                6= DISC SOURCE - SLAB SHIELDS
C                7= CYLINDRICAL SOURCE AND SHIELDS
C                8= CYLINDRICAL SOURCE - SLAB SHIELDS
C                9= CYLINDER WITH DETECTOR AT END
C               10= RECTANGULAR SOLID
C      C   IPHSUB(501) - SPECIFIES STARTING SUBSCRIPT IN PHOTON ARRAY
C      I   JBUF = SHIELD REGION TO BE USED FOR CALCULATING BUILD UP
C               WILL BE SET TO LAST SHIELD IF NOT SPECIFIED
C      L   LA(500)  - ATOMIC NUMBER
C      L   ML(500)  - MASS NUMBER
C      O   MODE SPECIFIES TYPE OF SOURCE STRENGTH INPUT
C               1, CURIES  OF EACH ISOTOPE CALCULATED BY RIBD
C               2, CURIES OF EACH ISOTOPE INPUT IN WEIGHT OR GROUP ARRAYS
C               3, PHOTONS INPUT IN SOURCE (1,I ) FOR EACH ENERGY GROUP
C                GROUP SOURCE STRENGTH IN MEV INPUT IN SOURCE (2,I)
C      C   MU (I,J) = MASS ABSORPTION COEFF.  I=SHIELD NO.  J=ENERGY GRP
C      C   NDT  NUMBER OF COOLING TIMES FOR RIBD
C      C   NPHEN = NUMBER OF PHOTON ENERGY GROUPS
C      I   NPSI = NO. OF VERTICAL INTERVALS FOR NUMERICAL INTEGRATION
C      I   NSHLD = NUMBER OF SHIELD REGIONS, MAXIMUM = 5
C      I   NTHETA = NO. OF LATERAL INTERVALS  FOR NUMERICAL INTEGRATION
C      L   PHOTON (2,1006) = PHOTON PROBABILITY LIBRARY
C               PHOTON(1,  ) = PROBABIITY AT
C               PHOTON(2,  ) = MEV
C      C   RANGE(17)  - RANGE OF PHOTON ENERGY IN MEV FOR 16 GROUPS
C      L   REC(500) - ISOTOPE NAME
C      CI  SOURCE (I,J)  SOURCE(1,J) = PHOTONS / SEC OF ENERGY
C              SOURCE(2,J) MEV.   SOURCE(3,J)= ATTENUATED ENERGY FLUX
C      I   SLTH = LENGTH OF LINE OR CYL SOURCE, RADIUS OF DISC OR END CYL
C               SOURCE, LENGTH OF RECT SOURCE
```

```
C       I   SSV1 = EXPONENTIAL SS DIST.  SS=SSV2*EXP(SSV1*VARIABLE)
C       I   T = THICKNESS OF SHIELD REGIONS - SOLID SOURCES ARE CONSIDERED
C                AS FIRST SHIELD REGION
C       I   WEIGHT(500) - ARRAY FOR SELECTING INDIVIDUAL ISOTOPES.  SUBSCRIPT
C                CORRESPONDS TO THE ISOTOPES LOCATION IN THE RIBD
C                AND PHOTON LIBRARY
C                         = WEIGHTING FACTOR WHEN MODE = 1
C                         = CURIES WHEN MODE = 2
C       I   X = DISTANCE TO DETECTOR, FROM CENTER OF CYL AND SPH SOURCES,
C                THROUGH SOURCE OF CONE, ENDCYL, AND RECT SOURCES
C       I   Y = OFFSET OF DETECTOR FROM SHIELD NORMAL OF POINT SOURCE AND
C                AND BASE OF CYL.  Y= HEIGHT OF RECT SOURCE
      DIMENSION PHOTON(2,1006),          JGROUP(5,3), WEIGHT(500),GROUP(5)
     1 ,CASE(12),DUMMY(17),COEF (16,2,20),IPHSUB(501),BETEN(500)
      DIMENSION SHNAM(2,20),USED(10),IUSED(10), DSRATE(16),DOSE(16)
     1 ,EAN(20), EAW(20), BAN(8) ,DUM(16)
      DIMENSION WT(10)
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR ,VOLUME
      REAL MU,MUE
      NAMELIST /INPUT/ NEXT,T,GROUP,WEIGHT,NSHLD,SLTH,X,Y,ANG1,ANG2,ANG3
     1 ,JBUF,IGEOM,SSV1,SSV2,SOURCE,NTHETA,NPSI,DELR
      DATA BLANK/ 06060606060 60/
      DATA DSRATE / 1.77E-6,1.96E-6,2.06E-6,2.04E-6,2.08E-6,2.0E-6,
     1 1.93E-6,1.84E-6,1.76E-6,1.71E-6,1.66E-6,1.60E-6,1.54E-6,1.52E-6,
     2 1.48E-6,1.43E-6/
      DATA JGROUP / 54,36,3*0,53,35,3*0,34,52,55,2*0/
      DATA(DUMMY(I),I=1,17) / .1,.2,.3,.4,.55,.75,.9,1.1,1.35,1.6,1.8,
     1 2.,2.2,2.4,2.6,2.8,3.2/
      DO 1 I=1,17
    1 RANGE(I) = DUMMY(I)
      DATA(DUM   (I),I=1,16) /.15,.25,.35,.475,.65,.825,1.,1.225,1.475,
     1 1.7,1.9,2.1,2.3,2.5,2.7,3.0/
      DO 2 I=1,16
    2 ENERGY(I) = DUM   (I)
      PI = 3.1415927
```

```
      1 1.7,1.9,2.1,2.3,2.5,2.7,3.0/
        DO 2 I=1,16
      2 ENERGY(I) = DUM  (I)
        PI = 3.1415927
     15 READ (5,20) NPHCD
        IF (MODE  .EQ. 3) GO TO 100
C           READ + STORE PHOTON LIBRARY
     20 FORMAT (I3)
        NPHTN  = 1
        IPHSUB(1) = 1
        DO  80  I=1,NPHCD
        IEND = NPHTN  + 5
        READ(5,30) MASS,LATNO,ANA,NPC,((PHOTON(J,K),J=1,2),K=NPHTN,IEND)
       1 ,BETEN(I)
     30 FORMAT ( I3,I2,A4,I1,13F5.0)
        NPHTN =  NPHTN  + NPC
        IPHSUB(I+1) = NPHTN
        IF (I.GT.NCD .OR. MODE.EQ.2) GO TO 46
     40 IF ( MASS .EQ. ML(I) .AND. LATNO .EQ. LA(I)) GO TO 50
        WRITE (3,45) I
     45 FORMAT (18H0 PHOTON LIBE CARD , I4,19H IS OUT OF SEQUENCE)
        STOP
     46 ML(I) = MASS
        LA(I) = LATNO
        REC(I) = ANA
     50 IF (NPHTN-1000) 80,  60, 60
     60 WRITE (3,70) I
     70 FORMAT ( 34H0 PHOTON LIBE EXCEEDS LIMIT, ONLY ,I3,11H CARDS USED)
        NISO = I
        GO TO 90
     80 CONTINUE
        NISO = NPHCD
     90 GO TO 200
C           READ PAST PHOTON LIBE
    100 DO 105 I=1,NPHCD
        READ(5,20)  J
    105 CONTINUE
```

```
C         READ SHIELD MATERIAL LIBRARY
  200 READ (5,201) (DUMMY(I),I=1,2),J,K,(DUMMY(I),I=3,10),AN,AW,KEY
  201 FORMAT (A6,A1, I2,I1,8F7.0,2F3.0,I1)
      IF (J.GT.20.OR.J.LT.1) GO TO 215
      IF ( K .GT. 1) GO TO 210
      SHNAM( 1,J) = DUMMY(1)
      SHNAM( 2,J) = DUMMY(2)
      EAN(J) = AN
      EAW(J) = AW
      DO 205  I=3,10
  205 COEF (I-2,1,J) = DUMMY (I)
      GO TO 220
  210 DO 212  I=3,10
  212 COEF (I+6,1, J) = DUMMY(I)
      GO TO 220
  215 WRITE (3,216) (DUMMY(I),I=1,2),J,K,(DUMMY(I),I=3,10)
  216 FORMAT (30H0INVALID MU LIBE CARD REJECTED/ 1XA6,A1,I2,I1,8E10.3)
  220 IF (KEY.EQ.0) GO TO 200
C         READ BUILDUP COEFICIENT LIBRARY
  225 READ (5,226) J,K, (DUMMY(I),I=1,8), AN, KEY
  226 FORMAT (8X 2I1,8F7.0,F3.0,2XI1)
      IF (J.GT.0 .AND.J.LE.8 .AND. K.GT.0.AND. K.LE.6) GO TO 230
      WRITE (3,228) J,K,(DUMMY(I),I=1,8), AN,KEY
  228 FORMAT ( 47H0FOLLOWING INVALID BUILDUP FACTOR DATA REJECTED /
     1  1X 2I1,8E10.3,-3PF3.3,I3)
      GO TO 235
  230 KS =(K+1)/ 2
      KM2= MOD(K+1,2)
      DO 232  L=1,8
      LS = L + KM2*8
  232 BLIB(LS,KS ,J) = DUMMY(L)
      IF (K.EQ.1) BAN(J) = AN
  235 IF (KEY.EQ.0) GO TO 225
      DO 238  I=1,8
      IF(BAN(I).GT.0.) GO TO 238
      NBUD = I-1
      GO TO 240
  238 CONTINUE
      NBUD = 8
  240 CONTINUE
```

```
  238 CONTINUE
      NBUD = 8
  240 CONTINUE
C           INITIALIZE
  250 DO 255 I=1,5
      GROUP(I) = 0.
      T(I) = 0.
  255 CONTINUE
      DO 260 I=1,500
      WEIGHT(I) = 0.
  260 CONTINUE
      DO 265 I=1,6
  265 CASE(I) = BLANK
      DO 270 I=1,3
      DO 270 J=1,16
  270 SOURCE(I,J) = 0.
      NSHLD = 0
      NEXT = 0
      SLTH = 0.
      X = 0.
      Y = 0.
      ANG1 = 0.
      ANG2 = 0.
      ANG3 = 0.
      JBUF = 0
      IGEOM = 0
      SSV1 = 0.
      SSV2 = 0.
C           READ NEXT CASE OF DATA
  300 READ (2,301) CASE
  301 FORMAT (12A6)
      READ (2,INPUT)
C           CONVERT DEG TO RADIANS
      ANG1 = ANG1 * PI / 180.
      ANG2 = ANG2 * PI / 180.
      ANG3 = ANG3 * PI / 180.
C           COUNT NUMBER OF PHOTON ENERGY GROUPS
```

```
      IF (MODE.NE.3) GO TO 310
      DO 309 I=1,16
      IF(SOURCE(1,I)) 309,308,309
  308 NPHEN = I-1
      GO TO 311
  309 CONTINUE
  310 NPHEN = 16
C          NEXT IDENTIFIES WHAT MUST BE DONE WITH THIS CASE
C          1-NEW ISOTOPE SELECTION AND SHIELD MAT. 2-NEW ISOT SEL
C          3-NEW SHIELD MATL  4-CHANGE IN GEOMETRY ONLY  5-REINITIALIZE
C          6-END OF RUN
  311 NEXT = MAX0(1,NEXT)
      NEXT = MIN0(6,NEXT)
      GO TO ( 400,400,500,600,250,320), NEXT
  320 CALL EXIT
      RETURN
C          BUILD ISOTOPE SELECTION TABLE
  400 IF (MODE .LE. 2)  GO TO 405
      WRITE (3,401) MODE, CASE
  401 FORMAT  ( 6H0 MODE, I3,40H DOES NOT ALLOW ISOTOPE SELECTION.  CASE
     1 , 6A6, 10H REJECTED.)
      GO TO 300
C          CHECK ISOTOPE GROUP SWITCHES
  405 DO 420  I=1,NCD
      IF (GROUP(5)) 410,410,407
  407 J = 5
      GO TO 416
  410 DO  412 J=1,3
      DO  412 K=1,5
  412 IF (JGROUP(K,J) .EQ. LA(I)) GO TO 416
  415 J= 4
  416 IF (GROUP(J).GT.0.) WEIGHT(I) = GROUP(J)
  420 CONTINUE
      WRITE (3,422)
  422 FORMAT ( 1H1, 40X22HISOTOPE SELECTION DATA //// 25H0 ISOTOPES CONS
     1IDERED ARE)
      IF (MODE.EQ.1)  GO TO 4225
      WRITE (3,4221)
 4221 FORMAT  (1H+, 60X, 22H VALUES SPECIFY CURIES)
```

```
      WRITE (3,4221)
 4221 FORMAT  (1H+, 60X, 22H VALUES SPECIFY CURIES)
      GO TO 423
 4225 WRITE (3,4226)
 4226 FORMAT  (1H+,60X,36H VALUES REPRESENT A WEIGHTING FACTOR)
  423 IF (GROUP(5)) 425,425,4231
 4231 WRITE(3,424) GROUP(5)
  424 FORMAT ( 1H+,26X,4H ALL,1PE14.3)
      GO TO 490
  425 IF (GROUP(1)) 427,427,4251
 4251 WRITE(3,426) GROUP(1)
  426 FORMAT (26X11HNOBLE GASES,1PE14.3)
  427 IF (GROUP(2)) 429,429,4271
 4271 WRITE (3,428) GROUP(2)
  428 FORMAT (26X8HHALOGENS,1PE14.3)
  429 IF (GROUP(3)) 431,431,4291
 4291 WRITE (3,430) GROUP(3)
  430 FORMAT (26X15HVOLATILE SOLIDS,1PE14.3)
  431 IF (GROUP(4)) 435,435,4311
 4311 WRITE (3,432) GROUP(4)
  432 FORMAT (26X57HALL EXCEPT THE NOBLE GASES, HALOGENS, AND VOLATILE S
     1OLIDS,1PE14.3)
  435 NI = 0
      DO 470  I=1,NPHCD
      IF (WEIGHT(I) ) 470,470,437
  437 DO 440  J=1,3
      DO 440  K=1,5
  440 IF (LA(I) .EQ. JGROUP(K,J)) GO TO 442
      J = 4
  442 IF (GROUP(J)) 443,443,470
  443 NI = NI + 1
      USED (NI)   = REC(I)
      IUSED(NI)  = ML(I)
      WT(NI) = WEIGHT(I)
      IF (NI .LT. 10) GO TO 470
      WRITE (3,445) (USED(L),IUSED(L),L=1,10),(WT(L),L=1,10)
  445 FORMAT (1H0,9X10(A3,I3,4X) / 10X10E10.3)
```

```
      NI = 0
  470 CONTINUE
      IF (NI.EQ.0 ) GOTO 490
      WRITE (3,445) (USED(L),IUSED(L),L=1,NI)
      WRITE (3,480) (WT(L),L=1,NI)
  480 FORMAT (10X10E10.3)
  490 IF (NEXT .EQ.2) GO TO 600
C           READ SHIELD MATERIAL SPECS
  500 DO 501 I=1,16
      DO 501 J=1,6
  501 MU(J,I) = 0.
      IF (JBUF.EQ.0) JBUF = NSHLD
      SUM1 = 0.
      SUM2 = 0.
      WRITE(3,502) (I,I=1,5)
  502 FORMAT (1H1,9X,25HSHIELD COMPOSITION  GR/CC,5I12)
  503 READ (2,504) MAT,(DUMMY(J),J=1,5),KEY
  504 FORMAT ( 8X,I2, 5E10.4, 11X,I1)
      WRITE (3,523)(SHNAM(I,MAT),I=1,2),(DUMMY(J),J=1,5)
  523 FORMAT (1H0,10X,2A6,16X,1P5E12.3)
      IF  (MAT.GT. 0 .AND. MAT.LE.20) GO TO 510
      WRITE (3,507)
  507 FORMAT (38H0 FOLLOWING SHIELD SPECS DATA REJECTED)
      WRITE (3,504) MAT,(DUMMY(I),I=1,5),KEY
      GO TO 525
C           CALCULATE MASS ABSORBTION COEFICIENTS
  510 DO 520  I=1,NPHEN
      IF (MODE .GE.3)  VALUE = TERP(ENERGY,COEF(1,1,MAT),SOURCE(2,I))
      DO 520  J=1,NSHLD
      IF (MODE .LT.3) GO TO 519
      MU(J,I) = MU(J,I) + DUMMY(J)*VALUE
      GO TO 520
  519 MU (J,I) = MU(J,I) + DUMMY(J) * COEF(I,1,MAT)
  520 CONTINUE
      SUM1 = DUMMY(JBUF)/ EAW(MAT)  + SUM1
      SUM2 = DUMMY(JBUF) * EAN(MAT) / EAW(MAT) + SUM2
  525 IF (KEY .EQ. 0) GO TO 503
```



```
      ABAN  = SUM2 / SUM1
C           BUILD MU FOR DUMMY SHIELD OF AIR
      DO  540 I=1,NPHEN
      IF (MODE .GE.3) GO TO 535
```

```
      ABAN  = SUM2 / SUM1
C         BUILD MU FOR DUMMY SHIELD OF AIR
      DO  540 I=1,NPHEN
      IF (MODE .GE.3) GO TO 535
      MU(NSHLD+1,I) = COEF(I,1,3) * 1.2929E-3
      GO TO 540
  535 MU(NSHLD+1,I) = TERP(ENERGY,COEF(1,1,3),SOURCE(2,I))* 1.2929E-3
  540 CONTINUE
      WRITE(3,541) MU
  541 FORMAT ( 1H0,9X50HMASS ABSORPTION COEFFICIENTS  (LAST REGION IS AI
     1R) / (/39X1P6E12.3))
C         BUILD SOURCE STRENGTH TABLE AND CALCULATE ATTENUATION
  600 IEND = 1
      IF (MODE.LT.2) IEND = NDT
      DO 960  I=1,IEND
      IF (MODE.GT.2) GO TO 630
      DO 602  J=1,16
      DUM(J) = SOURCE(1,J)
      DUMMY(J) = SOURCE(3,J)
      DO 601  K=1,3,2
  601 SOURCE (K,J) =0.
  602 SOURCE (2,J) = ENERGY(J)
      DO  620 J=1,NPHCD
      IF (WEIGHT(J)) 620,620,603
  603 IF (MODE .EQ.1.AND.J .LE. NCD .AND. DATA2(I,J).LT.1.E-35)GOTO620
      KBEG = IPHSUB(J)
      KEND = IPHSUB(J+1) -1
      IF (KBEG.GT.KEND) GO TO 620
      TERM = WEIGHT(J)
      IF (MODE.EQ.1.AND.J.LE.NCD)  TERM = DATA2(I,J) * WEIGHT(J)
      DO 610  K=KBEG,KEND
C         GROUP PHOTON ENERGIES
      IF (PHOTON(2,K   )) 610,610,604
  604 DO 605  L=1,17
  605 IF (PHOTON(2,K   ).LT. RANGE(L)) GO TO 607
      L = 16
      GO TO 608
```

```
  607 L = MAXO(L-1,1)
  608 SOURCE(1,L) = TERM * PHOTON(1,K    )* 3.7E10 + SOURCE(1,L)
  610 CONTINUE
  620 CONTINUE
  630 IGEOM = MAXO(1,IGEOM)
      IGEOM = MINO(10,IGEOM)
C          BUILD TWO SETS OF BUILD UP COEFFECIENTS FOR LATER INTERPOLATION
C          ON EFFECTIVE ATOMIC NO.(ABAN)
C          BUF (1,  ) = A1, BUF(2,  )= A2 =1.-A1, BUF(3,  )=ALPHA 1,
C          BUF (4, ) = ALPHA 2,  BUIF = BUILDUP INTERPOLATION FACTOR
C          THE CALCULATED BUILD UP FACTOR WILL BE INTERPOLATED RATHER
C          THAN THE COEF
      IF (BAN(1).LT.ABAN ) GO TO 631
      JBS1    = 1
      JBS2    = 2
      GO TO 635
  631 DO 634  J=2,NBUD
      IF (ABAN - BAN(J)) 632,633,634
  632 JBS1    = J-1
      JBS2    = J
      GO TO 635
  633 JBS1    = J
      JBS2    = J+1
      GO TO 635
  634 CONTINUE
      JBS1    = NBUD
      JBS2    = NBUD-1
  635 BUIF = (ABAN- BAN(JBS1)) / (BAN(JBS2)  -BAN(JBS1))
      DO 650 J=1,NPHEN
      IF (I.EQ.1) GO TO 636
C          NOT FIRST COOLING TIME - FLUX IS PROPORTIONAL TO SOURCE STRGTH
      SOURCE(3,J) = SOURCE(1,J)/DUM(J)*DUMMY(J)
      GO TO 650
  636 IF (SOURCE(1,J)) 6361,650,6361
 6361 BUF (1,1)= TERP (ENERGY,BLIB( ,1,JBS1),SOURCE(2,J))
      BUF (1,2)= TERP (ENERGY,BLIB(1,1,JBS2),SOURCE(2,J))
      BUF (2,1)= 1. - BUF(1,1)
```



```
      BUF (2,2)= 1. - BUF(1,2)
      DO 637 L=3,4
      BUF(L,1) = TERP (ENERGY,BLIB(1,L-1,JBS1), SOURCE(2,J))
```

```
      BUF (2,2)= 1. - BUF(1,2)
      DO 637 L=3,4
      BUF(L,1) = TERP (ENERGY,BLIB(1,L-1,JBS1), SOURCE(2,J))
  637 BUF(L,2) = TERP (ENERGY,BLIB(1,L-1,JBS2), SOURCE(2,J))
C          ATTENUATION CALCULATION
      JPH = J
      GO TO (641,642,643,643,645,646,647,647,648,649),IGEOM
  641 CALL POINT
      GO TO 650
  642 CALL LINE
      GO TO 650
  643 CALL SPHERE
      GO TO 650
  645 CALL TCONE
      GO TO 650
  646 CALL DISC
      GO TO 650
  647 CALL CYL
      GO TO 650
  648 CALL ENDCYL
      GO TO 650
  649 CALL RECT
      GO TO 650
  650 DOSE(J) = SOURCE(3,J) * TERP(ENERGY,DSRATE,SOURCE(2,J))
C          PRINT OUT
  900 WRITE (3,901) CASE,X
  901 FORMAT (1H1, 5X, 29HGAMMA ATTENUATION CALCULATION, 5X12A6/
     1 1H0,12X6HSOURCE, 15X, 7HSHIELDS, 3X16HDIST TO DETECTOR,1PE10.3,
     2 4H CM.)
      GO TO (910,912,914,916,918,920,922,924 ,9251,9253),IGEOM
  910 WRITE (3,911)
  911 FORMAT (1H+, 6X5HPOINT, 10X4HSLAB)
      GO TO 940
  912 DEG1  = ANG1 * 180./ PI
      DEG2  = ANG2 * 180./ PI
      WRITE (3,913) SLTH,DEG2,DEG1
  913 FORMAT (1H+,7X4HLINE,17X4HSLAB,46X 13HSOURCE LENGTH,1PE10.3  /
```

```
     1 1H0,7X14HDETECTOR ANGLE,0PF7.1,8H DEGREES, 12X,19HSHIELD NORMAL A
     2NGLE, F7.1,  8H DEGREES)
      GO TO 940
  914 WRITE (3,915) VOLUME
  915 FORMAT (12H+  SPHERICAL,12X, 9HSPHERICAL,66X5HVOL.=,1PE9.3,3H CC)
      GO TO 940
  916 WRITE (3,917) VOLUME
  917 FORMAT (12H+  SPHERICAL,17X, 4HSLAB,66X5HVOL.=,1PE9.3,3H CC)
      GO TO 940
  918 IF (ANG1 + 0.1 .GT. PI / 2.) GO TO 9191
      DEG1 = ANG1 * 180. / PI
      WRITE (3,919) DEG1,VOLUME
  919 FORMAT ( 12H+   TR. CONE, 17X4HSLAB, 43X10HCONE ANGLE,F7.1,3HDEG,
     1 3X5HVOL.=,1PE9.3,3H CC)
      GO TO 940
 9191 IF (T(1).GT.0.) GO TO 9194
      WRITE (3,9192)
 9192 FORMAT (12H+ INF. PLANE , 17X, 4HSLAB)
      GO TO 940
 9194 WRITE (3,9195)
 9195 FORMAT (12H+  INF. SLAB , 17X, 4HSLAB)
      GO TO 940
  920 WRITE (3,921) SLTH
  921 FORMAT (1H+,7X4HDISC,17X4HSLAB,46X6HRADIUS,F10.3,4H CM.)
      GO TO 940
  922 WRITE (3,923) SLTH,VOLUME
  923 FORMAT (12H+CYLINDRICAL,10X11HCYLINDRICAL,43X6HLENGTH,1PE10.3
     1 ,  4H CM.,3X5HVOL.=1PE9.3,3HCC   )
      GO TO 935
  924 WRITE (3,925) SLTH,VOLUME
  925 FORMAT (12H+CYLINRICAL,17X 4HSLAB,43X     6HLENGTH,1PE10.3,4H CM.,
     1 3X5HVOL.=,1PE9.3,3H CC)
      GO TO 935
 9251 WRITE (3,9252) VOLUME, T(1),SLTH
 9252 FORMAT (12H+END OF CYL.,17X4HSLAB,66X5HVOL.= ,1PE9.3,3H CC/ 1H0,
     1  7X 8HLENGTH =, E10.3, 3H CM, 20X 8HRADIUS =,E10.3,3H CM)
      GO TO 935
```



```
 9253 WRITE (3,9254) VOLUME, T(1),Y,SLTH
 9254 FORMAT (12H+       SLAB,17X4HSLAB,66X5HVOL.=,1PE9.3,3H CC / 1H0,
     1 7X11HTHICKNESS =,1PE10.3,3HCM,8X 8HHEIGHT =,E10.3,3H CM,8X7HWIDTH
```

```
9254 FORMAT (12H+        SLAB,17X4HSLAB,66X5HVOL.=,1PE9.3,3H CC / 1H0,
    1 7X11HTHICKNESS =,1PE10.3,3HCM, 8HHEIGHT =,E10.3,3H CM,8X7HWIDTH
    2 =,E9.3, 3H CM)
 935 WRITE (3,936) NTHETA, NPSI, DELR
 936 FORMAT ( 29H0 INTEGRATION SPECS  NTHETA = ,I5,5X 6HNPSI =, I5,
    1  5X 6HDELR =, E10.4)
 940 IF(MODE.GT.1) GO TO 930
     WRITE (3,928) CASER, FMWD, TET ,TLN(I),TLH(I)
 928 FORMAT ( 15H0 REACTOR DATA , 6A6, F7.1, 7H MWD IN, F7.1,5H DAYS,
    1  F10.1,A5,  15H AFTER SHUTDOWN)
 930 WRITE (3,931) JBUF,ABAN
 931 FORMAT ( 32H0 TAYLOR BUILDUP DATA FOR SHIELD, I2, 32H WITH EFFECTI
    1VE ATOMIC NUMBER OF, F5.1, 5H USED)
     WRITE (3,941) (T(J),J=1,NSHLD)
 941 FORMAT  (1H0,10X,16HSHIELD THICKNESS, 1P6E13.3, 4H CM.)
     WRITE(3,945)(K,(SOURCE(J,K),J=1,3),DOSE(K),K=1,NPHEN)
 945 FORMAT (1H0,5X,5HGROUP,12X5HGROUP,15X5HGROUP,12X11HENERGY FLUX,
    1 10X9HDOSE RATE / 18X15HPRODUCTION RATE,6X14HAVERAGE ENERGY,6X13HA
    2T DOSE POINT, 7X13HAT DOSE POINT / 22X7HPHOTONS,15X3HMEV,13X11HMEV
    3/CMS/SEC,8X14HROENTGENS/HOUR (/I10,1P4E20,3))
C        CALCULATE TOTALS
     SUM1 = 0.
     SUM2 = 0.
     SUM3 = 0.
     DO 946 J=1,NPHEN
     SUM1 = SUM1 + SOURCE(1,J)
     SUM2 = SUM2 + SOURCE(3,J)
 946 SUM3 = SUM3 + DOSE(J)
     WRITE (3,950) SUM1,SUM2,SUM3
 950 FORMAT  ( 10H0  TOTAL   ,1PE20.3,E40.3,E20.3)
 960 CONTINUE
C        CONVERT RADIANS TO DEG
     ANG1=ANG1*57.2958
     ANG2=ANG2*57.2958
     ANG3=ANG3*57.2958
     GO TO 300

     END
```

```
      SUBROUTINE ADJUST (ARG)
C          ADJUST THICKNESS OF LAST SHIELD OR ADD A DUMMY SHIELD SO THE
C          TOTAL SHIELD DISTANCE = DISTANCE TO DETECTOR
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1   JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      TOTT = 0.
      DO 10 I=1,NSHLD
      TOTT = TOTT + T(I)
   10 IF (ARG.LT.TOTT   )  GO TO 20
      NSHLDA= NSHLD + 1
      T(NSHLDA) = ARG    - TOTT
      GO TO 30
   20 NSHLDA= I
      T(I) =  T(I) - TOTT + ARG
   30 CONTINUE
      RETURN
      END
```

```
      FUNCTION BFUNC (C,D)
C          FUNCTION TO INTERPOLATE CALCULATED BUILD UP FACTORS
C          C= INTERPOLATION FACTOR    D= MEAN FREE PATHS OF TOTAL SHIELD
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      B = 0.
      B2 = 0.
      DO 400 J=1,2
      IF (C) 100,350,100
  100 ARG = -BUF(J+2,2)* D
      IF (ARG.LT.88.027) GO TO 340
      ARG = 88.027
      WRITE (3,200) J,BUF(J+2,2), D
  200 FORMAT ( 70H0 EXP(B) WHERE B GT. 88.027, B SET TO 88.027 IN CALC.
     1BUILD UP.  ALPHA, I1, 1H=,E10.4, 5H  B1=, E10.4)
  340 B2 = B2 + BUF(J,2) * EXP(ARG)
  350 ARG = -BUF(J+2,1) * D
      IF(ARG.LT.88.027) GO TO 400
      ARG = 88.027
      WRITE (3,200) J,BUF(J+2,1),D
  400 B = B + BUF(J,1) * EXP(ARG)
      BFUNC = B + C    * (B2-B)
      RETURN
      END
```

```
      SUBROUTINE CYL
C         CALCULATE GAMMA ATTENUATION FOR CYLINDRICAL SOURCE
C         USING SIMPSONS RULE FOR INTEGRATION OF POINT KERNEL
      DIMENSION  TM(6)
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      REAL L2
      CALL ADJUST (X)
      IF (MOD(NTHETA,2).EQ.0)  NTHETA = NTHETA + 1
      XS = X*X
      VOLUME = PI*SLTH*T**2
      IF (SSV1) 60,50,60
C         EXPONENTIAL SOURCE STRENGTH DISTRIBUTION
   50 SSV2 = SOURCE(1,JPH) * SOURCE(2,JPH) * SSV1**2 / 2. / PI /
     1    SLTH / (1. + EXP(SSV1*T) * (SSV1*T - 1.)  )
      GO TO 65
C         CONSTANT SOURCE STRENGTH
   60 SSV2 = SOURCE(1,JPH) * SOURCE(2,JPH) / VOLUME
   65 TH2 = ATAN2 ( T, SQRT(ABS(XS-T*T)))
      DELTH = TH2 / FLOAT(NTHETA - 1)
      IF (Y.GT.SLTH) Y=0.
      HMAX = AMAX1(Y,SLTH-Y)
      AMID = AMIN1 ( Y, SLTH-Y)
      THETA = 0.
      SUMI = 0.
      FLIPI = 2.
```



```
      DO 400  I=1,NTHETA
      SINT = SIN(THETA)
      COST = COS(THETA)
```

```
      DO 400  I=1,NTHETA
      SINT = SIN(THETA)
      COST = COS(THETA)
      XCOS = X * COST
      XSINS=(X * SINT)**2
      SUM = 0.
      IF (IGEOM.GE.8) GO TO 120
C         CYLINDRICAL SHIELD
      DO 100  J=1,NSHLDA
      SUM = SUM + T(J)
  100 TM(J) = XCOS - SQRT(ABS(SUM*SUM - XSINS))
      B1MFS =  TM(1) * MU(1,JPH)
      DO 110  J=2,NSHLDA
  110 B1MFS = B1MFS + (TM(J)-TM(J-1))*MU( J,JPH)
      B1MFS = - B1MFS
      GO TO 150
C         SLAB SHIELDS
  120 TTMFS = 0.
      B1MFS = 0.
      TM(1) = XCOS - SQRT(ABS(T*T - XSINS))
      IF (NSHLDA.LT.3)GOTO 140
      DO 130 J=3,NSHLDA
      TTMFS = TTMFS + T(J)
  130 B1MFS = B1MFS + MU(J,JPH)* T(J)
  140 B1MFS = (B1MFS-MU(2,JPH)*TTMFS)  / COST    + TM(1)*(MU(2,JPH) -
     1    MU(1,JPH))
  150 L2 = 2.*XCOS-TM
      PSI2     = ATAN2(HMAX,TM(1))
      SUMJ     = 0.
      IF (MOD(NPSI   ,2).EQ.0)NPSI=NPSI+1
      DELFSI  = PSI2   / FLOAT(NPSI - 1)
      PSI = 0.
      FLIPJ = 2.
      DO 300  J=1, NPSI
      COSPSI = COS(PSI)
      SECPSI = 1. / COSPSI
      SINPSI = SIN(PSI)
```

```
      COSPSS = COSPSI * COSPSI
      TANPSI  = SINPSI / COSPSI
      RHO= TM(1) * SECPSI
      IF (PSI.GT.0.) GO TO 160
      RHO2 = SECPSI * L2
      GO TO 170
  160 RHO2 = AMIN1(SECPSI*L2, HMAX/SINPSI)
  170 NRHO =  INT ((RHO2-RHO )/ DELR)
      IF (MOD (NRHO,2).EQ. 0) NRHO = NRHO+1
      DELRHO  = (RHO2 - RHO) / FLOAT(NRHO-1)
      FLIPK = 2.
      SUMK = 0.
      DO 260  K=1,NRHO
      IF (SSV1) 190,180,190
  180 SS = SSV2
      GO TO 200
  190 SS = SSV2 * EXP(SQRT(ABS(XS - 2.*RHO*XCOS*COSPSI + RHO*RHO*COSPSS
     1 ))* SSV1)
  200 B1 = RHO * MU(1,JPH) + B1MFS*SECPSI
      FACT = 1.
      B = BFUNC(BUIF,B1)
      IF (K.EQ.1 .OR.K.EQ.NRHO)  GO TO 250
      FLIPK = 6.-FLIPK
      FACT = FLIPK
  250 IF(RHO.LT.AMID/SINPSI+DELRHO/2.) FACT = FACT*2.
      VAL = FACT * B * SS * EXP(-B1)
      SUMK = SUMK + VAL
      IF (K.EQ.1) FRST = VAL
      IF (ABS(VAL/FRST).LT.1.E-4) GO TO 265
  260 RHO = RHO + DELRHO
  265 SUMK = SUMK * DELRHO
      FACT = 1.
      IF (J.EQ.1.OR. J.EQ. NPSI) GO TO 270
      FLIPJ = 6.-FLIPJ
      FACT = FLIPJ
  270 SUMJ =  SUMJ + FACT * SUMK
  300 PSI = PSI + DELPSI
```



```
      SUMJ = SUMJ * DELPSI
      FACT = 1.
```

```
      SUMJ = SUMJ * DELPSI
      FACT = 1.
      IF (I.EQ.1.OR. I.EQ.NTHETA) GO TO 340
      FLIPI=6.-FLIPI
      FACT = FLIPI
  340 SUMI = SUMI + FACT * SUMJ
  400 THETA = THETA + DELTH
      SUMI = SUMI/ 54./ PI * DELTH
      SOURCE (3,JPH) = SUMI
      RETURN
      END
```

```
      SUBROUTINE DISC
C          SUBROUTINE TO CALCULATE ATTENUATION FOR DISC SOURCE USING
C          SIMPS INTEGRATION FUNCTION.  DSCSRC IS THE FUNCTION WHICH
C          IS INTEGRATED OVER THE SOURCE
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      EXTERNAL DSCSRC
      CALL ADJUST(X)
      B1 = 0.
      DO 10 J=1,NSHLDA
   10 B1 = B1 + T(J)*MU(J,JPH)
      IF (SSV1)  25,20,25
C          CONSTANT SOURCE DIST.
   20 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH)/PI/SLTH**2
      GO TO 30
C          EXPONENTIAL SOURCE DIST.
   25 SSV2 = SOURCE(1,JPH) * SSV1**2 / 2. / PI / (1.+(SSV1*SLTH-1.) *
     1     EXP(SSV1*SLTH)) * SOURCE(2,JPH)
   30 SOURCE (3,JPH) = .5 * SIMPS(0,SLTH,.001,DSCSRC)
      RETURN
      END
```

```
      FUNCTION DSCSRC (ARG)
C         FUNCTION INTEGRATED OVER DISC SOURCE
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      RHOSQ = X * X + ARG * ARG
      RHO = SQRT (RHOSQ)
      B = BFUNC (BUIF,B1*RHO/X)
      DSCSRC = B * SSV2 * EXP(SSV1*ARG - B1*RHO/X) * ARG / RHOSQ
      RETURN
      END
```

```
      SUBROUTINE ENDCYL
C         CALCULATE ATTENUATION OF CYL. SOURCE WITH DETECTOR AT END
C         USING SIMPSONS RULE FOR INTEGRATION OF POINT KERNEL
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      CALL ADJUST(X)
      FLIPI = 2.
      B1MFS = 0.
      TTMFS = 0.
      DO 5 I=2,NSHLDA
      TTMFS = TTMFS + T(I)
    5 B1MFS = B1MFS + MU(I,JPH) * T(I)
      IF (MOD(NTHETA,2).EQ.0) NTHETA=NTHETA+1
      THETA= 0.
      TH2 = ATAN2(SLTH,X-T)
      DELTH = TH2/FLOAT(NTHETA)
      VOLUME = PI * SLTH**2* T
      IF (SSV1)  15 ,10,15
   10 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH)/ VOLUME
      GO TO 20
   15 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH) * SSV1**2 / 2. / PI / T /
     1  (1. +  EXP(SSV1*SLTH) * (SSV1* SLTH - 1.))
   20 SUMI = 0.
      DO 200  I=1,NTHETA
      SINT = SIN(THETA)
      SECANT = 1. / COS(THETA)
```



```
      RHO =(X-T) * SECANT
      RHO2 = AMIN1 (X * SECANT, SLTH / SINT )
```

```
      RHO =(X-T) * SECANT
      RHO2 = AMIN1 (X * SECANT, SLTH / SINT )
      NRHO = INT ( (RHO2- RHO) / DELR )
      IF (MOD(NRHO,2).EQ.0) NRHO = NRHO + 1
      DELRHO = (RHO2-RHO) / FLOAT(NRHO)
      SUMJ = 0.
      FLIPJ = 2.
      TT = TTMFS * SECANT
      B1 = B1MFS * SECANT
      DO  100 J=1,NRHO
      IF (SSV1) 35,30,35
   30 SS= SSV2
      GO TO 40
   35    SS    =           SSV2 * EXP (RHO*SINT*SSV1)
   40 B2 =  (RHO - TT)* MU(1,JPH) + B1
      B =  BFUNC (BUIF,B2)
      FACT = 1.
      IF (J.EQ.1 .OR. J.EQ.NRHO) GO TO 50
      FLIPJ = 6. - FLIPJ
      FACT = FLIPJ
   50 VAL  =        FACT * B * SS * EXP(-B2)
      IF (J.EQ.1) FRST = VAL
      IF ( ABS(VAL / FRST) .LT. 1.E-4) GO TO 110
      SUMJ = SUMJ + VAL
  100 RHO = RHO + DELRHO
  110 SUMJ = SUMJ * DELRHO
      FACT = 1.
      IF ( I.EQ.1 .OR. I.EQ.NTHETA) GO TO 150
      FLIPI = 6.-FLIPI
      FACT = FLIPI
  150 SUMI = SUMI + FACT * SUMJ * SINT
  200 THETA = THETA + DELTH
      SOURCE (3,JPH) = SUMI * DELTH / 18.
      RETURN
      END
```

```
      FUNCTION E1(ARG)
C         APPROXIMATES  INTEGRAL (ARG,INF) OF EXP(-T)/ T  DT FOR
C         POSITIVE ARG
      VALUE = 0.
      IF (ARG .GT. 0.0) GO TO 10
    4 WRITE (3,5) ARG
    5 FORMAT (19H0 INVALID ARGUMENT ,E10.3,36H FOR FUNCTION E1,  RESULT
     1 SET TO 0.)
      GO TO 100
   10 IF (1.0 .LT. ARG) GO TO 20
      VALUE = -0.57721566 - ALOG(ARG)
      FACT = 1.
      DIV = -1.
      DO 15 I=1,10
      FI = FLOAT(I)
      FACT = FACT * FI
      DIV = -DIV* ARG
   15 VALUE = VALUE + DIV/FI/FACT
      GO TO 100
   20 IF (ARG .GT. 88.)GO TO 100
      VALUE = EXP(-ARG)/ARG* (0.2372905+ ARG*(4.5307924 + ARG*(5.1266902
     1 + ARG))) / (2.476631+ARG*(8.6660126+ARG*(6.1265272+ARG)))
  100 E1 = VALUE
      RETURN
      END
```

```
      FUNCTION E2(ARG)
C         APPROXIMATES ARG* INTEGRAL(ARG,INF) OF EXP(-T)/T**2  DT
      VALUE = 1.
      IF (ARG ) 5,10,5
    5 VALUE = EXP(-ARG) - ARG* E1(ARG)
   10 E2 = VALUE
      RETURN
      END
```

```
      FUNCTION F1(T,A)
C         APPROXIMATION FOR INTEGRAL FROM 0 TO T  OF EXP(A*X)*E1(X) DX
      VALUE = 0.
      IF (T ) 5,100,5
    5 IF (A.GT.0. .OR. A.LT.0. .OR. ABS(T).GT.88.)  GO TO 9
      VALUE  =  1. - E2(T)
      GO TO 100
    9 IF (A) 10,20,10
   10 IF (1.0 .LT. A .OR. ABS(T*(1.-A)).GT.88.) GO TO 20
   11 VALUE =  (EXP(A*T)* E1(T) - E1(T*(1.-A)) -ALOG(ABS(1.-A))) / A
      GO TO 100
   20 IF (ABS(A-1.).GT.1.E-10 .OR. T.LT.1.E-38 .OR. T.GT.88.) GO TO 30
      VALUE = EXP(T)* E1(T) +ALOG(T) + 0.57721566
      GO TO 100
   30 IF ( A.GT.1.0 .AND.ABS(A*T).LT. 88.)  GO TO 11
      WRITE (3,40) T,A
   40 FORMAT (40H0 F1 INTEGRATION FUNCTION FAILED.  TAU =, E11.3,
     1  5H, A= ,E11.3)
  100 F1 = VALUE
      RETURN
      END
```

```
      SUBROUTINE LINE
C          CALCULATES GAMMA ATTENUATION FOR A LINE SOURCE. LINE SOURCE
C          IS ORIENTED SUCH THAT ONE END IS CONSIDERED ORIGIN, ANG1 =
C          ANGLE SHIELD NORMAL MAKES WITH THE LINE SOURCE, ANG2 = ANGLE
C          TO DETECTOR, X = DIST TO DETECTOR FROM ORIGIN, SLTH =SOURCE
C          LENGTH.   USES SIMPS INTEGRATION FUNCTION, INTEGRATING
C          FUNCTION LINSRC
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR ,VOLUME
      REAL MU,MUE
      EXTERNAL LINSRC
      XNORM = X * COS (ABS(ANG2-ANG1 ))
      IF (ANG1.LT.PI/2.) T = AMAX1(T,SLTH*COS(ANG1))
      CALL ADJUST (XNORM)
      B1MFS = 0.
      TTMFS = 0.
      DO 105 K=2,NSHLDA
      TTMFS = TTMFS + T(K)
  105 B1MFS = B1MFS + T(K)* MU(K,JPH)
      IF (SSV1)  106, 107,106
C          EXPONENTIAL SOURCE DIST.
  106 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH)* SSV1/(EXP(SSV1*SLTH)-1.)
      GO TO 108
C          CONSTANT SOURCE DIST.
  107 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH) / SLTH
  108 SOURCE (3,JPH) = SIMPS (0,SLTH,.001, LINSRC)
      CALL SLITET (1,LT1)
```

```
      GO TO ( 110, 120),LT1
  110 WRITE (3,115)  JPH,(SOURCE (J,JPH),J=1,3)
  115 FORMAT  (25H0 INTEGRATION FAILED FOR , I2,14H ENERGY LEVEL ,
     11PE11.4, 11H PHOTONS AT ,E12.4,15HMEV.    RESULT =,E12.4)
  120 RETURN
      END
```



```
      REAL FUNCTION LINSRC (ARG)
C         THIS FUNCTION IS INTEGRATED BY FUNCTION SIMPS TO CALCULATE
C         ATTENUATION FOR A LINE SOURCE
```

```
      REAL FUNCTION LINSRC (ARG)
C          THIS FUNCTION IS INTEGRATED BY FUNCTION SIMPS TO CALCULATE
C          ATTENUATION FOR A LINE SOURCE
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR ,VOLUME
      REAL MU,MUE
      RHOSQ = ARG**2 + X**2 - 2. *ARG*X*COS(ANG2)
      RHO = SQRT(RHOSQ)
      SINOM =  ARG * SIN(ANG2)/ RHO
      COSOM = (X**2  + RHOSQ - ARG**2) /2./ X /RHO
      OMEG= ATAN2 (SINOM,COSOM)
      THETA =  ABS (ANG1  - ANG2- OMEG)
      SECANT = 1. / COS (THETA)
      B1 =  (RHO- TTMFS* SECANT) * MU(1,JPH) + B1MFS * SECANT
      IF (SSV1) 200,150,200
  150 SS=SSV2
      GO TO 300
  200 SS = SSV2 * EXP(SSV1*ARG)
  300 B = BFUNC(BUIF,B1)
      LINSRC = B * SS * EXP(-B1) / 4. / PI / RHOSQ
      RETURN
      END
```

```
      SUBROUTINE POINT
C         SUBROUTINE POINT CALCULATES GAMMA ATTENUATION OF A POINT
C         SOURCE THROUGH MULTIPLE SLAB SHIELDS
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      CALL ADJUST (X)
      SECANT  = 1. / COS(ATAN2(Y,X))
C         CALCULATE B1 = SUM MU * THICKNESS OF SHIELDS, MU = ATTEN. COEF
      B1 = 0.
      DO  20  J=1,NSHLDA
   20 B1 = B1 + MU(J,JPH) * T(J)
      B1 = B1 * SECANT
      B = BFUNC(BUIF,B1)
      SOURCE(3,JPH) = B * SOURCE(1,JPH) * SOURCE(2,JPH) * EXP(-B1)
     1          / 4. / PI / (X * SECANT) **2
      RETURN
      END
```

```
      SUBROUTINE RECT
C          SUBROUTINE TO CALCULATE ATTENUATION FOR A RECTANGULAR SOURCE
C          USES SIMPSONS RULE FOR NUMERICAL INTEGRATION OF A POIN KERNEL
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,     SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      REAL MU,MUE
      VOLUME = SLTH *Y * T
C          CONSTANT SOURCE STRENGTH ONLY FOR RECT. SOURCE
      SSV2 =  SOURCE(1,JPH) * SOURCE(2,JPH) / VOLUME
      IF (MOD(NPSI,2).EQ.0) NPSI = NPSI+1
      DELPSI = Y/ FLOAT(NPSI) /2.
      FLIPI = 2.
      SUMI = 0.
      CALL ADJUST(X)
      B1MFS = 0.
      TTMFS = 0.
      DO 10 I=2,NSHLDA
      TTMFS = TTMFS + T(I)
   10 B1MFS = B1MFS + T(I)* MU(I,JPH)
      IF (MOD(NTHETA,2).EQ.0) NTHETA = NTHETA +1
      THETA = 0.
      DELTH = SLTH/ 2./ FLOAT(NTHETA)
      NZ =  INT(T/DELR)
      IF (MOD(NZ,2).EQ.0) NZ= NZ + 1
      DZ =  T / FLOAT (NZ)
      DO  300      I=1,NTHETA
      FLIPJ = 2.
```

```
      SUMJ = 0.
      PSI = 0.
      THSQ =  THETA**2
      DO 200   J=1,NPSI
      TSPS = THSQ + PSI**2
      SUMK = 0.
      FLIPK = 2.
      Z = 0.
      DO 100  K=1,NZ
      RHOSQ =        TSPS + (TTMFS+Z)**2
      RHO = SQRT (RHOSQ)
      SECANT = RHO /(TTMFS + Z )
      B1 =  (RHO-TTMFS*SECANT)* MU(1,JPH) + B1MFS * SECANT
      B = BFUNC (BUIF,B1)
      FACT = 1.
      IF (K.EQ.1.OR. K.EQ.NZ) GOTO 50
      FLIPK =6.-FLIPK
      FACT = FLIPK
   50 VAL = FACT * B * SSV2 * EXP(-B1) / RHOSQ
      IF (K.EQ.1) FRST=VAL
      IF (ABS(VAL/FRST).LT.1.E-4) GO TO 110
      SUMK = SUMK + VAL
  100 Z = Z + DZ
  110 FACT = 1.
      IF (J.EQ.1.OR.J.EQ.NPSI) GO TO 150
      FLIPJ = 6. - FLIPJ
      FACT = FLIPJ
  150 SUMJ = SUMJ + FACT * SUMK
  200 PSI = PSI + DELPSI
      FACT = 1.
      IF (I.EQ.1.OR.I.EQ.NTHETA) GO TO 250
      FLIPI = 6.-FLIPI
      FACT = FLIPI
  250 SUMI = SUMI + FACT * SUMJ
  300 THETA = THETA + DELTH
      SOURCE (3,JPH) = SUMI * DZ * DELTH * DELPSI / PI / 27.
      RETURN

      END
```

```
      SUBROUTINE SPHERE
C         CALCULATES GAMMA ATTENUATION OF A SPHERICAL SOURCE WITH EITHER
C         SPHERICAL OR SLAB SHIELDS - USES FUNCTION SIMPS TO  INTEGRATE
C         FUNCTION SPHSRC
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,     SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON        CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR,VOLUME
      REAL MU,MUE
      EXTERNAL SPHSRC
      CALL ADJUST (X)
      THETA2 = ATAN2(T,SQRT(ABS(X**2 - T**2)))
      VOLUME = 4.189*T**3
      IF (IGEOM-4) 10,8,8
C         SLAB SHIELDS
    8 TTMFS = 0.
      B1MFS = 0.
      IF(NSHLDA.LT.3)GO TO 10
      DO 9 K=3,NSHLDA
      TTMFS = TTMFS + T(K)
    9 B1MFS = B1MFS + T(K)*MU(K,JPH)
C         CONSTANT SOURCE STRENGTH ONLY FOR SPHERICAL SOURCE
   10 SSV2 =  SOURCE(2,JPH) * SOURCE(1,JPH) / VOLUME
      SOURCE (3,JPH) = .5 * SIMPS(0,THETA2,.001,SPHSRC) * SSV2
      CALL SLITET (1,LT1)
      GO TO ( 110, 120),LT1
  110 WRITE (3,115)  JPH,(SOURCE (J,JPH),J=1,3)
  115 FORMAT  (25H0 INTEGRATION FAILED FOR , I2,14H ENERGY LEVEL ,
     11PE11.4, 11H PHOTONS AT ,E12.4,15HMEV.   RESULT =,E12.4)

  120 RETURN
      END
```

```
      FUNCTION SPHSRC (ARG)
C          THIS FUNCTION IS INTEGRATED BY FUNCTION SIMPS TO CALCULATE
C          ATTENUATION OF A SPHERICAL SOURCE
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR
      REAL MU,MUE
      DIMENSION VAL(2)
      XCOS = X * COS(ARG)
      REAL L1, L2
      DIMENSION TM(6)
      SINA = SIN(ARG)
      XSINS = (X*SINA)**2
      XX = SQRT (ABS( T(1) **2 - XSINS))
      L1 =  XCOS - XX
      L2 =  XCOS + XX
      IF (IGEOM-3) 5,9,5
C          SLAB SHIELDS
    5 TT = TTMFS * X/XCOS
      B1    = L1*MU(1,JPH) - (L1-TT)*MU(2,JPH) - B1MFS*X/XCOS
      GO TO 21
C          SPHERICAL SHIELDS
    9 XX = T(1)
      DO 10   I=2,NSHLDA
      XX =XX + T(I)
   10 TM(I) = XCOS - SQRT (ABS( XX**2 - XSINS)   )
      B1    =  L1  * MU(1,JPH)
      TM(1) = L1
      DO 20  I=2,NSHLDA                     ... TM(I)) * MU(I,JPH)
```

```
      DO  20  I=2,NSHLDA
   20 B1    = B1    - (TM(I-1)-TM(I)) * MU(I,JPH)
   21 SPHSRC = 0.
      DO  30  K=1,2
      VAL(K) =0.
      DO 30   I=1,2
      A = 1. + BUF(I+2,K)
   30 VAL(K) = VAL(K) - BUF(I,K)/A/ MU(1,JPH)  * (EXP(A*(B1    -L2*
     1  MU(1,JPH))) - EXP(A*(B1    - L1*MU(1,JPH))))
      SPHSRC =(VAL(1) + BUIF*(VAL(2) - VAL(1)))* SINA
      RETURN
      END
```

```
      SUBROUTINE TCONE
C         CALCULATES ATTENUATION FOR TRUNCATED CONE SOURCE
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,      SLTH,TOTAL(4),T(6),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR,VOLUME
      REAL MU,MUE
      DIMENSION VAL(2)
      SECANT =  1. / COS(ANG1)
      CALL ADJUST (X)
      B1MFS = 0.
      DO 15 J=2,NSHLDA
   15 B1MFS = B1MFS + MU(J,JPH)* T(J)
      B1 = B1MFS + MU(1,JPH) * T(1)
      TANS = (SIN(ANG1)/COS(ANG1))** 2
      VOLUME = 1.047*TANS*(X**3-(X-T)**3)
      IF (SSV1) 38,16,38
C         CONSTANT SOURCE STRENGTH DISTRIBUTION
   16 IF (ANG1 - PI/2. +0.1) 18,20,20
   18 SSV2 = SOURCE(1,JPH) * SOURCE(2,JPH) / VOLUME
      GO TO 25
C         INFINITE SLAB SOURCE
   20 SSV2 = SOURCE(1,JPH) * SOURCE(2,JPH)
      VOLUME=9.999E30
      IF (T(1).GT. 0.) GO TO 25
C         INFINITE PLANE SOURCE
      DO  23  K=1,2
      VAL(K) = 0.
      DO 23 J=1,2
      A = 1.0 + BUF(J+2,K)
      VAL(K) = VAL(K) + BUF(J,K) * E1(A*B1)
   23 SOURCE(3,JPH) = .5 * SSV2 * (VAL(1) + BUIF*(VAL(2)-VAL(1)))
```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23 VAL(K) = VAL(K) + BUF(J,K) * E1(A*B1)
   SOURCE(3,JPH) = .5 * SSV2 * (VAL(1) + BUIF*(VAL(2)-VAL(1)))
   RETURN
25 DO 35 K=1,2
   VAL(K) = 0.
   DO 35 J = 1,2
   A=1.0 + BUF(J+2,K)
    IF (ANG1 .LT. PI/2. - 0.1) GO TO 30
   VAL(K) = VAL(K) + BUF(J,K)/A *(E2(A*B1MFS) - E2(A*B1) )
   GO TO 35
30 VAL(K) = VAL(K) + BUF(J,K)/A * (E2(A*B1MFS)-E2(A*B1) - E2(A*B1MFS*
  1    SECANT)/ SECANT + E2(A*B1*SECANT)/SECANT)
35 CONTINUE
   GO TO 100
C        EXPONENTIAL SOURCE STRENGTH DISTRIBUTION
38 IF (ANG1 .LT. PI/2. - 0.1) GO TO 40
   VOLUME=9.999E30
   SSV2 = SOURCE(1,JPH) * SOURCE(2,JPH)
   GO TO 42
40 SSV2 = SOURCE(1,JPH)* SOURCE(2,JPH) * SSV1/( EXP(SSV1*T) *(X*X
  1 - (SSV1* T - 1.) *(-2./SSV1*( X + 1./SSV1)) + T*T) - X*X - 2./SSV
  2 1* (X + 1./ SSV1))
42 DO 60 K=1,2
   VAL(K) = 0.
   DO 60 J=1,2
   A =1.0 + BUF(J+2,K)
   IF (PI/2.-0.1 .LT. ANG1)  GO TO 55
45 VAL(K) = VAL(K) + BUF(J,K)/A * (F1(A*B1,BUF(J+2,K)) -
  1  F1(A*B1MFS,BUF(J+2,K)) - F1(A*B1*SECANT,BUF(J+2,K))/SECANT
  2  + F1(A*B1MFS*SECANT,BUF(J+2,K)))
   GO TO 60
55 VAL(K) = VAL(K) + BUF(J,K)/A * (F1(A*B1,BUF(J+2,K))  -
  1     F1(A*B1MFS,BUF(J+2,K)))
60 CONTINUE
100 SOURCE (3,JPH) = .5 * SSV2 * EXP(SSV1/MU(1,JPH)*B1)/MU(1,JPH) *
  1  (VAL(1) +BUIF*(VAL(2)-VAL(1)))

   RETURN
   END
```

```
      FUNCTION SIMPS(A,B,DELTA,F00000)
C     A AND B ARE MIN AND MAX OF THE DEFINITE INTEGRAL
C     DELTA IS THE PERMISSIBLE DIFFERENCE BETWEEN  TWO SUCCESSIVE SUMS.
      N=1
      H=(B-A)/2.
      FJAY=H*(F00000(A)+F00000(B))
C     A MAXIMUM OF 2049 POINTS WILL BE USED WHEN L=11
      DO 35 L=1,11
   10 S=0.0
      DO 20 K=1,N
   20 S=S+F00000(A+(2.0*FLOAT (K)-1.0)*H)
      FI=FJAY+4.0*H*S
      IF(L-3)26,26,23
   23 CONTINUE
      IF(DELTA-ABS ((FI-BAR)/FI))30,40,40
   26 CONTINUE
   30 BAR=FI
      FJAY=(FI+FJAY)/4.0
      N=2*N
      H=H/2.0
   35 CONTINUE
      CALL SLITE (1)
   40 SIMPS =FI/3.0
      RETURN
      END
```

```
      FUNCTION TERP   (X,Y,A)
      COMMON ML(500), LA(500), REC(500), NCD, ENERGY(16),  RANGE(17),
     1  SOURCE(3,16), MU(6,16),MUE(6,16), NDT,DATA2(5,450)
      COMMON SSV1,SSV2,       SLTH,TOTAL(4),T(C),NSHLD,X,Y,ANG1,ANG2,ANG3,
     1  JBUF,IGEOM, JPH,BUF(4,2),BLIB(16,3,8 ), PI, NSHLDA, TTMFS,B1MFS,
     2  SECANT, BUIF,B1
      COMMON       CASER(6),FMWD,TET,TLN(5),TLH(5)
      COMMON NTHETA, NPSI, DELR, VOLUME
      DIMENSION X(16), Y(16)
C         PERFORMS LINEAR INTERPOLATION
      IF(A-AP) 5,30,5
    5 DO  10  I=1,16
   10 IF  (X(I) .GT.A ) GO TO 20
      J = 10
      K = 10
      GO TO 30
   20 K = MAX0 (I,2)
      J = MAX0(I-1,1)
   30 TERP = Y(J) + (A-X(J)) / (X(K)-X(K-1)) * (Y(K)-Y(K-1))
      AP=A
      RETURN
      END
```

APPENDIX D

ISOSHLD LIBRARIES

APPENDIX D

ISOSHLD LIBRARIES

RIBD ISOTOPE LIBRARY

This library is used by RIBD to calculate fission product inventory. The first card contains the number of isotopes in the library (Columns 1-3). There is one card for each isotope in the library and they are in an ascending atomic number order within an ascending atomic mass sequence. The current RIBD library (as listed) contains 450 fission products and daughters. The data format is:

Column	Format	Variable
1-3	I3	Atomic Mass Number
4-5	I2	Atomic Number
6-14	E9.3	Half life, days
15-23	E9.3	Fission yield from U^{235}, %
24-32	E9.3	Fission yield from U^{239}, %
33-41	E9.3	Absorption cross section, barns
42-46	F5.3	Fraction of (n,γ) captures that go to isometric state
47-51	F5.3	If in isomeric state, fraction of decays by beta emission; if in ground state, fraction that decays to an isomer
52-56	F5.3	Average beta energy release per disintegration, MeV
69-71	A3	Isotope name
72	I1	Isotope Type: 1 - Isomer 2 - Common

The fission product library listed in this appendix has been scanned and updated five times during the past two years, the latest revisions having been made in May 1965 by R. O. Gumprect.[4] The fission yield data were obtained from the work of Yu. A. Zysin, A. A. Lbov, and L. I. Sel'chenkof.[14] These data were compiled from over two hundred literature sources and appear to favor data presented by Catcoff.[15] Beta and gamma energies released during isotope or isomeric decay along with their branching ratios were developed from the decay schemes presented by Landolt-Bornstein.[9] Neutron capture cross sections and their branching ratios were taken from Goldman.[16] Half lives were obtained by cross checking all of the above sources.

PHOTON PROBABILITY LIBRARY

These data are used to calculate the number of photons of various energies produced by an array of radioactive isotopes. The first card contains the number of photon probability cards in this library (Column 1-3). Following this there is one card for each isotope of the RIBD library in the same order as in the RIBD library. Other isotopes may be added in any order following the RIBD isotopes. The listed library contains 48 activation products following the 450 RIBD fission products. The photon library format is:

Column	Format	Variable
1-3	I3	Atomic Mass number
4-5	I2	Atomic number
6-9	A4	Isotope name
10	I1	Number of decay energies on card
11-15	F5.0	Probability
16-20	F5.0	Photon decay energy, MeV
61-65	F5.0	Probability
66-70	F5.0	Photon decay energy, MeV
71-75	F5.0	Beta decay energy (average total), MeV

The data in the photon libraries were compiled from References 9 through 12.

MASS ATTENUATION COEFFICIENT LIBRARY

Two cards contain mass attenuation coefficients (in 16 group energy levels) for each shielding material in the library. The current materials and their material numbers are:

1. Water
2. Tissue
3. Air
4. Hydrogen
5. Lithium
6. Carbon
7. Aluminum
8. Titanium
9. Iron
10. Nickel
11. Zirconium
12. Tin
13. Tungsten
14. Lead
15. Uranium
16. Ordinary concrete
17. Magnetite concrete
18. Ferrophosphorus concrete

A total of 20 materials may be contained in this library. The card formats are:

Column	Format	Variable
1-7	A7	Material name (card one only)
8-9	I2	Material number (card one only)
10	I1	Card number - 1 or 2
11-66	8F7.0	Mass attenuation coefficient for 8 energy levels
67-69	F3.0	Atomic number (card one only)
70-72	F3.0	Atomic weight (card one only)
73	I1	1 for last card in library - all others 0 or blank

The data in this library were taken from Rockwell. Equation 4 was used to calculate unit density mixed mass attenuation coefficients for the mixtures. Concretes are the standard Hanford mixes referenced by Walker and Grotenhuis.[13]

BUILDUP FACTOR LIBRARY

This set of data contains buildup factor coefficients (A_1, α_1 and α_2) for a maximum of eight materials. The buildup factor is equal to $A_1 e^{-\alpha_1 b_1} + A_2 e^{-\alpha_2 b_1}$ where $A_2 = (1-A_1)$.

There are 6 materials currently in this library:

1. water
2. aluminum
3. iron
4. tin
5. tungsten
6. lead

There are 6 cards for each material. Cards 1 and 2 contain A_1 in six energy groups; cards 3 and 4 contain α_1, and cards 5 and 6 contain α_2. The card format is:

Column	Format	Variable
9	I1	Material number
10	I1	Card number
11-66	8F7.0	Coefficients
67-69	F3.0	Atomic number
72	I1	1 for last card, all other 0 or blank

These data were obtained from Goldstein.[5] This data was extrapolated from 0.5 down to 0.15 MeV to obtain buildup data for groups 1 to 4.

RIBD FISSON PRODUCT LIBRARY

```
450
 72301.938E 001.600E-051.200E-040.         0.    0.    .12  1.235        ZN 2   001
 72315.875E-010.      0.        0.                     .43  2.869        GA 2   002
 7232        0.       0.        1.                                       GE 2   003
 73301.390E-039.800E-050.                             2.25               ZN 2   004
 73312.000E-012.000E-06                                .42  .409         GA 2   005
 73320.      0.       0.        14.                                      GE 2   006
 74315.555E-033.500E-040.                             1.01  3.149        GA 2   007
 7432        0.       0.        .5         .4                            GE 2   008
 75311.389E-034.000E-04                               1.43  .58          GA 2   009
 75325.671E-044.000E-04                                     .139         GE*1   010
 75325.694E-02                                         .42  .038         GE 2   011
 7533        0.       0.        4.5                                      AS 2   012
 76313.704E-04 .001                                   2.74  1.           GA 2   013
 7632        .001               .2         .5                            GE 2   014
 76331.104E 000.      0.                              1.09  0.404        AS 2   015
 7634        0.       0.        85.        .259                          SE 2   016
 77326.250E-045.400E-030.                    0.640.77       0.096        GE*1   017
 77324.583E-013.700E-030.                              .64  1.134        GE 2   018
 77331.625E 000.      0.                               .22  0.022        AS 2   019
 77342.083E-04                                              .16          SE*1   020
 7734        0.       0.        42.                                      SE 2   021
 78328.750E-021.800E-020.                              .32  0.300        GE 2   022
 78336.319E-032.000E-030.                             1.47  0.888        AS 2   023
 7834        0.       0.        .41        .875                          SE 2   024
 79336.250E-034.000E-020.                    1.        .90               AS 2   025
 79342.708E-030.      0.                                    0.096        SE*1   026
 79342.555E 070.      0.                               .04               SE 2   027
 79350.      0.       0.        1.140E 010.2540.                         BR 2   028
 80331.736E-04 .08                                    2.73  .5           AS 2   029
```

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8034                         .6      .2                       SE 2   030
80351.875E-010.     0.                                 0.085  BR*1   031
80351.250E-020.     0.                        .72  .116       BR 2   032
8036        0.      0.       15.                              KR 2   033
81333.819E-041.250E-010.                      1.66            AS 2   034
81343.958E-028.400E-030.                           0.103      SE*1   035
81341.250E-020.     0.                        .53             SE 2   036
8135        0.      0.        3.                              BR 2   037
8136        0.      0.                                        KR 2   038
8234        3.800E-050.      5.400E-020.9200.                 SE 2   039
82351.471E 00                                 .14  2.648      BR 2   040
8236        0.      0.       45.     1.                       KR 2   041
83347.986E-043.000E-011.200E-01          1.0001.55 0.200      SE*1   042
83341.736E-021.800E-018.600E-02               .69  1.000      SE 2   043
83351.000E-010.     8.400E-020.      0.  1.000.34  0.010      BR 2   044
83367.750E-020.     0.       0.      0.  0.        0.041      KR*1   045
8336        0.      0.       180.                             KR 2   046
84342.083E-036.100E-023.000E-02               .49             SE 2   047
84354.167E-031.900E-021.000E-02          1.   .71  3.396      BR*1   048
84352.222E-029.200E-014.300E-01               1.23 1.863      BR 2   049
8436        0.      0.       .14     .714                     KR 2   050
85334.977E-065.500E-011.260E-01               1.28 5.0        AS 2   051
85344.514E-045.500E-011.260E-01               2.24            SE 2   052
85352.083E-034.000E-011.600E-01          1.   1.04            BR 2   053
85361.833E-010.     0.                   0.810.29  .179       KR*1   054
85363.927E 030.     1.270E-0115.              .25  0.004      KR 2   055
8537        0.      0.       1.000E 000.1                     RB 2   056
86341.852E-041.010E 003.800E-01               1.76            SE 2   057
86356.250E-041.010E 003.800E-01               3.23 .9         BR 2   058
8636                         .06                              KR 2   059
86377.222E-040.     0.                             0.56       RB*1   060
86371.870E 012.800E-052.300E-05               .66  0.097      RB 2   061
8638        0.      0.       .006    1.                       SR 2   062
87341.852E-042.700E 009.200E-01               3.73            SE 2   063
87356.366E-040.     0.                        1.87 3.780      BR 2   064
87365.278E-020.     0.       600.             1.34 1.089      KR 2   065
8737        0.      0.       .12                              RB 2   066
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87381.167E-010.      0.                                           0.388   SR*1  067
8738      0.         0.                                                   SR 2  068
88351.852E-042.900E 001.100E 00                              3.22 .035    BR 2  069
88361.167E-018.000E-013.200E-01                              .38  1.922   KR 2  070
88371.250E-020.      0.       1.                             1.99 .748    RB 2  071
8838      0.         0.       .005                                        SR 2  072
89355.208E-052.000E-017.000E-02                              3.   .075    BR 2  073
89362.222E-034.400E 001.640E 00                              1.39 2.265   KR 2  074
89371.042E-022.000E-010.      .55                            .60  2.455   RB 2  075
89385.04 E 010.      0.       .4                     .0002.58     .0002   SR 2  076
89391.852E-04                                                     .915     Y*1  077
8939      0.         0.       1.301        .00080.                        Y  2  078
90351.852E-052.600E 009.800E-01                              3.   .075    BR 2  079
90363.819E-042.600E 009.800E-01                              1.37 2.23    KR 2  080
90372.014E-037.000E-012.900E-01                              2.05 4.15    RB 2  081
90381.022E 040.      0.       1.                             .20          SR 2  082
90391.333E-01                                                     .68     Y* 1  083
90392.675E 000.      0.                                      .94  .0003   Y  2  084
9040      0.         0.       .1                                          ZR 2  085
91361.157E-043.700E 001.260E 00                      .5      1.56 2.      KR 2  086
91379.722E-032.000E-017.000E-02                      1.      1.27 2.8     RB*1  087
91378.338E-042.000E 001.100E 00                              2.04 0.4     RB 2  088
91384.042E-010.      0.                              .590    .63  0.742   SR 2  089
91393.472E-020.      0.                                           0.551   Y* 1  090
91395.900E 010.      0.       1.4                            .61  0.004   Y  2  091
9140      0.         0.       1.                                          ZR 2  092
92363.471E-052.700E 001.530E 00                              2.73         KR 2  093
92375.787E-052.800E 001.540E 00                              2.97         RB 2  094
92381.125E-016.000E-017.000E-02                              2.26 1.274   SR 2  095
92391.471E-010.      0.                                      1.44 0.266   Y  2  096
9240      0.         0.       .2                                          ZR 2  097
93362.315E-051.300E 007.700E-01                              3.82         KR 2  098
93376.944E-053.100E 001.820E 00                              2.83         RB 2  099
93385.764E-032.000E 001.320E 00                              1.40 1.0     SR 2  100
93394.208E-011.000E-016.000E-02                              1.18 0.102   Y  2  101
93403.468E 080.      0.       4.                     .25     .015         ZR 2  102
93411.351E 030.      0.                                           0.029   NB*1  103
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9341          0.        0.         1.1       .909                                  NB 2    104
94361.620E-056.000E-016.000E-01                           2.70                   KR 2    105
94373.472E-052.300E 001.500E 00                           4.57                   RB 2    106
94388.333E-042.900E 001.640E 00                           1.46                   SR 2    107
94391.389E-027.000E-017.400E-01                           2.23 1.                Y  2    108
9440          0.        0.         .08                                           ZR 2    109
94414.583E-030.         0.                          .001  .00050.042             NB*1    110
94417.300E 060.         0.         15.                    .16  1.570             NB 2    111
9442          0.        0.                                                       MO 2    112
95361.157E-053.200E 002.900E 00                           4.57                   KR 2    113
95372.314E-053.200E 002.900E 00                           3.58                   RB 2    114
95385.556E-04                                             2.72                   SR 2    115
95397.292E-03                                             2.09                   Y  2    116
95406.500E 010.         0.                          .02   .12  0.728             ZR 2    117
95413.750E 000.         0.                                     0.235             NB*1    118
95413.500E 010.         0.         7.                     .043 0.760             NB 2    119
9542          0.        0.         14.                                           MO 2    120
96391.597E-033.200E 002.585E 00                           1.55 1.7               Y  2    121
9640          3.200E 002.585E 00.05                                              ZR 2    122
96419.583E-015.700E-043.600E-03                           .22  2.456             NB 2    123
9642          0.        0.         1.                                            MO 2    124
97361.157E-052.400E 002.210E 00                           4.20                   KR 2    125
97372.315E-052.400E 002.210E 00                           4.39                   RB 2    126
97383.472E-05                                             3.57                   SR 2    127
97394.630E-05                                             2.31                   Y  2    128
97407.083E-011.400E 001.230E 00                     .9    .70  0.221             ZR 2    129
97416.944E-040.         0.                                     0.75              NB*1    130
97415.000E-020.         0.                                .47  .673              NB 2    131
9742          0.        0.         2.                                            MO 2    132
98406.944E-04 .2        1.000E-01                         1.99                   ZR 2    133
98413.576E-02 .064      1.000E-01                   1.    1.31 2.                NB*1    134
98411.806E-02 3.        2.845E 00                         1.26 1.2               NB 2    135
9842          2.516     2.845E 00.15                                             MO 2    136
99401.852E-053.050E 003.050E 00                           1.55                   ZR 2    137
99411.736E-033.050E 003.050E 00                           1.36 .26               NB 2    138
99422.750E 00                                       .92   .41  0.124             MO 2    139
99432.500E-010.         0.                                     .1423             TC*1    140
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99437.665E 070. 0.	22.			.084		TC 2	141
9944 0. 0.						RU 2	142
100412.083E-036.300E 007.100E 00				3.39	1.05	NB 2	143
10042 0. 0.	.2					MO 2	144
100431.968E-040. 0.				1.44	.114	TC 2	145
10044 0. 0.						RU 2	146
101416.944E-042.500E 002.950E 00				1.03		NB 2	147
101421.014E-022.500E 002.950E 00				.42	1.649	MO 2	148
101439.722E-030. 0.				.47	0.362	TC 2	149
10144 0. 0.						RU 2	150
102427.981E-034.200E 005.990E 00				.44	1.3	MO 2	151
102435.787E-050. 0.				1.79		TC 2	152
10244 0. 0.	1.4					RU 2	153
103435.787E-041.550E 002.835E 00				1.03		TC 2	154
103444.000E+011.450E 002.835E 00			.995	.063	0.488	RU 2	155
103453.958E-020. 0.					0.040	RH*1	156
10345 0. 0.	155.	.071				RH 2	157
104421.111E-031.800E 005.930E 00				1.08	1.	MO 2	158
104431.250E-020. 0.				.98	3.1	TC 2	159
10444 0. 0.	.7					RU 2	160
104453.056E-030. 0.	800.		.0013	.0002	.131	RH*1	161
104454.861E-040. 0.	40.			.98	0.013	RH 2	162
10446 0. 0.						PD 2	163
105424.630E-046.000E-012.600E 00				2.54		MO 2	164
105435.556E-033.000E-011.300E 00				2.09		TC 2	165
105441.846E-010. 0.	.2		.2690	.42	.7680	RU 2	166
105453.472E-040. 0.					0.129	RH*1	167
105451.500E 000. 0.	2.100E+04	.715	0.	.17	0.032	RH 2	168
10546 0. 0.						PD 2	169
106443.650E 023.800E-014.570E 00	.1			.01		RU 2	170
106459.167E-02			1.	.35	2.627	RH*1	171
106453.472E-040. 0.				1.40	.222	RH 2	172
10646 0. 0.						PD 2	173
107431.042E-031.600E-013.600E 00				2.71		TC 2	174
107442.917E-034.000E-020.				1.67	.144	RU 2	175
107451.507E-020. 0.				.42	0.328	RH 2	176
107462.555E 090. 0.				.014		PD 2	177

10747 0. 0.	35.	0.0100.				AG 2	178
108443.125E-038.000E-022.100E 00				.54	0.059	RU 2	179
108451.968E-040. 0.				1.74	0.553	RH 2	180
10846 0. 0.	12.2	.016				PD 2	181
108471.825E 030. 0.			.9		1.605	AG*1	182
108471.667E-030. 0.				.62	.017	AG 2	183
10848 0. 0.	10.					CD 2	184
109453.472E-042.800E-021.400E 00			1.	1.16	.31	RH 2	185
109463.333E-030. 0.					0.18	PD*1	186
109465.625E-010. 0.			1.	.36	.0002	PD 2	187
109474.630E-040. 0.					0.088	AG*1	188
10947 0. 0.	92.	.0326				AG 2	189
11046 2.000E-020.	.24	.167				PD 2	190
110472.600E 020. 0.	80.		0.98	.069	2.722	AG*1	191
110472.778E-040. 0.				1.17	0.033	AG 2	192
11048 2.000E-070.	3.1	.0322				CD 2	193
111462.292E-011.000E-031.000E-02			0.32	.048	.676	PD*1	194
111461.528E-021.800E-022.200E-01			1.	.85	.3	PD 2	195
111478.565E-04					.065	AG*1	196
111477.500E 00				.36	0.025	AG 2	197
111483.403E-020. 0.					0.397	CD*1	198
11148 0. 0.						CD 2	199
112468.750E-011.100E-021.200E-01				.08	0.018	PD 2	200
112471.333E-010. 0.				1.44	0.695	AG 2	201
11248 0. 0.	.03	1.				CD 2	202
113461.042E-031.100E-021.000E-02			1.	1.40		PD 2	203
113478.333E-040. 0.			.1	.08	0.200	AG*1	204
113472.208E-010. 0.				.79	0.030	AG 2	205
113485.110E 030. 0.			0.999	.18	.0003	CD*1	206
11348 0. 0.	2.000E 04					CD 2	207
11349	12.	.67				IN 2	208
114461.667E-031.000E-021.000E-02				.52		PD 2	209
114475.787E-050. 0.				2.02	0.5	AG 2	210
11448 0. 0.	1.24	0.1130.				CD 2	211
114495.000E 01					.192	IN*1	212
114498.333E-04				.779	.002	IN 2	213
115465.208E-04 .01 .0038			.28	1.91		PD 2	214

115472.315E-04					1.	1.49		AG*1	215
115471.458E-02	.0005	3.000E-04			.09	1.21	.2	AG 2	216
115484.300E 010.		0.			1.	.61	0.036	CD*1	217
115482.300E 000.		0.			1.	.32	0.192	CD 2	218
115491.833E-010.		0.			.055	.015	0.317	IN*1	219
11549	0.	0.	203.	.78		.15		IN 2	220
11550	0.	0.						SN 2	221
116463.472E-041.000E-020.						.93		PD 2	222
116471.736E-030.		0.				2.21	1.217	AG 2	223
11648	0.	0.	1.4					CD 2	224
116493.750E-020.		0.			1.	.29	2.495	IN*1	225
116491.620E-040.		0.				1.39		IN 2	226
11650	3.000E-030.		.006	1.				SN 2	227
117477.639E-041.100E-021.100E-02					.5	1.63		AG 2	228
117481.208E-010.		0.			1.	.35	1.6	CD*1	229
117483.472E-020.		0.			1.	.70	0.49	CD 2	230
117497.917E-020.		0.			0.8	.52	.132	IN*1	231
117493.125E-020.		0.				.24	.73	IN 2	232
117501.400E 010.		0.					0.32	SN*1	233
11750	0.	0.						SN 2	234
118483.472E-021.000E-021.000E-03						.27	.2	CD 2	235
118495.903E-050.		0.				1.85	0.244	IN 2	236
11850	0.	0.	.01	1.				SN 2	237
119481.875E-03	.01	4.000E-03			.99	1.56		CD*1	238
119486.597E-03					1.	1.44	.1	CD 2	239
119491.250E-02					.96	1.04	0.066	IN*1	240
119491.389E-03					.1	.61	.84	IN 2	241
119502.500E+02							.089	SN*1	242
11950	0.	0.						SN 2	243
120495.787E-040.500E-020.500E-03						.88	3.2	IN 2	244
12050	0.500E-020.500E-03.141			.007				SN 2	245
121482.431E-032.500E-042.500E-03						1.73	0.85	CD 2	246
121492.153E-032.500E-042.500E-03					1.	1.58		IN*1	247
121493.472E-04	.0005	.0053				1.20	.94	IN 2	248
121509.125E+030.500E-030.500E-02					1.	.15	.01	SN*1	249
121501.125E 001.400E-023.000E-02						.11		SN 2	250
12151	0.	0.	6.06	.01				SB 2	251

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122498.681E-050.650E-020.500E-03                        2.68 2.14          IN 2    252
12250          0.650E-020.500E-03.201        .005                          SN 2    253
122512.847E-030.          0.                                   0.136       SB*1    254
122512.750E 000.          0.                            .58    .405        SB 2    255
12252          0.         0.        3.       .333                          TE 2    256
123491.157E-040.600E-030.500E-03                        1.39 1.1           IN 2    257
123501.250E+020.600E-030.500E-03                 1.     .52    0.022       SN*1    258
123502.778E-021.400E-020.                               .46    0.160       SN 2    259
12351          0.         0.        3.345    .0135                         SB 2    260
123521.040E+02                                                 .248        TE*1    261
12352          0.         0.        400.                                   TE 2    262
12450          2.000E-020.          .104     .962                          SN 2    263
124511.458E-020.          0.                     .982   .97    0.427       SB*1    264
124516.020E+010.          0.        2000.               .38    1.899       SB 2    265
12452          0.         0.        7.       .714                          TE 2    266
125506.736E-031.100E-021.000E-03                 1.     .79    0.361       SN*1    267
125509.400E 001.200E-027.100E-02                        .92    0.094       SN 2    268
125519.855E 020.          0.        20.          .26    .096   .415        SB 2    269
 25525.800E 010.          0.                                   0.145       TE*1    270
12552          0.         0.        1.5                                    TE 2    271
126503.650E+071.000E-012.000E-01                 1.     .12    .09         SN 2    272
126511.319E-020.          0.                     .01    .00780.117         SB*1    273
126511.250E 010.          0.                            .74    1.780       SB 2    274
12652          0.         0.        1.       .1                            TE 2    275
127508.750E-022.400E-013.900E-01                        1.34 1.            SN 2    276
127513.900E 001.000E-021.000E-02                 .2     .38    0.505       SB 2    277
127521.050E 020.          0.                     .015   .00410.088         TE*1    278
127523.875E-010.          0.                            .23    0.004       TE 2    279
12753          0.         0.        6.4                                    I  2    280
128504.306E-023.700E-014.000E-01                 .03    3.85   3.27        SN 2    281
128514.000E-015.000E-020.                        1.     .35    3.6         SB*1    282
128516.944E-038.000E-021.000E-01                        1.20   1.7         SB 2    283
12852          0.         0.        .157     .108                          TE 2    284
128531.736E-023.000E-052.000E-04                        .77    0.093       I  2    285
12854          0.         0.        5.                                     XE 2    286
129511.792E-011.000E 001.000E 00                 .36    .542   .916        SB 2    287
129523.300E 010.          0.                                   0.106       TE*1    288
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129524,653E-020,          0.                                    .45  .238           TE 2    289
129535,840E 090,          0.        28.                         .050 .040           I  2    290
13954           0,        0.        25.                                             XE 2    291
130501,806E-032,000E 002,000E 00                                4,23                SN 2    292
130512,292E-020,          0.                                    1,72 1,0            SB 2    293
13052           0.        0.        ,23        ,13                                  TE 2    294
130535,208E-01 ,0005      ,0052     18.                         ,27  2,123          I  2    295
13054           0.        0.        5.                                              XE 2    296
131511,597E-022,700E 003,100E 00                          .15   1.33                SB 2    297
131521.200E 004,000E-021.300E-01                          ,783  .16  1,468          TE*1    298
131521.736E-021.600E-015,400E-01                                ,74  0.376          TE 2    299
131538,050E 00 ,2         0.        ,7                    ,007  ,18  0,399          I  2    300
131541,200E 010,          1.000E-02                                  0,164          XE*1    301
13154           0.        0.        85.                                             XE 2    302
132511,458E-033,400E 005,100E 00                                2.68                SB 2    303
132523,250E 001,000E 00 ,18                                     ,055 0.280          TE 2    304
132539,583E-020,          0,                                    ,49  2,249          I  2    305
13254                               5,2        ,962                                 XE 2    306
133512.847E-033,800E 003.000E 00                          ,72   1.72                SB 2    307
133523,472E-021,100E 001,000E 00                          ,87   ,49  1.613          TE*1    308
133521,38[illegible]-031,100E 001,000E 00                                ,97  0,6            TE 2    309
133538.750E-015,000E-012,000E-01                          ,02   .46  ,53            I  2    310
133542,300E 000,          0.                                         0,233          XE*1    311
133545,270E 000.          1,700E 00190,                         ,10  ,082           XE 2    312
13355           0,        0.        30,6       ,085                                 CS 2    313
134515,556E-043,000E 003,500E 00                                3.45 0.200          SB 2    314
134522,917E-023,700E 004,000E 00                                ,52  .1             TE 2    315
134533.681E-029,000E-010,                                       ,78  2.5            I  2    316
13454           0,        0.        5,2        ,962                                 XE 2    317
134551,208E-010,          0,                              ,01   ,00170.153          CS*1    318
134557,665E 020,          0.        136.                        ,16  1,588          [illegible]S 2    319
13456                               4,16       ,033                                 BA 2    320
135512,778E-04 4,3        1.1                                   3.16                SB 2    321
135526,944E-04                                                  2.68                TE 2    322
135532.792E-01 1.9        5,700E 00                       ,27   ,32  1.642          I  2    323
135541,111E-020,          0,                                         0.530          XE*1    324
135543.833E-013,000E-01 ,47         2.900E+06                   ,31  0,261          XE 2    325
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135557.300E+080.	8.7			.055		CS 2	326
135561.208E 000. 0.					0.268	BA*1	327
13556 0. 0.	5.					BA 2	328
136539.606E-043.100E 002.100E 00				1.68	3.237	I 2	329
13654 3.36 4.520E 00.15						XE 2	330
136551.300E 016.800E-031.100E-01				.11	2.466	CS 2	331
13656 0. 0.	1.01	.01				BA 2	332
137532.778E-044.900E 005.100E 00				2.19	.71	I 2	333
137542.708E-031.300E 001.530E 00				1.48	1.	XE 2	334
137551.095E+040. 0.	.11		.92	.20		CS 2	335
137561.806E-030. 0.					0.662	BA*1	336
13756 0. 0.	4.					BA 2	337
138537.292E-053.400E 003.700E 00				3.10	1.5	I 2	338
138549.722E-032.100E 002.210E 00				.96	0.420	XE 2	339
138552.236E-023.000E-014.000E-01				1.10	2.153	CS 2	340
13856 0. 0.	.4					BA 2	341
139532.314E-051.800E 001.700E 00				2.40		I 2	342
139544.745E-042.900E 002.800E 00				2.00	.4	XE 2	343
139556.597E-031.200E 001.230E 00				1.74	0.232	CS 2	344
139565.764E-021.000E-011.400E-014.				.91	.053	BA 2	345
13957 0. 0.	8.9					LA 2	346
140541.852E-043.700E 003.300E 00				1.09		XE 2	347
140557.639E-042.300E 002.100E 00				2.66	.59	CS 2	348
140561.280E 013.000E-010.	20.			.30	.222	BA 2	349
140571.675E 000. 2.000E-01				.48	2.468	LA 2	350
14058 0. 0.	.6					CE 2	351
141541.968E-051.800E 001.100E 00				2.36		XE 2	352
141552.778E-042.900E 003.700E 00				1.72		CS 2	353
141561.250E-021.200E 009.000E-01				1.14	.46	BA 2	354
141571.625E-011.000E-010.				.96	.0272	LA 2	355
141583.250E 010. 0.	30.			.15	0.101	CE 2	356
14159 0. 0.	12.					PR 2	357
142541.736E-053.500E-013.100E-01				1.70		XE 2	358
142552.662E-053.050E 002.870E 00				2.98		CS 2	359
142567.639E-032.200E 001.830E 00				.78	.112	BA 2	360
142575.833E-023.000E-010.				1.42	1.164	LA 2	361
14258 0. 0.	1.					CE 2	362

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142598.000E-010.        0.         20.                          .83  .063        PR 2    363
14260          0.       0.         17.                                           ND 2    364
143541.157E-053.100E 002.650E 00                                2.91             XE 2    365
143552.314E-053.100E 002.650E 00                                2.32             CS 2    366
143561.389E-04                                                  1.47             BA 2    367
143579.722E-03                                                  1.33 1.          LA 2    368
143581.375E 000.        0.         6.                           .37  .377        CE 2    369
143591.370E 010.        0.         89.                          .32              PR 2    370
14360          0.       0.         330.                                          ND 2    371
144541.157E-052.900E 001.600E 00                                2.19             XE 2    372
144552.315E-052.900E 001.600E 00                                3.50             CS 2    373
144563.472E-05                                                  1.00             BA 2    374
144574.630E-05                                                  2.23             LA 2    375
144582.850E 023.000E-015.900E-011.                              .080 0.030       CE 2    376
144591.201E-020.        1.400E-01                               1.22 .031        PR 2    377
                                                                                 ND 2    378
14460          0.       0.         5.                           .77              CE 2    379
145582.083E-034.200E 003.130E 00                                .68  .056        PR 2    380
145592.458E-010.        0.                                                       ND 2    381
14560          0.       0.         50.                          .22  0.320       CE 2    382
146589.722E-033.200E 002.600E 00                                1.27 1.107       PR 2    383
146591.667E-021.000E-010.                                                        ND 2    384
14660          0.       0.         2.                           1.55             CE 2    385
147588.333E-040.650E 000.550E 00                                1.12 1.          PR 2    386
147598.333E-030.650E 000.550E 00                                .23  0.196       ND 2    387
147601.110E+011.300E 001.100E 00                                .059             PM 2    388
147619.855E 020.        0.         230.       .522                               SM 2    389
14762          0.       0.         90.                          .95              CE 2    390
148584.861E-041.710E 001.730E 00                                2.17 0.300       PR 2    391
148591.354E-030.        0.                                                       ND 2    392
14860          0.       0.         4.                 1.        .39  1.343       PM*1    393
148615.400E 000.        0.         2000.                        .41  1.227       PM 2    394
148614.100E 010.        0.         3.000E+04                                     SM 2    395
14862          0.       0.                                      .55  .5          ND 2    396
149607.500E-021.300E 001.320E 00                                .36  .035        PM 2    397
149612.208E 000.        0.                                                       SM 2    398
14962          0.       0.         4.150E 04                                     ND 2    399
15060          7.400E-011.010E 001.5
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15062          0.        0.        100.                               SM 2    400
151608.333E-034.800E-018.000E-01                       .63  0.717     ND 2    401
151611.183E 002.000E-020.                              .38  .715      PM 2    402
151623.285E 040.         0.        1.500E 04           .019 .0004     SM 2    403
15163          0.        0.        8.700E 03.322                      EU 2    404
152614.167E-031.500E-013.100E-01                       .86  2.8       PM 2    405
15262          1.500E-013.100E-01210.                                 SM 2    406
152633.875E-010.         0.                      1.    .60  .238      EU*1    407
152634.745E 030.         0.        5000.               .19  1.209     EU 2    408
15264          0.        0.        180.                               GD 2    409
153613.819E-03 .075      .185                          .62  .3        PM 2    410
153621.958E 00 .075      .185                          .22  .108      SM 2    411
15363          0.        0.        320.                               EU 2    412
154611.736E-03 .045      .145                          1.             PM 2    413
15462          .045      .145      5.                                 SM 2    414
154635.840E 030.         0.        1400.               .20  1.351     EU 2    415
15464          0.        0.                                           GD 2    416
155621.528E-023.100E-022.300E-01                       .60  0.115     SM 2    417
155636.570E 020.         0.        1.300E 04           .046 0.072     EU 2    418
15564          0.        0.        5.800E 04                          GD 2    419
156623.917E-011.300E-021.100E-01                       .30            SM 2    420
156631.500E 010.         0.                            .70  1.2       EU 2    421
15664          0.        0.                                           GD 2    422
157636.417E-017.400E-037.400E-02                       .42  0.525     EU 2    423
15764          0.        0.        2.400E 05                          GD 2    424
158633.194E-022.000E-034.000E-02                       1.04 0.600     EU 2    425
15864          0.        0.        3.4                                GD 2    426
159631.319E-02.00055     .0105                         .86  .2        EU 2    427
159647.500E-01.00055     .0105                         .29  0.075     GD 2    428
15965          0.        0.        46.                                TB 2    429
160631.736E-02.00135     .00081                        1.5            EU 2    430
16064          .00135    .00081    .8                                 GD 2    431
160657.300E 010.         0.        525.                .20  1.193     TB 2    432
16066          0.        0.                                           DY 2    433
161642.569E-03 .008      3.900E-03                     .59  0.428     GD 2    434
161656.900E 000.         0.                            .15  0.037     TB 2    435
16166          0.        0.        580.                               DY 2    436
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162643.650E+02          1.800E-03                               .34   1.          GD 2    437
162658.333E-02                                                  1.68              TB 2    438
16266                                140.                                         DY 2    439
163652.917E-01          4.000E-04                               1.22 .2           TB 2    440
16366                   4.000E-04120.                                             DY 2    441
16466            0.     3.000E-042800.      .714                                  DY 2    442
165668.727E-040.        1.200E-04                    .03        .00840.120        DY*1    443
165669.583E-020.        0.           4700.                      .44   .0269       DY 2    444
16567            0.     0.           65.                                          HO 2    445
166663.333E 000.        6.800E-05                               .12  0.088        DY 2    446
166671.133E 000.        0.                                      .67   .0558       HO 2    447
16668            0.     0.           12.    .01                                   ER 2    448
167682.892E-050.        0.                                           0.208        ER*1    449
16768            0.     0.           700.                                         ER 2    450
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499
 7230ZN2 1 ,95 1.3                                                                     .12   001
 7231GA2 6 .41 3.343 .35 3.05  .07 2.515 .07 2.06  .05 1.465 .05  .835,.43   002
 7232GE2 0 .     .                                                                           003
 7330ZN2 0 .     .                                                                     2.25  004
 7331GA2 2 .07 1.04  .91  .295                                                          .42  005
 7332GE2 0 .     .                                                                           006
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 7531GA2 11.00  .5                                                                     1.43  009
 7532GE1 11.00  .139                                                                         010
 7532GE2 4 .41  .628 .29  .477 .114 .265 .014 .199                                     .42   011
 7533AS2 0                                                                                   012
 7631GA2 0                                                                             2.74  013
 7632GE2 0                                                                                   014
 7633AS2 5 .0192.670 .09 2.42  .0661.86  .0361.216 .306 .559                          1.09   015
 7634SE2 0                                                                                   016
 7732GE1 2 .08  .215  .14  .159                                                        .77   017
 7732GE2 6 .03 2.37  .15 1.99  .14 1.55  .24 1.19  .29  .632 .14  .475,.64   018
 7733AS2 2 .028 .52  .028 .246                                                         .22   019
 7734SE1 11.00  .161                                                                         020
 7734SE2 0                                                                                   021
 7832GE2 11.00  .3                                                                     .32   022
 7833AS2 6 .0222.85  .0212.78  .14 2.67  .0622.41  .0971.307 .19  .6151.47   023
 7834SE2 0                                                                                   024
 7933AS2 11.00  .096                                                                   .90   025
 7934SE1 11.00  .096                                                                         026
 7934SE2 0                                                                             .04   027
 7935BR2 0                                                                                   028
 8033AS2 11.00  .50                                                                    2.73  029
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8034SE2 0                                                                          030
8035BR1 21.00   .0491.00   .037                                                    031
8035BR2 2 .006 .665 .138 .62                                                .72    032
8036KR2 0                                                                          033
8133AS2 0                                                                   1.66   034
8134SE1 11.0    .103                                                               035
8134SE2 0                                                                   .53    036
8135BR2 11.0    .28                                                                037
8136KR2 0                                                                          038
8234SE2 0                                                                          039
8235BR2 11.0  2.648                                                         .14    040
8236KR2 0                                                                          041
8334SE1 1 .10 2.02                                                          1.55   042
8334SE2 21.00   .83 1.00   .17                                              .69    043
8335BR2 1 .2    .087                                                        .34    044
8336KR1 21.0    .0321.0    .009                                                    045
8336KR2 0                                                                          046
8434SE2 0                                                                   .49    047
8435BR1 4 .2  1.89  .6  1.46  .7   .88   .6   .44                           .71    048
8435BR2 6 .21 3.91  .02 3.70  .14 3.35  .0152.91  .15 1.90  .14  .85        1.23   049
8436KR2 0                                                                          050
8533AS2 12.0  2.5                                                           1.28   051
8534SE2 0                                                                   2.24   052
8535BR2 0                                                                   1.04   053
8536KR1 2 .22   .305 .78   .150                                             .29    054
8536KR2 1 .01   .514                                                        .25    055
8537RB2 0                                                                          056
8634SE2 0                                                                   1.76   057
8635BR2 0                                                                   3.23   058
8636KR2 0                                                                          059
8637RB1 11.0    .56                                                                060
8637RB2 1 .09 1.084                                                         .66    061
8638SR2 0                                                                          062
8734SE2 0                                                                   3.73   063
8735BR2 1 .7  5.4                                                           1.87   064
8736KR2 2 .25 2.97  .50   .847                                              1.34   065
8737RB2 0                                                                          066
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8738SR1 21.0    .51 1.0    .12                                                             067
8738SR2 0                                                                                  068
8835BR2 0                                                                           3.22   069
8836KR2 3 .70 2.40  .08 2.04  .22  .191                                             .38    070
8837RB2 3 .06 4.85  .14 2.74  .04 1.835                                             1.99   071
8838SR2 0                                                                                  072
8935BR2 12.0  2.5                                                                   1.76   073
8936KR2 12.0   .265                                                                 1.39   074
8937RB2 6 .02 3.52  .28 3.25  .03 2.75  .02 2.59  .53 2.31  .05 1.05                .60    075
8938SR2 0                                                                           .58    076
8939Y 1 11.0   .915                                                                        077
8939Y 2 0                                                                                  078
9035BR2 22.0  2.5  1.0  1.5                                                         1.76   079
9036KR2 11.0  1.0                                                                   1.37   080
9037RB2 11.0  1.976                                                                 2.05   081
9038SR2 0                                                                           .20    082
9039Y 1 11.0   .68                                                                         083
9039Y 2 1.00021.7                                                                   .94    084
9040ZR2 0                                                                                  085
9136KR2 11.0  2.0                                                                   1.56   086
9137RB1 11.0  2.8                                                                   1.27   087
9137RB2 11.0   .4                                                                   2.04   088
9138SR2 4 .07 2.06  .33 1.58  .29 1.3   .04  .065                                   .63    089
9139Y 1 11.0   .551                                                                        090
9139Y 2 1 .0031.208                                                                 .61    091
9140ZR2 0                                                                                  092
9236KR2 0                                                                           2.73   093
9237RB2 0                                                                           2.97   094
9238SR2 3 .90 1.37  .05  .44  .04  .23                                              2.26   095
9239Y 2 2 .09 2.35  .03  .48                                                        1.44   096
9240ZR2 0                                                                                  097
9336KR2 0                                                                           3.82   098
9337RB2 0                                                                           2.83   099
9338SR2 11.0  1.0                                                                   1.40   100
9339Y 2 5 .0022.44  .0182.18  .0091.42  .03  .935 .039 .267                         1.18   101
9340ZR2 0                                                                           .015   102
9341NB1 11.0   .029                                                                        103
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9341NB2 0                                                          104
9436KR2 0                                                   2.70   105
9437RB2 0                                                   4.57   106
9438SR2 0                                                   1.46   107
9439Y 2 3 .05 1.13  .43  .92  .06  .56                      2.23   108
9440ZR2 0                                                          109
9441NB1 2 .001 .87 1.0   .042                               .0005  110
9441NB2 3 .08 1.57  .92  .87  .92  .70                      .16    111
9442MO2 0                                                          112
9536KR2 0                                                   4.57   113
9537RB2 0                                                   3.58   114
9538SR2 0                                                   2.72   115
9539Y 2 0                                                   2.09   116
9540ZR2 2 .43  .76  .55  .73                                .12    117
9541NB1 11.0  .235                                                 118
9541NB2 1 .99  .768                                         .043   119
9542MO2 0                                                          120
9639Y 2 11.0  1.7                                           3.58   121
9640ZR2 0                                                          122
9641NB2 2 .8  2.79  .92 2.41                                .22    123
9642MO2 0                                                          124
9736KR2 0                                                   4.20   125
9737RB2 0                                                   4.39   126
9738SR2 0                                                   3.57   127
9739Y 2 0                                                   2.31   128
9740ZR2 1 .08 2.20                                          .70    129
9741NB1 11.0   .75                                                 130
9741NB2 2 .01 1.0   .99  .67                                .47    131
9742MO2 0                                                          132
9840ZR2 0                                                   1.99   133
9841NB1 11.0  1.5                                           1.31   134
9841NB2 11.0  1.2                                           1.26   135
9842MO2 0                                                          136
9940ZR2 0                                                   1.55   137
9941NB2 11.0   .260                                         1.36   138
9942MO2 2 .14  .92  .01  .514                               .41    139
9943TC1 2 .10  .142 .90  .140                                      140
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 9943TC2 0                                                                   .084  141
 9944RU2 0                                                                         142
10041NB2 11.0   .3                                                           3.39  143
10042MO2 0                                                                         144
10043TC2 0                                                                   1.44  145
10044RU2 0                                                                         1465
10141NB2 0                                                                   2.51  147
10142MO2 6 .03 2.16  .38 2.08  .13 1.98  .11 1.59  .25 1.21  .10  .59        .42   148
10143TC2 2 .05  .54  .91  .307                                               .47   149
10144RU2 0                                                                         150
10242MO2 11.0  1.3                                                           .44   151
10243TC2 0                                                                   1.79  152
10244RU2 0                                                                         153
10343TC2 0                                                                   1.03  154
10344RU2 4 .07  .65  .89  .538 .001 .362 .005 .297                           .063  155
10345RH1 11.0   .04                                                                156
10345RH2 0                                                                         157
10442MO2 0                                                                   1.08  158
10443TC2 11.0  3.1                                                           .98   159
10444RU2 0                                                                         160
10445RH1 3.00032.26  .0012.09 1.0   .077                                     .0002 161
10445RH2 2 .0011.81  .019 .556                                               .98   162
10446PD2 0                                                                         163
10542MO2 0                                                                   2.54  164
10543TC2 0                                                                   2.09  165
10544RU2 2 .35  .795 .50  .723                                               .42   166
10545RH1 11.0   .129                                                               167
10545RH2 1 .20  .319                                                         .17   168
10546PD2 0                                                                         169
10644RU2 0                                                                   .01   170
10645RH1 4 .40 2.78  .38 2.68  .11 2.46  .10 2.05                            .35   171
10645RH2 6 .0012.88  .0052.44  .0072.01  .02 1.56  .11 1.125 .08  .5131.40         172
10646PD2 0                                                                         173
10743TC2 0                                                                   2.71  174
10744RU2 1 .12 1.05                                                          1.67  175
10745RH2 3 .03  .69  .13  .390 .84  .305                                     .42   176
10746PD2 0                                                                   .014  177
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10747AG2 0                                                                        178
10844RU2 1 .36  .165                                                        .54   179
10845RH2 3 .28 1.049 .11  .942 .17  .434                                   1.74   180
10846PD2 0                                                                        181
10847AG1 4 .90  .72  .90  .62  .90  .43  .10  .081                                182
10847AG2 2 .01  .63  .002 .43                                               .62   183
10848CD2 0                                                                        184
10945RH2 0                                                                 1.16   185
10946PD1 11.0   .18                                                               186
10946PD2 0                                                                  .36   187
10947AG1 11.0   .088                                                              188
10947AG2 0                                                                        189
11046PD2 0                                                                        190
11047AG1 2 .65 2.925 .33 2.478                                              .069  191
11047AG2 1 .05  .656                                                       1.17   192
11048CD2 0                                                                        193
11146PD1 1 .04 1.75                                                         .048  194
11146PD2 0                                                                  .85   195
11147AG1 11.0   .065                                                              196
11147AG2 2 .062 .342 .011 .247                                              .36   197
11148CD1 21.0   .2471.0   .150                                                    198
11148CD2 0                                                                        199
11246PD2 11.0   .018                                                        .08   200
11247AG2 6 .10 2.82  .13 2.43  .51 2.03  .12  .41  .0281.31  .18  .6151.44        201
11248CD2 0                                                                        202
11346PD2 0                                                                 1.40   203
11347AG1 11.00  .20                                                         .08   204
11347AG2 1 .10  .31                                                         .79   205
11348CD1 1 .001 .27                                                         .18   206
11348CD2 0                                                                        207
11349IN2 0                                                                        208
11446PD2 0                                                                  .52   209
11447AG2 11.00  .50                                                        2.02   210
11448CD2 0                                                                        211
11449IN1 3 .035 .722 .035 .556 .965 .192                                    .006  212
11449IN2 1 .0021.30                                                         .74   213
11546PD2 0                                                                 1.97   214
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11547AG1 11.00  .60                                          1.21   216
11547AG2 0                                                    .61   217
11548CD1 3 .0031.42  .01 1.30  .02  .935                      .32   218
11548CD2 3 .244 .858 .126 .825 .01  .595                      .015  219
11549IN1 1 .945 .335                                          .15   220
11549IN2  0                                                         221
11550SN2 0                                                    .93   222
11646PD2 0                                                   2.21   223
11647AG2 11.0   .517                                                224
11648CD2 0                                                    .29   225
11649IN1 4 .02 3.04  .18 2.76  .38 2.49  .42 2.35            1.39   226
11649IN2 0                                                          227
11650SN2 0                                                   1.63   228
11747AG2 0                                                    .35   229
11748CD1 11.0  1.6                                            .70   230
11748CD2 11.0   .42                                           .52   231
11749IN1 2 .04  .82  .23  .16                                 .24   232
11749IN2 11.00  .73                                                 233
11750SN1 11.00  .32                                                 234
11750SN2 0                                                    .27   235
11848CD2 0                                                   1.85   236
11849IN2 1 .20 1.22                                                 237
11850SN2 0                                                   1.56   238
11948CD1 0                                                   1.44   239
11948CD2 11.0   .10                                          1.04   240
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11949IN2 11.0   .84                                                 242
11950SN1 11.00  .089                                                243
11950SN2 0                                                    .88   244
12049IN2 13.0  1.1                                                  245
12050SN2 0                                                   1.73   246
12148CD2 11.0   .85                                          1.58   247
12149IN1 0                                                   1.20   248
12149IN2 11.0   .94                                           .15   249
12150SN1 11.00  .070                                          .11   250
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12252TE2 0                                                                     256
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12350SN1 1 .02 1.08                                                     .52    258
12350SN2 11.00  .16                                                     .46    259
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12352TE1 21.00  .1591.00  .089                                                 261
12352TE2 0                                                                     262
12450SN2 0                                                                     263
12451SB1 0                                                              .97    264
12451SB2 4 .07 2.09  .46 1.69  .10  .72  .98  .60                       .38    265
12452TE2 0                                                                     266
12550SN1 2 .0221.71  .978 .326                                          .79    267
12550SN2 4 .0211.972 .0151.878 .0011.410 .0131.068                      .92    268
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12552TE1  21.00  .1101.00  .035                                                270
12552TE2 0                                                                     271
12650SN2 11.0   .092                                                    .12    272
12651SB1 11.0   .117                                                    .0078  273
12651SB2 11.0   .117                                                    .74    274
12652TE2 0                                                                     275
12750SN2 11.0                                                           1.34   276
12751SB2 3 .40  .77  .05  .71  .35  .46                                 .38    277
12752TE1 21.00  .089 .015 .059                                          .0041  278
12752TE2 1 .01  .42                                                     .23    279
12753I 2 0                                                                     280
12850SN2 0                                                              .47    281
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12851SB2 21.0   .90 1.0   .75                                           1.20   283
12852TE2 0                                                                     284
12853I 2 2 .02  .990 .155 .450                                          .77    285
12854XE2 0                                                                     286
12951SB2 1 .20  .534                                                    .42    287
12952TE1 11.00  .106                                                           288
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12952TE2 4 .10 1.15  .04  .713 .15  .502 .71  .027                       .45   289
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12954XE2 21.00  .1961.00  .040                                                  291
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13052TE2 0                                                                      294
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13054XE2 0                                                                      296
13151SB2 0                                                                1.33  297
13152TE1 3 .52  .204 .17 1.76  .0461.50                                   .16   298
13152TE2 5 .08 1.12  .04  .95  .06  .60  .23  .45  .94  .147             .74   299
13153I 2 3 .028 .724 .093 .638 .876 .365                                  .18   300
13154XE1 11.00  .164                                                            301
13154XE2 0                                                                      302
13251SB2 0                                                                2.68  303
13252TE2 21.00  .23 1.00  .053                                            .055  304
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13351SB2 0                                                                1.72  307
13352TE1 2 .70 2.0   .17 1.0                                              .49   308
13352TE2 11.0   .6                                                        .97   309
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13354XE1 11.00  .233                                                            311
13354XE2 3.0002 .382 .01  .160 .99  .081                                  .10   312
13355CS2 0                                                                      313
13451SB2 11.0   .2                                                        3.45  314
13452TE2 0                                                                .52   315
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13454XE2 0                                                                      317
13455CS1 11.0   .153                                                      .0017 318
13455CS2 3 .94  .80  .97  .60  .13  .57                                   .16   319
13456BA2 0                                                                      320
13551SB2 0                                                                3.16  321
13552TE2 0                                                                2.68  322
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13554XE1 11.0   .53                                                             324
13554XE2 3 .03  .61  .001 .36  .97  .25                                   .31   325
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13556BA1	11.00 .026		327
13556BA2	0		328
13653I 2	3 .09 4.20 .23 2.64 .16 1.32	1.68	329
13654XE2	0		330
13655CS2	2 .9262.49 .0742.24	.11	331
13656BA2	0		332
13753I 2	11.0 .5	2.19	333
13754XE2	11.0 .8	1.48	334
13755CS2	1 .92 .662	.20	335
13756BA1	11.00 .662		336
13756BA2	0		337
13853I 2	11.0 1.5	3.10	338
13854XE2	11.0 .4	.96	339
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13856BA2	0		341
13953I 2	0	2.40	342
13954XE2	11.0 .2	2.00	343
13955CS2	11.0 .232	1.74	344
13956BA2	2 .0031.51 .29 .166	.91	345
13957LA2	0		346
14054XE2	0	1.09	347
14055CS2	0	2.66	348
14056BA2	4 .25 .567 .10 .466 .05 .162 .60 .042	.30	349
14057LA2	4 .88 1.60 .40 .81 .44 .49 .35 .33	.48	350
14058CE2	0		351
14154XE2	0	2.36	352
14155CS2	0	1.72	353
14156BA2	1 .25 .54	1.14	354
14157LA2	1 .02 1.36	.96	355
14158CE2	1 .70 .145	.15	356
14159PR2	0		357
14254XE2	0	1.70	358
14255CS2	0	2.98	359
14256BA2	11.0 .3	.7[illegible]	360
14257LA2	4 .14 3.60 .04 3.30 .14 2.40 .30 .64	1.42	361
14258CE2	0		362

14259PR2	1 .04 1.57	.83	363
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14355CS2	0	2.32	366
14356BA2	0	1.47	367
14357LA2	0	1.33	368
14358CE2	5 .06 1.16 .12 .918 .05 .722 .40 .351 .37 .057	.37	369
14359PR2	0		370
14360ND2	0		371
14454XE2	0	2.19	372
14455CS2	0		373
14456BA2	0	1.00	374
14457LA2	0	2.23	375
14458CE2	2 .20 .134 .04 .080	.080	376
14459PR2	3.00032.86 .01 2.18 .012 .696	1.22	377
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14558CE2	11.0 .03	.77	379
14559PR2	1 .001 .5	.68	380
14560ND2	0		381
14658CE2	11.0 .320	.22	382
14659PR2	2 .44 1.94 .56 .453	1.27	383
14660ND2	0		384
14758CE2	0	1.55	385
14759PR2	0	1.12	386
14760ND2	3 .03 .688 .20 .532 .77 .091	.23	387
14761PM2	1.0001 .121	.059	388
14762SM2	0		389
14858CE2	0	.95	390
14859PR2	11.0 .3	2.17	391
14860ND2	0		392
14861PM1	2 .87 1.460 .13 .560	.39	393
14861PM2	5 .33 2.205 .142.120 .09 1.91 .15 1.590 .04 1.19	.41	394
14862SM2	0		395
14960ND2	11.0 .1	.55	396
14961PM2	3 .006 .850 .003 .582 .10 .285	.36	397
14962SM2	0		398
15060ND2	0		399

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15160ND2 6 .01 2.17  .03 1.87  .30 1.29  [illegible]7  .852 .15  .534 .45  .25 .63   401
15161PM2 11.00  .715                                                     .38   402
15162SM2 1 .017 .022                                                     .019  403
15163EU2 0                                                                     404
15261PM2 12.0  1.4                                                       .86   405
15262SM2 0                                                                     406
15263EU1 4 .09  .96  .11  .84  .24  .56  .13  .122                       .60   407
15263EU2 4 .25 1.41  .13 1.11  .26  .34  .62  .122                       .19   408
15264GD2 0                                                                     409
15361PM2 2 .5   .18  .5   .125                                            .58  410
15362SM2 3 .001 .70  .38  .173 .40  .103                                 .22   411
15363EU2 0                                                                     412
15461PM2 0                                                                .95  413
15462SM2 0                                                                     414
15463EU2 6 .06 1.82  .32 1.72  .36 1.4   .12 1.129 .04  .998 .10  .12 .20   415
15464GD2 0                                                                     416
15562SM2 2 .04  .246 .01  .142 .96  .104                                 .60   417
15563EU2 3 .30  .105 .40  .087 .10  .060                                 .046  418
15564GD2 0                                                                     419
15662SM2 0                                                               .30   420
15663EU2 11.0   .62                                                      .70   421
15664GD2 0                                                                     422
15763EU2 11.0   .525                                                     .42   423
15764GD2 0                                                                     424
15863EU1 1.0    .6                                                       1.04  425
15864GD2 0                                                                     426
15963EU2 0                                                                .85  427
15964GD2 2 .20  .362 .06  .058                                           .29   428
15965TB2 0                                                                     429
16063EU2 0                                                               1.44  430
16064GD2 0                                                                     431
16065TB2 6 .08 1.358 .03 1.286 .47 1.264 .09 1.049 .27  .966 .004 .08 .20   432
16066DY2 0                                                                     433
16164GD2 3 .04  .586 .05  .481 .91  .418                                 .59   434
16165TB2 3 .17  .132 .11  .074 .12  .049                                 .15   435
16166DY2 0                                                                     436
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16265TB2 0                                                              1.68   438
16266DY2 0                                                                     439
16365TB2 0                                                              1.22   440
16366DY2 0                                                                     441
16466DY2 0                                                                     442
16566DY1 2 .97  .108 .03  .515                                          .0084  443
16566DY2 3.00061.07  .014 .994 .13  .094                                .44    444
16567HO2 0                                                                     445
16666DY2 3 .028 .43  .001 .37  .92  .082                                .12    446
16667HO2 3 .0031.663 .0091.46  .467 .080                                .67    447
16668ER2 0                                                                     448
16768ER1 11.00  .208                                                           449
16768ER2 0                                                                     450
 14 6C 2 0                                                              .06    451
 16 7N 2 2 .05 7.12  .73 6.13                                           2.69   452
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 2511NA2 3 .15  .98  .15  .58  .15  .40                                 1.45   454
 2712MG2 2 .30 1.01  .70  .83                                           .63    455
 2813AL2 11.00 1.78                                                     .07    456
 2913AL2 2 .15 2.43  .85 1.28                                           1.02   457
 3114SI2 1.00071.27                                                     .25    458
 3215P 2 0                                                              .70    459
 3516S 2 0                                                              .06    460
 4520CA2 0                                                              .10    461
 4621SC2 21.00 1.12 1.00  .89                                           .12    462
 4721SC2 1 .64  .159                                                    .41    463
 5124CR2 1 .10  .32                                                     .24    464
 5425MN2 11.00  .84                                                     .18    465
 5524CR2 0                                                              1.18   466
 5526FE2 0                                                              .07    467
 5624CR2 21.00  .0831.00  .026                                          .57    468
 5625MN2 3 .14 2.11  .23 1.81  .99  .84                                 .82    469
 5827CO2 0                                                              1.70   470
 5926FE2 3 .01 1.43  .44 1.29  .56 1.10                                 .86    471
 6027CO  12.00 1.25                                                     .10    472
 6429CU2 1 .01 1.34                                                     .68    473
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6930ZN2	0													.31	475
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14661PM2	2	.65	.75	.65	.45									.06	477
18774W 2	2	.10	1.00	.70	.686									.23	478
19879AU2	3	.01	1.09	.01	.69	.99	.412							.33	479
20380HG2	1	1.00	.279											.06	480
20580HG	0													.56	481
20982PB2	0													.20	482
21083BI2	0													.39	483
21084PO2	0													2.25	484
22688RA2	1	.032	.187											4.72	485
22788RA2	2	.01	.50	.04	.29									.42	486
22789AC2	0													.18	487
22888RA2	0													.001	488
23390TH2	5	.01	.453	.003	.195	.007	.171	.027	.087	.021	.029			.40	489
23391PA2	0													.06	490
23792U 2	4	.015	.332	.019	.267	.89	.208	.07	.165	1.0	.060			.06	491
23894PU2	1	.28	.044											5.48	492
23994PU2	1	.17	.013											5.14	493
24094PU2	1	.24	.045											5.15	494
24194PU2	0													.050	495
24195AM2	2	.13	.103	.85	.059									5.47	496
24294PU2	1	.24	.045											4.83	497
24295AM1	1	1.0	.35											5.20	498
24295AM2	1	.50	.042											.006	499-

MASS ABSORPTION COEFFICIENTS

H2O	11	0.1500	0.1275	0.1130	0.1015	0.0832	0.0775	0.0705	0.0635	4	6	1
	12	0.0580	0.0537	0.0505	0.0480	0.0457	0.0436	0.0418	0.0395			2
TISSUE	21	0.1455	0.1225	0.1080	0.0995	0.0835	0.0750	0.0685	0.0615	4	6	3
	22	0.0555	0.0520	0.0493	0.0465	0.0443	0.0425	0.0418	0.0395			4
AIR	31	0.1334	0.1140	0.1015	0.0915	0.0865	0.0695	0.0635	0.0573	7	14	5
	32	0.0515	0.0478	0.0450	0.0425	0.0407	0.0387	0.0370	0.0339			6
H	41	0.2650	0.2440	0.1975	0.1750	0.1570	0.1385	0.1260	0.1125	1	1	7
	42	0.1025	0.0950	0.0892	0.0835	0.0800	0.0765	0.0730	0.0688			8
LI	51	0.115	0.0990	0.0880	0.0775	0.0685	0.0605	0.0550	0.0505	3	7	9
	52	0.0447	0.0420	0.0390	0.0375	0.0360	0.0350	0.0335	0.0304			10
C	61	0.135	0.115	0.1015	0.0915	0.0865	0.0695	0.0635	0.0573	6	12	11
	62	0.0515	0.0478	0.0450	0.0425	0.0407	0.0387	0.0370	0.0339			12
AL	71	0.1780	0.1280	0.0990	0.0868	0.0755	0.0676	0.0615	0.0553	13	27	13
	72	0.0498	0.0467	0.0438	0.0414	0.0390	0.0375	0.0365	0.0357			14
TI	81	0.163	0.120	0.0970	0.0840	0.0730	0.0640	0.0585	0.0530	22	48	15
	82	0.0478	0.0455	0.0435	0.0410	0.0400	0.0390	0.0375	0.0350			16
FE	91	0.2040	0.1370	0.0998	0.0875	0.0720	0.0637	0.0588	0.0513	26	56	17
	92	0.0470	0.0446	0.0415	0.0402	0.0381	0.0378	0.0366	0.0355			18
NI	101	0.221	0.140	0.110	0.0880	0.0780	0.0680	0.0614	0.0610	28	59	19
	102	0.0500	0.0485	0.0445	0.0430	0.0420	0.0410	0.0380	0.0372			20
ZR	111	0.378	0.195	0.120	0.0905	0.0750	0.0640	0.0579	0.0540	40	91	21
	112	0.0468	0.0440	0.0425	0.0405	0.0400	0.0395	0.0380	0.0363			22
SN	121	0.640	0.220	0.130	0.0935	0.0720	0.0620	0.0550	0.0490	50119		23
	122	0.0445	0.0415	0.0405	0.0390	0.0380	0.0365	0.0365	0.0360			24
W	131	1.52	0.600	0.275	0.145	0.095	0.0775	0.0655	0.0600	74184		25
	132	0.0498	0.0480	0.0450	0.0440	0.0435	0.0430	0.0420	0.0408			26
PE	141	1.92	0.5950	0.3065	0.1775	0.1280	0.0975	0.0726	0.0618	82207		27
	142	0.0534	0.0488	0.0463	0.0443	0.0428	0.0419	0.0413	0.0411			28
U	151	2.49	0.7680	0.3880	0.2275	0.1370	0.0995	0.0815	0.0670	92238		29
	152	0.0560	0.0515	0.0483	0.0462	0.0450	0.0441	0.0436	0.0432			30
ORDINAR	161	0.1780	0.1280	0.0990	0.0890	0.0860	0.0750	0.0637	0.0610	12		31
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0385	0.0366			32

ORDINAR161	0.1780	0.1280	0.0990	0.0890	0.0860	0.0750	0.0637	0.0610	12		31
ONCRET162	0.0550	0.0520	0.0460	0.0440	[illegible]	0.0410	0.0395	0.0366			32
AGNETI171	0.1800	0.1220	0.0945	0.0870	[illegible]	0.0750	0.0618	0.0600	17		33
CONCRET172	0.0550	0.0520	0.0470	0.0430	0.0420	0.0410	0.0395	0.0364			34
FEROPHO181	0.1820	0.1220	0.0935	0.0860	0.0830	0.0670	0.0609	0.0590	21		35
CONCRET182	0.0540	0.0500	0.0450	0.0420	0.0410	0.0400	0.0390	0.0363		1	36-

BUILD UP FACTOR COEFFICIENTS

DOSE	11	24.	24.	24.	24.	19.	14.9	11.0	8.9	4
BUILD-UP	12	7.8	8.2	7.8	7.4	7.0	6.7	6.5	6.2	
FACTOR	13	-0.14	-0.14	-0.14	-0.14	-0.122	-0.114	-0.104	-0.095	
DATA,	14	-0.088	-0.082	-0.078	-0.074	-0.070	-0.068	-0.065	-0.062	
WATER	15	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.06	
	16	0.074	0.083	0.088	0.094	0.097	0.102	0.104	0.108	
DOSE	21	9.0	9.0	9.0	9.0	9.0	8.2	8.0	7.3	13
BUILD-UP	22	6.4	5.95	5.65	5.3	5.15	4.95	4.75	4.5	
FACTOR	23	-0.15	-0.15	-0.15	-0.15	-0.15	-0.12	-0.11	-0.10	
DATA,	24	-0.091	-0.087	-0.084	-0.081	-0.079	-0.077	-0.076	-0.074	
ALUMINUM	25	0.00	0.00	0.00	0.00	0.00	0.025	0.044	0.055	
	26	0.075	0.084	0.09	0.096	0.101	0.106	0.11	0.115	
DOSE	31	11.2	10.8	10.7	10.2	9.5	9.1	8.6	8.0	26
BUILD-UP	32	7.5	7.1	6.7	6.5	6.1	5.8	5.5	5.0	
FACTOR	33	-0.099	-0.097	-0.097	-0.095	-0.092	-0.09	-0.088	-0.081	
DATA,	34	-0.080	-0.077	-0.075	-0.073	-0.072	-0.072	-0.072	-0.072	
IRON	35	0.0	0.001	0.004	0.009	0.016	0.022	0.028	0.034	
	36	0.039	0.044	0.048	0.05	0.054	0.056	0.059	0.062	
DOSE	41	4.8	4.7	4.7	4.65	4.6	4.55	4.5	4.4	50
BUILD-UP	42	4.3	4.1	4.05	3.95	3.8	3.65	3.5	3.3	
FACTOR	43	-0.088	-0.086	-0.085	-0.084	-0.082	-0.081	-0.08	-0.079	
DATA,	44	-0.078	-0.078	-0.079	-0.08	-0.082	-0.084	-0.086	-0.09	
TIN	45	0.1	0.105	0.11	0.114	0.12	0.125	0.13	0.134	
	46	0.139	0.141	0.142	0.141	0.14	0.137	0.135	0.13	
DOSE	51	3.6	3.6	3.5	3.5	3.44	3.4	3.3	3.18	74
BUILD-UP	52	3.05	2.95	2.93	2.88	2.84	2.8	2.78	2.70	
FACTOR	53	-0.00	-0.008	-0.01	-0.02	-0.028	-0.035	-0.042	-0.05	
DATA,	54	-0.058	-0.063	-0.068	-0.07	-0.074	-0.076	-0.08	-0.086	
TUNGSTEN	55	0.06	0.07	0.08	0.10	0.12	0.13	0.146	0.164	
	56	0.18	0.184	0.187	0.187	0.184	0.176	0.166	0.135	

DOSE	61	1.0	1.2	1.3	1.5	1.7	2.5	2.9	2.6	82

DOSE	61	1.0	1.2	1.3	1.5	1.7	2.5	2.9	2.6	82
BUILD-UP	62	2,65	2,65	2,6	2,5	2,5	2,35	2,3	2,1	
FACTOR	63	-0,01	-0,015	-0,02	-0,03	-0,03	-0,04	-0,04	-0,05	
DATA,	64	-0,055	-0,06	-0,07	-0,075	-0,08	-0,08	-0,085	-0,095	
LEAD	65	0,37	0,37	0,35	0,29	0,25	0,20	0,17	0,15	
	66	0,13	0,12	0,11	0,10	0,09	0,08	0,075	0,07	1

APPENDIX E

SAMPLE PROBLEMS

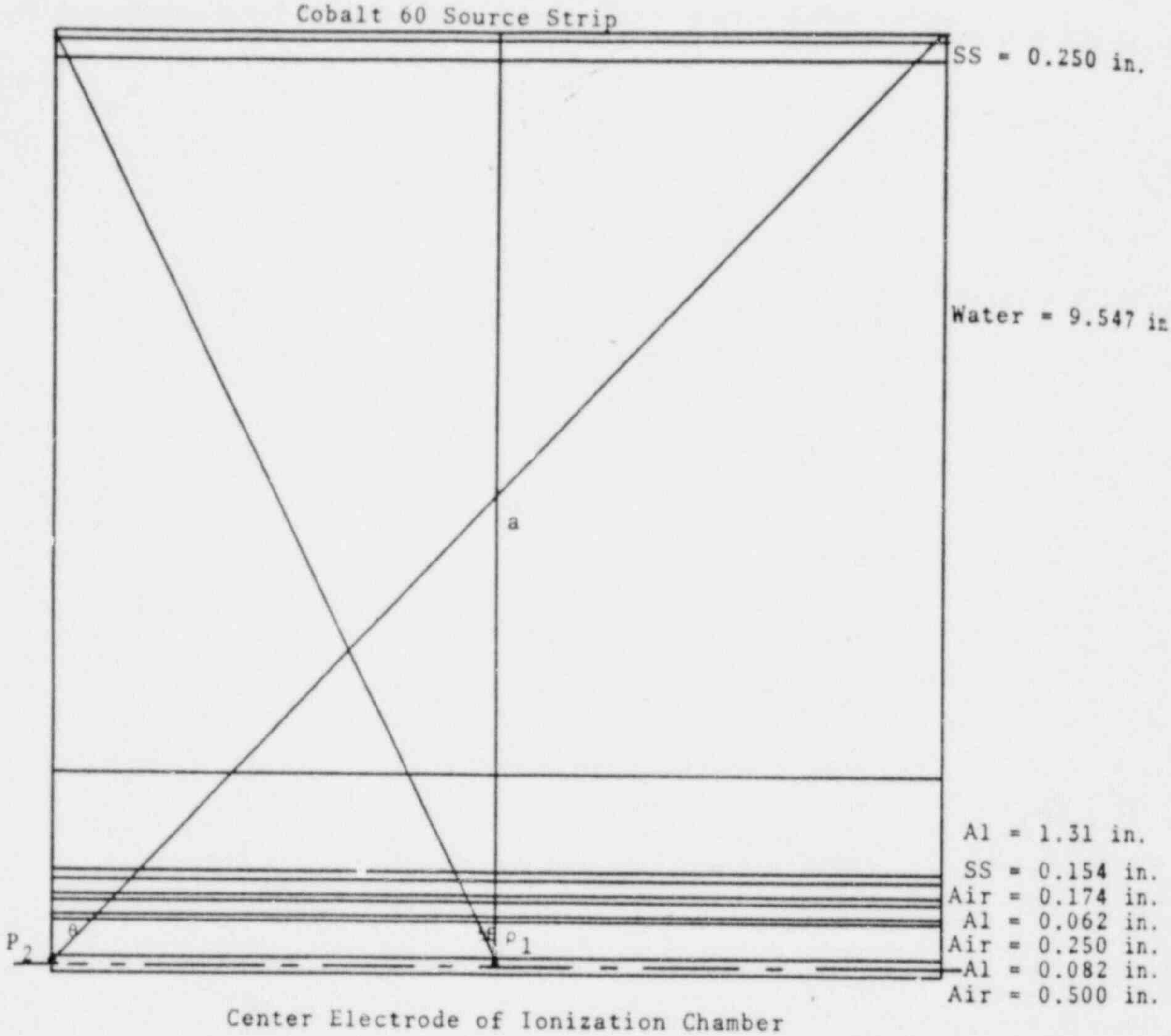
APPENDIX E
SAMPLE PROBLEMS
ACTIVITY OF CO^{60} BNL STANDARD STRIP*

In support of the Co^{60} production at the Hanford Atomic Products Operation it was necessary to design a device for routine determination of the specific activity of irradiated BNL standard strip.[17] The device (Figure E-1) consists of a calibrated ion chamber mounted about 11 inches from a Co^{60} strip holder. The assembly is immersed in a water-filled storage basin. ISOSHLD was used to calculate the expected dose rates at the ion chamber so that a chamber of the correct dose rate operating range could be obtained. ISOSHLD calculated (input listing following Figure E-1) dose rates and the subsequent measured dose rates (using the accurately calibrated ion chamber and Co^{60} strips of known activity) are summarized in Table E-I.

TABLE E-I. Comparison of Calculated and Measured Dose Rates.

Co^{60} Specific Activity Ci/g	Calculated dose rates R/hr	Measured dose rates R/hr
10	3,141	2,984
12	3,770	3,582
14	4,398	4,178
16	5,026	4,774

*Courtesy of: M. H. Montgomery
Douglas-United Nuclear
Richland, Washington



At Point P_1:

a = 12.309 in. = 31.30 cm

θ = 26.0°

At Point P_2:

a = 12.309 in. = 31.30 cm

θ = 44.2°

FIGURE E-1. BNL Standard Co^{60} Source

```
MPLE PROBLEM - ACTIVITY OF CO60 BNL STANDARD STRIP


     2
BALT - 60 SOURCE DOSE VS ACTIVITY  10 CI/GM
INPUT IGEOM=2,NSHLD=5,JBUF=5,NEXT=1,T(1)=.7163,T(2)=31.30,T(3)=3.3274,
T(4)=.39116,T(5)=.31496,WEIGHT(472)=651.7,ANG1=90.0,ANG2=64.0,
SLTH=30.48,X=34.9,SSV1=0.0 $
     97.94                            7.94
     1          1.0
     7                    2.70                  2.70                 1
BALT - 60 SOURCE DOSE VS ACTIVITY  12 CI/GM
INPUT NEXT=2,WEIGHT(472)=782.04 $
BALT - 60 SOURCE DOSE VS ACTIVITY  14 CI/GM
INPUT NEXT=2,WEIGHT(472)=912.38 $
BALT - 60 SOURCE DOSE VS ACTIVITY  16 CI/GM
INPUT NEXT=2,WEIGHT(472)=1042.72 $
BALT - 60 SOURCE DOSE VS ACTIVITY  16 CI/GM  NEXT=6
INPUT NEXT=6,WEIGHT(472)=1042.72 $
```

DOSE RATES FROM AQUEOUS-FILLED CYLINDERS*

A family of curves showing dose rate versus distance from various sized cylinders, containing aqueous solutions of radioactive isotopes, was desired by the Personnel Protection Section of the Hanford Chemical Processing facilities.

Since there are several variables involved in each calculation of a given dose rate (hand calculations are extremely tedious), the speed and accuracy gained by the use of a computer was thought to be ideal for such a problem. ISOSHLD (input on next page) was used to compute dose rates from a cylinder of specified dimensions containing Cs^{137}. (This work has since been extended to many cylinder sizes and isotopes.)

The dose rates o tained were plotted against the distance from the cylinder giving a smooth continuous curve (Figure E-2). Dose rates, which were determined by hand with the formulas and data of Rockwell,[1] are plotted on this same graph. It can be seen from Figure E-2 that the points are similar except when the dose rate is determined at a short distance from the cylinder.

*Courtesy of D. T. Vladimiroff and J. Dirlam
ISOCHEM Inc.
Richland, Washington

AMPLE PROBLEM - DOSE RATES FROM AQUEOUS FILLED CYLINDERS

```
        2
 CYLINDER ATTENUATION CALCULATION     AT EDGE       CS137
$INPUT NEXT=1,T=10.,.635,4*0.,WEIGHT(335)=2.0,NSHLD=2,SLTH=200.,
 X=10.635,Y=100., JBUF=2,IGEOM=7,NTHETA=6,NPSI=6,DELR=3.$
WATER    1     1.1
IRON     9              7.86                                          1
 CYLINDER ATTENUATION CALCULATION    30 CM FROM EDGE
$INPUT NEXT=4, X=40.635$
 CYLINDER ATTENUATION CALCULATION    50 CM FROM EDGE
$INPUT X=60.635 $
 CYLINDER ATTENUATION CALCULATION    70 CM FROM EDGE
$INPUT X=80.635 $
 CYLINDER ATTENUATION CALCULATION    90 CM FROM EDGE
$INPUT X=100.635 $
 CYLINDER ATTENUATION CALCULATION   110 CM FROM EDGE
$INPUT X=120.635 $
 CYLINDER ATTENUATION CALCULATION   130 CM FROM EDGE
$INPUT X=140.635 $
 CYLINDER ATTENUATION CALCULATION   150 CM FROM EDGE
$INPUT X=160.635 $
 CYLINDER ATTENUATION CALCULATION   170 CM FROM EDGE
$INPUT X=180.635 $
 CYLINDER ATTENUATION CALCULATION   190 CM FROM EDGE
$INPUT X=200.635 $
 CYLINDER ATTENUATION CALCULATION   210 CM FROM EDGE
$INPUT X=220.635 $
 CYLINDER ATTENUATION CALCULATION   250 CM FROM EDGE
$INPUT X=260.635 $
 CYLINDER ATTENUATION CALCULATION   300 CM FROM EDGE
$INPUT X=310.635 $
            END OF RUN
$INPUT NEXT=6 $
```

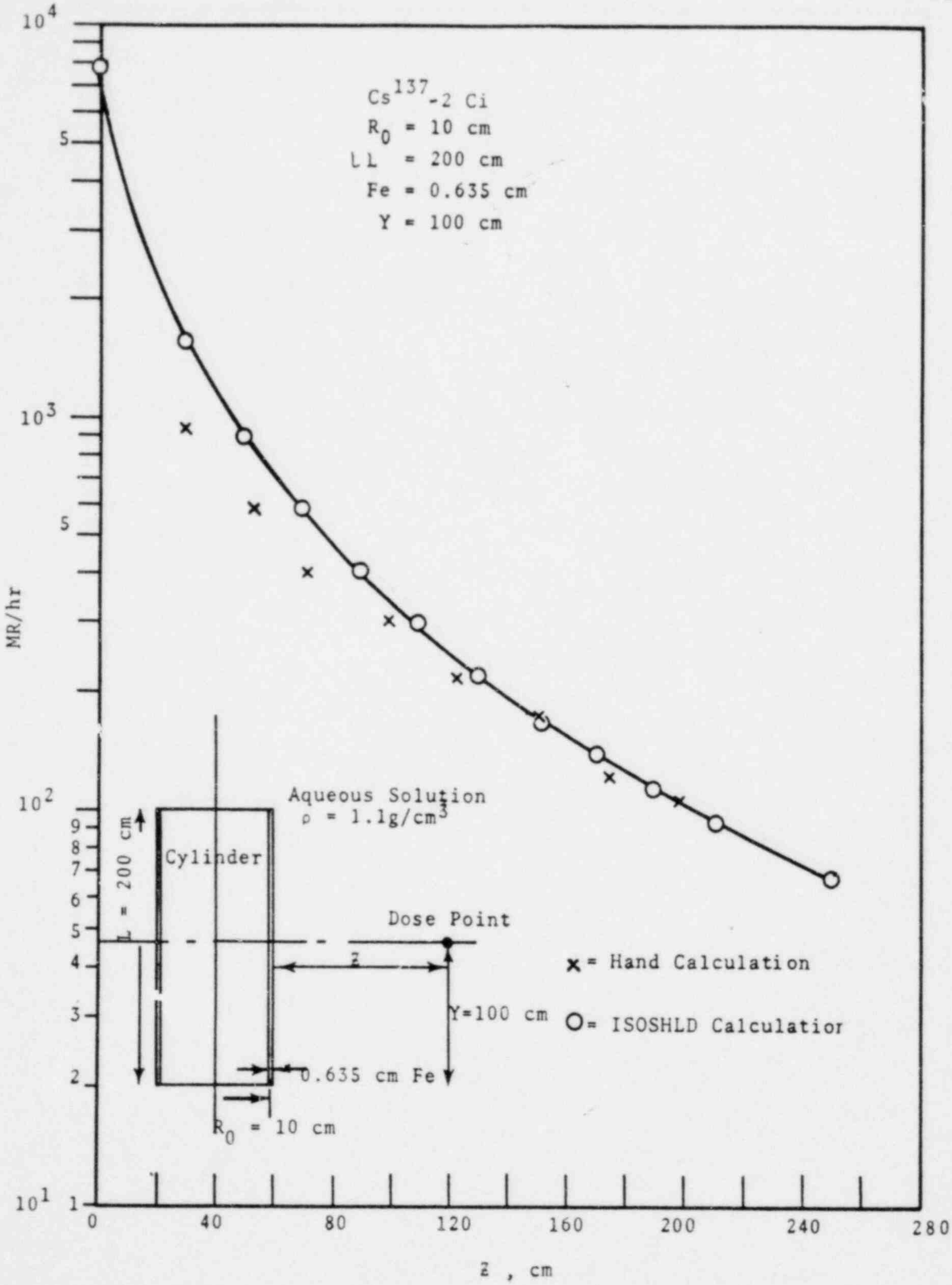


FIGURE E-2. Dose Rate Versus Distance

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ISOSHLD-II: CODE REVISION TO INCLUDE CALCULATION OF DOSE RATE FROM SHIELDED BREMSSTRAHLUNG SOURCES

G. L. SIMMONS
J. J. REGIMBAL
J. GREENBORG
E. L. KELLY, JR.
H. H. VAN TUYL

MARCH 1967

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G. L. Simmons, J. J. Regimbal, J. Greenborg
E. L. Kelly, Jr., H. H. Van Tuyl

ABSTRACT

The ISOSHLD-II shielding code is principally intended for use in calculating the radiation dose, at a field point, from bremsstrahlung and/or decay gamma rays emitted by radioisotope sources. This program, with the newly-added bremsstrahlung mode, is an extension of an earlier version (ISOSHLD). Five shield regions can be handled with up to twenty materials per shield; the source is considered to be the first shield region, i.e., bremsstrahlung and decay gamma rays are produced only in the source. Point kernel integration (over the source region) is used to calculate the radiation dose at a field point.

Data needed to calculate fission-product isotopic concentrations, source spectrum distributions and attenuation coefficients are contained in libraries used by the code. Problem input data is thereby minimized; the information required specifies the source-shield configuration and identifies the relevant materials and their densities.

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ISOSHLD-II: CODE REVISION TO INCLUDE CALCULATION OF DOSE RATE FROM SHIELDED BREMSSTRAHLUNG SOURCES

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INTRODUCTION

The solution of radioisotope shielding problems often requires a consideration of the amount and distribution of bremsstrahlung produced by the slowing down and stopping of beta particles. Indeed, problems are often encountered in which a mixed emission of beta and gamma rays must be treated. Using ISOSHLD-II--an extension of the point kernel computer code ISOSHLD[1]--one has the added capability of solving shielding problems for which bremsstrahlung may contribute totally or partially to the dose of radiation. The user of ISOSHLD-II need only supply information about the geometry of the problem, radioisotopes in the source, and the material composition of the source and shield regions. The code libraries contain information used to calculate the dose and radiation spectra, i.e., attenuation coefficients, gamma-ray decay energies and probabilities, maximum beta energies and probabilities, fission product data, and buildup factor data.

The point kernel integration technique is used to perform the attenuation calculation, the integration being performed over the source region to obtain the dose at an exposure point. Bremsstrahlung is produced only in the source region; i.e., the beta particles are completely stopped by the material in that source region.

The code will obtain solutions for any combination of source-shield geometry and source type as listed in BNWL-236.

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THEORY

CALCULATION OF THE SOURCE STRENGTH

ISOSHLD-II will include a bremsstrahlung source as part of the total strength or will construct a source that is due to bremsstrahlung alone. Three methods of constructing the source strength and distribution are available as described below.

Method 1

The source in this case consists of fission nuclide emissions and other decay and neutron activation product emissions from fuel irradiated under known conditions. A choice can be made of (1) one isotope, (2) any combination of isotopes, (3) all of the isotopes, or (4) several grouping--volatile solids, halogens, or noble gases. Bremsstrahlung spectra can be generated in 1, 2, and 4 above. Also a weighting factor may be applied to the source spectra to represent a recovery efficiency.

At the completion of the fission product inventory determination, ISOSHLD-II calculates the photon yields (photon/sec) in 25 energy groups. The group structure is given in Table I.

TABLE I. Gamma-Ray Groups

Group	Average Energy, MeV	Maximum Energy, MeV
1	0.015	0.02
2	0.025	0.03
3	0.035	0.04
4	0.045	0.05
5	0.055	0.06
6	0.065	0.07
7	0.075	0.08
8	0.085	0.09
9	0.095	0.10
10	0.150	0.20
11	0.250	0.30
12	0.350	0.40
13	0.475	0.55
14	0.650	0.75
15	0.825	0.90
16	1.00	1.10
17	1.225	1.35
18	1.475	1.60
19	1.700	1.80
20	1.90	2.00
21	2.1	2.20
22	2.3	2.40
23	2.5	2.60
24	2.7	2.80
25	3.0	∞

Method 2

The source consists of a specified number of curies of an isotope or isotopes. The decay properties of these isotopes are contained in the photon abundance library. Bremsstrahlung source spectra can be constructed for those isotopes that emit beta particles. The total gamma yield--decay photons alone, bremsstrahlung alone, or decay photons and bremsstrahlung combined--is summed into the energy group structure listed in Table I.

Method 3

The source consists of an input number of curies of photons at (each of) up to 25 selected energies. Energy dependent parameters relating to dose conversion, attenuation, and buildup are obtained by linearly interpolating on the values of the parameters found in the library. The source distribution is considered uniform over the volume of the source region unless an exponential distribution of the form

$$S(x) = ce^{ax}$$

is specified. Of course, a bremsstrahlung spectrum will not be constructed if Method 3 is used to construct the photon source.

BREMSSTRAHLUNG SOURCE SPECTRA GENERATION

Bremsstrahlung is produced when an electron emits part of its energy while being accelerated or decelerated. If this occurs while the beta particle is penetrating the electronic shells of the emitting nuclide, the resulting radiation is called internal bremsstrahlung. Radiation produced by braking in neighboring atoms is called external bremsstrahlung. The internal bremsstrahlung produced is roughly 10% of the external bremsstrahlung. In both cases, the spectral distribution is from zero energy to the maximum beta energy.

The computer code BREMRAD[2] was used to calculate internal and external bremsstrahlung spectral distributions (photons/beta). For internal bremsstrahlung, BREMRAD uses the Knipp-Uhlenbeck[3] approximation to calculate the spectral distribution as a function of the emitting nuclide atomic number, maximum beta energy, and gamma-ray energy to maximum beta energy ratio. The external bremsstrahlung spectral distribution is a function of these same variables, having an additional dependence upon the absorbing nuclide atomic number. BREMRAD uses the Bethe-Heitler[4] approximation for calculating the external bremsstrahlung contribution.

ISOSHLD-II uses resolved bremsstrahlung spectra from BREMRAD to calculate a bremsstrahlung source for the particular isotopes and shield combinations under consideration. Internal bremsstrahlung spectra are tabulated for 5 source nuclide atomic numbers (10, 30, 50, 70, 90), 6 maximum beta energies (0.1, 0.2, 0.5, 1.0, 2.0, 4.0), and 25 gamma-ray energy to maximum beta energy ratios (0.00375, 0.00750, 0.01375, 0.02125, 0.0250, 0.0750, 0.125, 0.175, 0.225, 0.275, 0.325, 0.375, 0.425, 0.475, 0.525, 0.575, 0.625, 0.675, 0.725, 0.775, 0.825, 0.875, 0.925, 0.975, 1.000). For each source isotope that emits a beta,* an internal bremsstrahlung spectrum is generated for each maximum beta energy that is characteristic of the isotope.

Similarly, an external bremsstrahlung spectrum is produced by the emitted beta particle being stopped by a particular nuclide (absorber nuclides are tabulated for atomic numbers 10, 30, 50, 70, and 90). The first shield region (source region in most cases) can be composed of several materials; the external bremsstrahlung contribution due to one such absorber material is proportional to its nuclide density. The total effect for all materials in the first shield region is the sum of the individual contributions.

BUILDUP FACTORS

Buildup factors for gamma-ray groups 1 through 9 have been calculated using the "straight ahead" approximation. The buildup factors are tabulated (Appendix B) for six atomic numbers (13, 26, 50, 74, 82, 92), five energies (0.01, 0.02, 0.05, 0.1, 0.2) and seven absorption mean free path (μx) values (1, 2, 4, 7, 10, 17, 20). Buildup factors for a particular

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* See the Beta End-Point Library, Appendix B.

solution are obtained by linearly interpolating on this table. ISOSHLD-II does not extrapolate beyond the limits of the buildup factor table, but chooses the value at the limit. This approximation is made for energies less than 0.01 MeV, μx values greater than 20, or effective atomic number less than 13 or greater than 92. Thus, for example, some error may be introduced should the user require the buildup factor to be characteristic of a shield which has an effective atomic number less that of 13.

The buildup factor library for groups 10 through 25 contains coefficients A, α_1, and α_2 for Taylor' formula,

$$B = Ae^{\alpha_1 \mu t} + (1-A)e^{\alpha_2 \mu t} \tag{3}$$

for the point isotopic source dose buildup factor. These data are tabulated for five materials with effective atomic numbers (4, 13, 50, 74, 82). The effective atomic number of a single shield region (in which buildup is considered characteristic of all shield regions) is used for interpolating on this library.

ATTENUATION COEFFICIENTS

ISOSHLD-II has available a library of attenuation coefficients for 20 common shielding materials. The attenuation coefficients are tabulated (Appendix B) for 25 average group energies in Table I. These data were taken from NBS-8681[(5)] and LA-2237.[(6)] For high atomic number materials, the florescence yield is included by modifying the attenuation coefficients, in energy ranges of interest, to include the effect of the production of the florescent gamma ray.

The attenuation coefficients in the library are based on materials of unit density. Mixed attenuation coefficients are calculated using the formula:

$$\mu(E) = \sum_{i=1}^{NMAT} \rho_i \mu_i(E) \tag{4}$$

where ρ_i is the density of the i^{th} material in the shield and NMAT is the number of materials in the shield.

INPUT CHANGES

One variable, ISPEC, has been added to the namelist array described on Page 22 of BNWL-236. This variable is used to indicate that a bremsstrahlung contribution is to be included in the source. Listed below are the values of ISPEC and the resulting calculation.

ISPEC	RESULT
1	Photon calculation only
2	Bremsstrahlung calculation only
3	Bremsstrahlung and photon calculations

If ISPEC is not given a value in the namelist statement, then the program automatically sets ISPEC equal to 1.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the timely help of H. A. Moulthr of Isochem Inc. in project preplanning, and of D. T. Vladimiroff, also of Isochem Inc., in code debugging.

APPENDIX A

SAMPLE PROBLEMS

APPENDIX A

SAMPLE PROBLEMS

PROBLEM 1. SHIELDING CALCULATIONS FOR STRONTIUM-YTTRIUM-90 SOURCE

In support of the SNAP-7A radioisotope generator program, Oak Ridge National Laboratory personnel measured the attenuation by lead absorbers of the radiation from a 1000 Ci strontium-yttrium-90 source.(7) The geometry for these measurements is shown in Figure A-1. ISOSHLD-II was used to calculate the dose rate for varying thicknesses of lead. The listing of the input data is shown on Pages 8 and 9. A comparison between the calculated dose rate and the measured dose rate is shown in Figures A-2 and A-3.

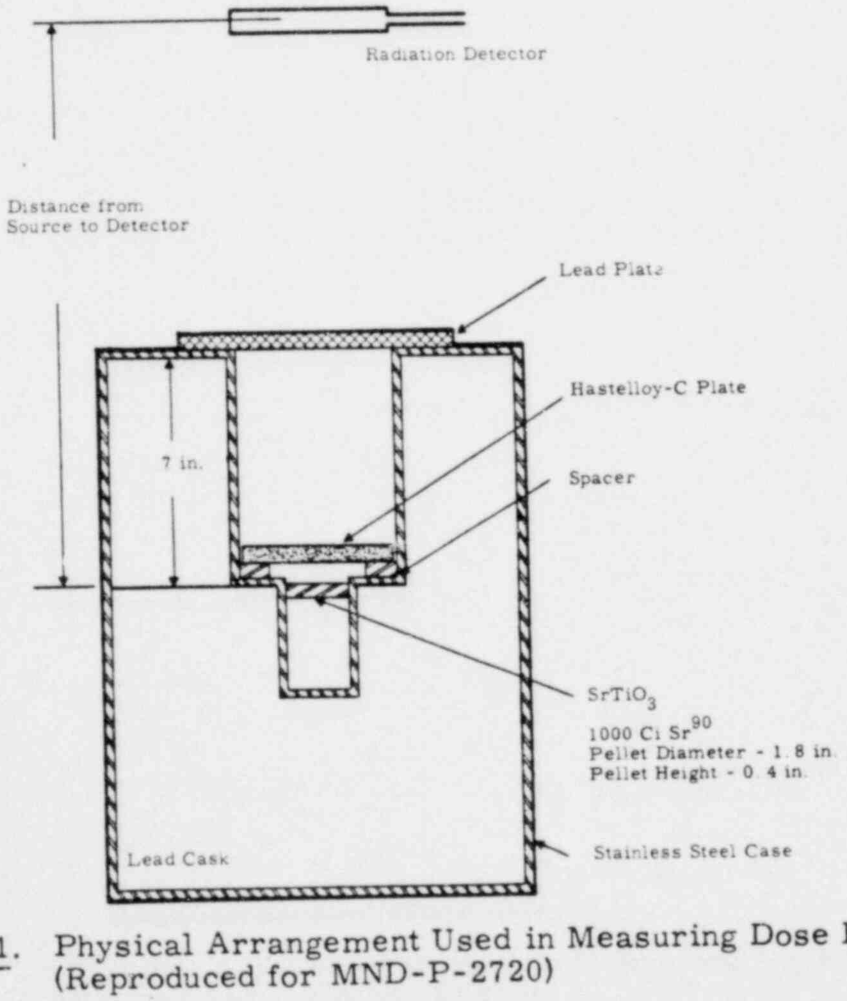

FIGURE A-1. Physical Arrangement Used in Measuring Dose Rates (Reproduced for MND-P-2720)

```
          2 SAMPLE PROBLEM SR-Y SOURCE
 DETECTOR DISTANCE 19.75 INCHES  1/2 INCH HASTELLOY  SR-90 SNAP 7A
 $INPUT NEXT=1,ISPEC=3,WEIGHT(82)=500,WEIGHT(84)=500,WEIGHT(376)=.305,
     IGEOM=9,NSHLD=5,JBUF=5,SLTH=2.286,NTHETA=10,DELR=.1016,
     X=50.1650,T(1)=1.016,T(2)=1.27,T(3)=1.27,T(4)=15.24,T(5)=0$
AIR      3  1.1716    .0012929                  .0012929
HAST AL  7                         .018914
HAST TI  8  1.1716                 .7785
HAST FE  9                          .58875
HAST NI 10                        5.99415
HAST ZR 11                         .448
PROMETH 18   1.229
    PB  14                                          11.35           1
 ONE SIXTEENTH INCH OF LEAD
 $INPUT NEXT=4,T(5)=.15875$
   ONE EIGHT INCH OF LEAD
 $INPUT T(5)=.31750$
  ONE FOURTH INCH OF LEAD
 $INPUT T(5)=.635$
    THREE EIGHT INCHES OF LEAD
 $INPUT T(5)=.9525$
 ONE HALF INCHES OF LEAD
 $INPUT T(5)=1.27,NEXT=4$
ONE INCH OF LEAD
 $INPUT T(5)= 2.54$
ONE AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 3.81$
TWO INCHES OF LEAD
 $INPUT T(5)= 5.08$
TWO AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 6.35$
THREE INCHES OF LEAD
 $INPUT T(5)= 7.62$
THREE AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 8.89$
FOUR INCHES OF LEAD
 $INPUT T(5)= 10.16$
FIVE INCHES OF LEAD
 $INPUT T(5)= 12.70$
```



```
SIX INCHES OF LEAD
```

```
SIX INCHES OF LEAD
 $INPUT T(5)= 15.24$
SEVEN INCHES OF LEAD
 $INPUT T(5)= 17.78$
FOLLOWING RUNS FOR 1/8 INCH OF HASTELLOY
 $INPUT  X=41.5925,T(3)=.3175,T(5)=0,NEXT=4$
 ONE SIXTEENTH INCH OF LEAD
 $INPUT NEXT=4,T(5)=.15875$
   ONE EIGHT INCH OF LEAD
 $INPUT T(5)=.31750$
  ONE FOURTH INCH OF LEAD
 $INPUT T(5)=.635$
    THREE EIGHT INCHES OF LEAD
 $INPUT T(5)=.9525$
 ONE HALF INCHES OF LEAD
 $INPUT T(5)=1.27,NEXT=4$
ONE INCH OF LEAD
 $INPUT T(5)= 2.54$
ONE AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 3.81$
TWO INCHES OF LEAD
 $INPUT T(5)= 5.08$
TWO AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 6.35$
THREE INCHES OF LEAD
 $INPUT T(5)= 7.62$
THREE AND ONE HALF INCHES OF LEAD
 $INPUT T(5)= 8.89$
FOUR INCHES OF LEAD
 $INPUT T(5)= 10.16$
FIVE INCHES OF LEAD
 $INPUT T(5)= 12.70$
SIX INCHES OF LEAD
 $INPUT T(5)= 15.24$
SEVEN INCHES OF LEAD
 $INPUT T(5)= 17.78$
   ENDE
 $INPUT NEXT=6$
```

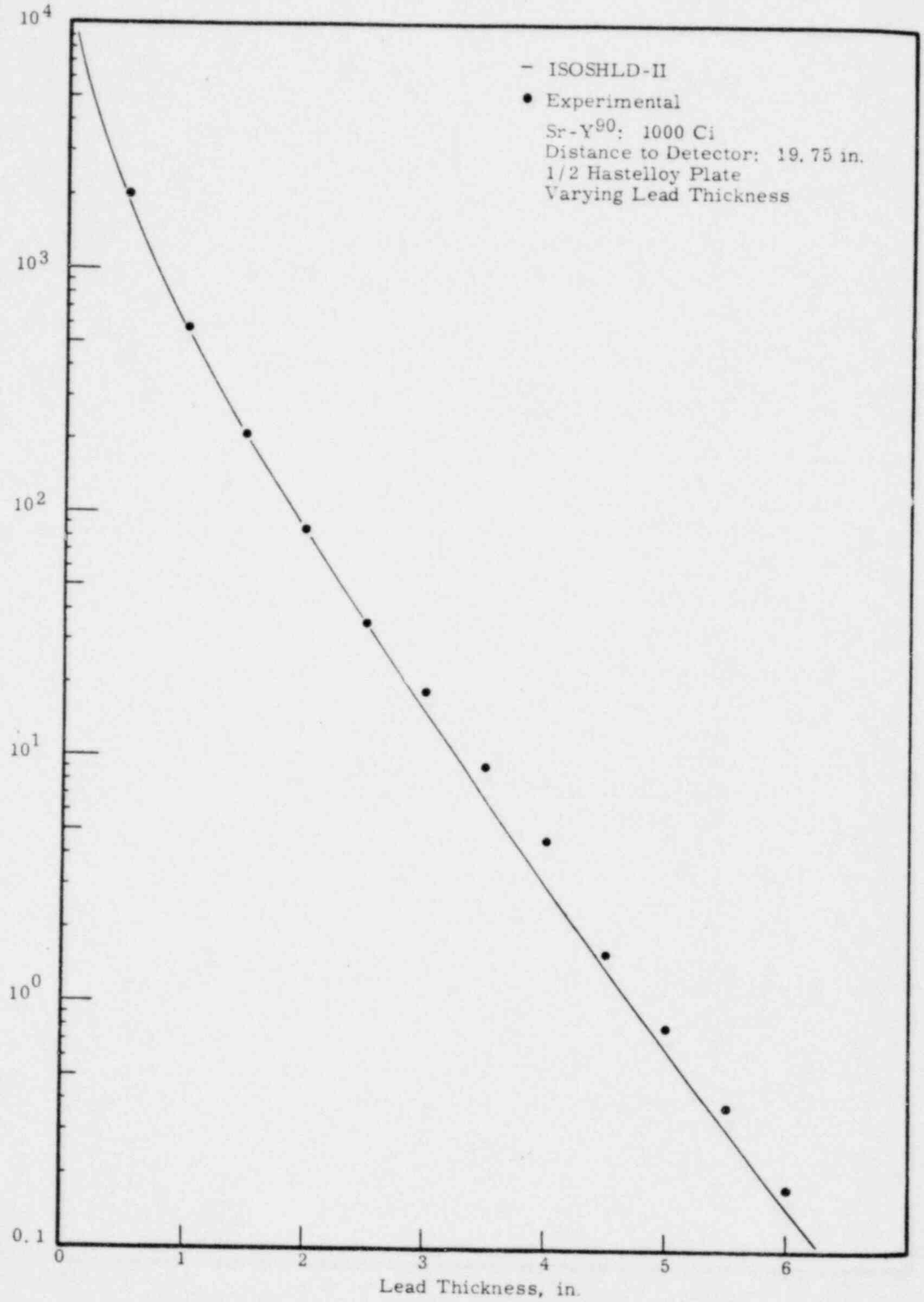

FIGURE A-2. Dose Rate from 1000 Ci $Sr\text{-}Y^{90}$ with Different Thicknesses of Lead Shielding

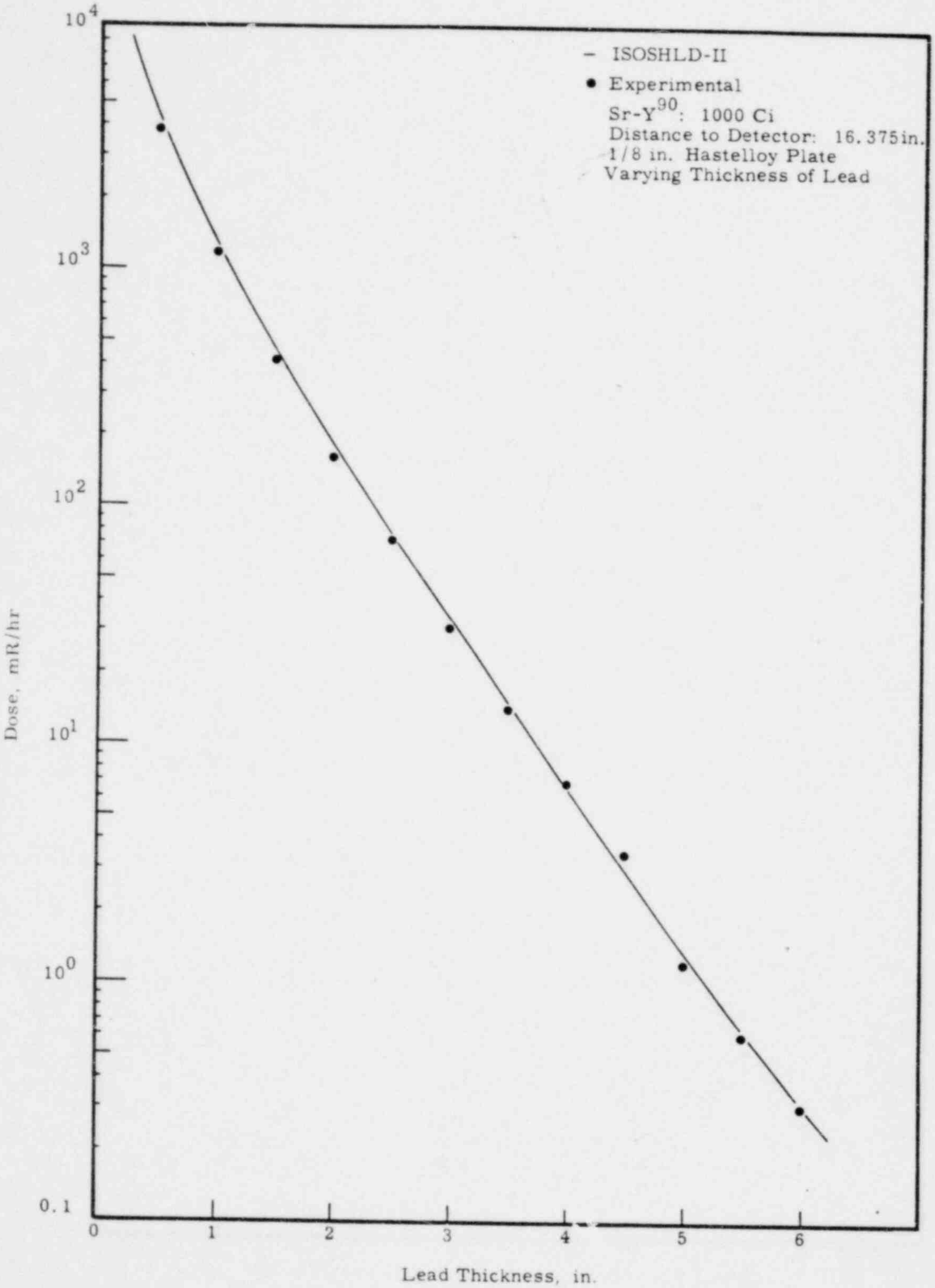

FIGURE A-3. Dose Rate from 1000 Ci $Sr-Y^{90}$ with Varying Thicknesses of Lead Shielding

PROBLEM 2. SHIELDING CALCULATIONS FOR PROMETHIUM SOURCE

Measurements of the dose rate from a promethium source shielded by varying thicknesses of lead have been made by Van Tuyl, et al.[8] The promethium source used in the experiment contained Pm-146, Pm-147, and Pm-148. The geometry of the experimental measurement is shown in Figure A-4 and the input data for ISOSHLD-II are shown on Pages 13 and 14. The comparison between the experimental measurements and the dose calculated by ISOSHLD-II is shown in Figure 5-A.

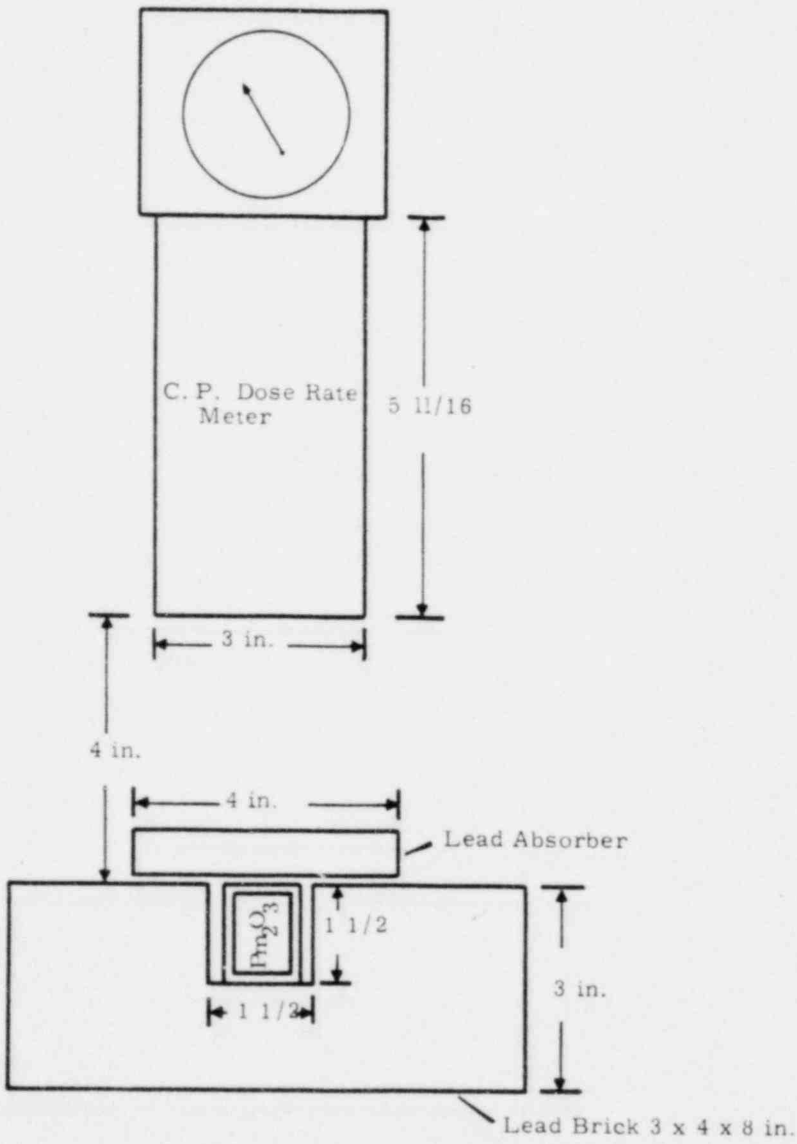

FIGURE A-4. Experimental Arrangement for Promethium Shielding Measurements (Reproduced from HW-77375)

```
        2  SAMPLE PROBLEM PROMETHIUM SOURCE
 PROMETHIUM SOURCE NO LEAD SHIELDING
 $INPUT  NEXT=1,WEIGHT(394)=.00045,WEIGHT(388)=1300.,WEIGHT(476)=.0006,
  IGEOM=9,NSHLD=3,JBUF=3,T(1)=1.74625,T(2)=.63500,SLTH=.635,NTHETA=10,
   DELR=.127,X=11.90625,ISPEC=3$
OXYGEN   3  .89792
PROMETH.18  5.5021
       7            2.702
      14                       11.347                              1
  .1  INCHES OF LEAD
 $NEXT=4,T(3)=.254$
 .2 INCHES OF LEAD
 $ T(3)= .508$
 .3 INCHES OF LEAD
 $ T(3)= .762$
 .4 INCHES OF LEAD
 $ T(3)=1.016$
 .5 INCHES OF LEAD
 $ T(3)=1.27$
 .6 INCHES OF LEAD
 $ T(3)=1.524$
 .7 INCHES OF LEAD
 $ T(3)=1.778$
 .8 INCHES OF LEAD
 $ T(3)=2.032$
 .9 INCHES OF LEAD
 $ T(3)=2.286$
1.0 INCHES OF LEAD
 $ T(3)=2.54$
1.1 INCHES OF LEAD
 $ T(3)=2.794$
1.2 INCHES OF LEAD
 $ T(3)=3.048$
1.3 INCHES OF LEAD
 $ T(3)=3.302$
1.4 INCHES OF LEAD
 $ T(3)=3.556$
```

```
1.5 INCHES OF LEAD
 $ T(3)=3.810$
1.6 INCHES OF LEAD
 $ T(3)=4.064$
1.7 INCHES OF LEAD
 $ T(3)=4.318$
1.8 INCHES OF LEAD
 $ T(3)=4.572$
1.9 INCHES OF LEAD
 $ T(3)=4.826$
2.0 INCHES OF LEAD
 $ T(3)=5.08$
2.1 INCHES OF LEAD
 $ T(3)=5.334$
2.2 INCHES OF LEAD
 $ T(3)=5.588$
2.3 INCHES OF LEAD
 $ T(3)=5.842$
2.4 INCHES OF LEAD
 $ T(3)=6.096$
2.5 INCHES OF LEAD
 $ T(3)=6.35$
ENDE
 $NEXT=6$
```

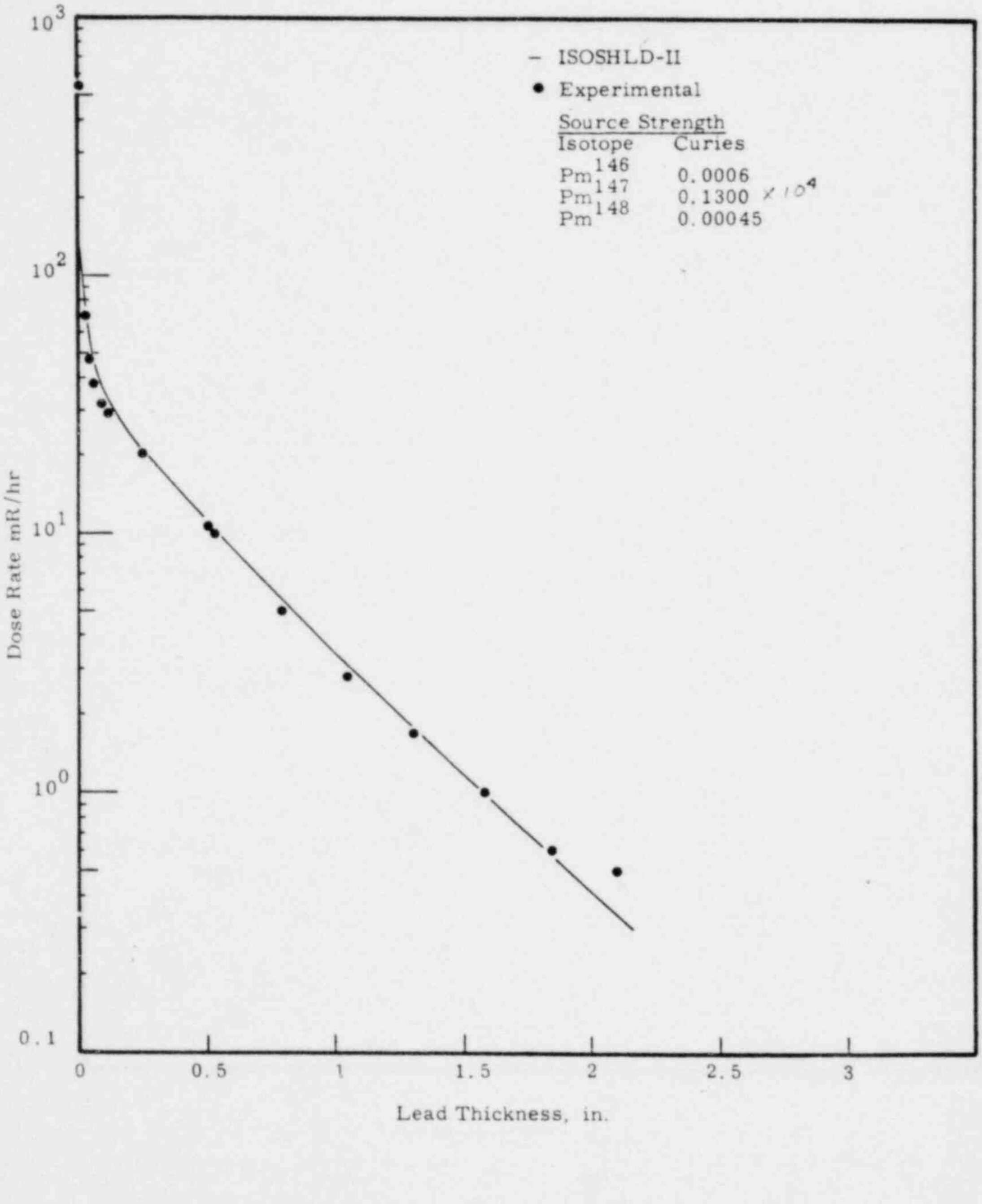

FIGURE A-5. Dose rate from Promethium Source with Varying Thicknesses of Lead Shielding

APPENDIX B

LIBRARIES

APPENDIX B

LIBRARIES

BETA END-POINT LIBRARY

These data[9] are used to calculate the total number of beta particles emitted with up to a given maximum (end-point) beta energy by a particular radioactive isotope. The first card in the library contains the number of beta end-point cards that are contained in the library (Columns 1-3). Following this card, there is one card for each isotope in the library. These isotopes are identical to the isotopes in the photon probability library described in BNWL-236. The beta end-point library format is as follows:

Column	Format	Variable
1-3	I3	Atomic Mass Number
4-5	I2	Atomic Number
6-9	A4	Isotope Name
10	I1	Number of maximum beta energies on the card
11-15	F5.0	Probability
16-20	F5.0	Maximum beta energy
21-25	F5.0	Probability
26-30	F5.0	Maximum beta energy
.	.	Continue alternating probability and maximum beta energy.
.	.	(Maximum of 6 each card.)
.	.	
77-79	I3	Card Number

PHOTON ATTENUATION LIBRARY

Three cards contain mass attenuation coefficients for each of the shielding materials in the library. The current materials in the library and their material numbers are:

1. Water
2. Tissue
3. Air
4. Hydrogen
5. Lithium
6. Carbon
7. Aluminum
8. Titanium
9. Iron
10. Nickel
11. Zirconium
12. Tin
13. Tungsten
14. Lead
15. Uranium
16. Ordinary Concrete
17. Magnetite Concrete
18. Strontium
19. Promethium
20. Curium

The card formats are as follows:

- Card #1

Card Column	Format	Variable
1-7	A7	Material Name
8-9	I2	Material Number
10	I1	Card Number -1
11-73	9F7.0	Attenuation Coefficients - Groups 1 - 9
74-75	I2	Effective Atomic Number
76-78	I3	Effective Atomic Weight

- Card #2

Card Column	Format	Variable
8-9	I2	Material Number
10	I1	Card Number -2
11-73	9F7.0	Attenuation Coefficients - Groups 10 - 18

- Card #3

Card Column	Format	Variable
8-9	I2	Material Number
10	I1	Card Number -3
11-59	7F7.0	Attenuation Coefficients - Groups 19 - 25

LOW ENERGY BUILDUP FACTOR LIBRARY

Three cards contain the buildup factor data for one effective atomic number value. The card format is as follows:

Card Column	Format	Variable
1-2	I2	Effective atomic number
3-4	I2	μx value for the first set of buildup factors.
5-6	I2	μx value for the second set of buildup factors.
7-36	5F6.3	Buildup factor data for 5 energies, first μx value.
37-66	5F6.3	Buildup factor data for 5 energies, second μx value.

```
500      BETA END POINT LIBRARY
7230ZN2 2 .05 1.6    .95  .3
7231GA2 6 .05 3.166 .05 2.529 .07 1.94  .07 1.508 .35  .959 .41  .67
7232GE2 0
7330ZN2 0
7331GA2 3 .02 1.48   .91 1.19  .07  .4
7332GE2 0
7431GA2 6 .03 4.3    .69 2.65  .1  2.27  .03 2.05  .04 1.84  .11 1.1
7432GE2 0
7531GA2 11.   1.01
7532GE1 0
7532GE2 5 .8651.19  .014 .98  .114 .92  .003 .72  .004 .55
7533AS2 0
7631GA2 11.   2.74
7632GE2 0
7633AS2 6 .5642.97  .3062.41  .0361.75  .0661.2   .009 .55  .019 .305
7634SE2 0
7732GE1 2 .46 2.9    .18 2.7
7732GE2 6 .14 2.27   .29 2.12  .24 1.56  .15 1.25  .15  .76  .03  .38
7733AS2 3 .944 .684 .028 .438 .028 .16
7734SE1 0
7734SE2 0
7832GE2 11.    .9
7833AS2 6 .47 4.27   .19 3.65  .0972.96  .0621.86  .14 1.6   .0431.455
7834SE2 0
7933AS2 11.   2.2
7934SE1 0
7934SE2 11.    .16
7935BR2 0
8033AS2 11.   6.
8034SE2 0
8035BR1 0
8035BR2 2 .78 2.0    .1381.38
8036KR2 0
8133AS2 11.   3.8
8134SE1 0
8134SE2 11.   1.4
8135BR2 0
8136KR2 11.    .3
8234SE2 0
8235BR2 11.    .444
8236KR2 0
8334SE1 2 .9  3.75  .1  1.75
8334SE2 21.   1.75
8335BR2 2 .8   .96
8336KR1 0
8336KR2 0
8434SE2 11.0   .49
```

```
8435BR1 3 .08 3.2    .72 1.9    .2    .8
8435BR2 6 .32 4.68   .14 3.83   .15 2.80   .0151.81   .16 1.185 .21  .665
8436KR2 0
8533AS2 11.0   1.25
8534SE2 11.0    .45
8535BR2 11.    2.5
8536KR1 2 .81   .824 .19   .305
8536KR2 2 .99   .672 .007 .15
8537RB2 0
8634SE2 11.0   1.76
8635BR2 11.0   3.23
8636KR2 0
8637RB1 0
8637RB2 2 .91 1.777 .09   .696
8638SR2 0
8734SE2 11.0   3.73
8735BR2 2 .[illegible]   8.      .7   2.6
8736KR2 3 .65 3.8     .1   3.3    .25 1.25
8737RB2 11.     .273
8738SR1 0
8738SR2 0
8835BR2 11.0   3.22
8836KR2 3 .2   2.7    .1    .9    .7    .52
8837RB2 3 .76 5.2    .04 3.4    .14 2.5
8838SR2 0
8935BR2 11.0  3.0
8936KR2 2 .65  3.9    .35 2.
8937RB2 6 .07  3.92   .05 2.87   .53 1.61   .05 1.25   .28   .67   .02   .4
8938SR2 11.    1.463
8939Y 1 0
8939Y 2 0
9035BR2 11.0  3.0
9036KR2 1 .5   3.2
9037RB2 5 .39  6.59   .21 5.81   .20 4.4    .10 2.21   .10 1.2
9038SR2 11.     .544
9039Y 1 0
9039Y 2 11.    2.27
9040ZR2 0
9136KR2 11.    3.6
9137RB1 11.    3.
9137RB2 11.    4.6
9138SR2 5 .27 2.67   .04 2.03   .29 1.36   .33 1.09   .07   .61
9139Y 1 0
9139Y 2 2 .9971.54   .003 .33
9140ZR2 0
9236KR2 11.0   2.73
9237RB2 11.0   2.97
9238SR2 2 .1   1.5    .9    .545
9239Y 2 3 .88 3.6    .03 1.75   .09 1.26
9240ZR2 0
[illegible]
```

```
9239Y 2 3 .88 3.6   .03 1.75  .09 1.26
9240ZR2 0
9336KR2 11.0  3.82
9337RB2 11.0  2.83
9338SR2 11.0  1.4
9339Y 2 6 .9  2.89  .0392.62  .03 1.95  .0091.47  .018 .71  .002 .45
9340ZR2 2 .75  .063 .25  .034
9341NB1 0
9341NB2 0
9436KR2 11.0  2.70
9437RB2 11.0  4.57
9438SR2 11.0  1.46
9439Y 2 11.   5.
9440ZR2 0
9441NB1 2 .0011.3  1.0   .50
9441NB2 11.    .5
9442MO2 0
9536KR2 11.0  4.57
9537RB2 11.0  3.58
9538SR2 11.0  2.72
9539Y 2 11.0  2.09
9540ZR2 4 .0041.13  .02  .885 .55  .396 .43  .36
9541NB1 0
9541NB2 2 .01  .93  .99  .16
9542MO2 0
9639Y 2 11.0  1.55
9640ZR2 0
9641NB2 2 .92  .7   .08  .37
9642MO2 0
9736KR2 11.0  4.20
9737RB2 11.0  4.39
9738SR2 11.0  3.57
9739Y 2 11.0  2.31
9740ZR2 3 .9  1.91  .1   .45
9741NB1 0
9741NB2 2 .99 1.267 .01  .93
9742MO2 0
9840ZR2 11.0  1.99
9841NB1 11.0  1.31
9841NB2 11.0  1.26
9842MO2 0
9940ZR2 11.0  1.55
9941NB2 11.   3.2
9942MO2 3 .85 1.23  .01  .87  .14  .45
9943TC1 0
9943TC2 11.    .292
9944RU2 0
10041NB2 11.0  3.39
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10042MO2 0                                                                 144
10043TC2 31.    3.37   .02 2.9    .02 2.2                                  145
10044RU2 0                                                                 146
10141NB2 11.0   1.03                                                       147
10142MO2 6 .1   2.23   .25 1.6    .11 1.2    .13  .8    .38  .7    .03  .6 148
10143TC2 2 .87  1.32   .06 1.07                                            149
10144RU2 0                                                                 150
10242MO2 11.0    .44                                                       151
10243TC2 11.    4.1                                                        152
10244RU2 0                                                                 153
10343TC2 11.0   2.5                                                        154
10344RU2 5 .03   .71   .005 .45   .001 .39   .89  .212 .07  .1             155
10345RH1 0                                                                 156
10345RH2 0                                                                 157
10442MO2 11.0   1.08                                                       158
10443TC2 11.    2.4                                                        159
10444RU2 0                                                                 160
10445RH1 0                                                                 161
10445RH2 3 .98  2.44   .0191.88   .001 .64                                 162
10446PD2 0                                                                 163
10542MO2 11.0   2.54                                                       164
10543TC2 11.0   2.09                                                       165
10544RU2 2 .5   1.18   .35 1.115                                           166
10545RH1 0                                                                 167
10545RH2 2 .9    .56   .1   .25                                            168
10546PD2 0                                                                 169
10644RU2 11.     .039                                                      170
10645RH1 11.0    .7                                                        171
10645RH2 5 .78  3.54   .08 3.     .13 2.2    .0071.4    .0051.1            172
10646PD2 0                                                                 173
10743TC2 11.0   2.73                                                       174
10744RU2 3 .79  4.     .09 3.8    .12 3.                                   175
10745RH2 3 .84  1.2    .13 1.1    .03  .9                                  176
10746PD2 11.     .035                                                      177
10747AG2 0                                                                 178
10844RU2 2 .64  1.5    .36 1.3                                             179
10845RH2 4 .38  4.5    .17 4.1    .11 3.6    .28 3.5                       180
10846PD2 0                                                                 181
10847AG1 0                                                                 182
10847AG2 2 .9381.65    .0191.02                                            183
10848CD2 0                                                                 184
10945RH2 11.0   1.16                                                       185
10946PD1 0                                                                 186
10946PD2 11.    1.025                                                      187
10947AG1 0                                                                 188
10947AG2 0                                                                 189
11046PD2 0                                                                 190
11047AG1 3 .33   .53   .65   .085 .02                                      191
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11047AG2 3 .95 2.87  .05 2.21                                                  192
11048CD2 0                                                                     193
11146PD1 1 .04  .61                                                            194
11146PD2 11.    2.13                                                           195
11147AG1 0                                                                     196
11147AG2 3 .9271.05  .011 .79  .062 .69                                        197
11148CD1 0                                                                     198
11148CD2 0                                                                     199
11246PD2 11.    .28                                                            200
11247AG2 6 .56 4.04  .18 3.42  .0532.643 .0592.105 .1441.49  .009 .71          201
11248CD2 0                                                                     202
11346PD2 11.    3.3                                                            203
11347AG1 1 .10 2.0                                                             204
11347AG2  1.    2.                                                             205
11348CD1 1 .999 .575                                                           206
11348CD2 0                                                                     207
11349IN2 0                                                                     208
11446PD2 11.    1.4                                                            209
11447AG2 11.    4.6                                                            210
11448CD2 0                                                                     211
11449IN1 0                                                                     212
11449IN2 2 .9891.984 .002 .67                                                  213
11546PD2 11.0  1.91                                                            214
11547AG1                                                                       215
11547AG2 11.    2.9                                                            216
11548CD1 4 .9671.63  .02  .687 .01  .335 .003 .2                               217
11548CD2 4 .6211.11  .009 .85  .126 .63  .244 .59                              218
11549IN1 1 .055 .84                                                            219
11549IN2 11.    .5                                                             220
11550SN2 0                                                                     221
11646PD2 11.0   .93                                                            222
11647AG2 11.    5.                                                             223
11648CD2 0                                                                     224
11649IN1 4 .42 1.    .38  .87  .18  .6   .02  .34                              225
11649IN2 11.    3.29                                                           226
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11747AG2 11.0  1.63                                                            228
11748CD1 11.0  1.0                                                             229
11748CD2 21.0  2.3  1.0  1.8                                                   230
11749IN1 3 .53 1.77  .23 1.62  .04  .95                                        231
11749IN2 11.    .74                                                            232
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11750SN2 0                                                                     234
11848CD2 11.    .8                                                             235
11849IN2 2 .8  4.5   .2  3.3                                                   236
11850SN2 0                                                                     237
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11948CD2 11.0  1.44                                                            239
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11949IN2 11.   4.4
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12149IN2 11.   2.9
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12150SN2 11.    .383
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12252TE2 0
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12550SN2 5 .95 2.33  .0131.3   .001 .93  .015 .47  .021 .37
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12552TE1 0
12552TE2 0
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12753I 2 0
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12851SB2 11.   2.9
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12854XE2 0
12951SB2 3 .20 1.87  .46 1.45  .10 1.0
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12954XE2 0                                               291
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13054XE2 0                                               296
13151SB2 11.   1.33                                      297
13152TE1 4 .0472.46  .046 .98  .17  .57  .52  .42        298
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13153I 2 4 .007 .81  .876 .606 .093 .33  .028 .25        300
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13154XE2 0                                               302
13251SB2 11.   2.68                                      303
13252TE2 11.    .22                                      304
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13254XE2 0                                               306
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13352TE2 11.   2.4                                       309
13353I 2 1 .94 1.4                                       310
13354XE1 0                                               311
13354XE2 2 .99  .347 .01  .266                           312
13355CS2 0                                               313
13451SB2 11.   3.45                                      314
13452TE2 11.   1.4                                       315
13453I 2 2 .30 2.5   .70 1.5                             316
13454XE2 0                                               317
13455CS1 1 .01  .55                                      318
13455CS2 3 .66  .654 .03  .41  .27  .086                 319
13456BA2 0                                               320
13551SB2 11.   3.16                                      321
13552TE2 11.   2.68                                      322
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13554XE1 0                                               324
13554XE2 2 .97  .91  .03  .55                            325
13555CS2 11.    .21                                      326
13556BA1 0                                               327
13556BA2 0                                               328
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13654XE2 0                                               330
13655CS2 2 .074 .657 .926 .341                           331
13656BA2 0                                               332
13753I 2 11.   2.19                                      333
13754XE2 11.   3.5                                       334
13755CS2 2 .0461.18  .954 .518                           335
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13756BA2 0                                                                                   337
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13854XE2 11.    2.4                                                                          339
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13953I 2 11.    2.4                                                                          342
13954XE2 11.    2.0                                                                          343
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13956BA2 3 .71  2.34   .29 2.17   .003 .96                                                   345
13957LA2 0                                                                                   346
14054XE2 11.    1.09                                                                         347
14055CS2 11.    6.                                                                           348
14056BA2 4 .6   1.01   .05  .9    .1   .6    .25  .48                                        349
14057LA2 5 .07  2.2    .1   1.71  .45 1.38   .26 1.1    .12  .83                             350
14058CE2 0                                                                                   351
14154XE2 11.    2.36                                                                         352
14155CS2 11.    1.72                                                                         353
14156BA2 11.    2.8                                                                          354
14157LA2 2 .98  2.43   .02  .98                                                              355
14158CE2 2 .3    .58   .7   .435                                                             356
14159PR2 0                                                                                   357
14254XE2 11.    1.70                                                                         358
14255CS2 11.    2.98                                                                         359
14256BA2 11.    0.78                                                                         360
14257LA2 5 .39  4.5    .3   3.9   .14 2.1    .04 1.2    .14  .9                              361
14258CE2 0                                                                                   362
14259PR2 2 .96  2.15   .04  .58                                                              363
14260ND2 0                                                                                   364
14354XE2 11.    2.91                                                                         365
14355CS2 11.    2.32                                                                         366
14356BA2 11.    3.5                                                                          367
14357LA2 11.    3.2                                                                          368
14358CE2 6 .02  1.44   .37 1.38   .4  1.09   .05  .72   .12  .52   .06  .22                  369
14359PR2 11.    7.6                                                                          370
14360ND2 0                                                                                   371
14454XE2 11.    2.19                                                                         372
14455CS2 11.    3.50                                                                         373
14456BA2 11.    1.0                                                                          374
14457LA2 11.    1.23                                                                         375
14458CE2 3 .65   .320  .05  .245  .30  .184                                                  376
14459PR2 3 .95  3.15   .03 2.45   .02  .9                                                    377
14460ND2 0                                                                                   378
14558CE2 11.    2.                                                                           379
14559PR2 1 .95  1.8                                                                          380
14560ND2 0                                                                                   381
14658CE2 11.     .7                                                                          382
14659PR2 2 .56  3.7    .44 2.3                                                               383
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14759PR2 11.    1.12                                                          386
14760ND2 3 .77  .81  .2   .368 .03  .212                                      387
14761PM2 11.     .225                                                         388
14762SM2 11.    2.19                                                          389
14858CE2 11.    0.95                                                          390
14859PR2 11.    2.17                                                          391
14860ND2 0                                                                    392
14861PM1 2 .13 1.9   .87 1.                                                   393
14861PM2 6 .4  2.33  .04 1.14  .15  .74  .09  .42  .14  .21  .33  .125        394
14862SM2 0                                                                    395
14960ND2 3 .50 1.5   .30 1.1   .20 0.95                                       396
14961PM2 4 .89 1.064 .1   .784 .003 .47  .006 .19                             397
14962SM2 0                                                                    398
15060ND2 0                                                                    399
15062SM2 0                                                                    400
15160ND2 6 .45 2.06  .15 1.82  .07 1.65  .30 1.19  .03  .54  .01  .24         401
15161PM2 11.    1.1                                                           402
15162SM2 2 .983 .075 .017 .053                                                403
15163EU2 0                                                                    404
15261PM2 11.    2.2                                                           405
15262SM2 0                                                                    406
15263EU1 3 .74 1.87  .02 1.55  .016 .56                                       407
15263EU2 5 .0751.47  .0181.04  .12  .71  .027 .36  .02  .22                   408
15264GD2 0                                                                    409
15361PM2 11.     .62                                                          410
15362SM2 4 .22  .803 .4   .698 .38  .64  .001 .13                             411
15363EU2 0                                                                    412
15461PM2 11.    1.                                                            413
15462SM2 0                                                                    414
15463EU2 6 .1  1.85  .04  .96  .12  .83  .36  .57  .32  .25  .06  .15         415
15464GD2 0                                                                    416
15562SM2 2 .93 1.65  .07 1.5                                                  417
15563EU2 4 .2   .25  .1   .19  .4   .16  .3   .15                             418
15564GD2 0                                                                    419
15662SM2 11.     .9                                                           420
15663EU2 3 .40 2.455 .40 1.22  .20  .50                                       421
15664GD2 0                                                                    422
15763EU2 2 .25 1.7   .75 1.                                                   423
15764GD2 0                                                                    424
15863EU1 1 .5  2.6                                                            425
15864GD2 0                                                                    426
15963EU2 11.     .86                                                          427
15964GD2 3 .74  .948 .06  .89  .2   .59                                       428
15965TB2 0                                                                    429
16063EU2 11.    1.5                                                           430
16064GD2 0                                                                    431
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16164GD2 3 .91 1.6   .05 1.54  .04 1.44
16165TB2 4 .6   .54  .12  .49  .11  .46  .17  .41
16166DY2 0
16264GD2 11.    .34
16265TB2 11.   1.68
16266DY2 0
16365TB2 11.   1.22
16366DY2 0
16466DY2 0
16566DY1 1 .03  .84
16566DY2 4 .85 1.28  .13 1.19  .014 .29  .001 .21
16567HO2 0
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16668ER2 0
16768ER1 0
16768ER2 0
 14 6C 2 11.    .158
 16 7N 2 4 .26 10.4  .68 4.3   .05 3.29  .01 1.53
 2411NA2 11.   1.39
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 2712MG2 2 .58 1.75  .42 1.59
 2813AL2 11.   2.868
 2913AL2 2 .9382.5   .0621.33
 3114SI2 21.   1.477 .001 .21
 3215P 2 11.   1.708
 3516S 2 11.    .167
 4520CA2 11.    .254
 4621SC2 11.    .357
 4721SC2 2 .3   .6   .7   .44
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 5425MN2 0
 5524CR2 11.   2.85
 5526FE2 0
 5624CR2 11.   1.5
 5625MN2 4 .6  2.86  .24 1.05  .15  .75  .01  .33
 5827CO2 0
 5926FE2 4 .0031.56  .54  .462 .46  .271 .01  .13
 6027CO2 11.    .313
 6429CU2 1 .38  .573
 6530ZN2 0
 6930ZN2 11.    .9
14661PM2 1 .35  .779
17169TM2 2 .98  .098 .02  .031
18774W 2 3 .2  1.315 .7   .63  .1   .34
19879AU2 2 .99  .959 .01  .29
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20982PB2 11.      .635                                                  482
21083BI2 11.     1.155                                                  483
21084PO2 0                                                              484
22688RA2 0                                                              485
22788RA2 31.     1.31  .04 1.02  .006 .81                               486
22789AC2 3 .55    .042 .35   .034 .10   .019                            487
22888RA2 11.0     .055                                                  488
23390TH2 1 .87 1.245                                                    489
23391PA2 5 .05    .568 .36   .528 .18   .246 .18   .169 .22   .152      490
23792U 2 6 .001 .515 .01   .412 .95   .247 .05   .183 .5    .144        491
23894PU2 0                                                              492
23994PU2 0                                                              493
24094PU2 0                                                              494
24194PU2 11.      .021                                                  495
24195AM2 0                                                              496
24294PU2 0                                                              497
24295AM1 0                                                              498
24295AM2 2 .34    .667 .50   .625                                       499
24496CM2 0                                                              500
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          13  .0537  .0505  .0480  .0457  .0436  .0418  .0395                     3
TISSUE    21 2.5497  .4690  .2920  .2320  .2060  .1910  .1800  .1720  .1660 4  6 4
          22  .1455  .1225  .1080  .0995  .0835  .0750  .0685  .0615  .0555       5
          23  .0520  .0493  .0465  .0443  .0425  .0418  .0395                     6
AIR       31 3.4220  .5060  .2710  .2100  .1860  .1738  .1653  .1585  .1535 7 14 7
          32  .1334  .1140  .1015  .0915  .0865  .0695  .0635  .0573  .0515       8
          33  .0478  .0450  .0425  .0407  .0387  .0370  .0339                     9
H         41  .3770  .3630  .3510  .3400  .3305  .3223  .3126  .3053  .2978 1  110
          42  .2650  .2440  .1975  .1750  .1570  .1385  .1260  .1125  .1025      11
          43  .0950  .0892  .0635  .0600  .0765  .0730  .0688                    12
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          52  .1150  .0990  .0880  .0775  .0685  .0605  .0550  .0505  .0447      14
          53  .0420  .0390  .0375  .0360  .0350  .0335  .0304                    15
CARBON    61 1.4520  .3055  .2110  .1855  .1735  .1660  .1600  .1550  .1510 6 1216
          62  .1350  .1150  .1015  .0915  .0665  .0695  .0635  .0573  .0515      17
          63  .0478  .0450  .0425  .0407  .0387  .0370  .0339                    18
AL        71 17.907 2.1100  .7610  .4055  .3555  .2308  .2003  .1788  .166313 2719
          72  .1340  .1280  .0990  .0668  .0755  .0676  .0615  .0553  .0498      20
          73  .0467  .0438  .0414  .0390  .0375  .0365  .0357                    21
TI        81 37.000 10.617 3.6200 1.7050  .9800  .6698  .4893  .3673  .303822 4822
          82  .1630  .1200  .0970  .0840  .0730  .0640  .0585  .0530  .0478      23
          83  .0455  .0435  .0410  .0400  .0390  .0375  .0350                    24
IRON      91 44.165 12.277  5.685  2.635  1.455  .9710  .6930  .5023  .398826 5625
          92  .2040  .1370  .0998  .0875  .0720  .0637  .0588  .0513  .0470      26
          93  .0446  .0415  .0402  .0381  .0378  .0366  .0355                    27
NICKEL   101 47.543 13.170  7.535  3.500  1.970  1.316  .9265  .6603  .516828 5928
         102  .2210  .1400  .1100  .0880  .0780  .0680  .0614  .0610  .0500      29
         103  .0485  .0445  .0430  .0420  .0410  .0380  .0372                    30
ZR       111 47.267 12.190 10.71   7.342  4.559  2.999  2.082  1.510  1.13540 9131
         112  .3780  .1950  .1200  .0905  .0750  .0640  .0579  .0540  .0468      32
         113  .0440  .0425  .0405  .0400  .0395  .0380  .0363                    33
SN       121 87.223 13.670  8.748  8.166  6.125  4.607  3.273  2.399  1.8155011934
         122  .6400  .2200  .1300  .0935  .0720  .0620  .0550  .0490  .0445      35
         123  .0415  .0405  .0390  .0380  .0365  .0365  .0360                    36
W        131 94.667 36.000 12.890  6.230  3.485  3.016  3.313  3.241  3.1347418437
         132  1.477  .4399  .2750  .1450  .0950  .0775  .0655  .0600  .0498      38
         133  .0480  .0450  .0440  .0435  .0430  .0420  .0408                    39
LEAD     141 72.317 47.750 17.000  8.115  4.640  3.077  2.133  2.211  2.5168220740
         142  1.379  .5590  .3065  .1775  .1280  .0875  .0726  .0618  .0534      41
         143  .0488  .0463  .0443  .0428  .0419  .0413  .0411                    42
URANIUM151 95.850 51.550 23.100 11.050  6.260  4.105  2.850  1.988  1.5039223843
         152  2.116  .7174  .3880  .2275  .1370  .0995  .0815  .0670  .0560      44
         153  .0515  .0483  .0462  .0450  .0441  .0436  .0432                    45
ORDINAR161 21.533  3.506  .9744  .6746  .4345  .3315  .2703  .2280  .204610 1946
CONCRET162  .1780  .1280  .0990  .0690  .0860  .0750  .0637  .0610  .0550      47
```

	163	.0520	.0460	.0440	.0430	.0410	.0395	.0336			48
MAGNETI	171	28.073	7.901	2.994	1.364	.7915	.5368	.3891	.2877	.232512	2449
CONCRET	172	.1800	.1220	.0945	.0870	.0830	.0750	.0618	.0600	.0550	50
	173	.0520	.0470	.0430	.0420	.0410	.0395	.0364			51
STRONT	181	24.755	16.026	11.080	6.017	3.575	2.311	1.593	1.154	.871038	8852
	182	.3360	.1600	.1109	.0875	.0724	.0623	.0569	.0547	.0466	53
	183	.0439	.0417	.0401	.0391	.0381	.0370	.0355			54
PROMETH	191	71.000	21.000	7.430	6.296	5.705	5.367	4.738	3.839	2.9926114555	
	192	.9418	.3550	.1815	.1153	.0849	.0682	.0605	.0546	.0481	56
	193	.0454	.0433	.0419	.0412	.0404	.0396	.0385			57
CURIUM	201	48.000	39.800	20.450	7.430	12.800	7.210	3.270	2.270	1.7109624558	
	202	1.477	.7998	.4250	.2330	.1440	.1020	.0848	.0735	.0610	59
	203	.0566	.0535	.0516	.0507	.0499	.0491	.0478			60

```
LOW ENERGY BUILDUP FACTOR LIBRARY
13 1 2 1.007 1.058 2.060 2.820 2.710 1.014 1.110 3.190 5.640 5.350
13 4 7 1.027 1.210 4.870 12.90 13.20 1.043 1.340 9.390 40.60 45.30
131015 1.058 1.450 14.30 91.00 117.0 1.078 1.590 24.00 245.0 345.0
1320   1.095 1.720 34.80 457.  718.
26 1 2 1.001 1.007 1.086 1.350 1.710 1.002 1.013 1.160 1.670 2.620
26 4 7 1.004 1.024 1.270 2.280 4.880 1.006 1.037 1.390 3.070 9.250
261015 1.008 1.047 1.480 3.830 14.80 1.011 1.060 1.600 5.040 24.20
2620   1.013 1.070 1.700 6.250 37.3
50 1 2 1.002 1.009 1.013 1.054 1.200 1.003 1.017 1.023 1.093 1.350
50 4 7 1.006 1.031 1.038 1.150 1.580 1.009 1.048 1.054 1.200 1.870
501015 1.012 1.062 1.065 1.250 2.110 1.016 1.080 1.078 1.300 2.460
5020   1.021 1.094 1.089 1.350 2.76
74 1 2 1.001 1.003 1.030 1.019 1.073 1.001 1.006 1.054 1.033 1.120
74 4 7 1.002 1.012 1.090 1.052 1.190 1.004 1.018 1.130 1.073 1.260
741015 1.005 1.023 1.160 1.090 1.320 1.006 1.030 1.190 1.120 1.390
7420   1.008 1.035 1.220 1.15  1.450
82 1 2 1.000 1.002 1.022 1.018 1.055 1.001 1.005 1.039 1.033 1.091
82 4 7 1.002 1.009 1.066 1.062 1.140 1.003 1.013 1.093 1.100 1.200
821015 1.004 1.017 1.110 1.140 1.230 1.005 1.022 1.140 1.220 1.290
8220   1.006 1.026 1.160 1.300 1.330
92 1 2 1.000 1.002 1.016 1.058 1.042 1.001 1.004 1.029 1.100 1.069
92 4 7 1.001 1.006 1.048 1.160 1.110 1.002 1.010 1.069 1.230 1.150
921015 1.003 1.013 1.083 1.280 1.180 1.004 1.017 1.100 1.340 1.230
9220   1.004 1.020 1.120 1.390 1.280
```

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H. S. Zwibel
Technical Files (5)
Technical Publications (2)

6. Criticality Evaluation

Not Applicable.

7. Operating Procedures

The procedures for loading and unloading will follow those already presented in the original SAR for the SN-1 licensing package with the additional step for removal of the insert plug. These steps are shown in section 7.1 The loading, unloading and preparation of an empty package for transport will be accomplished in accordance with Three Mile Island Nuclear Station Health Physics Procedures 1618 A and D, where applicable.

7.1 Procedures for Loading the Package

7.1.1 Remove upper impact limiter from cask by removing four hold-downs and lifting with crane.

7.1.2 Remove closure head by loosening and removing 24 nuts.

7.1.3 Remove concrete insert plug.

7.1.4 Using the bell and alignment plate, place liner in cask.

7.1.5 If liner has attached sling, assure it is easily accessible for unloading.

7.1.6 Replace concrete insert plug.

7.1.7 Replace closure head and torque to 200 - 450 foot pounds.

7.1.8 Replace upper impact limiter and bolt down.

7.1.9 Insure cask is secure and properly labeled; the truck and trailer have been inspected and properly placarded, and all applicable forms have been properly completed in accordance with station Health Physics Procedures 1618 A and D.

7.2 Procedures for Unloading the Package

7.2.1 Complete steps 7.1.1 and 7.1.2 above.

7.2.2 Using slings or lifting bar or shield bell remove liner from cask.

7.2.3 Complete steps 7.1.6 and 7.1.9 above.

7.3 Preparation of an Empty Package for Transport

7.3.1 This procedure is fully covered in Three Mile Island Nuclear Station Health Physics Procedure 1618 A and D, Section 7.4 Appendix.

7.4 Appendix

7.4.1 Three Mile Island Nuclear Station Health Physics Procedure 1618 A.

7.4.2 Three Mile Island Nuclear Station Health Physics Procedure 1618 D.

7.4.3 OQA Checklist 1618 A.

"TEMPORARY CHANGE" Disposal Group

AP 1001

Figure 1001 - 5

NOTE: Instructions and guidelines in AP 1001 must be followed when completing this form.

Three Mile Island Nuclear Station
Temporary Change Notice (TCN)

SIDE 1

TCN NO. 2-81-357 (From TCN Log Index)

Unit No. II

Date ~~10-8-81~~ 11-6-81

1. Procedure U-2 RCP 1618A (No.) Radioactive Material Shipping (Title)

2. Change (Include page numbers, paragraph numbers, and exact wording of change.)
Delete Present Attachment 4 Page 82 add New Attachment 4 Pages 82.0 and 82.1 that are here to attached
– see attached page for additional change

3. Reason for Change:
To Consolidate Radioactive Material Shipment data.

4. Recommended by W. D. Love 10-8-81 (Date)   5. [signature] (Supervisor's Signature) 10/15/81 (Date)

6. Duration of TCN - No longer than ninety days from effective date of TCN or as in (a) or (b) below whichever occurs first.

(a) TCN will be cancelled by a procedure revision issued as a result of a Procedure Change Request to be submitted by L Zehnor (Supervisor Submitting TCN) (Submit PCR as soon as possible) ☒

(b) TCN is not valid after ______ (fill in circumstances which will result in TCN being cancelled) ☐

7. (a) Is the procedure on the Nuclear Safety Related Procedure List? (Sec. AP 1001 – Appendix B)
If "Yes", complete Nuclear Safety Evaluation. (Side 2 of this Form) Yes ☒ No ☐

(b) Is the procedure on the Environmental Impact Procedure List? (Sec. AP 1001 – Appendix B)
If "Yes", complete Environmental Evaluation. (Side 2 of this Form) Yes ☐ No ☒

(c) Does the change effect the intent of the original procedure? Yes ☐ No ☒

NOTE: If all answers are "no" the change may be approved by the Shift Supervisor. If question (c) is answered "yes", the change must be reviewed by the PORC and approval by the Station/Unit Superintendent prior to implementation. If the answer to question (c) is "no" the change may be approved by two members of the plant management staff at least one of whom holds a senior reactor operators license on the unit affected in accordance with paragraph 3.6.4.2 of AP 1001.

8. Review and Approval

Block (c) "yes"

Approved [signature] (Shift Supervisor/Foreman) 11-6-81 (Date)

Reviewed ______

Members Of PORC ______

Contacted [signature] (PORC Members) 10/23/81 (Date)

Approved [signature] (Unit Superintendent) 10/23/81 (Date)

Block (c) "no"

Approved ______ (SRO License) ______ (Date)

C P [signature] (Member Plant Mrg. Staff) 10/13/81 (Date)

Reviewed ______ (Chairman of PORC) ______ (Date)

Approved ______ (Unit Superintendent) ______ (Date)

NRC: L A Barrett 10/29/81

NOTE: The block (c) "Yes" review and approval chain may be followed at anytime.

9. Approval
Manager, Generation Quality Assurance [signature] Date 11/3/81

NOTE: M.G.Q.A. approval required only on certain Administrative Procedures listed in Enclosure 7 of AP 1001

10. TCN is Cancelled ______ (Shift Supervisor/Shift Foreman) ______ (Date)

TMI 56 Rev. 8.77

"EVALUATION"

AP-1001 | Three Mile Island Nuclear Station | SIDE 2

Figure 1001-4 | Nuclear Safety/Environmental Impact Evaluation

1. Procedure 4.2 RCP 1618A (No.) | Radioactive Material Shipping (Title) | 2-81-357 (Temporary Change Notice No.)

2. Nuclear Safety Evaluation

Does the attached procedure change:

* (a) increase the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety? . . . . . yes ☐ no ☒
* (b) create the possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report? . . . . . yes ☐ no ☒
* (c) reduce the margin of safety as defined in the basis for any technical specification? . . . . . yes ☐ no ☒

Details of Evaluation (Explain why answers to above questions are "no". Attach additional pages if required.)

Changes are editorial and do not affect nuclear safety

Evaluation By [signature] Date 10/15/81

3. Environmental Impact Evaluation

Does the attached procedure change:

(a) possibly involve a significant environmental impact? . . . . . yes ☐ no ☐
(if 3(a) is "yes", answer questions (b) and (c) and fill in "Details of Evaluation" below. If "no", state why by filling in the "Details of Evaluation" below) . . . . . yes ☐ no ☐

* (b) have a significant adverse effect on the environment? . . . . . yes ☐ no ☐
* (c) involve a significant environmental matter or question not previously reviewed and evaluated by the N.R.C. . . . . . yes ☐ no ☐

Details of Evaluation (Attach additional pages if required)

N/A

Evaluation By ______________ Date __________

4. Unit Superintendent requests PORC review ☐ Check if YES.

5. Approval

Evaluation Accompanying PCR

______________ Unit Superintendent ______ Date

Evaluation Accompanying TCN

Approval [signature] (SRO Licensee) 11-6-81 (Date)

Reviewed [signature] (Member of Plant Staff) 10/23/81 (Date)

Approval [signature] (Unit Superintendent) 11/6/81 (Date)

NOTE: The Evaluation "Accompanying a PCR" evaluation and approval chain may be followed at anytime.

CURIE CALCULATION AND SHIPPING CONTAINER SURVEY
(CONTINUED)

Container Number	Contamination dpm/100 cm		Dose Rate mr/hr			Conversion Factor	Millicurie	Label Type	Gross Wt.	Date Shipped	Inspection Performed by
	βγ	α	contact								
			Avg	Hi	3 ft						

Page Totals

CURIE CALCULATION AND SHIPPING CONTAINER SURVEY

Container Number	Contamination dpm/100 cm		Dose Rate mr/hr			Conversion Factor	Millicurie	Label Type	Gross Wt.	Date Shipped	Inspection Performed by
	βγ	α	contact Avg	contact Hi	3 ft						

Surveyed by: ____________________

Date: ____________________

Inspected by: ____________________

Date: ____________________

Torque Wrench Data

Serial No. ____________

CAl. Due Date ____________

FOR USE IN UNIT II ONLY

1618A
Revision 6
09/07/81

THREE MILE ISLAND NUCLEAR STATION
UNIT NO. 2 RADIOLOGICAL CONTROL PROCEDURE 1618A
RADIOACTIVE MATERIAL SHIPPING

CONTROLLED COPY FOR
USE IN UNIT II ONLY

Disposal Group

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3.0	6	26.0	6	50.0	6	73.0	6
4.0	6	27.0	6	51.0	6	74.0	6
5.0	6	28.0	6	52.0	6	75.0	6
6.0	6	29.0	6	53.0	6	76.0	6
7.0	6	30.0	6	54.0	6	77.0	6
8.0	6	31.0	6	55.0	6	78.0	6
9.0	6	32.0	6	56.0	6	79.0	6
10.0	6	33.0	6	57.0	6	80.0	6
11.0	6	34.0	6	58.0	6	81.0	6
12.0	6	35.0	6	59.0	6	82.0	6
13.0	6	37.0	6	60.0	6	83.0	6
14.0	6	38.0	6	61.0	6	84.0	6
15.0	6	39.0	6	62.0	6	85.0	6
16.0	6	40.0	6	63.0	6	86.0	6
17.0	6	41.0	6	64.0	6	87.0	6
18.0	6	42.0	6	65.0	6	88.0	6
19.0	6	43.0	6	66.0	6	89.0	6
20.0	6	44.0	6	67.0	6	90.0	6
21.0	6	45.0	6	68.0	6	91.0	6
22.0	6	46.0	6	69.0	6	92.0	6
23.0	6	47.0	6	70.0	6		

Unit 2 Staff Recommends Approval

Approval C. P. Deltete Date 7/14/81
Cognizant Dept. Head

Unit 2 PORC Recommends Approval

[signature] Date 7/28/81
Chairman of PORC

Unit 2 Superintendent Approval

[signature] Date 8/24/81

Mgr QA Approval
[signature] Date 8/21/81

NRC Approval
[signature] Date 8/19/81

Effective Date: 09/07/81

Document ID: 0122q

FOR USE IN UNIT II ONLY

THREE MILE ISLAND NUCLEAR STATION
UNIT 2 RADIOLOGICAL CONTROL PROCEDURE 1618A
RADIOACTIVE MATERIAL SHIPPING

1.0 PURPOSE

To delineate responsibilities and set forth requirements and methods for the shipment of radioactive material packaged in accordance with the requirements of 10 CFR 71 and 49 CFR 171-178.

2.0 DISCUSSION

The NRC, Department of Transportation and other federal agencies have jurisdiction over the transportation of radioactive materials. The transportation of radioactive materials from the TMI site will be either by rail, air or highway. All the regulations reflect the standards set by the DOT, since the materials usually have to be handled by ground transportation at one time or another. The transportation of radioactive material in interstate commerce is controlled by the Public Utilities Commission of the various states. In Pennsylvania, transportation is controlled by the Pennsylvania Hazardous Substances Transportation Board. In general, the regulations follow the standards set forth by the DOT. In addition to the Federal and State Regulations governing the transportation of radioactive material, there are regulations imposed by various city, county, turnpike, and port authority governing bodies.

3.0 REFERENCES

3.1 49 CFR Part 171-178, Transportation.

3.2 10 CFR 71, Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions.

3.3 10CFR 30.41 Transfer of By Product Material.

3.4 Pennsylvania Department of Transportation Regulation.

FOR USE IN UNIT II ONLY

3.5 Publication 6, U.S. Postal Service.

3.6 Procedure 1618D - Packaging of Radioactive Material

3.7 Attachment (1) - Driver's Instruction Handout.

3.8 Attachment (5) - Shipments to Richland, Washington.

3.9 Attachment (6) - Shipments to Barnwell, South Carolina.

4.0 EQUIPMENT

4.1 HP survey equipment (instrumentation, forms, etc.).

4.2 DOT labels and placards.

4.3 Radioactive material shipping and receiving forms - Attachment (3)

4.4 Radioactive material shipment checklist - Attachment (2)

4.5 Vehicle inspection checklist - Attachment (4) Special Forms

5.0 DEFINITIONS

5.1 Unit II Site Ops - TMI Unit II Site Operations Organization

5.2 Rad-Con - Radiological Controls Department/Technicians

5.3 RMC - Radioactive Material Coordinator within the Unit II Site Operations.

5.4 Exclusive use (sole use) - shipments that are loaded at the site and is not unloaded (or the cargo shifted in any way) until it has reached its final destination. No other commodity can be shipped with the radioactive material.

5.5 Mixed Lading - shipments of radioactive material which are or can be shipped on the same vehicle or temporarily stored at a terminal with other commodities.

5.6 Special Form - encapsulated radioactive materials which will withstand a series of tests described in 49 CFR 173.398(a).

5.7 Normal Form - any radioactive material which isn't in special form, essentially all of the radioactive material shipped from the site.

5.8 Transport Group - a classification of radionuclides into groups according to their potential hazard. Limits for shipping are established for groups rather than individual radionuclides.

5.9 Low Specific Activity (LSA) - radioactive material which meets the criteria as specified in 49 CFR 173.392 (c)(1) thru (c) (5).

5.10 Limited Quantity, Type A, Type B and Large Quantities: When material does not qualify as LSA, then it must be shipped under the more restrictive sections of reference 3.1 and 3.2 which specify the appropriate restrictions according to the quantity of radioactive material in each package. The limits are in curies and associated with the Transport Group. The maximum curie content for each type of package is as follows:

Transport Group	Limited Quantity (Ci)	Type A Quantity(Ci)	Type B Quantity(Ci)	Large Quantity (Ci)
I	0.00001	0.001	20	>20
II	0.0001	0.05	20	>20
III	0.001	3.0	200	>200
IV	0.001	20	200	>200

5.11 Transportation Index: a classification which identifies the radiation levels being emitted from a package. The Transportation Index (T.I.) is the highest radiation level measured at a distance of three feet from any surface of the package in mRem/hr.

6.0 FUNCTIONS AND RESPONSIBILITIES

6.1 The TMI Unit II Site Operations Organization is ultimately responsible for ensuring all radioactive material shipments from and receipt at TMI are in accordance with the requirements of the applicable regulatory agencies. Final approval for release of radioactive material from the TMI site boundary must be granted by one of the following individuals or their alterantes, as designated in writing:

6.1.1. Manager, Radwaste Processing Support.

6.1.2. Supervisor, Waste Disposal.

6.1.3. Director, Site Operations.

6.1.4 Supervisor, Tech. Spec. Compliance.

6.2 The Radioactive Material Coordinator (RMC) is responsible for:

6.2.1 Coordination of all movement of radioactive material outside of the protected area boundary and offsite.

6.2.2 Ensuring the requirements of References 3.0 - 3.6 are satisfied for all shipments of radioactive material.

6.2.3 Safe storage of radioactive material outside of areas controlled by Health Physics.

6.2.4 Coordination of activities associated with shipping, packaging, movement and storage of radioactive material with the TMI site Rad Waste Staff.

6.2.5 Perform load inspection as identified in Section 7.3.2 of this procedure.

6.2.6 Answer inquiries regarding the requirements of Reference 3.1 and 3.2.

6.2.7 Perform Curie Estimates in accordance with Procedure 1655.

6.3 Radiological Controls (Rad-Con) is responsible for:

6.3.1 Identification, accountability, control of radioactive material from receipt/generation to final disposition and to:

1. Minimize personnel radiation exposure.
2. Prevent the uncontrolled release of radioactivity.
3. Ensure effective HP monitoring controls.
4. Establish the radiological condition of radioactive material being received by or being shipped from TMI.

6.3.2. The specific duties associated with this responsibility shall include, but are not limited to:

1. Monitoring and tagging radioactive material.
2. Escorting radioactive material transfers.
3. Coordinating transfers within the protected area boundaries.
4. Ensure the package is properly marked for transfer.

6.4 The Met-Ed Transportation Department is responsible for vehicle inspections as identified in section 7.2.3 of this procedure.

6.5 The TMI QA group is responsible for maintenance of the QA program required by Ref. 3.2, part 71.12.

6.6 The TMI Operations QA group is responsible for visual verification of the holddown inspection and proper completion of paperwork as specified in para. 7.3.2.4, 7.3.6 and 8.1.10.

7.0 PROCEDURE FOR SHIPPING BY RAIL OR HIGHWAY IN "SOLE USE VEHICLES"

7.1 Upon receipt of notification of the intent to ship radioactive material packaged in accordance with Procedure 1618D:

7.1.1. The RMC shall contact Rad-Con and arrange for a survey to determine the radiological status of the package(s).

7.1.2. Rad-Con shall perform the following surveys and analysis:

1. Beta-gamma swipe surveys.
2. Alpha swipe surveys.
3. Max radiation levels contact with the surface of the package and a 6-point radiation survey, if required.
4. Max radiation levels at 3 feet from the surface of the package.

   NOTE: Contamination levels shall be within the limitations of 49 CFR 173.397. Radiation levels shall be within the limitations of 49 CFR 173.393(j).

5. The above survey results shall be recorded on the current site smear and radiation survey forms. One copy of the survey results shall be forwarded to the RMC for attachment to the Unit II Site Ops copy of the shipping papers. The original copy shall be retained in the Rad-Con files. See Para 11 for record retention.

7.1.3. The RMC shall initiate arrangements for the carrier and verify the recipient's license in accordance with 10 CFR 30.41.

7.1.4 The RMC shall perform curie estimate and document the results in accordance with Procedure 1655.

7.1.5. Upon receipt of the above survey results and completion of the curie estimate, the RMC shall determine the shipping requirements using 49 CFR 173.390-396.

7.2 Upon arrival/availability of the transport vehicle: The RMC shall arrange with Rad-Con for a survey of the vehicle. Use the preload Vehicle Survey Form. (Attachment 1)

NOTE: An arrival survey shall be performed on the vehicle in accordance with Procedure 1518-B.

7.2.1 The RMC shall initiate and coordinate the completion of the Radioactive Material shipment checklist. (Attachment 2).

NOTE: To expedite the loading and shipping operation, a copy of the above checklist may be telecopied to the Pennsylvania State DER for signature as soon as the following information is recorded:

1. Description of material being shipped.
2. Shipment destination.
3. Travel route.

7.2.1.1 A request should be made to the DER to telecopy a signed copy back to the UII Site Ops. This signed copy should be attached to the UII Site Ops copy and maintained on file. See para 11 for Records Retention.

NOTE: Pennsylvania State DER has provided a letter which waives the notification requirement for routine samples. Notification is required for shipments of radioactive waste or any unusual shipment.

7.2.2 The RMC shall contact the Met-Ed Transportation and arrange for the vehicle inspection. Vehicle inspection to be completed prior to shipment.

7.2.3 The Met-Ed Transportation Department shall perform a vehicle inspection following the attributes contained on the "Vehicle Inspection Checklist", the "Vehicle Inspection Criteria", and the "Vehicle Out of Service Criteria", (Attachment 4) and notify the RMC if any out of service defects are observed. The shipment shall not be released without correcting all out of service defects.

NOTE: Met-Ed Transportation Department vehicle inspection is not required if:

(1) U.S. Department of Transportation inspected the vehicle and that fact is recorded on the "Radioactive Materials Shipment Checklist".

(2) Shipment is made by a lightweight vehicle (automobile, van, etc.).

7.2.4 The RMC shall coordinate the loading of the transport vehicle to ensure the shipping regulations are not exceeded.

7.2.5 During loading of the vehicle, each package shall be inspected to ensure they are in proper condition for transport. Verification of the inspection shall be entered by the RMC by initialing the appropriate space on the shipping container survey form (Attachment 4). The following inspections will be performed as indicated.

7.2.5.1 Drums

1. Check drum integrity (no holes, penetrations, weaknesses, etc.)
2. Drum is properly labeled/marked. (see section 7.2.6)
3. Drum closure ring bolt and lock nut are tightened to greater than 40 ft/lbs. Verify with torque wrench. Record torque wrench Serial No. and Cal. due date on the shipping container survey form.

   NOTE: If the torque on the bolt and lock nut are less than 40 ft/lbs, first ensure the ring is fully seated by tapping the rim with a mallet or hammer, then retighten with the torque wrench to greater than 40 ft/lbs.
4. Drum is numbered, weighed and surveyed and information recorded on the shipping container survey form.

7.2.5.2 LSA Boxes

1. Check box integrity (no holes, penetrations, weaknesses, etc.)
2. Box is properly labeled/marked. (See section 7.2.6)
3. Box is properly closed and banded (if required)
4. Box is numbered, weighed and surveyed and information recorded on the shipping container survey form.

7.2.5.3 Liners

1. Check liner integrity
2. Liner is properly closed, quick disconnect caps wired
3. Liner is properly braced in shipping cask.
4. The cask is properly labeled/marked. (See section 7.2.6)

7.2.5.4 Miscellaneous Containers

1. Check container integrity
2. Container properly closed
3. Container properly labeled/marked. (See section 7.2.6)

7.2.5.5 The remainder of the shipping container survey form shall be completed as follows:

1. The RMC shall enter radiation and contamination levels as provided by Rad-Con.
2. The RMC shall complete the remainder of the form using information on file for each container.

7.2.6 Packages shall be marked and labeled as specified in section 6.8 of Procedure 1618D.

7.2.7 The RMC shall contact Rad-Con and arrange for the required radiological surveys on the transport vehicle. Surveys shall consist of the following:

1. A contact dose rate survey on the external surface of the vehicle (closed transport vehicle only). Limit-200 millirem per hour at any point.
2. A dose rate survey at 6 feet (2 meters) from the vertical planes projected by the outer lateral surfaces of the vehicle, or if the load is transported in an open transport vehicle, at any point 6 feet (2 meters) from the vertical planes projected from the outer edges of the vehicle. Limit-10 millirem per hour.
3. A dose rate survey in any normally occupied position in the vehicle. Limit-2 millirem per hour. This provision does not apply to private motor carriers.
4. Survey the external surface for spreadable contamination. Contamination levels shall be within the limitations of 49 CFR 173.397.

7.2.8 Rad-Con personnel shall perform the radiation surveys required by 7.2.7 and record the results on the Post Load Vehicle Survey Record (Attachment 4). A copy of the results shall be forwarded to the RMC. The original shall be filed in the Rad-Con record files. See para 11 for records retention.

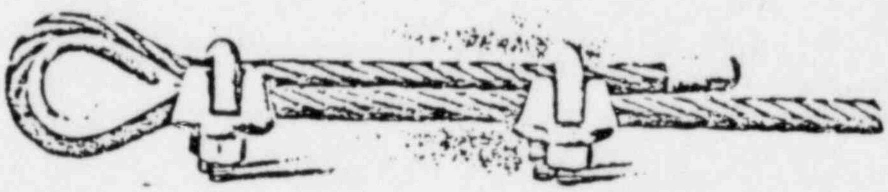
7.3 When the radioactive material shipment is loaded and properly secured in/on the transport vehicle:

7.3.1 The RMC shall inspect the load hold down system (if applicable) and arrange for the vehicle inspections.

7.3.2 The RMC shall:

7.3.2.1. Inspect the load hold down mechanisms (if used) to secure the load. As a minimum, the following should be checked:

1. When cables are used in conjunction with crosby clips to secure the load, the crosby clips should be checked to ensure they have been properly installed.



NOTE: Ensure the "u" bolt is on the cable end, not the anchor.

2. Chains

(1) Check for defective links.

(2) Ensure chain has been tested and certified. If certification is not available, inspect carefully for soundness.

FOR USE IN UNIT II ONLY

3. Drum tie downs:

(1) Ensure cables, chains, or other means to secure drum loads are adequately installed to prevent shifting.

(2) Partial loads shall be loaded for proper weight distribution and secured to prevent shifting.

4. Casks - ensure cask is properly secured to the trailer.

7.3.2.2 Check the engagement of the fifth wheel with the tractor by having the driver lock the trailer brakes and pulling forward with the tractor.

7.3.2.3 If the above inspections were performed and the results indicated that the load is securely fastened, the RMC shall sign the appropriate line on the "Vehicle Survey Record" (Attachment 4).

7.3.2.4 Operations QA will visually verify the inspection for type B shipments or large quantity shipments and signify acceptance by their signature on the appropriate line on the "Vehicle Survey Record" (Attachment 4).

FOR USE IN UNIT II ONLY

7.3.3 The RMC shall initiate and coordinate the completion of the applicable Radioactive Material Shipping and Receipt Record. (Attachment 3).

NOTE: If shipment is being sent for burial in U. S. ECOLOGY'S Richland, Wash. site, U. S. ECOLOGY'S "Radioactive Waste Shipment and Disposal Form" (Attachment NO. 5) shall be used instead of Attachment NO. 3. Insure that the cover sheet delineated in Attachment NO. 4 is completed and included in the shipping papers.

NOTE: If shipment is being sent for burial in CNSI's Barnwell, S.C. site, CNSI's "Radioactive Shipment Record Form" (Attachment NO. 6) shall be used instead of Attachment NO. 3. Insure that the cover sheet delineated in Attachment NO. 4 is completed and included in the shipping papers.

7.3.4 The RMC shall provide the vehicle driver with the following information prior to allowing the driver to drive the vehicle carrying Radioactive Material out of the site boundary:

1. Ensure the driver understands what to do in the event of an emergency/accident.
2. Ensure the driver understands how to use and interpret radiation detection instruments if provided for the shipment.

3. Provide the driver with a completed handout (Enclosure 1) describing the actions to be taken in the event of an accident.

4. Documentation of this action shall be performed on the Post Load Vehicle Survey Record as signified by the RMC's signature in the "Driver's Instructions Completed by" block.

7.3.5 To document the fact that placards were posted on the vehicle (if required) prior to leaving the site boundary, the RMC shall instruct the driver to sign the applicable space on the applicable Radioactive Material Shipment and Receipt Record (Attachment 3), or the cover sheet for CNSI/U.S. Ecology Radioactive Waste Shipping and Disposal form in Attachment 4.

7.3.5.1 Placards are required for each shipment of Radioactive LSA shipped on a vehicle consigned for "Exclusive Use" and any shipment which contains a package requiring a Yellow III label. (49 CFR 172.504).

7.3.5.2 Placards shall be placed on each side and each end of the vehicle (49 CFR 172.504). The required placarding of the front of the vehicle may be on the front of the truck instead of or in addition to the placarding on the front of the cargo body to which the truck is attached (49 CFR 172.516).

7.3.5.3 Each placard on a transport vehicle must meet the following requirements of 49 CFR 172.516(c).

1. Be securely attached or affixed thereto or placed in a holder thereon.
2. Be located clear of appurtenances and devices such as ladders, pipes, doors and tarpaulins.
3. So far as practicable, be located so that dirt or water is not directed to it from the wheels of the transport vehicle.
4. Be located away from any marking (such as advertising) that could substantially reduce its effectiveness, and in any case at least 3 inches away from such markings.
5. Have the words printed on it displayed horizontally, reading from left to right.
6. Be maintained by the carrier in a condition so that the format, legibility, color and visibility of the placard will not be substantially reduced due to damage, deterioration, or obscurement by dirt or other matter.

7.3.5.4 Additional placards, if required, shall be used in accordance with the requirements of 49 CFR 172.500.

7.3.5.5 Placards must meet the general specifications or placards in 49 CFR 172.519.

7.3.6 Upon satisfactory completion of the applicable Radioactive Material Shipment and Receipt Record and the Radioactive Materials Shipment Checklist, one of the individuals listed in 6.1 will review both records to insure consistency and grant final approval for shipment by signing the applicable block on the Radioactive Material Shipment Checklist.

NOTE: Prior to release of the shipment by Unit II Site Ops the Operations Q.A. Group reviews the Radioactive Material Shipment Checklist and the Radioactive Material Shipment Record to insure that they meet the requirements of this procedure. Completion of this will be signified by the Ops. Q.A. Monitor signature in the appropriate block on the Radioactive Material Shipment Checklist. This requirement applies only to greater than Type A Shipments. Copies of completed shipping documentation shall be made available to Ops. Q.A. Monitor.

7.3.7 Upon receipt of notification that the shipment has arrived at its' destination. this information shall be entered on the Radioactive Materials Shipment checklist filed along with the UII Site Ops copy of the shipping record by the RMC. The RMC shall provide Rad-Con with a completed copy of the shipping document for the Rad-Con files. See para 11 for records retention.

8.0 SHIPMENT OF RADIOACTIVE MATERIAL BY AIR

8.1 Upon notification of the intended shipment of Radioactive Material packaged in accordance with Procedure 1618D:

8.1.1 The RMC shall contact Rad-Con and arrange for a pre-shipment survey of the package(s).

8.1.2 Rad-Con personnel shall perform the following surveys and analysis:

1. Beta-gamma swipe survey of package.
2. Alpha swipe survey of package.
3. Radiation survey:
   (1) Contact (maximum).
   (2) 3 feet from package (maximum).

   NOTE: Contamination levels shall be within the limitations of 49 CFR 173.397. Radiation levels shall be within the limitations of 49 CFR 173.393(i).
4. The results of the above surveys shall be recorded on standard survey forms. A copy of the survey results shall be forwarded to the RMC for attachment to the Unit II Site Ops. copy of the shipping documents. The original copy of the survey shall be maintained in the Rad-Con files. See para 11 of records retention.

8.1.3 The RMC shall perform curie estimates in accordance with Procedure 1655.

8.1.4 The RMC shall initiate arrangements for transportation including transportation from the site to the air cargo depot. The RMC shall arrange with Rad-Con for a Preload survey of the vehicle. Use the Preload Vechicle Survey Form (Attachment 4).

8.1.5 The RMC shall initiate and coordinate the completion of Radioactive Material Shipment checklist (Attachment 2). The notes contained in sections 7.2.1 and 7.2.1.1 apply.

8.1.6 The RMC shall ensure the package is in accordance with 49 CFR 173.390-396 and is properly labeled for air shipment.

8.1.7 The RMC shall initiate and coordinate the completion of the Radioactive Material Shipment Record - Air (Attachment 3).

8.1.8 The RMC shall contact the transportation group to arrange the inspection listed in 7.2.3 of this procedure, if applicable.

8.1.9 The RMC shall contact Rad-Con and arrange for a radiation survey of the transfer vehicle as outlined in 7.2.8 of this procedure.

FOR USE IN UNIT II ONLY

8.1.10 The UII Site Ops (one of the individuals listed in 6.1 of this procedure) must grant final approval for shipments of Radioactive Material prior to release from the site.

<u>NOTE</u>: Prior to release of the shipment by UII Site Ops, the Operations Q.A. Group reviews the Radioactive Material Shipment Checklist and the Radioactive Material Shipment Record to insure that they meet the requirements of this procedure. Completion of this will be signified by the Ops. Q.A. Monitor signature in the appropriate block on the Radioactive Material Shipment Checklist. This requirement applies only to greater than Type A Shipments. Copies of completed shipping documentation shall be made available to Ops. Q.A. Monitor.

8.1.11 Rad-Con Technician that accompanies the material to the airport shall ensure that the air craft is loaded in accordance with the following chart, to comply with the requirements of 49 CFR 175.701.

Transport index or sum of transport indexes of all packages in the aircraft or predesignated area	Minimum separation distances	
	Centimeters	Inches
0.1 to 1.0	30	12
1.1 to 2.0	50	20
2.1 to 3.0	70	28
3.1 to 4.0	85	34
4.1 to 5.0	100	40
5.1 to 6.0	115	46
6.1 to 7.0	130	52
7.1 to 8.0	145	57
8.1 to 9.0	155	61
9.1 to 10.0	165	65
10.1 to 11.0	175	69
11.1 to 12.0	185	73
12.1 to 13.0	195	77
13.1 to 14.0	205	81
14.1 to 15.0	215	85
15.1 to 16.0	225	89
16.1 to 17.0	235	93
17.1 to 18.0	245	97
18.1 to 20.0	260	102
20.1 to 25.0	300	118
25.1 to 30.0	330	130
30.1 to 35.0	360	142
35.1 to 40.0	390	154
40.1 to 45.0	420	166
45.1 to 50.0	450	[illegible]

NOTE: If the material is left at the air cargo terminal for later shipment, compliance with 49 CFR 175.701 is the responsibility of the carrier.

8.1.12 The RMC or his representative shall request the air cargo operator to sign the appropriate lines on the Radioactive Shipment Record-Air (Attachment 3) and provide two additional copies of the completed shipping record for the pilot in command.

8.1.13 Upon return to TMI-1 the vehicle used to transport the material, the RMC shall have Rad-Con survey the vehicle for spreadable contamination and direct radiation in accordance with 49 CFR 173.397 (c).

8.1.14 The UII Site Ops copy of the shipping record, along with attached applicable survey form copies, shall be maintained on file by the UII Site Ops. The Rad-Con copy shall be maintained on file by Rad-Con. The original of the shipping document shall accompany the shipment. See para 11 for records retention.

8.1.15 Upon receipt of notification that the shipment has arrived at its destination, this information shall be entered on the Radioactive Materials Shipment checklist and filed along with the UII Site Ops copy of the shipping record by the RMC. The RMC shall provide Rad-Con with a completed copy of the shipping document for the Rad-Con files. See para 11 for records retention.

FOR USE IN UNIT II ONLY

9.0 PROCEDURE FOR SHIPPING BY MAIL

9.1 Upon receipt of notification of the intent to mail Radioactive packaged IAW Procedure 1618D.

9.1.1 The RMC shall contact Rad-Con and arrange for a survey to determine the radiological status of the package(s).

9.1.2 Rad-Con shall perform the following surveys and analysis:

1. Beta-gamma swipe survey
2. Alpha swipe survey
3. Maximum radiation levels contact with the surface of the package
4. Maximum radiation levels at 3 feet from the surface of the package

NOTE: Contamination levels shall be within the limitations of 49 CFR 173.397. Radiation levels shall be in accordance with 49 CFR 173.391.

9.1.2.1 The above survey results shall be recorded on the current site smear and radiation survey forms. One copy of the survey results shall be forwarded to the RMC for attachment to the UII Site Ops copy of the shipping papers. The original copy shall be retained in the Rad-Con files. See para 11 for records retention.

9.1.3 The RMC shall perform curie estimates in accordance with Procedure 1655.

9.1.4 Upon receipt of the above survey results and completion of the curie estimate, the RMC shall determine if the package meets the requirements of Publication 6 of the U. S. Postal Service.

9.1.5 The RMC shall verify the recipient's license IAW 10CFR30.41.

9.2 The RMC shall initiate and coordinate the completion of the Radioactive Material shipment checklist. (Attachment 2).

NOTE: To expedite the shipping operation, a copy of the above checklist may be telecopied to the Pennsylvania State DER for signature as soon as the following information is recorded.

1. Description of material being shipped
2. Shipment destination

9.2.1 A request should be made to the DER to telecopy a signed copy back to the UII Site Ops. This signed copy should be attached to the Rad-Con copy and maintained on file. See para 11 for records retention. The note in section 7.2.1.1 applies.

9.3 The RMC shall initiate and coordinate the completion of the applicable Radioactive Material Shipping and Receipt Record. (Attachment 3).

9.4 Upon satisfactory completion of the Radioactive Material shipment and receipt record, and the Radioactive Material shipment checklist, one of the individuals listed in 6.1 will review both records to ensure consistency and grant final approval for shipment by signing the applicable block on the above records, as applicable for the forms used.

9.5 When final approval for shipment has been made, the RMC shall:

9.5.1 Insure the package is properly addressed.

PAGE 4 PARA 6.1.1 Change to Read
- PLANT Operations Director

- PARA 6.1.4 Change to Read
- MANAGER, Support Services

PAGE 35 # 28 GuidLINES
ITEM 1 Change to Read
- PLANT Operations Director
ITEM 4 Change to READ
- MANAGER, Support Services

The Above changes reflect the current positions Authorized to release radioactive waste shipments.

9.5.2 Place the first two copies of the Radioactive Shipment and receipt record in an envelope. The envelope is to be taped to the outside of the package and marked "shipping documents".

9.5.3 Deliver the package to the mailroom for shipment as certified mail, with return receipt requested. Receipt to be returned to the RMC.

9.6 Upon receipt of notification that the shipment has arrived at its destination, the RMC shall enter this information on the Radioactive Materials shipment checklist and the return receipt is attached to the UII Site Ops copy of the shipment record. The RMC shall provide Rad-Con with a completed copy of the shipping document for the Rad-Con files. See para 11 for records retention.

10.0 MIXED LADING SHIPMENTS

10.1 Upon receipt of notification of the intent to ship radioactive material packaged in accordance with Procedure 1618D:

10.1.1. The RMC shall contact Rad-Con and arrange for a survey to determine the radiological status of the package(s).

10.1.2. Rad-Con shall perform the following surveys and analysis:

1. Beta-gamma swipe surveys.
2. Alpha swipe surveys.
3. Max radiation levels contact with the surface of the package.

4. Max radiation levels at 3 feet from the surface of the package.

   NOTE: Contamination levels shall be within the limitations of 49 CFR 173.397. Radiation levels shall be within the limitations of 49 CFR 173.393(i).

5. The above survey results shall be recorded on the current site smear and radiation survey forms. One copy of the survey results shall be forwarded to the RMC for attachment to the UII Site Ops copy of the shipping papers. The original shall be retained in the Rad-Con files. See para 11 for records retention.

10.1.3 The RMC shall perform curie estimates in accordance with Procedure 1655.

10.1.4 Upon receipt of the above survey results and completion of the curie estimate, the RMC shall determine the shipping requirements using 49 CFR 173.390-396.

10.1.5 The RMC shall initiate arrangements for the carrier and verify the recipient's license in accordance with 10 CFR 30.41.

10.2 The RMC shall initiate and coordinate the completion of the Radioactive Material shipment checklist. (Attachment 2).

NOTE: To expedite the loading and shipping operation, a copy of the above checklist may be telecopied to the Pennsylvania State DER for signature as soon as the following information is recorded:

1. Description of material being shipped.
2. Shipment destination.
3. Travel route (to be determined by carrier).

10.2.1 A request should be made to the DER to telecopy a signed copy back to the UII Site Ops. This signed copy should be attached to the Rad-Con copy and maintained on file. See para 11 for records retention. The note in section 7.2.1.1 applies.

10.3 The RMC shall initiate and coordinate the completion of the applicable Radioactive Material Shipping and Receipt Record. (Attachment 3).

10.4 Upon satisfactory completion of the applicable parts of the Radioactive Material Shipment and Receipt Record and the Radioactive Materials Shipment Checklist, one of the individuals listed in 6.1 will review both records to insure consistency and grant interim approval for shipment by initialing the applicable block on the Radioactive Material Shipment Checklist.

NOTE: Vehicle survey information will be completed at the time of shipment.

10.5 When release for the shipment is obtained, the package will be delivered to the warehouse for shipment.

10.6 Upon arrival of the transport vehicle, the warehouse shall notify the RMC. The RMC shall contact Rad-Con and arrange for the required Radiological Surveys on the transport vehicle.

10.7 The RMC shall coordinate the loading of the transport vehicle to ensure the shipping regulations are not exceeded. When loaded the RMC shall complete the Radioactive Material Checklist and the Radioactive Material Shipment Record.

10.8 The RMC shall ensure that the package is properly secured on the transport vehicle. Documentation of this action shall be performed by signing the appropriate space on the vehicle survey form.

10.9 To document the fact that placards were posted on the vehicle (if required) prior to leaving the site boundary, the RMC shall instruct the driver to sign the applicable space on the applicable Radioactive Material Shipment and Receipt Record (Attachment 3).

10.10 When loading and surveys are complete, one of the individuals listed in 6.1 will review the records and grant final approval by signing the applicable block on the Radioactive Materials Shipment Check List.

10.11 Upon receipt of notification that the shipment has arrived at its' destination, this information shall be entered on the Radioactive Materials Shipment checklist filed along with the UII Site Ops copy of the shipping record by the RMC. The RMC shall provide Rad-Con with a completed copy of the shipping document for the Rad-Con Files. See para 11 for records retention.

11.0 RECORDS RETENTION

11.1 Radiation surveys taken in support of radioactive material shipments shall be retained for the life of the plant. This includes but is not limited to the following:

1. Radiation survey of containers.
2. Contamination survey of containers.
3. Preload survey of vehicle.
4. Post load survey of vehicle.

11.2 Radiation shipping documents shall be retained for the life of the plant. This includes but is not limited to the following:

1. Radioactive shipment forms (MET-ED, CNSI, and NECO).
2. Radioactive material shipment checklist.
3. DER telecopy.
4. Curie calculations.

11.3 Container certification for TYPE A shipping containers shall be retained for 1 year after the last shipment.

11.4 The following records shall be maintained for the life of the plant for each shipment of fissile material or shipments of greater than TYPE A quantities.

1. Identification of the packaging by model number.
2. Details of any significant defects in the packaging, with the means employed to repair the defects and prevent their recurrence.
3. Volume and identification of coolant.
4. Type and quantity of licensed material in each package, and the total quantity in each shipment.

5. For each item of irradiated fissile material:

   (1) Identification by model number

   (2) Irradiation and decay history to the extent appropriate to demonstrate that its nuclear and thermal characteristics comply with license conditions.

   (3) Any abnormal or unusual condition relevant to radiation safety.

6. Date of the shipment.

7. For Fissile Class III, any special controls exercised.

8. Name and address of the transferee.

9. Address to which the shipment was made.

10. Results of the determinations required by 10 CFR 71.54.

11.5 The licensee shall make available to the Commission for inspection, upon reasonable notice, all records required by this part.

11.6 The licensee shall maintain, during the life of the packaging to which they pertain, sufficient quality assurance records to furnish documentary evidence of the quality of packaging components which have safety significance, and of services affecting such quality, including records of the results of the determinations required by 10 CFR 71.53, and of monitoring, inspection and auditing of work performance during the design, fabrication, assembly, testing, modification, maintenance, and repair of the packaging.

ATTACHMENT 1

Driver's Instruction Handout

EMERGENCY PROCEDURES TO BE FOLLOWED BY VEHICLE DRIVER

IN THE EVENT OF AN ACCIDENT

1. Remove injured persons from any possibly contaminated areas and provide first aid.
2. Using Survey Instrumentation, if provided, survey the container of radioactive material to determine whether any of the radioactive material is leaking. In the unlikely event that the survey meter is found to be inoperable, or if not provided, the following procedure should be followed:
   2.1 If there are no visible signs of leakage, a restricted area at least 20 feet from the truck on all sides shall be established.
   2.2 If there is visible leakage, a restricted area at least 20 feet from any visible contamination shall be established.
3. If a container/package is visibly damaged or material is leaking from the container/package, establish the restricted area and obtain the help of the police in keeping people out of the restricted area and on the upwind side if possible. Do not allow the taking of souvenirs.
4. If there is a fire, keep everyone upwind and do not breathe any of the smoke and fumes coming from the fire. Notify the fire department of the fire, and inform them that the truck is carrying radioactive materials.
5. Notify the state or local police as appropriate.

6. Notify ______________________________, area code ________ telephone number ____________________, of the accident, giving the following information:

   6.1 Your name.

   6.2 Your employer.

   6.3 The location and time of the accident.

   6.4 What authorities, such as state and local police, have been notified.

   6.5 Whether a fire is involved.

   6.6 The extent of damage to the shipping container and vehicle. (Is there an obvious breach, or are materials leaking from the container?)

   6.7 The number of people injured and the extent of their injuries.

   6.8 The location from which you are calling.

   6.9 How you or the police can be contacted (give telephone number).

   6.10 Whether or not a radiation hazard exists and the extent of the hazard.

7. Limit your discussion with the press and public to a statement that the shipment consists of radioactive material (as described in your shipping papers) packaged in accordance with DOT and NRC Regulations. Any additional information will be given to the public and press by a Met-Ed information officer or representative of the State Health Department.

8. Get the names, addresses, and telephone numbers of the injured and any witnesses.

ATTACHMENT 2
Radioactive Material Shipment Checklist -
Description and Documentation Instructions

TABLE I

GUIDELINES FOR COMPLETING RADIOACTIVE MATERIAL SHIPMENT CHECKLIST

RMC - Radioactive Material Coordinator or individual preparing radioactive material for shipment

UII OPS Unit II Site Operations

	Item	Entered By	Guidelines
1.	Shipment Number	RMC	Assigned in accordance with Procedure Attachment 3, para. 1.3.A.1.
2.	Unit Number	RMC	Specify Unit 1 or Unit 2. If unknown, specify Unit 2.
3.	Date Shipped	RMC	Enter date upon release for shipment.
4.	Material being shipped	RMC	Description of Material being shipped.
5.	Shipping Container Type	RMC	Enter Type (e.g. 55 gal drum, 50 cu. ft. liner, etc.)
6.	Number of Containers	RMC	Enter quantity of containers in shipment.
7.	Cask Model	RMC	Information obtained from cask supplier.
8.	D.O.T. Number	RMC	Information obtained from cask supplier.
9.	Cask Certification checked by	RMC	Name of individual checking certification. Copy of certificate of compliance in hand.
10.	Curie content calculation performed by	RMC	Name of individual performing calcs. Attach worksheets to form.
11.	Receiving Facility	RMC	Identify receiving facility with which arrangements for receipt have been made.
12.	License Number	RMC	Information obtained from receiving facility.

ATTACHMENT 2
TABLE I
GUIDELINES FOR COMPLETING RADIOACTIVE MATERIAL SHIPMENT CHECKLIST

Item	Entered By	Guidelines
13. Facility License checked by	RMC	Quantity, form and isotopic content of material being shipped is within limits specified in the recipient's license.
14. Shipment Acceptability verified with receiving facility	RMC	Acceptability of the shipment shall be verified with the receiving facility when arrangements are being made for receipt. Enter the name of the person associated with the facility who verified acceptability.
15. Contamination Survey performed by	RMC	Enter the name of the individual performing survey.
16. Beta/Gamma Survey performed by	RMC	Enter the name of the individual performing survey.
17. Vehicle Survey performed by	RMC	Enter the name of the individual performing survey.
18. Shipping Forms prepared by	RMC	Enter the name of the individual preparing the radioactive shipment record.
19. Receiving Agent	RMC	Enter the name of the receiving agent after arrangements have been made for the receiving agent to receive the material.
20. Carrier	RMC	Enter the name of the carrier after arrangements have been made to transport material.
21. Scheduled to arrive at receiving site	RMC	Enter information from carrier obtained when making shipping arrangements. Information must be available prior to arrival of the truck at the TMI site.
22. Actual Arrival Date	RMC	Arrangements should be made with recipient to provide notification of arrival. When information is received it shall be entered on the file copy of the checklist by the RMC.

ATTACHMENT 2
TABLE I
GUIDELINES FOR COMPLETING RADIOACTIVE MATERIAL SHIPMENT CHECKLIST

Item	Entered By	Guidelines
23. D.O.T. notified	RMC	D.O.T. must be notified of scheduled shipments. At their option, they will inspect the vehicle or waiver inspection.
24. Routing notification	RMC	NRC TMI Support, NRC Radiation Specialist, the receiving site and the State of PA shall be notified of routing prior to shipment; see back of checklist for routing information. Enter name of individual contacted.
25. Letter of Certification verifying Unit 1 material only	RMC	For all shipments of Unit 1 Waste to Barnwell, S.C., a letter to Chem Nuclear is required certifying that the shipment contains only Unit 1 waste and that it contains less than 10 nanocuries/gram of transuranics. Letter must be signed by Director of TMI Unit 1.
26. Routing	RMC	This information is obtained from the carrier when making shipping arrangements. The information must be available prior to arrival of the truck at the TMI site.
27. Above routing information received by	RMC	Following completion of the checklist, obtain the signature of a representative of the PA DER. This may be done by handcarrying the checklist to the DER or by telecopy.

ATTACHMENT 2
TABLE I
GUIDELINES FOR COMPLETING RADIOACTIVE MATERIAL SHIPMENT CHECKLIST

Item	Entered By	Guidelines
28. Waste Management Approval	UII SITE OPS	Approval to ship will be given when the radioactive shipment record and the radioactive material shipment checklist are complete except for the actual arrival date of shipment at the receiving site; assuming that no holds have been placed on the shipment as a result of inspections or notifications. Approval must be by one of the following: 1. Manager, Radwaste Processing Support 2. Supervisor, Waste Disposal 3. Director, Site Operations 4. Supervisor, Tech. Spec. Compliance.
29. OQA Approval	OQA Monitor	To be signed by Ops. Q.A. after visually verifying that the Radioactive Material Shipment Checklist and the Radioactive Material Shipment Record are filled out in accordance with this procedure. This item is applicable to greater than Type A shipments only.
30. D.O.T. Inspection	RMC	Enter name of D.O.T. Inspector if vehicle inspection is performed by D.O.T.

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THREE MILE ISLAND NUCLEAR STATION

1
(SHIPMENT NUMBER)

RADIOACTIVE MATERIAL SHIPMENT CHECKLIST

UNIT NO. 2 DATE SHIPPED 3

MATERIAL BEING SHIPPED: 4

SHIPPING CONTAINER TYPE: 5

NUMBER OF CONTAINERS: 6

CASK MODEL: 7 D.O.T.NO. 8

CASK CERTIFICATION CHECKED BY: 9 DATE:

CURIE CONTENT CALCULATION PERFORMED BY: 10 DATE:
(ATTACH WORK SHEETS)

RECEIVING FACILITY: 11 LICENSE NO. 12

FACILITY LICENSE CHECKED BY 13 DATE:

SHIPMENT ACCEPTABILITY VERIFIED WITH RECEIVING FACILITY:

PERSON CONTACTED 14 DATE:

CONTAMINATION SURVEY PERFORMED BY: 15 DATE:

BETA/GAMMA SURVEY PERFORMED BY: 16 DATE:

VEHICLE SURVEY PERFORMED BY: 17 DATE:

SHIPPING FORMS PREPARED BY: 18 DATE:

RECEIVING AGENT: 19

CARRIER: 20

SCHEDULED TO ARRIVE AT RECEIVING SITE: 21
(DATE)

ACTUAL ARRIVAL DATE: 22

D.O.T. NOTIFIED NAME: 23 DATE:

ROUTING NOTIFICATION:

NRC: 24
NAME DEPUTY DIRECTOR, TMI SUPPORT DATE TIME

NRC: 24
NAME OF RADIATION SPECIALIST DATE TIME

RECEIVING SITE: 24
(NAME) (DATE) (TIME)

STATE OF PA: 24
(NAME) (DATE) (TIME)

FOR USE IN UNIT II ONLY

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LETTER OF CERTIFICATION VERIFYING UNIT NO. 1 MATERIAL ONLY

25 ______________________________ ______________
(PREPARED BY) (DATE)

ROUTING

DEPARTURE FROM TMI VIA 26 ______________________________

ABOVE ROUTING INFORMATION RECEIVED 27 ______________________________ ______________
(SIGNATURE, PENNSYLVANIA DER) (DATE)

WASTE MANAGEMENT APPROVAL 28 ______________________________ ______________
(SIGNATURE) (DATE)

Q.A. MONITOR 29 ______________________________ ______________
(SIGNATURE) (DATE)

D.O.T. INSPECTON PERFORMED BY 30 ______________________________ ______________
(NAME OF INSPECTOR) (DATE)

ATTACHMENT 3

Radioactive Material Shipping and Receiving Records -

Description and Documentation Instructions

NOTE: This attachment contains the shipping records to be used for:

1. Highway
2. Air cargo

1.0 Documentation Instructions for Radioactive Material Shipment and Receipt Record for Highway, Mail or Rail.

1.1 Background

The purpose of this record form is to provide documentation of all radioactive shipment and receipt information as required by applicable regulatory documents.

A Radioactive Material Shipment Record shall accompany every shipment of radioactive material, whether it is exempt from packaging and labeling or not.

1.2 General instruction for completion of shipping papers in accordance with 49 CFR 172 Subpart C.

1.2.1 Each person who offers a hazardous material for transportation shall describe the hazardous material on the shipping paper in the manner required by 49 CFR 172 Subpart C.

1.2.2 General Entries

1. When a hazardous material and a material not subject to the requirements of 49CFR 172 are described on the same shipping paper, the hazardous material description entries required by 49 CFR 172.202 and 172.203 must be:

(1) Entered first or;

(2) Entered in a color that clearly contrasts with any description on the shipping paper of a material not subject to the requirements of 49 CFR 172. The description on a reproduction of the shipping paper may be highlighted rather than printing in a contrasting color. The provisions of this paragraph apply only to the entries described in section 1.2.3 Sub-section 1-3 of Attachment 3.

2. The descriptions must be legible and printed (manually or mechanically) in English.
3. Unless authorized or required by 49CFR 172 the description may not contain any code or abbreviation.
4. A shipping paper may contain additional information concerning the material provided the information is not inconsistent with the required description. Unless otherwise permitted or required by 49CFR 172 additional information must be placed after the basic description as found in section 1.2.3, Sub-sections 1-4 of Attachment 3.
5. For a material meeting the definition of more than one hazard class, the additional hazard class(es) may be entered after the basic description.

1.2.3 The description of hazardous material on shipping papers must include the following.

1. The proper shipping name from the HAZARDOUS MATERIALS TABLE in 49CFR 172.101.
2. The hazard class prescribed for the material from the same Table. Inclusion of the hazard class is not required when the words of the proper shipping name contain the key word(s) of the class.
3. The Identification Number (proceeded by "UN" or "NA" as appropriate) prescribed for the material in the same table.

   NOTE: The display of Identification Numbers on shipping papers does not apply prior to 1 July 1981.
4. Except for empty packages, the total quantity (by weight, volume or as otherwise appropriate) of the hazardous material covered by the description.
5. The basic description as outlined above must be shown in sequence. Example: "Gasoline, Flammable Liquid" UN1203.
6. The total quantity of material covered by one description must appear before/or after the basic description required and authorized by 49CFR 172 Subpart C.
7. The type of packaging may be entered in any appropriate manner.

1.2.4 The following additional descriptions are required for Radioactive Material as appropriate.

1. The name of each radionuclide present, as listed in 49CFR 173.390. Abbreviations authorized.
2. A description of the physical and chemical form of the material, if the material is not in Special Form. Generic chemical description is acceptable for chemical form.
3. The activity contained in each package of the shipment in terms of curies, millicuries or microcuries. Abbreviations are authorized.
4. The category of label applied to each package in the shipment.

   Example: "Radioactive White I"
5. The Transport Index assigned to each package in a shipment bearing "Radioactive Yellow II or Radioactive Yellow III" labels.
6. For a shipment of fissile radioactive materials.
   (1) The words "Fissile Exempt" if the package is exempt, in accordance with 49CFR 173.396(a).
   (2) If not exempt, the Fissile Class of each package in the shipment, in accordance with 49CFR 173.389(a).

(3) For a Fissile Class III shipment, the additional notation:
"WARNING-FISSILE CLASS III SHIPMENT. DO NOT LOAD MORE THAN **** PACKAGES PER VEHICLE". (Asterisks to be replaced by appropriate number). "IN LOADING AND STORAGE AREAS, KEEP AT LEAST 20 FEET (6 METERS) FROM OTHER PACKAGES.

1.2.5 The description on the shipping paper for any empty package containing residue of a hazardous material may contain the word(s) "EMPTY" or "EMPTY: Last Contained ***" (followed by the name of the hazardous material last contained in the package). This entry may be before or after the basic description.

1.2.6 Each person who offers a hazardous material for transportation shall certify that the material offered for transportation is in accordance with 49 CFR 172, by printing (manually or mechanically) the following statement on the shipping paper, containing the required shipping description.
"This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled and are in proper condition for transportation according to the applciable regulations of the Department of Transportation."

1.2.7 For transportation of hazardous materials by air the following certification may be used in place of the certification in seciton 1.2.5.

"I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labeled, and in proper condition for carriage by air according to applicable National Governmental Regulations."

1. The following additional certification must also be made of transportation of hazardous materials by air. "This shipment is within the limitations prescribed for Passenger Aircraft/Cargo-Only Aircraft." (Delete nonapplicable).
2. Each person who offers a hazardous material to an aircraft operator for transportation by air shall provide two (2) copies of the required certification.

1.2.8 The certifications required in section 1.2.6 and 1.2.7 must be legibly signed by a principal, officer, partner or employee of the shipper or his agent. They may be signed manually, by typewriter or by other mechanical means.

1.3 Instructions for completion of shipping forms

The following detailed documentation instructions, as identified by alpha numeric characters, coincide with the attached Radioactive Material Shipment and Receipt record form.

A. Heading:

Used to identify the transaction, shipment or receipt.

1. For shipments, place an "X" in the block provided and record the shipment number using the following format:

   Shipment Number

   Shipments of Radioactive Material will be numbered consecutively during each calendar year.

   RS 74-1, 2, 3, etc.

   RS 75-1, 2

   RS - is Radioactive Shipment

   Where 74 is the year during which shipments is made 1, 2 etc. is the nth shipment of that year.

2. For receipts, place an "X" in the block provided and record the receipt number for all radioactive material and containers previously used to transport radioactive material, using the above numbering format.

3. Record the date in which the transaction occurred.

4. Page:

   In the first space record the page number applicable to the sheet being filled in, in the second space, record the total number of pages applicable to the shipment.

B. Shipped to/received from block.

1. Place an "X" in the box provided if the material is being shipped.

2. Record the name of the individual/concern receiving or who shipped the material.

3. Record the name of the company the above individual or activity represents.

4. Record the address of the above company.
5. For shipments only, place an "X" in the box provided and record the cosignee's NRC license number if applicable.
6. For shipments only, place an "X" in the box provided and record the cosignee's state license number, if applicable.
7. This line is provided for the signature of the Authorized TMI Unit II Site Ops individual verifying that the cosignee is authorized to receive radioactive material.

C. Shipped from

1. Record Met-Ed's address (Unit I or II).
2. Record Met-Ed's telephone number.

D. Transport Information

1. Place an "X" in the applicable shipped or received via boxes.
2. Place an "X" in the applicable mode of transportation box.
3. Record the name of the individual/organization who owns the transportation vehicle.
4. Identify the type of vehicle used to transport the Rad Material (i.e. closed van, tractor trailer, etc.).
5. Record the type of placard used. Have the vehicle operator sign on the line provided to document that the placard was in place prior to leaving the site.
6. Record the applicable highest results obtained on the radiation survey of the transport vehicle.
7. This space is provided for the signature of the technician who performed the vehicle radiation survey.

FOR USE IN UNIT II ONLY

E. Material description block.

1. Place an "X" in the appropriate box describing the material shipped/received.
2. Record the total activity in the shipment.
3. Indicate, by placing an "X" in the appropriate box, whether or not the material is classified as limited quantity.
4. List the radionuclides (major nuclides) present in the ship- ment.

F. Description of package contents.

1. Record the package identification number.
2. Describe the contents of the package (i.e. compacted, solid waste, solidified waste, etc).
3. Record the major radionuclides present in the package.
4. Record the total amount of radioactivity present in the package as determined by Procedure 1655. Also record the total activity for the each page on the bottom line. The total for the shipment is recorded as per step E.2.
5. Record the physical form of the material in the package (solid, liquid, gaseous).
6. Record the chemical form of the material, if known. If unknown, or self descriptive as indicated by the content description, leave blank.
7. Record the transport group number (i.e. I through VII) If more than one transport group is represented in a pack- age, enter each group number.
8. The Rad-Con Foreman/Supervisor signs this space after reviewing the recorded activity estimate for accuracy.

G. Package description

1. Enter package description.
2. Record DOT Spec. No. for container if applicable, if package is a strong tight container, record N/A.
3. Record USNRC identification number for container if applicable, otherwise record N/A.
4. Enter the volume in cubic feet for the package. The total of each page entered on the bottom line.
5. Enter the weight of the package in pounds and record the total for each page on the bottom line.
6. Record the maximum radiation levels obtained at contact and at 3 feet on each package.

   NOTE: If the shipment is to be made on a mixed lading vehicle, total the exposure rates in the 3 foot column and verify that the shipment does not exceed 50 total (the exposure rate at 3' in mrem/hr is the transportation index).
7. Record the external loose surface contamination levels for the package.
8. Place an "X" in the appropriate box indicating whether or not the package is sealed (a seal is not required for Limited Quantity Packages or LSA shipped on an exclusive use vehicle).
9. Place an "X" in the appropriate box indicating what shipping label was used.
10. The Rad-Con Foreman/Supervisor signs this space after reviewing the recorded radiation and contamination data.

H. Shippers Certification: The Radioactive Materials Coordinator (RMC) signs this block after ensuring that:

1. The package is proper for the contents to be shipped.
2. The package is in an unimpaired physical condition except for superficial marks.
3. Each closure device, including any required gaskets, is properly installed, secured, and free of defects.
4. Any special instructions for filling, closing, and preparation of the package for shipment has been followed.
5. Any closure, valve and other openings of the containment system through which radioactive contents might escape is properly closed and sealed.
6. External radiation and contamination levels are within the allowable limits.
7. For type B and Large Quantity Packages, ensure that all QA requirements have been met.

I. Instructions for Maintenance of Exclusive Use Controls (Exclusive use vehicles only):

For exclusive use shipments, have the vehicle driver read the included statement and sign to verify understanding of the requirements. For other than exclusive use shipments, record N/A.

J. Consignee Acknowledgement of Receipt.

This block is provided to achieve formal documentation of receipt of the shipment in addition to any telephone verification.

2.0 Documentation Instructions for Radioactive Material Shipment by <u>Cargo Air Craft</u> only.

2.1 Background

The purpose of this record is to provide documentation for all Radioactive Material Shipments by Cargo Aircraft. A Radioactive Material Record must accompany every shipment of radioactive material, whether it is exempt from specific packaging and labeling or not. In addition, for air cargo, two copies of this document must be provided for the pilot-in-command.

2.2 Instructions

Documentation for this form is similar to the Radioactive Material Shipment and Receipt Record contained in this attachment with the following exceptions:

2.2.1. Heading D

1. Place a X in Air Cargo Box
2. Enter name of transport owner
3. Enter type of placard (if applicable)
4. Operator to sign to verify that proper placards (if required) are installed prior to departure.
5. Enter vehicle survey information for vehicle used to transport shipment to air cargo depot.
6. Technician performing step 5 to sign this space

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2.2.2 Heading F and G

1. Across the bottom of these spaces, enter the following additional certification. "THIS SHIPMENT IS WITHIN THE LIMITATIONS PRESCRIBED FOR PASSENGER AIRCRAFT/CARGO-ONLY AIRCARFT" (Delete Non applicable).

2.2.3 Heading H:

1. The shippers certification for air shipments is different than the certification required for highway shipments. The line provided is for RMC signature.

2.2.4 Heading I:

In accordance with federal regulations, the airline operator must inspect packages prior to loading them on the aircraft. The space provided is to document that this inspection was performed. This space is signed by the airline operator's representative.

FOR USE IN UNIT II ONLY

A ☐ Shipment No. 1 ☐ Receipt No. 1 Date 2

B ☐ Shipped To

Name 2
Company 3
Address 4
For Shipment Only:
☐ Consignee NRC License No. 5
☐ Consignee State License No.: 6
Consignee is authorized to receive this radioactive material 7
Waste Management

C Shipped From

Name 1
Company
Address
Telephone No. 2
Area Number

D Transport Information

☐ Shipped ☐ Received via: 1
☐ Truck ☐ Car ☐ Mail ☐ Rail 2
Transport Owner: 3
Vehicle Type: 4
Placard 5
Operator

6 Vehicle Radiation Survey
Highest Contact (MR/hr)
6 ft. Reading (MR/hr)
Occupied Area (MR/hr)
7
Technician Sign.

E

Shipping Name 1
☐ Empty
☐ Radioactive Material, Limited Quantity, N.O.S.
☐ Radioactive Material, LSA, N.O.S.
☐ Radioactive Material, N.O.S.
☐ Radioactive Material, Special Form, N.O.S.
Hazard Class: Radioactive Material
Total Quantity: 2 Curies
Limited Quantity: ☐ NO ☐ YES 3
Radionuclide(s): 4

F Description of Package Contents / **G Package Description**

Package Number	Contents 2	Radio-nuclides 3	Package Radio-activity (Curies) 4	Physical Form 5	Chemical Form 6	Trans. Group No. 7	Type (box, drum, ect.) 1	DOT Spec. No. 2	USNRC I.D. Marking 3	Volume (ft³) 4	Weight (lbs) 5	Max. Exp. Rate (mrem/hr) 6 Contact	3'	External Loose Cont. Level (dpm/100cm²) 7	Sealed 8 NO	YES	DOT Label 9 None	Empty	Radioactive LSA	White I	Yellow II	Yellow III
	TOTAL							TOTAL														

8 HP Foreman/Supervisor Review
10 HP Foreman/Supervisor Review

H Shippers Certification

This is to certify that the above named materials are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation.

Waste Management Activity

I Instructions for Maintenance of Exclusive Use Controls (Exclusive use vehicle only)

This vehicle shall not be used to carry packages from another consignee. The packages on this vehicle shall be unloaded by the consignee named in block 1 or his designated agent only.

Signature of Vehicle Driver Date

J Consignee Acknowledgement of Receipt

Consignee, please sign and return a copy of this record to the consignor named in block 2 to indicate receipt of this shipment.

Consignee Signature Date

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FOR USE IN UNIT II ONLY

Page ______

RADIOACTIVE MATERIAL SHIPMENT RECORD – AIR

FORM ...8-2

A ☐ Shipment No. 1 ☐ Receipt No. ______ Date 3

FOR USE IN UNIT II ONLY

B Shipped To
Name 2
Company 3
Address 4
For Shipment Only:
☐ Consignee NRC License No. 5
☐ Consignee State License No.: 6
Consignee is authorized to receive this radioactive material 7
Waste Management

C Shipped From
Name 1
Company
Address
Telephone No. 2
Area Number

D Transport Information
SHIPPED VIA:
☐ 1 Air Cargo
Transport Owner: 2
Placarded 3
4
Operator's Signature

5 Vehicle Radiation Survey
Highest Contact ______ (MR/hr)
6 ft. Reading ______ (MR/hr)
Occupied Area ______ (MR/hr)
6
Technician Sign.

E Shipping Name 1
☐ Empty
☐ Radioactive Material, Limited Quantity, N.O.S.
☐ Radioactive Material, LSA, N.O.S.
☐ Radioactive Material, N.O.S.
☐ Radioactive Material, Special Form, N.O.S.
Hazard Class: Radioactive Material
Total Quantity: 2 Curies
Limited Quantity: ☐ NO ☐ YES 3
Radionuclide(s): 4

F Description of Package Contents — **G** Package Description

PACKAGE NUMBER	Contents	Radionuclides	Package Radioactivity (Curies)	Physical Form	Chemical Form	Trans. Group No.	Type (box, drum, ect.)	DOT Spec. No.	USNRC I.D. Marking	Volume (ft³)	Weight (lbs)	Max. Exp. Rate (mrem/hr) Contact	Max. Exp. Rate (mrem/hr) 3'	External Loose Cont. Level (dpm/100cm²)	Sealed NO	Sealed YES	DOT Label: None	Air Cargo	Radioactive LSA	White I	Yellow II	Yellow III
1	2	3	4	5	6	7	1	2	3	4	5	6	6	7	8			9				

THIS SHIPMENT IS WITHIN THE LIMITATIONS PRESCRIBED FOR PASSENGER AIRCRAFT/CARGO-ONLY AIRCRAFT

FOR USE IN UNIT II ONLY

52.10

TOTAL ______ 8 HP Foreman/Supervisor Review

TOTAL ______ 10 HP Foreman/Supervisor Review

H Shippers Certification for Air Shipment

I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and in proper condition for carriage by air according to applicable National Governmental Regulations.

1.
WMA Signature ______ Date ______

I Operator's Inspection

In accordance with National Governmental Regulations, I have inspected the package(s) contained in this shipment prior to loading.

Operator's Signature ______ Date ______

J Consignee Acknowledgement of Receipt

Consignee, please sign and return a copy of this record to the consignor named in block 2 to indicate receipt of this shipment.

Consignee Signature ______ Date ______

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Shipment - White Shippers Copy - Canary H.P. File - Pink WMA - Goldenrod

TMI 118 7.79

ATTACHMENT 4

SPECIAL FORMS

4.1 Vechicle Inspection Checklist

4.2 Vehicle Inspection Criteria

4.3 Vehicle "Out of Service" Criteria

4.4 Preload Vehicle Survey Record

4.5 Post Load Vehicle Survey Record

4.6 Pre Load Vehicle Survey Record (Casks)

4.7 Post Load Vehicle Survey Record (Casks

4.8 CNSI/U.S. ECOLOGY Cover Sheet

4.9 Shipping Container Survey

FOR USE IN UNIT II ONLY

ATTACHMENT 4.1

FOR USE IN UNIT II ONLY

VEHICLE INSPECTION CHECKLIST

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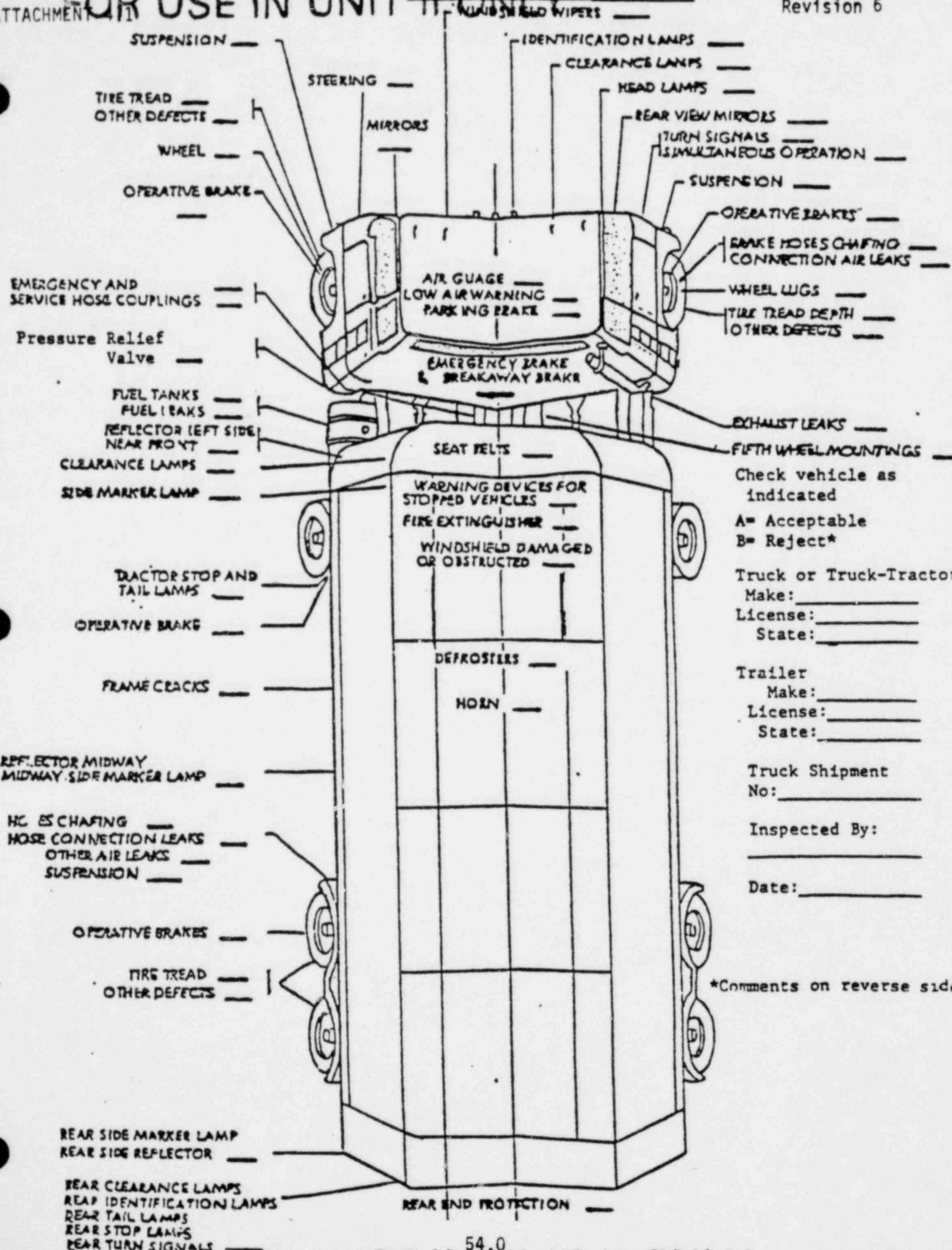


Check vehicle as indicated

A= Acceptable
B= Reject*

Truck or Truck-Tractor
Make:__________
License:__________
State:__________

Trailer
Make:__________
License:__________
State:__________

Truck Shipment
No:__________

Inspected By:
____

Date:__________

*Comments on reverse side

FOR USE IN UNIT II ONLY

ATTACHMENT 4.2

VEHICLE INSPECTION CRITERIA

CAB INSPECTION

STEP NO.	ITEM TO CHECK	CRITERION
1.	Parking brake	Check operation.
2.	Air pressure reading ________psi (fully charged)	Check air pressure reading in psi required.
3.	Leakage	a. With engine stopped and no brakes applied, observe gauge reading. Loss should not exceed 3 pounds per minute.
		b. With engine stopped, make full brake application for 2 minutes. Loss should not exceed 4 pounds per minute.
4.	Warning device	Check that warning device (visible or audible) operates at all pressures at and below 50 percent of cut out pressure.
5.	Pressure build-up	Run engine at fast idle. Time to raise pressure to cut out should not exceed 5 minutes.
6.	Horn(s)	a. Horn required to give an adequate and reliable warning signal.
		b. If equipped with two horns, both must be in proper operating condtion.
7.	Windshield wipers	Two required unless one will clean all but one inch at right and left sides.
8.	Windshield and windows	a. Windshield must not have any crack over 1/4 inch wide.
		b. Windshield must not have any intersecting cracks.
		c. Windshield must not have any damaged area which cannot be covered by a 3/4 inch disc (size of a US penny).

STEP NO.	ITEM TO CHECK	CRITERION
		d. No labels, stickers or other material permitted on windows or either side of driver's compartment.
		e. No labels, stickers or other vision reducing material permitted on windshield except those required by law. Such stickers must be affixed entirely within 4 1/2 inches from bottom of the windshield.
9.	Rear vision mirrors	a. Two required, one on each side.
		b. Attached firmly to outside of vehicle.
		c. So located as to reflect a view of the highway along both sides of the vehicle.
10.	Protection valve	a. Emergency position or method of operations must be clearly indicated.
		b. Manual control device must be operable by person seated in driver's seat.
11.	Cab-General	a. Objects must not obscure driver's vision ahead, to left, to right.
		b. Objects must not prevent driver's ready access to emergency items.
		c. Objects must not interfere with driver's free movement or exit from the cab.
		d. Check for defroster.
		e. Check for installation of driver's seat belts in 1965 and newer trucks.

STEP NO.	ITEM TO CHECK	CRITERION
12.	Emergency equipment	a. Fire extinguisher must be properly sealed and mounted. b. Spare fuses required if not equipped with circuit breakers. c. One set of tire chains required for one driving wheel on each side if snow or ice conditions are likely to be encountered. d. Warning devices must be one of following four options: (1) 3 flares, 4 fuses and 2 red flags, or (2) 3 red electric lanterns and 2 red flags, or (3) 3 red emergency reflectors and 2 red flags, or (4) 3 red refective triangles.

FRONT END INSPECTION

STEP NO.	ITEM TO CHECK	CRITERION
13.	Headlamps	a. Two required, equal number on each side. b. Upper and low beam selectable at driver's will.
14.	Clearance lamps	Trucks, truck-tractors, semi-trailers and trailers: a. Two amber clearance lamps required. b. Visible to front to indicate extreme width and height of truck or the cab of a truck-trailer.

STEP NO.	ITEM TO CHECK	CRITERION
15.	Identification lamps	a. Truck-tractors: (1) Three amber lamps required; (2) Placed above the top of the windshield on the vertical center line of the vehicle. b. Semitrailers and trailers: Front identification lamps are not required.
16.	Turn signals	Truck and truck-tractors: a. Two amber turn signals required, one on each side. b. Turn signals must have switch to flash simultaneously as a traffic hazard warning. System must be capable of simultaneous flashing with ignition turned on or off.
17.	Tires	a. No tire shall have fabric exposed thru tread or side-wall. b. No tire shall have less than 2/32 inch tread depth. c. Front tires on power units must have at least 3/4 inch of tread depth.
18.	Wheels	Check for visible cracked wheels, loose lug nuts or missing studs.
19.	Brake tubing and hose	a. Check for visible chafing, kinking or other mechanical damage. b. Check that connections are free of leaks.

STEP NO.	ITEM TO CHECK	CRITERION
20.	Brakes	a. Brakes required on all wheels. b. Check visually that linkage works on each installed brake.
21.	Brake drums, chambers and component parts	Check visually (but not by dismantling) cracked or broken drums, blown diaphrams, other chamber leaks, missing or broken or disconnected parts.
22.	Steering	Check visually for loose or missing nuts and bolts or positioning parts for steering column or gear box; excessive play; steering which will not turn full right and left.

LEFT SIDE INSPECTION

STEP NO.	ITEM TO CHECK	CRITERION
23.	Fuel tank	a. Check that tank is free of leaks. b. Check that tank has a securely attached fuel tank cap.
24.	Sidemarker lamps and reflectors	a. Trucks, semitrailers and trailers: (1) Sidemarkers - one on each side, at or near front, amber in color - one each side, at or near rear, red in color; (2) Reflectors - all mounted not more than 60 inches high one at or near front - amber in color; one at or near rear - red in color. b. Semitrailers and trailers 30 feet or more in length must have intermediate sidemarker lamp (amber) and reflector (amber).

FOR USE IN UNIT II ONLY

STEP NO.	ITEM TO CHECK	CRITERION
		c. Lamps and reflectors must not be obscured by parts of the vehicle, parts of the load, by dirt, or otherwise.
25.	Battery	Required to be covered unless in engine compartment or covered by fixed part of the vehicle.

REAR OF POWER UNIT INSPECTION

26.	Lamps and reflectors	a. Trucks require the following in red: (1) Two tail lamps, one at each side; (2) Two stop lamps, one at each side; (3) Two reflectors, one at each side; (4) Two clearance lamps, one at each side; (5) Two turn signals, one at each side; (6) Three identification lamps on vertical line (80 inches or more in width). b. Truck-tractors required the following in read: (1) One tail lamp, one stop lamp, two reflectors - one on each side; (2) Two turn signals, one at each side unless front signals are "double faced" and mounted so as to be visible to passing drivers.

STEP NO.	ITEM TO CHECK	CRITERION
27.	Tires	Same as in Step No. 17.
28.	Wheels	Same as in Step No. 18.
29.	Brake tubing and hose	Same as in Step No. 19.
30.	Brakes	Same as in Step No. 20.
31.	Brake drums, chambers and component parts	Same as in Step No. 21.
32.	Wiring	Check visually for bare, loose, dangling or poorly connected wires.
33.	Suspension system	Check visually for broken leaves, missing or loose U-bolts or other defective conditions likely to cause an axle shift.
34.	Fifth wheel	a. Lower half must be securely affixed by U-bolts or other secure means so that lower half cannot shift on frame. b. Check visually for cracks or breaks, loose or missing mounting brackets, and missing or inoperative locking devices.

REAR OF TOWED UNIT INSPECTON

35.	Lamps and reflectors	Semitrailers and trailers require the following in red: a. Two tail lamps, one at each side; b. Two stop lamps, one at each side; c. Two trun signals, one at each side;

STEP NO.	ITEM TO CHECK	CRITERION
		d. Two clearance lamps, one at each side;
		e. Two reflectors, one at each side;
		f. Three identification lamps mounted on vertical center line.
36.	Tires	Same as in Step No. 17.
37.	Wheels	Same as in Step No. 18.
38.	Brake tubing and hosing	Same as in Step No. 19.
39.	Brakes	Same as in Step No. 20.
40.	Brake drums, chambers and component parts	Same as in Step No. 21.
41.	Wiring	Same as in Step No. 32.
42.	Suspension system	Same as in Step No. 33.

RIGHT SIDE INSPECTION

STEP NO.	ITEM TO CHECK	CRITERION
43.	Fuel tank	Same as in Step No. 23.
44.	Sidemarker lamps and reflectors	Same as in Step No. 24.
45.	Exhaust system	a. Check visually for burning, charring or damage to electrical wiring, the fuel supply or any combustible part of the vehicle caused by the exhaust system.
		b. Check visually that the exhaust system is securely fastened.
		c. Check visually that exhaust systemis not leaking forward of or under cab.

STEP NO.	ITEM TO CHECK	CRITERION
46.	Control (service) and supply (emergency) hoses and connections	a. Check visually that they are secured against chafing, kinking, or other mechanical damage. b. Check visually that they must not drag on frame, fuel tank, deck plate, etc. c. Check that connections are free of leaks. d. Check that suitable provision has been made to prevent accidental disconnection.
47.	Breakaway and emergency braking (disconnect lines)	By observing brake linkage, check that trailer brakes apply immediately upon disconnect.
48.	Detachable electrical connections	a. Detachable connections made by twisting together wires from towing and towed units are prohibited. b. Check that wiring is contained in a cable or cables or entirely within a substantially constructed protective device. c. Check that there are no incorrect connections or accidental disconnections. d. Check for bare, loose, dangling, chafing or poorly connected wires.

TRAILER FRAME

STEP NO.	ITEM TO CHECK	CRITERION
49.	Trailer frame	Check visually for cracks and breaks.

ATTACHMENT 4.3

VEHICLE OUT OF SERVICE CRITERIA

The criteria set forth in this appendix shall be governing and unequivocally observed by the field staff in declaring and marking vehicles "out of service". All such criteria shall be based solely upon visual inspection and will not involve dismantling.

1. STEERING MECHANISM

   a. Turning - The steering wheels are incapable of being turned from full right to full left because of interference by parts of the steering mechanism, or by other damaged or dislocated parts of the vehicle. Power steering mechanism in this test is permitted.

   b. Steering wheel play - If total movement of more than 30 degrees is required at the steering wheel rim before the front wheels move when the wheels are initially in the stright-ahead position.

   c. Steering Column - Any absence or looseness of bolts or positioning parts resulting in motion of the steering column from its normal position.

   d. Steering gear attachment - Any absence or looseness of bolts or other parts resulting in motion of the steering gear at the point of attachment to the vehicle's frame.

   e. Ball and socket joints - Any looseness at any ball and socket joint in the steering linkage in excess of 3/8 inch measured in alignment with the shank or neck of the ball.

   f. Front wheel play - The play about either a horizontal or vertical axis of either front wheel exceeds 1/2 inch measured at the tread surface of the tire.

FOR USE IN UNIT II ONLY

2. BRAKE SYSTEMS

a. Missing or inoperative brakes - Brakes missing, not operating, or the shoes not touching the drum on any wheel required to have operative brakes. (Three axle trucks or truck tractors having on the front wheels brakes which have been rendered inoperative, shall not be placed "out of service" because the front wheel brakes are inoperative.)

b. Pedal reserve - On hydraulic, mechanical or power assisted brake systems, the service brake pedal first meets firm resistance at a point closer to the floor board or other fixed obstruction to the pedal travel than 20 percent of the total pedal travel from released position when measured in a straight line.

c. Brake linings and pads - Any brake lining or pad which has:

(1) Rivets or bolts loose or missing.

(2) Lining friction surface contaminated with oil, grease, or brake fluid, in such a manner as to change its frictional characteristics.

d. Drums and discs - Any drum or disc which:

(1) Is contaminated with oil, grease, or brake fluid in such a manner as to change the frictional characteristics of the friction face.

(2) Has any crack visible on the exterior of any brake drum extending more than 3/4 the width of the drum, except when the drum is properly banded to prevent the crack from expanding to any degree upon the applcation of brakes or otherwise. (Bands so used must be free of cracks.)

e. Brake internal components - Any internal mechanical parts misaligned, broken, or missing.

f. Hydraulic brake systems and external components - Any hydraulic brake system which:

(1) Has leaks in the master cylinder.

(2) Has hydraulic hoses worn, chaffed, cut or cracked through the outer casing and through one ply of fabric.

(3) Has hydraulic hoses, tubes, or connections leaking, restricted, crimped, cracked, or broken.

(4) The hydraulic service brake pedal, while applied with uniform foot pressure continues to move forward or downward.

(5) Lacks an operative warning signal.

(6) Has any visually observed leaking hydraulic fluid anywhere in the brake system.

(7) Has connecting lines or tubes not properly attached or supported to prevent damage by vibration or abrasion by contact with the frame, axle, other lines, or any other part of the vehicle and damage as set forth in f.(2) or f.(3) is present.

g. Vacuum systems - Any vacuum system which:

(1) Has evidence of leakage in the system.

(2) Has a vacuum hose worn, chaffed, cut, or cracked through the casing and through one ply of fabric.

(3) Has a hose, tube, or connection leaking, restricted, crimped, cracked, or broken.

(4) Has a collapsed vacuum hose when vacuum is applied.

(5) Has connecting lines or tubes not properly attached or supported to prevent damage by vibration or abrasion by contact with the frame, axle, other lines, or any other part of the vehicle and damage as set forth in g(2) or g(3) is present.

(6) Lacks an operative low-vacuum warning device.

(7) In vacuum-assisted systems and the system at atmospheric pressure (no vacuum), the service brake pedal does not move slightly as the engine is started while pressure is maintained on the brake pedal.

(8) With all vacuum brakes fully applies, with the trailer brake connections open (if a trailer is connected) and the engine operated long enough to reach constant vacuum, and the trailer brake connections disconnected from the towing vehicle, the trailer brake application cannot be maintained for at least 5 minutes.

(9) Fails to have an operative second independent means for applying brakes on towed vehicles equipped with vacuum brakes.

(10) Has any vacuum reservior not securely attached to the motor vehicle.

h. Air-mechanical brake systems - Any air-mechanical brake system which:

(1) Has an air hose worn, chaffed, cut or carcked through the outer casing and through one ply of fabric.

(2) Has an air hose, tube, or connection leaking, restricted, crimped or broken.

(3) Has connecting line or tubes not properly attached or supported to prevent damage by vibration or abrasion by contact with the frame, axle, other lines or any other part of the vehicle and damage as set forth in h.(1) or h.(2) is present.

(4) Has a brake chamber, foot valve, or any other valve in the system or stop-light switch with a clearly audible leak.

(5) Has an air reservoir not securely attached to the motor vehicle.

(6) Has a belt-driven compressor subject to intermittent operation due to looseness of belts or defective pulley condition, or <u>any</u> looseness of mounting bolts on any compressor.

(7) Has an air pressure drop of more than 3 psi in 1 minute for single-unit vehicles, and 4 psi in 1 minute for vehicle combinations, with engine running at idling speed and the service brake applied.

(8) With control (service) and supply (emergency) lines disconnected, the towed vehicle brakes fail to remain in the applied position for at least 5 minutes.

(9) Lacks an oeprative low-air warning device.

(10) On an air-mechanical braked power unit, towing a trailer with air-mechnaical brakes, the power unit is: (a) not equipped with automatic and manual means for activition, (b) found to be inoperative, or (c) malfunctioning to the extent that towing unit air supply vented to atmosphere when either of the means are used.

FOR USE IN UNIT II ONLY

(11) The brakes on air-mechanical braked towed vehicles do not apply automatically when the power unit air pressure is reduced to some point between 45 and 20 psi.

i. Electric brake systems - Any electric brake system that:

(1) Has loose or dirty terminal connections, or broken, frayed, or unsupported wires.

(2) Has brakes that do not apply and remain applied for at least 5 minutes when the breakaway safety switch is activated.

j. Parking brake system - Any parking brake system that:

(1) Has any mechanical part of the parking brake missing, broken, or disconnected.

(2) Is not capable under any load condition of holding the vehicle or combination of vehicles on the grade on which it is tested.

(3) The application mechanism, when fully applied, will not hold in the applied position without manual effort.

(4) Uses fluid pressure, air pressure, or electric energy to hold it in the applied position.

3. LIGHTING DEVICES AND REFLECTORS

During the period of 1/2 hour after sunset to 1/2 hour before sunrise:

a. Headlamps - The single vehicle or towing vehicle does not have at least one operative headlamp on one side and at least one other operative road lighting device on the other, or all required front clearance lamps installed and operative.

FOR USE IN UNIT II ONLY

b. Lamps on rear

(1) Buses, trucks, and towed vehicles, including driveaway-towaway operations, 80 inches or more in width. There are not at least two operative red lamps, other than stop lamps, on the rear of the rearmost vehicle visible from a distance of 500 feet.

(2) Truck-tractors as single vehicles, and all other vehicles and combintaion of vehicles less than 80 inches in width. There is not at least one operative red lamp, other than a stop lamp, on the rear of the rearmost vehicle visible from a distance of 500 feet.

c. Lamps on projecting loads - There are not at least two operative red lamps on the rear of loads projecting 4 or more feet beyond the vehicle body.

d. None of the turn signals or vehicle or combination of vehicles are operative, regadless of light conditions.

e. At least one operative stop lamp on the rear of a single unit vehicle or the rearmost vehicle of a combination of vehicles, at any time the vehicle or combination is being operated, regardless of light conditions.

4. TIRES

a. Tread depth - Any tire on:

(1) Front wheels worn so that less than 2/32-inch tread remains when measured in any two adjacent major tread grooves at three equally spaced intervals around the circumference of the tire.

(2) Any wheel other than a front wheel that has a tire worn so that less than 1/64-inch tread remains when measured in any two adjacent major tread grooves at three equally spaced intervals around the circumference of the tire.

b. Any tire that:

(1) Has any visually observed bump, bulge, or knot apparently related to tread or sidewall separation.

(2) Has any tread separation from the carcass:

(a) Exposing fabric in excess of 4 square inches.

(b) Exposing buffed or prepared carcass surface in excess of 4 square inches.

(c) Extending across 3/4 of the width of the tread.

(3) Has cuts - Any tire cut through three or more layers of textile plies, and the cut being 4 inches or more long at the third layer.

(4) Is flat - Any tire, on any wheel, flat or having an audible leak.

(5) Contacts mate - Any dual tire so mounted or inflated that it comes in contact with its mate.

(6) Is marked "Not for highway use" or otherwise marked and having like meaning.

(7) Any steering axle tire with any textile ply showing in the tread area or worn through one play in the sidewall.

FOR USE IN UNIT II ONLY

5. WHEELS AND RIMS

a. Rims and rings which are mismatched, bent, sprung, or cracked. (Not to be confused with rims purposely split or cut at manufacture.)

b. Disc wheels with elongated bolt holes or cracks between hand holes or stud holes, or both.

c. Cast wheels (spoke type) that are cracked.

d. Two or more of the wheel bolts, nuts, or clamps are loose, broken, missing, or mismatched.

e. Any disc, spoke type wheel, or rim with welded repair.

6. EXHAUST SYSTEMS

a. Exhaust systems not securely fastened. (Some exhaust systems have mounting brackets that are intended to allow movement to counteract thermal expansion. Such vehicles shall not be written up as in violation of the regulations, unless the bolts or other method of attaching the mounting brackets are loose.)

b. Exhaust systems determined to be leaking at a point forward of or directly below the driver compartment of any truck or truck-tractor, or forward of or below the passenger compartment of any bus or closed body of any truck used for transporting migratory workers. (For purposes of this item, a vehicle body is not considered to be closed if it uses a canvas tarpaulin or flexible material to exclude weather at the top, sides, or ends.)

(1) NOTE: The criteria in 6a. and 6b. are to be construed to exclude vehicles equipped with exhaust systems intentionally designed to exhaust to the front end of the vehicle.

FOR USE IN UNIT II ONLY

(2) NOTE: Carbon or other types of residue are found in flexible pipe and joints in exhaust systems. The carbon and other materials will work through the flexible pipe and joints. Therefore, actual leakage of exhaust gases must be occurring at the locations specified above. This can be determined by placing a piece of paper on your hand near the suspected leak point to detect escaping gases.

7. FUEL SYSTEMS

a. Any fuel system with visible leaks at any point in the fuel system.

b. Any fuel tank filler cap missing, poorly fitted or with a defective gasket.

c. Any fuel tank not securely attached to the motor vehicle. (Some fuel tanks use springs or rubber bushing to permit movement.)

8. COUPLING DEVICES

a. Any tow-bar or adjustable fifth wheel assembly with 1/4 or more of the locking pins missing.

b. Any adjustable fifth wheel locking mechanism that does not remain in the locked position without manual effort.

c. Any leakage in adjustable fifth wheel locking mechanisms dependent on fluid energy or air pressure.

d. Fifth wheel and tow-bar play.

(1) Play lengthwise of the vehicle exceeding on inch between the upper and and lower fifth wheel halves.

(2) Where provision is made for adjustment of a fifth wheel lower half or tow-bar, relative to the vehicle frame, there is more than 1 inch of play length wise of the vehicle in any such adjustment when locked or latched in position.

e. Fifth wheel mounting - Fifth wheel mountings including bolts, nuts, welds, and brackets, but not including adjustable features, which are loose, worn, or broken so as to permit 1/4-inch or more observable relative motion between the fifth wheel mounting and the frame of the vehicle.

f. Fifth wheel and tow-bar cracks or breaks - Any cracks or breaks in the tow-bar of fifth wheel except:

(1) Cracks in the ramps or horns of fifth wheels.

(2) Casting shrinkage cracks in the ribs of the body of cast fifth wheels.

9. SUSPENSION

a. Axle positioning parts - Any torque arms, U-bolts, spring hangers, or other axle positioning parts cracked, broken, loose, or missing so as to permit displacement of an axle from its normal position.

b. Spring assembly

(1) One-fourth or more of the leaves in any leaf spring assembly broken or missing, or the main leaf depended upon for positioning the axle is broken.

(2) One or more leaves shifted from normal position that could permit coming in contact with a tire, rim, brake drum, or frame.

(3) Air suspension, leaking.

c. Torsion bar assembly or torque arm - Any part of the torsion arm assembly or torque arm or any part used for attaching the same to the vehicle frame or axle, cracked, broken, or missing.

d. Frame member - Any cracked, loose, or broken frame member (permitting shifting of the body onto moving parts or collapse of the frame).

e. Any suspension system defect or any condition of loading that permits the body or frame to come in contact with a tire or any part of the wheel assemblies.

f. Adjustable axle assemblies - any:

(1) Adjustable axle assembly with 1/4 or more of the locking pins missing.

(2) Adjustable axle assembly with more than 1 inch of play lengthwise along the vehicle in any such adjustment when locked or latched in position.

10. SAFE LOADING

a. Any loading within any passenger-carrying space which interferes with the ready exit of passengers from the vehicle.

b. Any loading within the driver's compartment which obscures his view ahead or to the right or left sides or to the rear.

c. Protection against shifting cargo.

(1) Any vehicle without front-end structures, or equivalent devices.

(2) Vehicles and loading condition such that any part of the load can fall onto the roadway.

11. ENGINE

The engine cannot be started without external assistance within 5 minutes.

12. POWER TRAIN

Engine cannot be started with the transmission in neutral because of a defective or improperly adjusted clutch. (Transmission cannot be shifted from neutral after engine is started).

13. MIRRORS

Any power unit with only one mirror on the driver's side that is cracked, pitted, or clouded to the extent that rear vision is obscured.

14. WINDSHIELD WIPERS:

Any power unit that has inoperative wiper or parts of blades or arms are missing or are severely damaged on the driver's side.

FOR USE IN UNIT II ONLY

THREE MILE ISLAND
NUCLEAR GENERATING STATION
PRELOAD
VEHICLE SURVEY RECORD

Trailer ID______________ Lic #_________

Truck ID______________ Lic #_________

Company______________ _________

Date______________

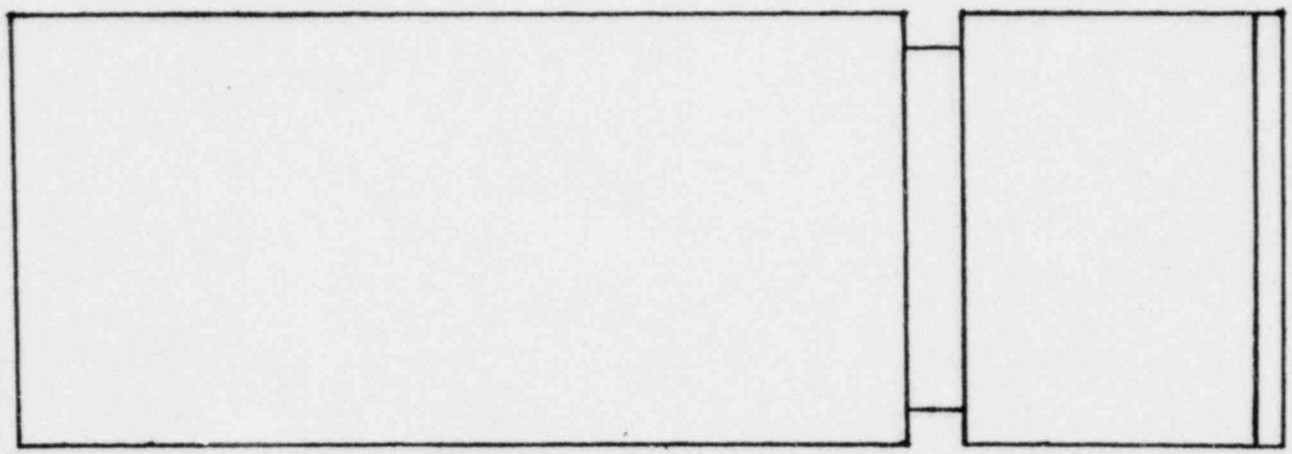
Time______________

Location______________

Inst______________

Tech______________

Shipment#______________



Perform radiation survey (contact) with interior surface/bed of trailer. Perform appropriate survey, scan and/or swipe of trailer. Swipes taken shall be counted for Beta-Gamma and Alpha. Attach results.

FOR USE IN UNIT II ONLY

FOR USE IN UNIT II ONLY

ATTACHMENT 4.4

THREE MILE ISLAND
NUCLEAR GENERATING STATION
POST LOAD
VEHICLE SURVEY RECORD

Trailer ID____________ Lic #______
Truck ID____________ Lic #______
Company______________ ________
Date__________ ______
Time__________ ______
Location______________
Inst______________
Tech______________
Shipment #____________

Maximum at 6'
After Load _____

LOAD HOLDDOWN: SATISFACTORY

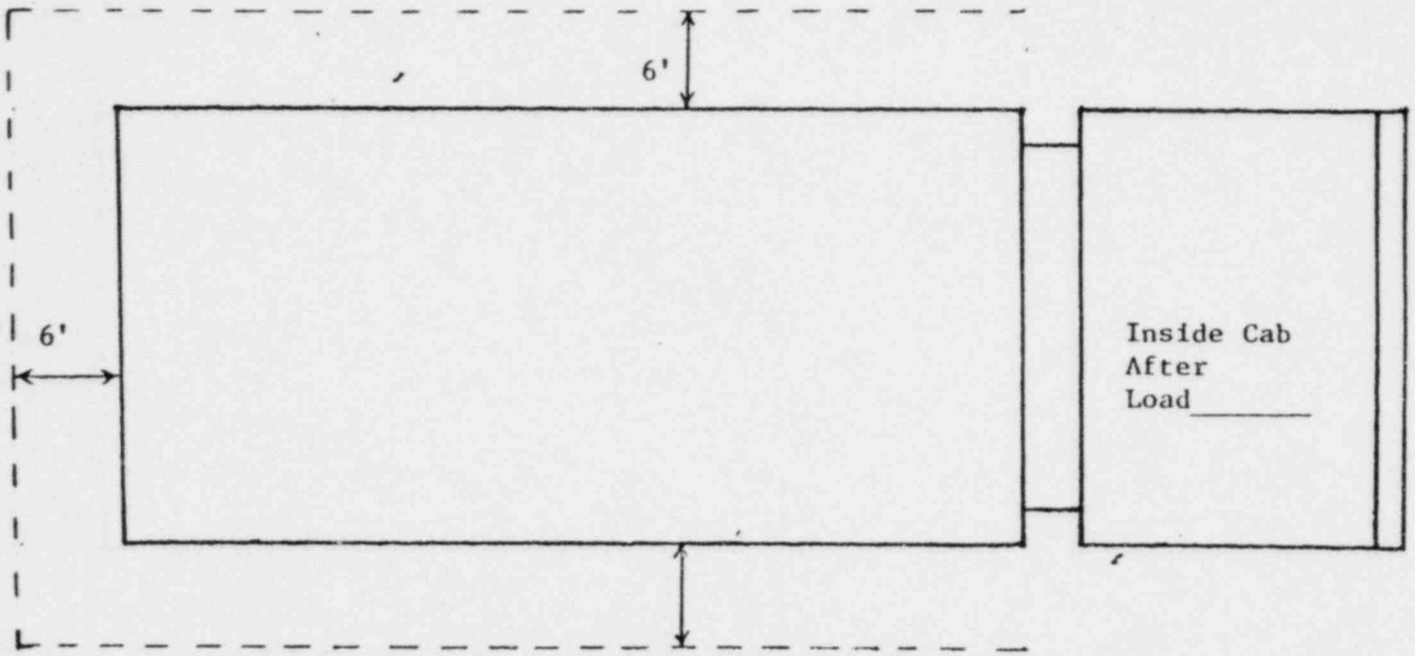
______________ __________
Signature Date
RMC

______________ __________
Signature
OPS QA

FOR USE IN UNIT II ONLY

ATTACHMENT 4.5

Maximum at 6'
After
Load________



Maximum at 6'
After Load______

FOR USE IN UNIT II ONLY

78.0

VEHICLE SURVEY LIMITS

1. 200 mr/hr--surface of vehicle
2. 10 mr/hr--6' from vehicle
3. 2 mr/hr--In any normally occupied area

NOTE: These limits apply to exclusive use shipments only.

Perform a radiation survey(contact and 6' from vehicle). Perform a swipe survey on vehicle exterior and accessible loading area. Count swipes for Beta-Gamma and Alpha. Attach results.

DRIVERS INSTRUCTIONS
Completed by____________________, Date __________

1618A
Revision 6

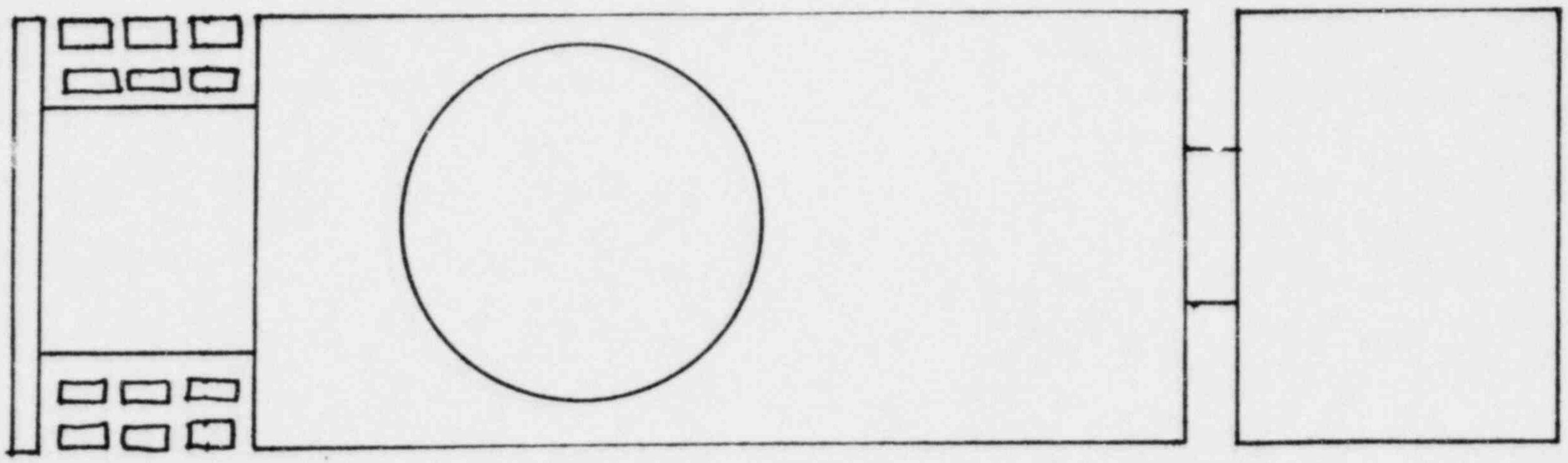
FOR USE IN UNIT II ONLY

ATTACHMENT 4.6

THREE MILE ISLAND
NUCLEAR GENERATING STATION
PRELOAD
VEHICLE SURVEY RECORD

Trailer ID_______________ Lic#__________
Truck ID_______________ Lic #__________
Company___________________________________
Date______________________
Time______________________
Location____________________
Inst______________________
Tech______________________
Shipment#____________________

FOR USE IN UNIT II ONLY



MAXIMUM EXTERIOR LEVELS

__________ mr/hr
__________ dpm/100 cm^2 Beta-Gamma
__________ dpm/100 cm^2 Alpha

MAXIMUM INTFRIOR LEVELS

__________ mr/hr
__________ dpm/100 cm^2 Beta-Gamma
__________ dpm/100 cm^2 Alpha

Perform radiation survey (contact) with exterior surface of cask. Perform appropriate survey, scan and/or swipe of cask and trailer. Swipes taken shall be counted for Beta-Gamma and Alpha. Attach results.

ATTACHMENT 4.7

FOR USE IN UNIT II ONLY

Trailer ID________________ Lic # ________
Truck ID________________ Lic # ________
Company________________________
Date________________
Time________________
Location________________
Inst________________
Tech________________
Shipment #________________

THREE MILE ISLAND
NUCLEAR GENERATING STATION
POST LOAD
VEHICLE SURVEY RECORD

LOAD HOLDDOWN: SATISFACTORY

________________ ________
Signature-RMC Date

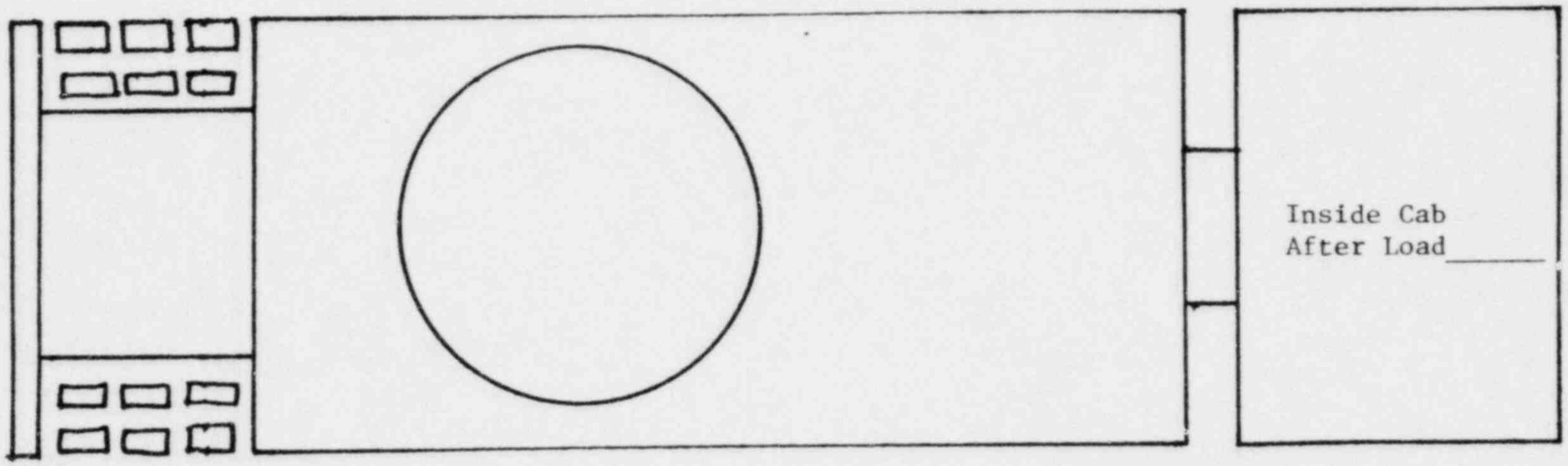
________________ ________
Signature-OPS.QA Date

Maximum at 6'
After Load________

Maximum at 3'
After Load________

Maximum at 3'
After Load________

Maximum at 6'
After Load________



Inside Cab
After Load________

Maximum at 3'
After Load________

Maximum at 6'
After Load________

Maximum contact with
cask surface________

VEHICLE SURVEY LIMITS

200 mr/hr.....Surface of cask
10 mr/hr......6' from vehicle
2 mr/hr.......In any normally occupied area

FOR USE IN UNIT II ONLY

DRIVERS INSTRUCTIONS
Completed by________________
Date____________

Perform a radiation survey (contact, 3 foot and 6 foot), Perform appropriate survey, scan and/or swipe of cask and trailer. Swipes to be counted for Beta-Gamma and Alpha. Attach results.

1618A
Revision 6

FOR USE IN UNIT II ONLY

1618A
Revision 6

ATTACHMENT 4.8

COVER SHEET TO ACCOMPANY CNSI'S/U. S. ECOLOGY'S
"RADIOACTIVE WASTE SHIPMENT AND DISPOSAL FORM"

1. Consignee's State License Number: ______________________
2. Consignee is authorized to receive this Radioactive Material.

   ____
   Waste Management

3. Shipment Number: ______________________ Total CUries: ______________
4. Vehicle Type: ______________________
5. Placard: ______________________

   Operator Signature: ______________________
6. Vehicle Radiation Survey:

   Highest Contact: ______________ mr/hr.

   6 ft. Reading: ______________ mr/hr.

   Occupied Area: ______________ mr/hr.

   Technician Signature: ______________________
7. Instructions for Maintenance of Exclusive Use Controls (Exclusive Use Vehicle Only).

   This vehicle shall not be used to carry packages from another consignee. The packages on this vehicle shall not be moved or unloaded except by the consignee designated on the shipping forms or his designated agent only. Do not change tractors before arrival at burial site or change fifth wheel adjustment on tractor without notification and approval of shipper. Notify shipper immediately if involved in a situation where a shift in the load is suspected.

   Signature of Vehicle Driver: ______________________

   Date: ______________________
8. Sealed: ______________________
9. The recorded package contents and radiation and contamination data have been reveiwed.

   HP Foreman/Supervisor Signature: ______________________
10. Consignee Acknowledgement of Receipt

    Consignee, please sign and return a copy of this cover sheet to the consignor, as indicated on the Radioactive Shipment Record Form, to indicate receipt of this shipment.

    Consignee, Signature and Title: ______________________

    Date: ______________________

816

FOR USE IN UNIT II ONLY

1618A
Revision 6

SHIPPING CONTAINER SURVEY

Container Number	Dose Rate mr/hr Contact			Contamination dpm/100cm^2		Millicurie Content	Label (Type)	Gross Wt.	Date Shipped	Inspection Performed (Initial)
	Avg.	Hi	3ft	β γ	Alpha					

Torque Wrench Data

Serial No.________________

Cal. Due Date________________

Surveyed by:____________________

Date:____________________

Inspected by:____________________

Date:____________________

FOR USE IN UNIT II ONLY

HP PROCEDURE 1618A

ATTACHMENT 5

U. S. ECOLOGY, INC.

RADIOACTIVE WASTE SHIPMENT AND DISPOSAL FORM

DESCRIPTION AND DOCUMENTATION INSTRUCTIONS

NOTE: This attachment is to be used in lieu of Attachment 3 for shipments to U. S. ECOLOGY's Richland, Washington Disposal Site.

37165

SHIPPER
ADDRESS
CITY STATE
PHONE
DATE SHIPPED SHIPMENT NO
CARRIER

RADIOACTIVE WASTE SHIPMENT & DISPOSAL FORM

US ECOLOGY, INC.

EXECUTIVE OFFICE: (502) 426-7160

P.O. BOX 7246 • LOUISVILLE, KENTUCKY 40207

Illinois Office: (815) 454-2376

NO. 18201 PAGE ____ OF ____

[ ] P. O. Box 578 Beatty, NV 89003 (702) 553-2203

Permit Number

[ ] P. O. Box 638 Richland, WA 99352 (509) 377-2411

Permit Number

1?8A Revision 6

FOR USE IN UNIT II ONLY

TOTAL QUANTITY	PROPER SHIPPING NAME & HAZARD CLASS (PER 49 CFR 172.101)	IDENTIFICATION NUMBER	TOTAL WEIGHT IN POUNDS
	Waste Radioactive Device, N.O.S. — Radioactive Material	UN2911	
	Waste Radioactive Material, Fissile, N.O.S. — Radioactive Material	UN2918	
	Waste Radioactive Material, Low Specific Activity, N.O.S. — Radioactive Material	UN2912	
	Waste Radioactive Material, N.O.S. — Radioactive Material	NA9181	
	Waste Radioactive Material, Limited Quantity, N.O.S. — Radioactive Material	UN2910	
	Waste Radioactive Material, Special Form, N.O.S. — Radioactive Material	NA9182	

(1) Container No.	(2) Cubic Feet	(3) Weight (Pounds)	(4) Physical Form	(5) Chemical Form	(6) Radionuclide	(7) Special Nuclear Material (Grams)	(8) Source Material (Kilograms)	(9) Activity [ ] Curies [ ] Millicuries	(10) Radiation Levels mR/HR Surface	3 Feet	(11) Transport Group	(12) Transport Index	(13) Label	(14) Fissile Class	(15) Type of Container
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
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													Radioactive –		
													Radioactive –		
													Radioactive –		
TOTALS															

FOR USE IN UNIT II ONLY

LIPPS-NATIONAL CORP NEW ALBANY, IND

THIS IS TO CERTIFY THAT THE ABOVE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION

Authorized Signature Title

THIS IS TO CERTIFY THAT ARTICLES ARE IN COMPLIANCE WITH ALL REGULATIONS APPLICABLE AT THE DESIGNATED DISPOSAL SITE.

Authorized Signature Title

84.0

DISPOSAL SITE COPY

FOR USE IN UNIT II ONLY

1618A
Revision 6

Nuclear Engineering Company Inc.

INSTRUCTIONS FOR COMPLETING THE
RADIOACTIVE WASTE SHIPMENT AND DISPOSAL FORM

Nuclear Engineering Company, Inc. (NECO) requires that customers shipping radioactive waste to NECO's disposal sites complete NECO's Radioactive Waste Shipment and Disposal (RWSD) Form.

It is most important that the wastes shipped be properly described and classified according to Department of Transportation (DOT) regulations.

The instructions outlined herein are supplied to aid you in completing the RWSD form. ALL SECTIONS MUST BE COMPLETED.

General questions regarding the use of NECO's RWSD Form may be directed to the NECO site serving you or the NECO's sales office at 502-426-7160. Specific questions should be referred to your Radiation Safety Officer or Legal Advisor.

DISTRIBUTION

WHITE (Original)	- NECO
WHITE	- NECO
YELLOW	- CARRIER
PINK	- CUSTOMER

NOTE: Due to Company name change all references to Nuclear Engineering Co., Inc. (NECO) are to be replaced with U. S. ECOLOGY, INC.

FOR USE IN UNIT II ONLY

1618A
Revision 6

EXAMPLE FORM

FOR USE IN UNIT II ONLY

SECTION A

(1) SHIPPER METROPOLITAN EDISON CO
(2) ADDRESS P.O. BOX 480
CITY Middletown STATE Pa.
(3) PHONE 717-948-8665
(5) DATE SHIPPED 6-30-81 (4) SHIPMENT NO RS 81-052II
(6) CARRIER TRISTATE MOTOR TRANSIT CO

RADIOACTIVE WASTE SHIPMENT & DISPOSAL FORM
US ECOLOGY, INC.
EXECUTIVE OFFICE: (502) 426-7160
P.O. BOX 7246 • LOUISVILLE, KENTUCKY 40207
Illinois Office: (815) 454-2376

NO. 18201

PAGE 1 OF 1

SECTION B
☐ P. O. Box 578
Beatty, NV 89003
(702) 553-2203
Permit Number

(1) ☒ P. O. Box 638
Richland, WA 99352
(509) 377-2411
(2) Permit Number 4580

SECTION C

(2) TOTAL QUANTITY	(1) PROPER SHIPPING NAME & HAZARD CLASS (PER 49 CFR 172.101)	IDENTIFICATION NUMBER	(3) TOTAL WEIGHT IN POUNDS
1 DRUM	Waste Radioactive Device, N.O.S. — Radioactive Material	UN2911	325
1 DRUM	Waste Radioactive Material, Fissile, N.O.S. — Radioactive Material	UN2918	430
1 DRUM	Waste Radioactive Material, Low Specific Activity, N.O.S. — Radioactive Material	UN2912	600
	Waste Radioactive Material, N.O.S. — Radioactive Material	NA9181	
	Waste Radioactive Material, Limited Quantity, N.O.S. — Radioactive Material	UN2910	
	Waste Radioactive Material, Special Form, N.O.S. — Radioactive Material	NA9182	

SECTION D

(1) Container No	(2) Cubic Feet	(3) Weight (Pounds)	(4) Physical Form	(5) Chemical Form	(6) Radionuclide	(7) Special Nuclear Material (Grams)	(8) Source Material (Kilograms)	(9) Activity [ ] Curies [x] Millicuries	(10) Radiation Levels mR/HR Surface	(10) 3 Feet	(11) Transport Group	(12) Transport Index	(13) Label	(14) Fissile Class	(15) Type of Container
1	7.5	325	SOLID	FILTER	Cs137	–	–	5	10	1	III	1	Radioactive – YELLOW II	–	DRUM
													Radioactive –		
1	7.5	430	SOLID	OXIDE	U 235	5	–	.0017	3	1	III	1	Radioactive – WHITE I	I	DRUM
													Radioactive –		
1	7.5	600	SOLID	OXIDE	T 232	–	8	87.2	1	1	III	1	Radioactive – WHITE I	–	DRUM
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
													Radioactive –		
TOTALS	22.5	1355				5	8	92.2017							

SECTION E

THIS IS TO CERTIFY THAT THE ABOVE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION

John Doe RMC
Authorized Signature Title

DISPOSAL SITE COPY

THIS IS TO CERTIFY THAT ARTICLES ARE IN COMPLIANCE WITH ALL REGULATIONS APPLICABLE AT THE DESIGNATED DISPOSAL SITE

John Doe RMC
Authorized Signature Title

FOR USE IN UNIT II ONLY

SECTION A

1 SHIPPER - INDICATE YOUR COMPANY'S NAME

2 ADDRESS - INDICATE YOUR COMPANY'S ADDRESS

3 PHONE - INDICATE YOUR COMPANY'S PHONE NUMBER (INCLUDE AREA CODE)

4 SHIPMENT NO. - OPTIONAL

5 DATE OF SHIPMENT - INDICATE DATE SHIPMENT LEAVES YOUR FACILITY

6 CARRIER - INDICATE NAME OF CARRIER - NOT THE MODE

SECTION B

1 FACILITY - INDICATE THE FACILITY TO WHICH THE MATERIAL IS DESTINED BY PLACING AN "X" BY THE APPROPRIATE MAILING ADDRESS.

2. PERMIT NUMBER - Enter Site Use Permit Number.

SECTION C

1 PROPER SHIPPING NAME & HAZARD CLASS - INDICATE INFORMATION REQUESTED IN (2) AND (3) BELOW ON THE LINE CORRESPONDING TO THE PROPER MATERIAL DESCRIPTION OF THE WASTE. (SEE APPENDIX I) IF MORE THAN ONE TYPE OF WASTE IS SHIPPED, SO INDICATE.

2 TOTAL QUANTITY - INDICATE THE TOTAL NUMBER OF PACKAGES AND THE TYPE.

3 TOTAL WEIGHT IN POUNDS - INDICATE THE TOTAL WEIGHT OF THE PACKAGES WHICH FALL INTO THE CATEGORIES LISTED ON THE SHIPMENT.

SECTION D

1 ITEM NUMBER - EACH PACKAGE OF RADIOACTIVE WASTE MATERIAL MUST BE LISTED INDIVIDUALLY, EVEN IN THE UNUSUAL CIRCUMSTANCES THAT THEY ARE EXACTLY ALIKE.

2 CUBIC FEET - THE CUBIC FOOTAGE OF THE OUTSIDE DIMENSIONS OF EACH CONTAINER MUST BE CALCULATED TO THE NEAREST HUNDREDTH OF A CUBIC FOOT.

3 WEIGHT (POUNDS) - THE COMBINED WEIGHT OF THE WASTE AND THE CONTAINER THAT IS TO BE DISPOSED OF MUST BE LISTED TO THE NEAREST POUND.

4 PHYSICAL FORM - THIS SHOULD BE LISTED AS SOLID, ABSORBED LIQUIDS, OR VIALS. PLEASE CHECK INDIVIDUAL DISPOSAL FACILITIES FOR ACCEPTABILITY.

5 CHEMICAL FORM - REQUIRED UNLESS SPECIAL FORM

THE PURPOSE OF THIS COLUMN IS TO POINT OUT ANY POSSIBLE CHEMICAL TOXICITY INVOLVED INTEGRALLY WITH THE RADIOACTIVE MATERIAL. THOSE CHEMICAL MATERIALS WHICH ARE CLASSIFIED AS GROUP 3 TOXIC ACCORDING TO IRVING SAX'S DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS ARE GENERALLY NOT ACCEPTABLE FOR DISPOSAL WITHOUT PRIOR NOTIFICATION AND/OR AUTHORIZATION. WHEN VERY COMPLEX CHEMICAL FORMS ARE PRESENT, A GENERAL GENERIC NAME WILL USUALLY SUFFICE, SUCH AS VINYL CHLORIDES OR ALCOHOLS. EXPERIMENTAL ANIMALS WHICH HAVE BEEN SACRIFIED MAY BE LISTED AN "ANIMAL CARCASSES" UNLESS THE CHEMICAL TO WHICH THEY WERE EXPOSED ARE GROUP 3 TOXIC OR ARE ETIOLOGIC IN NATURE. IF EXPERIMENTAL ANIMALS HAVE BEEN EXPOSED TO GROUP 3 TOXIC, OR ETIOLOGIC SUBSTANCES, BOTH "ANIMAL CARCASSES" AND A DESCRIPTION OF THE CHEMICAL IS REQUIRED.

6 RADIONUCLIDE (SEE APPENDIX II)

LIST ALL RADIONUCLIDES PRESENT IN EACH PACKAGE. LISTING ONLY THE MAJOR RADIONUCLIDES OR THE CATEGORY "MIXED FISSION PRODUCTS" IS NOT ACCEPTABLE.

EXAMPLE: 60-CO; 125-I; 238-U

7 SPECIAL NUCLEAR MATERIALS (GRAMS)

LIST ANY SPECIAL NUCLEAR MATERIAL IN GRAMS AS WELL AS ANY TRANSURANIC MATERIAL. THE TERM SPECIAL NUCLEAR MATERIAL REFERS TO 239-PU, 233-U, URANIUM CONTAINING MORE THAN THE NATURAL ABUNDANCE OF 235-U, OR ANY MATERIAL ARTIFICALLY ENRICHED IN ANY OF THESE SUBSTANCES. TRANSURANIC MATERIAL REFERS TO ANY ELEMENT WHOSE ATOMIC NUMBER IS GREATER THAN 92.

8 SOURCE MATERIAL (KILOGRAMS)

INDICATE THE KILOGRAMS OF SOURCE MATERIAL. THIS REFERS TO A CLASS OF MATERIALS CONSISTING OF NATURAL OR DEPLETED URANIUM, NATURAL THORIUM, OR URANIUM OR THORIUM ORES. DO NOT CONFUSE THIS WITH THE WEIGHT OF THE PACKAGE - THEY ARE NOT THE SAME.

9 ACTIVITY - CURIES OR MILLICURIES

ACTIVITY FOR EACH RADIONUCLIDE MUST BE LISTED. YOU MAY USE EITHER CURIES OR MILLICURIES; HOWEVER, YOU MUST BE CONSISTANT. IF BOTH ARE NEEDED, TWO RSWD FORMS MUST BE USED.

10 mR/HR @ SURFACE AND mR/HR @ 3 FEET

THESE COLUMNS MUST BE COMPLETED FOR EACH PACKAGE AND GENERALLY ARE TAKEN USING A G-M INSTRUMENT WITH A 30 MG/CM2 PROBE, WHICH PRODUCES A BETA-GAMMA EXPOSURE READING. THESE READINGS ARE IMPORTANT WHEN TRANSPORTING MATERIAL. BE SURE TO CHECK THE APPLICABLE REGULATIONS.

11 TRANSPORT GROUPS (SEE APPENDIX III)

EACH RADIONUCLIDE HAS BEEN ASSIGNED A TRANSPORT GROUP NUMBER AND MUST BE LISTED.

12 TRANSPORT INDEX (SEE APPENDIX IV)

INDICATE THE INDEX WHICH APPLIES.

13 LABEL (SEE APPENDIX IV)

EACH PACKAGES MUST BE LABELED PROPERLY AND THIS LABELING RECORDED.

EXAMPLE: RADIOACTIVE - WHITE I
RADIOACTIVE - YELLOW II
RADIOACTIVE - YELLOW III
RADIOACTIVE - LSA

SIMPLY INDICATING I, II, III WILL NOT SUFFICE.

14 FISSILE CLASS (SEE APPENDIX VI)

INDICATE THE FISSILE CLASS I, II, OR III WHICHEVER APPLIES

SECTION E

1 AUTHORIZED SIGNATURE

EACH FORM MUST BE SIGNED AND DATED BY A PERSON RESPONSIBLE FOR THE PACKAGING AND LABELING OPERATIONS AND CAPABLE OF SIGNING ON BEHALF OF THE COMPANY.

SHIPMENTS WILL NOT BE ACCEPTED WITHOUT THIS SIGNATURE.

RAD-CON PROCEDURE 1618-A

Attachment 6

CHEM NUCLEAR SYSTEMS, INC.
BARNWELL WASTE MANAGEMENT FACILITY
RADIOACTIVE SHIPMENT RECORD FORM

NOTE: This Attachment is to be used in lieu of Attachment 3 for shipments to CNSI's Barnwell, South Carolina Disposal Site.

FOR USE IN UNIT II ONLY

FOR USE IN UNIT II ONLY

NOTE: SEE NEXT PAGE FOR INSTRUCTIONS FOR COMPLETION OF THIS FORM.

BARNWELL WASTE MANAGEMENT FACILITY

Operated by: CHEM-NUCLEAR SYSTEMS, INC.

P. O. Box 726, Barnwell, South Carolina 29812

(803) 259-1781

RADIOACTIVE SHIPMENT RECORD FORM

Page ________ of ________

(4) Volume Allocation No. ______________

(1) FROM Company Name ______________

Address ______________

____

Contact ______________

Phone # ______________

(2) TO ______________

____

CARRIER ______________

DRIVER SIGNATURE ______________

DATE AND TIME RECEIVED ______________

(5) Shipping Date ______________

Shipment No ______________

Type of Cask ______________

Trailer No ______________

LINER SERIAL # ______________

CNSI USE ONLY

Arrival date ______________ AS# ______________

Date/Time Buried ______________ By ______________

Radiation Readings ______________ Weight ______________

Trench # ______ LOC ______ WCC ______

Total Personnel Exp ______________ (mRem)

Project # ______________

(3) – (a) Description of Materials	(b) Total # of Pkgs This Shipment	(c) Total Activity This Shipment	(d) Total Volume This Shipment	(e) Type Containers This Shipment
( ) RADIOACTIVE MATERIAL L.S.A. N.O.S. ( ) RADIOACTIVE MATERIAL N.O.S. ( ) RADIOACTIVE MATERIAL SPECIAL FORM N.O.S. ( ) RADIOACTIVE DEVICE N.O.S. RAD MATERIAL		mci	cu. ft	

(6) Item No.	(7) Radio-nuclide each container	(8) Percent Abundance Each Nuclide	(or) Activity Each Nuclide (mCi)	(9) Physical form	(10) Chemical form	(11) Waste Description	(12) U-235 (grams)	(13) U-238 Th-232 (pounds)	(14) Disposable Container Weight (pounds)	(15) Disposable Container Volume (Cu. Ft.)	(16) Container Spec.	(17) RADIATION LEVELS Disposable Container Surface	Package Surface	3 Ft. (TI)	(18) Removable Contamination Package Surface (a) DPM/100cm²(B-Y)	(19) Transport Group	(20) Label Used
(21) TOTAL																	

(22) ( ) Yes ( ) No THIS VEHICLE IS CONSIGNED EXCLUSIVE USE. LOADING AND UNLOADING MUST BE ACCOMPLISHED BY CONSIGNOR OR CONSIGNEE OR HIS DESIGNATED AGENT.

(23) **IMPORTANT** "This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

Signature ______________

Company ______________ Date ______________

(See Reverse Side for Instructions for Completing This Form)

(24) "Certification is hereby made to the South Carolina Department of Health and Environmental Control that this shipment of low-level radioactive waste has been inspected in accordance with the requirements of South Carolina Radioactive Material License No. 097 as amended, and the Nuclear Regulatory Commission's License No. 46-13536-01 as amended, and the effective Barnwell Site Disposal Criteria within 48 hours prior to shipment, and further certification is made that the inspection revealed no items of non compliance with all applicable laws, rules and regulations."

Date ______________ By ______________

Title and Organization ______________

Telephone No ( ) ______________

Form No. CNS-201

(4/80)

1618A
Revision 6

FOR USE IN UNIT II ONLY

FOR USE IN UNIT II ONLY

INSTRUCTIONS FOR COMPLETING RADIOACTIVE SHIPMENT RECORD FORM

NOTE: SHIPMENT MAY BE REFUSED IF CONTENTS, SUPPORTING DOCUMENTATION AND PACKING REQUIREMENTS ARE NOT IN COMPLIANCE WITH CHEM-NUCLEAR SYSTEMS, INC.'S STATE AND FEDERAL LICENSES, THE BARNWELL SITE CRITERIA AND APPLICABLE DOT AND NRC SHIPPING REGULATIONS.

GENERAL

Customer or shipper must provide (printed or typed) information in all numbered column headings.

An authorized representative of the company must sign and date the State of South Carolina and DOT Certification statements.

ITEM	REFERENCE	DESCRIPTION OF ITEMS
(1)	10 CFR 71.62 49 CFR 172.306	Indicate company name (consignor), address, contact person and phone number of person for shipment.
(2)	10 CFR 71.62 49 CFR 172.306	Indicate company name (consignee) to whom shipment is being made and company name of carrier transporting material. Driver to sign and date form at pickup.
(3a)	49 CFR 172.202	Check appropriate block for material being shipped.
(3b)	49 CFR 172.202	Enter total number of containers in this shipment.
(3c)	10 CFR 71.202 49 CFR 172.202	Enter total quantity of radioactivity in this shipment in millicuries. *NOTE: 3 (b) (c) and (d) constitutes a summary for the entire shipment and need be entered one time on page one of shipping papers.
(3d)	49 CFR 172.202	Enter total volume of waste in this shipment in cubic feet.
(3e)	49 CFR 172.202	Enter type of containers in this shipment (55 gal. drums, wood boxes, steel liner(s), 55 gal drums and boxes, etc.)
(4)	BSDC	Indicate volume allocation number assigned to this shipment.
(5)	10 CFR 71.62	Record the date of shipment and other data as requested. For CNSI liners, record liner serial # on side of liner, or if liner is in cask, serial # is on ID tag in pouch affixed to placard on trailer.
(6)	49 CFR 172.203	List each container separately. Identification on package itself shall match number in this column.
(7)	10 CFR 71.62 49 CFR 172.203 49 CFR 173.390	List each radionuclide contained in each container. The terms MFP and MCP **are not permitted.** Use as many lines as are required. Corresponding entries are required in column 8. NOTE: If more than one container in the shipment contains the same activity distribution of each radionuclide, then a listing of radionuclides is required only for the first container of this series. Subsequent containers in a series must be so designated.
(8)	49 CFR 172.203 BSDC	Record the % abundance OR the activity in mci of each isotope in each container (see item 7 above).
(9)	49 CFR 172.203	Indicate whether material is solid, gas, or biological.
(10)	49 CFR 172.203	Indicate chemical form of material. For example:

CHEMICAL FORM	WASTE DESCRIPTION	SPECIAL NOTE
Metal oxides Deposited metal oxides Urea Formaldehyde SrCl, Na, etc.	Compacted Trash Dewatered Resin Solidified Liquid Laboratory Trash	**ALL RESIN** shipments **MUST** be accompanied with a **COMPUTER PRINTOUT** ANALYSIS.

ITEM	REFERENCE	DESCRIPTION OF ITEMS
(11)	BSDC	Indicate whether evaporator bottoms, filters, resin, metal, animal carcasses, trash, etcetera.
(12)	NRC License	Weight, in grams, of isotope U-235 contained in each container.
(13)	NRC License	Weight, in pounds, of isotope U-238 or Th-232.
(14)	49 CFR 172.310	Indicate weight of disposable container (including contents).
(15)	BSDC	List the volume of the disposable container including skids (if used). Pallets, bracework, and dunnage are chargeable, but not classified as radioactive waste and will not be deducted from a customer's allocation.
(16)		Indicate DOT/NRC container specification if applicable, such as: Spec 7A, Type B, Strong Tight Container (STC), DOT 17H.
(17)	49 CFR 173.389 49 CFR 177.842	Record the highest measured radiation level for each disposable container surface. Package surface maybe the same as disposable container if a cask is not used. Transport Index (T.I.) equals mR/HR at three feet from **accessible** container(s).
(18)	49 CFR 173.397 BSDC	Record removable contamination levels on package surfaces. Do not use the initials BKG for background unless the background level is indicated on the shipping papers.
(19)	49 CFR 173.390	List Transport group of each radionuclide.
(20)	49 CFR 172.403	List the type label applied to each package, if not excepted by 49 CFR 173.391 or 392.
(21)		Total each page in specified columns. The totals of each page in columns 6, 8, and 15 should be added together and entered in 3b, 3c, and 3d respectively **on page one only.** The shipment total in box 3d should match the volume allocated on the PNP Form for this shipment.
(22)	49 CFR 173.392	Indicate if shipment is transported as exclusive use or not applicable. If "yes" is checked, **instructions for maintenance of exclusive use vehicles must be provided by the shipper to the carrier.**
(23)	49 CFR 172.204	Sign form as required per DOT. Signed by the RMC.
(24)	S.C. LIC. 097	Sign form as required per S.C. 097 License. Signed by one of the individuals listed in paragraph 6.1.

FOR USE IN UNIT II ONLY

FOR USE IN UNIT II ONLY

RECOVERY

1618D
Revision 2
12/03/81

CONTROLLED COPY FOR USE IN UNIT II ONLY

Disposal Group

THREE MILE ISLAND NUCLEAR STATION
UNIT NO. 2 RADIOLOGICAL CONTROLS PROCEDURE 1618D
PACKAGING OF RADIOACTIVE MATERIAL

Table of Effective Pages

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4.0	1	27.0	2	50.0	2		
5.0	1	28.0	2	51.0	2		
6.0	1	29.0	2	52.0	2		
7.0	1	30.0	2	53.0	2		
8.0	1	31.0	2	54.0	2		
9.0	1	32.0	2	55.0	2		
10.0	1	33.0	2	56.0	2		
11.0	1	34.0	2	57.0	2		
12.0	1	35.0	2	58.0	2		
13.0	1	36.0	2	59.0	2		
14.0	1	37.0	2	60.0	2		
15.0	1	38.0	2	61.0	2		
16.0	1	39.0	2	62.0	2		
17.0	1	40.0	2	63.0	2		
18.0	1	41.0	2	64.0	2		
19.0	1	42.0	2	65.0	2		
20.0	1	43.0	2	66.0	2		
21.0	1	44.0	2	67.0	2		
22.0	1	45.0	2	68.0	2		
23.0	2	46.0	2	69.0	2		

Unit 2 Staff Recommends Approval

Approval C P Dittele Date 11/17/81
Cognizant Dept. Head

Unit 2 PORC Recommends Approval

[signature] Date 11/17/81
Chairman of PORC

Unit 2 Superintendent Approval

[signature] Date 12/3/81

Mgr QA Approval

NA Date ________

NRC Approval

L A Barrett Date 12/2/81

Document ID: 0117q

FOR USE IN UNIT II ONLY

THREE MILE ISLAND NUCLEAR STATION
UNIT NO. 2 HEALTH PHYSICS PROCEDURE 1618D
PACKAGING OF RADIOACTIVE MATERIAL

1.0 PURPOSE

To delineate responsibilities and set forth requirements and methods of packaging radioactive materials in preparation for shipment from TMI.

2.0 REFERENCES

2.1 10CFR71.12, 71.33, 71.36, 71.38 - 71.40, 71.42, 71.53 - 71.55, 71.61, 71.62.

2.2 49CFR172 subparts B, D, E; 173 subparts A, B, H; 174 subparts A, C; 175 subpart A; 176 subpart A; 177 subpart A; 178 subpart A, D, K

2.3 HP Procedure 1618A Radioactive Material Shipping

2.4 Domestic Mail Manual

2.5 Burial Ground Criteria

2.6 Agreement State Licenses

3.0 ATTACHMENTS

3.1 Attachment 1; Quantitiy Determination Calculations

3.2 Attachment 2; Type A Packaging Check Lists

3.3 Attachment 3; Packaging Liquid Scintillation Vials

3.4 Attachment 4; Packaging of Contaminated Oil

3.5 Attachment 5; Packaging Compactible Trash

3.6 Attachment 6; Packaging Dirty Laundry

4.0 RESPONSIBILITIES

4.1 The Radioactive Material Coordinator (RMC) is responsible for:

4.1.1 Ensuring radioactive material to be shipped offsite is packaged and shipped in accordance with the requirements of References 2.1 - 2.6.

4.1.2 Coordination of activities associated with shipping, packaging, movement and storage of radioactive material with the TMI site personnel.

4.1.3 Curie level estimates for radioactive material intended for shipment (with assistance from the Radiological Technical Support Branch if required).

4.1.4 Preparation and incorporation into this procedure, as part of Attachment 2, a packaging checklist for all Type A shipments. New checklists will be developed for each Type A package not previously used.

4.1.5 Completion of checklists, Attachment 2, for Type A shipments.

4.2 Radiological Control Department (Rad Con) personnel are responsible for:

4.2.1 Radiological surveys associated with the packaging and subsequent shipment of radioactive material to:

4.2.1.1 Ensure personnel exposure to radioactive material and associated radiation is minimized.

4.2.1.2 Prevent the uncontrolled release of radioactivity.

4.1.1.3 Positive control and identification of radioactive material from generation/receipt to final disposition.

4.3 The Packaging Coordinator/RMC is reponsible for the proper packaging of samples in preparation for shipment in accordance with attachments to this procedure. The RMC is available for guidance in this effort and must approve all packaging of radioactive material prior to these materials being shipped from the site.

4.4 The TMI QA Group is responsible for the maintenance and execution of the QA Program required by 10CFR part 71.12 (reference 2.1).

5.0 DISCUSSION

The NRC and Department of Transportation have jurisdiction over the transportation of radioactive materials. These agencies have established specific requirements for the packaging of radioactive materials in References 2.1 and 2.2. This procedure details general packaging, marking and labeling requirements and details requirements for radioactive materials commonly shipped from TMI. Specific procedural guidance is required for the packaging of radioactive material in excess of a Type A quantity. Type A quantities will be packaged in accordance with the generic procedure as outlined in section 6.6, Type A packaging requirements and the packaging checklist in attachment 2. The RMC shall approve all packaging of radioactive materials prior to those materials being shipped from the Site.

5.1 Upon determination that it will be necessary for radioactive material (or potentially radioactive material) to be shipped from TMI, the personnel requesting the shipment shall provide the following information to the RMC:

1. Type of material (laundry, trash, etc)
2. Volume (or number of containers)
3. Weight (if applicable for type of shipment being made)
4. Sufficient information to determine curie content
5. Radiation levels (maximum contact and 3 ft levels and 6 point average readings when required)
6. Proposed shipment method
7. Sample Request Form

NOTE: The Rad Con Department should be contacted to obtain 5.1.4 and 5.1.5 above.

5.2 The RMC shall determine the quantity type of material (limited quanitity, Type A, Type B, Large Quantity, and if the the material qualifies as LSA) for each package of radioac*ive material based on information provided in Section 5.1 using Attachment 1

5.3 The RMC shall be consulted regarding any packaging requirement interpretations.

5.4 With the concurrence of the RMC, radioactive materials shall be packaged in accordance with the requirments of the applicable sections of this procedure.

5.5 Material requiring shipment can be divided into two (2) groups.

5.5.1 Material to be packaged - primarily limited quantity and Type A quantities. In most cases the curie estimate is made prior to packaging.

5.5.2 Prepackaged Material - primarily LSA and Type B quantities. For packages of LSA (compacted waste, non-compacted waste and laundry) the curie estimate is made after the packaging is completed. Solidified material and resin liners also have their curie estimates made after the material is packaged.

5.5.3 Some of the pre-packaged items may contain Type B quantities of radioactive material (solidified, resins, and compacted trash). Packaging for these items must be selected to ensure they meet shipping criteria.

5.6 Items that require special packaging (liquid scintillation vials and contaminated oil) are covered i Attachments 3 and 4.

5.7 The actual packaging of LSA (compacted and non-compacted) is covered und... separate procedures, however the packaging requirements are discussed in this procedure in section 6.5 and Attachment 5.

5.8 General packaging instructions for laundry are provided in Attachment 6.

6.0 INSTRUCTIONS

6.1 Upon determination that it will be necessary to ship radioactive material from TMI, the personnel requesting such a shipment shall provide the following information to the Radioactive Material Coordinators (RMC).

1. Type of Material (laundry, trash, etc.)
2. Volume (number of containers, etc.)
3. Weight (if applicable for type of shipment)
4. Sufficient isotopic information for fissile determination, curie estimation, etc.
5. Radiation levels - maximum contact, 3-ft levels and 6-point average conact level (as required by RMC).

NOTE: Information for items 4 and 5 may be obtained from Rad Con department.

6. If material is/are sample(s), the sample request tag is required.

6.2 The RMC shall determine if the material contains fissile isotopes. If the material is fissile, proceed with the following steps. If the material does not contain fissile material go to section 6.3.

NOTE: If it has been determined that greater than 20 curies of plutonium is present in the material, refer to 10CFR 71.42 for specific packaging requirements.

6.2.1 Determine if the material satisfies the exempt criteria set forth in 49CFR 173.396(a). If the material is classified "Fissile Exempt", proceed to section 6.3, if not proceed with the following steps.

6.2.2 Submit all information to the Nuclear Fuels Group in Parsippany or the Group at TMI they designate who shall determine the fissile class as specified in 10CFR 71.33, 71.38 thru 71.40.

6.2.3 After the Group in 6.2.2 has evaluated the information and determined the "Fissile Class", determine the quantity of material (i.e. Type A, Type B) using Attachment 1.

6.2.4 If material is calculated to be Type A, it shall be packaged as follows:

1. The packaging shall satisfy the "General Packaging Requirements" of 49CFR 173.393.
2. The packaging shall also be in accordance with the specification packaging in 49CFR 173.396(b).
3. For any packaging used, the shipper shall have supporting safety analysis documentation on file as required by 49CFR 173.395(a)(1).

6.2.5 If material is calculated to be Type B, it shall be packaged as follows:

1. The packaging shall satisfy the "General Packaging Requirements" of 49CFR 173.393.
2. The packaging shall also be in accordance with the specification packaging in 49CFR 173.396(c).
3. For any packaging used, the shipper shall have licenses, certificates of compliance, and other supporting documentation including specific authorization to use such packaging from the NRC, and comply with the terms and provisions of such documentation as required in 10CFR 71.12(b)(1), 49CFR 173.393(a) and (a)(1).
4. In addition, the package shall be marked with the package identification number as indicated on the NRC license as required by 49CFR 173.393(a)(2) and the "General Marking and Labeling Requirements" as set forth in Section 6.8 of this procedure.

6.3 The RMC shall determine if the material is Limited Quantity, Low Specific Activity (LSA), Type A, Type B, or Larger Quantity using Attachment 1. Once the quantity has been calculated proceed to the appropriate packaging section as shown below:

1. Limited Quantity - See Section 6.4.
2. LSA - see Section 6.5
3. Type A - See Section 6.6
4. Type B - See Section 6.7.

6.4 Any radioactive material determined to be "Limited Quantity" in Section 6.3 shall be packaged as follows:

Packaging containing Limited Quantities of radioactive material are exempted from specification packaging, marking and labeling, and are exempted from the provisions of 49CFR 173.393 if the following conditions are met (as specified in 49CFR 173.391(a)).

1. The materials are packaged in strong, tight packages such that there will be no leakage of radioactive materials under conditions normally incident to transportation.
2. The package must be such that the radiation dose rate at any point on the external surface of the package does not exceed 0.5 millirem per hour.
3. There must be no significant removable surface contamination on the exterior of the package in accordance with 49CFR 173.397.
4. The outside of the inner container (sample container) must be marked "RADIOACTIVE".

6.4.1 Packaging - the following packaging meets or exceeds the requirements of 49CFR 173.391 and publication 6 of the U.S. Postal Service.

1. The shipment shall be packaged in two packages, one within the other (inner package and outer package).
2. The sample container shall be contained within a leak tight poly bag.

3. Providing the inner package contains liquid, the sample container (inner container inside the inner package) shall be manufactured of non-breakable material. For samples shipped by mail the inner container must be corrosion and leak resistant. The sample container (inner container) is not considered the inner package.
4. The inner and outer package shall be lined with a leak tight poly liner.
5. Enough absorbent material must be added to absorb at least twice the volume of liquid present. The absorbent material shall be placed between the inner container and the outer package.
6. The poly liners of the inner and outer package shall be sealed to prevent possible leakage.
7. Seal the outer package to withstand normal transport and handling.
8. Providing the shipment is solid material, packing shall be placed between inner and outer package to prevent shifting of material.
9. The outside of the package shall be surveyed for loose surface contamination, the loose surface contamination shall be within plant limits.

6.4.2 Shipment of the radioactive devices and manufactured articles are not addressed in this procedure. If shipment of these items are required follow the specific requirements of 49CFR 173.391(b) and/or 173.391(c).

FOR USE IN UNIT II ONLY

6.5 Material containing Type A quantities of LSA, as determined in section 6.3, must be packaged according to the method of shipment as listed below:

1. "Sole Use" shipments - see section 6.5.1 and 6..5.2.
2. Mixed lading shipments - see Section 6.5.3.

6.5.1 "Sole Use" shipments (except aircraft). Packages of LSA, in Type A quantities, shipped under the provisions of 49CFR 173.392(b) are exempt from specification marking, labeling and packaging provided the requirements of 49CFR 173.392(c) or (d) are met. The following additional requirements also apply to packages of LSA.

1. Packages shall meet plant limits for loose surface contamination.
2. Packages shall contain no free standing liquid.
3. LSA boxes shall not be loaded to the extent that they exceed Type A quantities of radioactive material.
4. Drums of radioactive LSA should be loaded so as not to exceed Type A quantities. Drums which contain greater than Type A quantities shall be shipped under Section 6.5.2.

NOTE: The RMC shall have available, the current limitations (maximum average contact readings and minimum weight) to qualify a package as Type A LSA.

6.5.2 Packages containing greater than Type A quantities of radioactive LSA must be shipped under the more restrictive regulations of 10CFR71. These requirements are discussed in Section 6.7. However, packaging for greater than Type A LSA need not satisfy the requirements of 10CFR 71.36 (Standards for Hypothetical Accident Conditions for a Single Package) if it is shipped in a vehicle assigned for the sole use of the licensee.

6.5.3 Mixed Lading Shipments. Packages shipped under the provisions of 49CFR 173.392(a) are exempt from the package requirements of 49CFR 173.393(a-e) and (g) (the remaining portions of 173.393 apply) provided the requirements of 173.395 are satisfied. The following additional requirements also apply to packages of LSA.

1. Packages shall meet plant limits for loose surface contamination.
2. Packages shall contain no free standing liquid.

6.5.4 Packages shall be marked and labeled in accordance with Section 6.8.

6.6 Material determined to contain Type A quantities of radioactive material must be packaged in packaging that meets the requirements of the following regulation of 49CFR.

1. 173.24 - standard requirements for all packages
2. 173.389(j) - definition of Type A packaging
3. 173.393 - general packaging and shipping requirements
4. 173.398(b) - standards for Type A packaging
5. 178.350 - specification 7A, general packaging, Type A

6.6.1 A complete certification and supporting safety analysis demonstrating that the construction methods, packaging design and materials of construction for each specification 7A package shall be maintained on file for at least one year after the last shipment.

6.6.2 The following additional requirements apply to Type A packaging.

1. Packages shall meet plant limits for loose surface contamination.
2. If the package is a metal drum it shall be yellow in color (unless otherwise authorized in writing by the Supervisor, Waste Disposal).
3. Packages that contain liquids should, if practicable, have a poly liner on the inside of the outer package. This requirement is dependent on the packaging configuration.
4. Packages that contain liquids shall also have a poly liner on the outside of the inner package.
5. Each Type A sample shipment will have a diagram of the shipping container, showing the location of the samples, affixed to the outside of the shipping container.
6. The package shall be prepared in accordance with the checklist for the Type A shipment being prepared. the checklists are included in Attachment 2.

6.7 Type B and Large Quantity Packaging Requirments

6.7.1 This section applies to the packaging of radioactive material that would have a curie content per package defined as Type B or Large Quantity in accordance with Step 6.3.

6.7.2 In general Type B or Large Quantity packaging must meet the standards established for Type A packaging, and in addition must meet the standards for the hypothetical accident conditions of transport as described in 10CFR 71.36.

6.7.3 Packaging and shipment of Type B and Large Quantity radioactive materials are to be performed under a Quality Assurance plan. An approved procedure with any appropriate Quality Assurance hold points shall be used for loading and closing packages of Type B and Large Quantity radioactive materials.

6.7.4 The following prerequisites shall be met prior to loading any Type B or Large Quantity radioactive material into a shipping cask:

6.7.4.1 A current copy of the specific license, certificate of compliance, or other approval authorizing use of the package shall be on file in accordance with the appropriate document control procedure.

6.7.4.2 All documents (including but not limited to the safety analysis report) referred to in the above certificate, license or other approval shall be on file in accordance with the appropriate document control procedure.

FOR USE IN UNIT II ONLY

6.7.4.3 Prior to the first use of the package the RMC shall register Met-Ed as a user of the specific package in accordance with 10CFR 71.12(b)(1)(iii). The required letter or users list shall be maintained with the document authorizing use referred in 6.7.4.1 of this Section.

6.7.5 The package user shall determine, and the RMC and the Operations Quality Assurance Department shall concur, that the package is appropriate for the subject radioactive material prior to loading the package.

6.7.6 Preliminary determinations shall be made in accordance with 10CFR 71.53.

6.7.7 Routine determinations shall be made in accordance with 10CFR 71.54.

6.7.8 Prior to delivery of a package to a carrier for transport, the licensee shall assure that any special instruction needed to safely open the package are sent to or have been made available to the consignee.
IAW 10CFR 71.55.

6.7.9 The licensee shall report to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, within 30 days any instance in which there is substantial reduction in the effectiveness of any authorized packaging during use.
IAW 10CFR 71.61.

6.7.10 Records will be maintained in accordance with 10CFR 71.62.

6.7.11 A package need not satisfy the requirements of 10CFR 71.36 - Standards for Hypothetical Accident Conditions for a Single Package, if it contains only low specific activity materials and is transported in a vehicle assigned for the sole use of the licensee.

6.7.12 The package shall be marked/labeled in accordance with the requirments outlined in Section 6.8.

6.8 Marking and Labeling of Packages

6.8.1 The package will be marked in accordance with 49CFR 172 Subpart D.

6.8.1.1 A package having a rated capacity of 110 gallons or less shall be marked with the proper shipping name and identification number (preceded by "UN" or "NA" as appropriate) assigned to the material in 49CFR 172.101.

NOTE: The requirements of 6.8.1.1 applies to packages filled after 1 July 1983.

6.8.1.2 The marking required must be durable, in English and printed on or affixed to the surface of package or on a label or sign. In addition they:

1. Must be displayed on background of sharply constrasting color.
2. Must be unobscured by labels or attachments.
3. Must be located away from any other markings (such as advertising) that could substantially reduce its effectiveness.

6.8.1.3 Each package must be marked with the name and address of the consignee or consignor except when the package is:

1. Transported by highway and will not be transferred from one motor carrier to another, or
2. Part of a carload lot, truckload lot, or freight container load, and the entire contents of the rail car, truck or freight container are tendered from one consignor to one consignee.

6.8.1.4 Each package of radioactive materials in excess of 110 pounds (50 kilograms) must have its gross weight plainly and durably marked on the outside of the package. This requirement does not apply to packages of LSA shipped "Sole Use".

6.8.1.5 Each package of radioactive material which conforms to the requirements for Type A or Type B packaging must be plainly and durably marked on the outside of the package in letters at least 1/2-inch (13 mm.) high, with the words "Type A" or "Type B" as appropriate. A package which is not in compliance with these requirements may not be so marked.

6.8.1.6 Each package having an inside packaging containing liquid hazardous material must be:

1. Packed with closures upward.
2. Legibly marked "THIS SIDE UP" or "THIS END UP" as appropriate, to indicate the upward position of the inside packaging.

6.8.1.7 Each Specification 7A package shall be marked with letters at least 1/2-inch high as follows: "USA DOT-7A TYPE A" and "RADIOACTIVE MATERIAL" in accordance with 49CFR 178.350-3 and 173.24(c)(1)(iv).

6.8.2 The package must be labeled in accordance with 49CFR 172 Subpart E.

6.8.2.1 Each person who offers a package, overpack, or freight container for transportation shall label it, when required, with labels prescribed for the material as specified in 49CFR 172.101.

6.8.2.2 A label is not required on packages of low specific activity radioactive material, when being transported in a transport vehicle assigned for sole use of the consignor, however the package must be marked "RADIOACTIVE - LSA".

6.8.2.3 Unless excepted from labeling, each package of radioactive material must be labeled as provided in this section.

6.8.2.4 A RADIOACTIVE WHITE-I label must be affixed to each package measuring 0.5 millirem or less per hour at each point on the external surface of the package, provided the package:

1. Is not a Fissile Class II or III, or
2. Does not contain a "large quantity" of radioactive material, as defined in 49CFR 173.389.

6.8.2.5 A RADIOACTIVE YELLOW-II label must be affixed to each:

1. Package measuring more than 0.5 millirem but not more than 50 millirem per hour at each point, and not exceeding one (1.0) millirem per hour at three feet from each point on the external surface of the package.

2. Fissile Class II package having a transport index of one (1.0) or less.

6.8.2.6 A RADIOACTIVE YELLOW-III label must be affixed to each package which:

1. Measures more than 50 millirem per hour at each point, or exceeds one (1.0) millirem per hour at three feet from each point on the external surface.
2. Is a Fissile Class III or
3. Contains a "large quantity" of radioactive material as defined in 49CFR 173.389.

NOTE: Radioactive materials labels required by the regulations in effect prior to November 20, 1980, may continue to be used until July 1, 1983.

6.8.2.7 Each package containing radioactive material that also meets the definition of one or more additional hazards must be labeled as a radioactive material as required by this section and for each additional hazard.

EXAMPLE: Packages containing nitric acid solutions of radioactive material must be labeled RADIOACTIVE and CORROSIVE.

6.8.2.8 Each package required by this section to be labeled with a RADIOACTIVE label must have two of these labels, affixed to opposite sides of the package, excluding the bottom.

6.8.2.9 The following applicable items of information must be entered on the RADIOACTIVE label by legible printing (manual or mechanical), using a durable weather resistant means of marking:

1. "Contents". The name of the radionuclides as taken from the listing of radionuclides in 49CFR 173.390 (symbols which conform to established radiation protection terminology are authorized, i.e. 99Mo, 60Co, etc.). For mixtures of radionuclides, the most restrictive radionuclides on the basis of radiotoxicity must be listed as space on the label allows.

2. "Number of Curies". Units shall be expressed in appropriate curie units, i.e., curies (Ci), millicuries (mCi) or microcuries (uCi) (abbreviations are authorized). For a fissile material, the weight in grams or kilograms of the fissile radioisotope also may be inserted.

3. The transport index to be assigned to a package of radioactive materials shall be determined by either the highest radiation dose rate, in millirem per hour at three feet from any accessible external surface of the package or for Fissile Class II packages only, the transport index number calculated by dividing the number "50" by the number of similar packages which may be transported together (see 49CFR 173.396), as determined by the procedures prescribed in the regulations of the U.S. Nuclear Regulatory Commission, 10CFR 71.

NOTE: The number expressing the transport index shall be rounded up to the next highest tenth: i.e., 1.01 becomes 1.1.

6.8.2.10 Each person who offers for transportation by air a package containing a hazardous material authorized only on cargo aircraft shall affix to the package a "CARGO AIRCRAFT ONLY" label.

6.8.2.11 Placement of Labels.

1. When labeling is required, the labels must be displayed on at least two sides or two ends (excluding the bottom).
2. Each label required by this part must be printed on or affixed to the surface of the package near the marked proper shipping name.
3. When two or more different labels are required, they must be displayed or affixed next to each other.
4. Each label must be affixed to a background of contrasting color, or must have a dotted or solid line outer border.

6.8.2.12 All labels used shall meet the label specifications of 49CFR 172.407.

ATTACHMENT 1

QUANTITY DETERMINATIONS

(49CFR 173.390)

1. Quantity determination for a single isotope is as follows:

   1.1 Determine transport group of isotope - use Table in 49CFR 173.390.

   1.2 Using 173.389 determine if the quantity is Type A, Type B, or Large Quantity.

   1.3 If material is within Type A quantity, check 173.391(a) to see if the material qualifies as Limited Quantity.

   1.4 For manufacture articles or radioactive devices check 173.391(b) (5).

2. Quantity determination for a Mixture of Isotopes

   2.1 Determine transport group of each isotope - Table 173.390.

   2.2 Determine total curies in each transport group.

   2.3 To determine if material is Type A quantity use the following formula, using 173.389(1) values.

$$\frac{\text{total curies GpI}}{\text{type A limit GpI}} + \frac{\text{total curies GpII}}{\text{type A limit GpII}} + \text{---} + \frac{\text{total curie Gp VII}}{\text{type A limit Gp VII}} = 1 \text{ or less}$$

   2.4 If the result was 1 or less the material is Type A quantity. If the result was greater than 1, repeat the formula substituting Type B limits to determine if it is Type B or Large Quantity.

2.5 Material that qualifies as Type A may also be checked to see if it qualifies as Limited Quantity (use limited quantity values from 173.391(a).

3. Low Specific Activity (LSA) Determination

3.1 For LSA determination, the specific activity, curies/grams, of each isotope must be known.

3.2 Determine the transport group of each isotope - Table 173.390.

3.3 Determine the total specific activity for each transport group.

3.4 To determine if material qualifies as LSA use the following formula. Use LSA limits from 173.389(c).

$$\frac{\text{mCi/gm of GpI}}{\text{.0001 mCi/gm of GpI}} + \frac{\text{mCi/gm of GpII}}{\text{.005 mCi/gm of GpII}} + \frac{\text{mCi/gm of GpIII + IV}}{\text{.3 mCi/gm of GpIII + IV}}$$

= one or less

3.5 If the result of one or less the material qualifies as LSA.

3.6. Material that qualifies as LSA must also be classified as either Type A or greater than Type A.

4. Complete the "Quantity Determination Worksheet of this Attachment.

SHIPMENT NUMBER ____________ RMC ____________ DATE ____________

ITEM DESCRIPTION ____________________________

REFERENCE DOCUMENT ____________________________

ISOTOPE	GROUP I	GROUP II	GROUP III	GROUP IV
	CURIE CONTENT			

TOTALS

LIMITED QUANTITY: (microcuries) $\frac{\_\_\_(I)}{10} + \frac{\_\_\_(II)}{100} + \frac{\_\_\_(III, IV)}{1000} + \frac{\_\_\_}{3E6\ H3+} {}^{\star} = \frac{\_\_\_}{\leq 1}$

LSA: (microcuries/g) $\frac{\_\_\_(I)}{0.1} + \frac{\_\_\_(II)}{5} + \frac{\_\_\_(III, IV)}{300} = \frac{\_\_\_}{\leq 1}$

TYPE A QUANTITY: (millicuries) $\frac{\_\_\_(I)}{1} + \frac{\_\_\_(II)}{50} + \frac{\_\_\_(III)}{3000} + \frac{\_\_\_(IV)}{20,000} = \frac{\_\_\_}{\leq 1}$

* Not to exceed 0.5 millicuries per milliliter

CALCULATED BY ____________ DATE ____________

VERIFIED BY ____________ DATE ____________

ATTACHMENT 2

Type "A" Packaging Checklists

1. A series of packaging checklist comprise this attachment. As new packages are developed for shipment of Type "A" quantities of radioactive materials, a packaging checklist will be developed and included in this attachment.

2. The following checklist are authorized for use:

   2.1 Package configuration and packaging checklist for the reactor coolant sample, for shipment of radioactive material in liquid form.

   2.2 Package configuration and packaging checklist for 10 sample shipping container for radioactive material in liquid form.

   2.3 Package configuration and packaging checklist for 5 sample shipping container for radioactive material in liquid form.

   2.4 Package configuration and packaging checklist for 5/10 sample shipping container for radioactive material in solid form.

   2.5 Package configuration and packaging checklist for large samples or samples that require special shielding for radioactive materials in solid form.

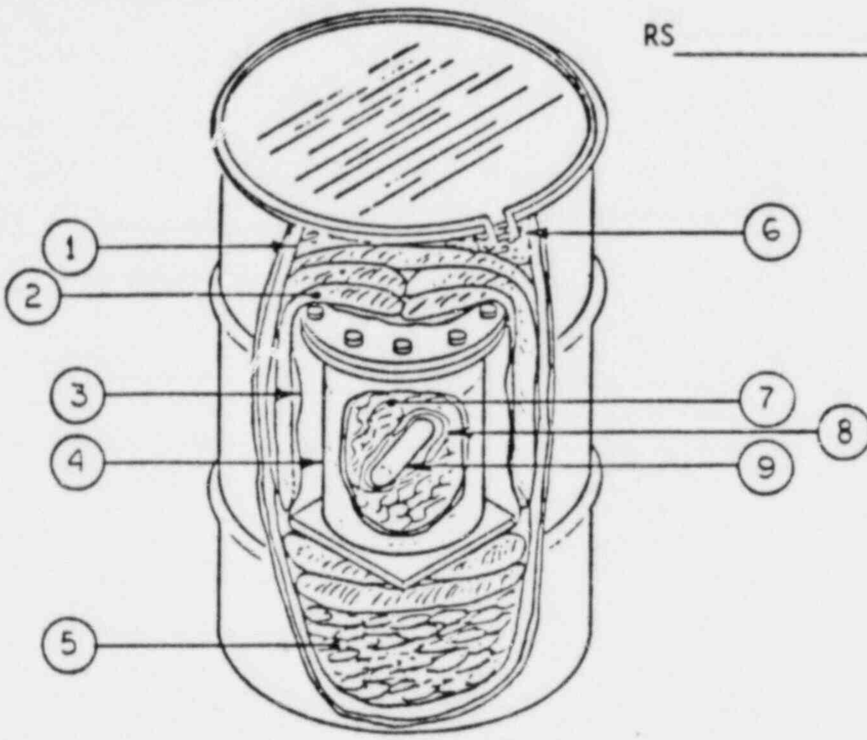
   2.6 Package configuration and packaging checklist for radioactive liquid samples in shielded sample bombs up to one liter.

FOR USE IN UNIT II ONLY

ATTACHMENT 2.1
PACKAGE CONFIGURATION AND PACKAGING CHECKLIST FOR THE REACTOR COOLANT SAMPLE AND OTHER TYPE "A" QUANTITIES OF LIQUIDS

1.0 PACKAGE CONFIGURATION

RS______________________



1. Sealed Plastic Bag Liner
2. Lead Blankets
3. Sealed Plastic Bag
4. Steel Secondary Container
5. Absorbent Material - Rags (Top, Bottom and Sides)
6. Nut and Bolt - Torque to greater than 40 ft/lbs
7. Absorbent Material - Paper Towels
8. Two Sealed Plastic Bags
9. Inner Containment Vessel - Sample Flask with Valve Handles Removed and End Caps in Place
10. DOT-17H, 55 Gallon Drum

2.0 PREREQUISITES

NOTE: These steps may be performed in any order provided they are completed prior to commencement of the packaging operations.

2.1 Initiate an RWP with specific dress requirements for both the Packager and the Packager-Helper________________.RMC

2.2 Stage the following items at the Sample Packaging Area, outside the RWP area.

2.2.1 One new, yellow, DOT 17H, 55 Gallon drum with lid, ring, bolt, nut and undamaged drum lid gasket.

Ensure drum has DOT specification marking in accordance with 49 CFR 178.118-10 and 178.118-11, and that drum is in unimpaired physical condition except for superficial marks.______________.RMC

2.2.2 Four (4) large heavy duty plastic bags suitable for lining the 55 gallon drum ______________.RMC

2.2.3 One (1) plastic bag suitable for lining the secondary container ______________.RMC

2.2.4 Eight (8) cubic feet of rags______________.RMC

2.2.5 One (1) roll of duct tape______________.RMC

2.2.6 Two (2) packages of paper towels (Teri Towels) ______________RMC.

2.2.7 One (1) extra nut and bolt for the 55 gallon drum ______________.RMC

2.2.8 One (1) extra set of nuts and bolts for the steel secondary container (8 nuts and bolts) ______________.RMC

2.2.9 One (1) hammer or mallet ______________.RMC

2.2.10 One (1) crescent wrench (10 inch or greater) ______________.RMC

2.2.11 One (1) calibrated torque wrench (appropriate range for greater than 40 ft/lbs. ______________.RMC

Serial NO. ______________ Cal. Due Date ______________

2.2.12 At least one (1) lead seal and Met-Ed seal crimper

______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2" high, in durable contrasting colors. ______________.RMC

METROPOLITAN EDISON CO.
P.O. BOX 480
MIDDLETOWN, PA 17057

U.S. DOT 7A, TYPE A
RADIOACTIVE MATERIAL
N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce its effectiveness.

2.4 Brief the Packager and Packager-Helper on the provisions of the RWP and the function they are to perform______________.RMC

a. The provisions of the RWP and functions of the packaging operation are understood:

________________________ ________________________

Packager Packager-Helper

2.5 Brief the Rad Con Tech. on the functions of the packaging operation ______________.RMC

a. The functions of the packaging operation are understood:

____

Rad Con Tech.

2.6 Place the steel secondary container in the RWP area adjacent to the sample packaging area and inspect the gasket, bolts, nuts and general condition of the container______________.RMC

2.7 Place two (2) of the larger, heavy duty plastic bags on the floor, set the new DOT-17H, 55 gallon drum on it and position a radiation boundary around the drum ______________RMC ______________Rad. Con.

NOTE: Ensure all materials are the same as those used in the RCS Certification package.

3.0 PACKAGING OPERATION

NOTE: Rad Con should be present during all phases of the packaging operation.

3.1 Place a large, heavy duty plastic drum liner into the drum ______________.RMC

3.2 Place absorbent material (rags) in the drum to at least 1/3 full ______________.RMC

3.3 Place lead blanket(s) on top of the absorbent material ______________.RMC

3.4 Place a secondary heavy duty plastic bag in the drum ______________.RMC

3.5 Place plastic bag liner into the secondary container, followed by approximately one inch (1") of absorbent material (paper towels) ______________.RMC

3.6 Page the Sampler and inform them that the Packager is prepared to receive the sample ______________.RMC

NOTE: The sign-off of Step NO. 3.7 may be postponed until the Sampler exits the RWP area, provided that the carrier of the sample flask assures the RMC that Step NO. 3.7 has been accomplished.

3.7 Sample Flask: Valve handles removed, end caps installed on connections and flask sealed in at least two (2) plastic bags

_______________.Sampler

3.8 Survey the double-bagged sample flask after flask is received by the Packager.

_______________mr/hr _______________RAD CON

_______________mRad/hr.

3.9 Place the sample flask into the secondary container, pack absorbent material (paper towels) around the sample flask until the secondary container is completely filled and then seal the plastic bag

_______________.RMC

3.10 Place the gasket, lid, bolts, and nuts on the secondary container and tighten the nuts as much as possible with the crescent wrench

_______________.RMC

3.11 Place the prepared secondary container inside the second plastic bag previously positioned in the drum, and seal the bag around the container_______________.RMC

3.12 Place lead blankets around the bagged secondary container

_______________.RMC

3.13 Fill and pack the drum with absorbent material (rags) so that the secondary container will not move under normal conditions of transportation. Seal the plastic drum liner_______________.RMC

3.14 Place the drum lid with gasket, ring and bolt on the drum

_______________.RMC

FOR USE IN UNIT II ONLY

3.15 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place lock nut on bolt outside of ring cleats and tighten______________.RMC

3.16 Permission to remove sample drum from the packaging area ______________.Rad-Con

3.17 Using the torque wrench, check the nut and bolt to ensure that they are greater than 40 ft/lbs______________.RMC

3.18 Seal the drum with a lead seal______________.RMC

3.19 Perform a package survey consisting of 3-point contact and 3-foot radiation levels plus Beta-Gamma and Alpha swipe surveys on the exterior of the drum______________.RMC

3.20 Place two (2) Cargo-Only aircraft labels on the sides of the drum. One label near the marking and the other on the outer, opposite side, excluding the bottom______________.RMC

NOTE: Ensure labels are not obscured by any markings or attachments.

3.21 Place two (2) applicable Radioactive labels on the drum ______________.RMC

Affix labels next to the Cargo-Only aircraft labels.

3.22 Remove sample drum and transfer to the transport vehicle. Secure the drum for transport to the scales for weighing ______________.RMC

CAUTION: MAXIMUM WEIGHT ALLOWED - 538 lbs.

3.23 Weigh the drum and mark the weight on the side of the drum in letters at least 1/2" high in the durable, contrasting color ______________.RMC

Drum Weight ______________lbs.

3.24 Ensure drum is in unimpaired physical condition except for superficial marks ______________.RMC

3.25 Tie and secure the drum in the transport vehicle for transport to the airport______________.RMC

I certify that all the above steps were completed in the preparation of this sample for shipment:

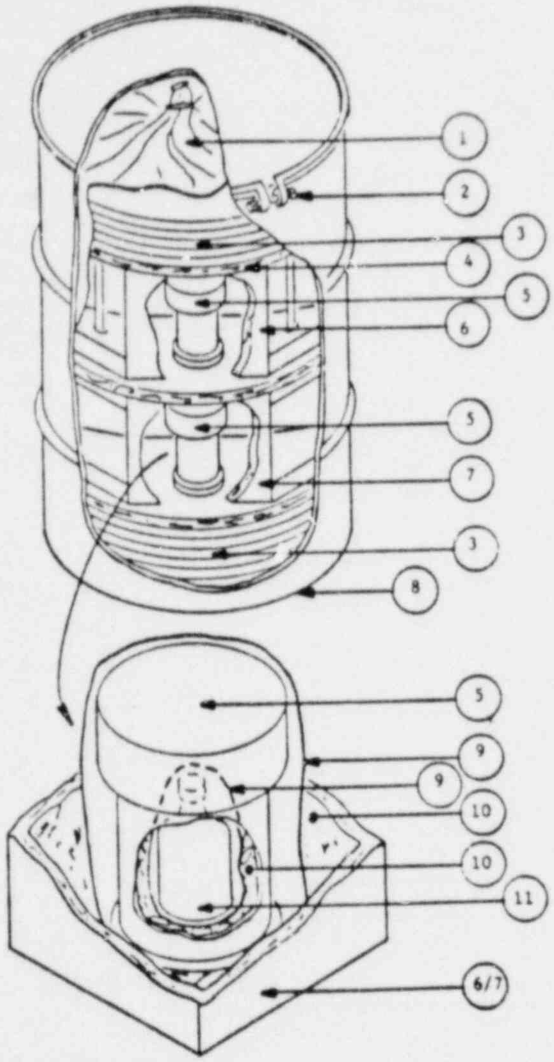
______________________________ ______________________________
RMC Signature Date

NOTE: When sample is transported to the airport, ensure that the pilot receives a copy of the shipping documents in addition to the two (2) copies that accompany the package.

NOTE: This checklist, when completed, will be attach to and become part of the shipping document file

ATTACHMENT 2.2
PACKAGE CONFIGURATION AND PACKAGING CHECKLIST FOR UP TO 10 SAMPLE CONTAINERS FOR RADIOACTIVE MATERIALS IN LIQUID FORM.

1.0 PACKAGING CONFIGURATION



1. Poly drum liner
2. Bolt and lock nut
3. Styrofoam spacers
4. Insert lid
5. Metal sample container (shielded or unshielded)
6. Upper wood insert
7. Lower wood insert
8. DOT 17-H, 55 gallon drum
9. Plastic bag
10. Absorbent material
11. Poly or glass sample bottle

2.0 PREREQUISITES

NOTE: These steps may be performed in any order providing they are completed prior to commencement of the packaging operation.

2.1 Initiate an RWP, if required, with specific dress requirements for both the Packager and the Packager-helper.______________.RMC

2.2 Stage the following items at the sample packaging area, outside the RWP area.

NOTE: Some items may be omitted if samples were previously packaged.

2.2.1 One new, yellow, DOT-17H, 55 gallon drum, undamaged (except for superficial marks) with lid, ring, bolt and locknut and an undamaged drum lid gasket. Ensure the drum has DOT specification markings in accordance with 49CFR 178.118-10 and 178.118-11.______________.RMC

2.2.2 Three (3) large heavy duty plastic bags suitable for lining the 55 gallon drum______________.RMC

2.2.3 Upper and lower wood inserts______________.RMC

2.2.4 Ten (10) plastic bags suitable for lining wood insert ______________.RMC

2.2.5 Ten (10) metal sample containers______________.RMC

2.2.6 Ten (10) plastic bags suitable for wrapping samples ______________.RMC

<u>NOTE</u>: Materials required in 2.2.4 - 2.2.6 are dependent on the number of samples to be packaged.

2.2.7 Eleven (11) styrofoam spacers______________.RMC

2.2.8 Approved absorbent material______________.RMC

2.2.9 One (1) roll of duct tape______________.RMC

2.2.10 One (1) extra nut and bolt for the 55 gallon drum ______________.RMC

2.2.11 One (1) extra set of nuts for wood insert (4) nuts ______________.RMC

2.2.12 One (1) hammer or mallet______________.RMC

2.2.13 One (1) cresent wrench (10 inch or greater) ______________.RMC

2.2.14 One (1) calibrated torque wrench (appropriate range for greater than 40 ft/lbs)______________.RMC

2.2.15 At least one (1) lead seal and the MET-ED seal crimping tool______________.RMC

2.2.16 The RMC shall verify that all the materials used in this package are the same as those used in certification package for this TYPE 7A container______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2 inch high in a durable, contrasting color

______________.RMC

METROPOLITAN EDISON CO.
P.O. BOX 480
MIDDLETOWN, PA 17057

U.S. DOT 7A, TYPE A
RADIOACTIVE MATERIAL
N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce its effectiveness.

2.4 Brief the Packager and Packager-helper on the provisions of the RWP and the function they are to perform______________.RMC

The provisions of the RWP and functions of the packing operation are understood

Packager______________Packager-helper______________

2.5 Brief the Rac-Con Tech. on the functions of the packaging operation

______________.RMC

The functions of the packaging operation are understood.

Rad-Con Tech______________

CAUTION: A Rad-Con Tech shall be present during all phases of the packaging operation, if required.

2.6 Place the metal sample containers in the RWP area adjacent to the sample packaging area. Inspect the general condition of the containers. All of the containers are satisfactory.

______________.RMC

2.7 Place two (2) of the large, heavy duty plastic bags on the floor. Set the new DOT-17H, 55 gallon drum on them and position a radiation boundry around the drum______________RMC

______________Rad-Con

3.0 PACKAGING OPERATION

3.1 Place a heavy duty plastic drum liner into the drum

______________.RMC

3.2 Place six (6) styrofoam spacers into the bottom of the drum.

______________.RMC

3.2.1 Place lower wood insert into drum.

NOTE: Steps 3.3 and 3.4 may be accomplished prior to commencement of the final packaging operation. Sign off applicable steps used.

3.3 Sample preparation

3.3.1 Tape lids of bottles______________.RMC

3.3.2 Seal bottles into plastic bag______________.RMC

3.4 Rad-Con will survey each packaged sample. Surveys completed

______________Rad-Con

3.5 Place absorbent material in the bottom of each metal sample container. Insert the prepared sample and add additional absorbent material______________.RMC

3.6 Apply non-hardening sealant to metal sample container threads and install metal sample container lids______________.RMC

NOTE: If five or less samples are to be packaged go to step 3.9.

3.7 Place a plastic bag into each section of the lower wood insert

______________.RMC

3.8 Place each metal sample container into the prepared insert section. Add absorbent material to fill all void spaces. Seal each bag______________.RMC

3.9 Assemble upper wood insert to the lower wood insert

______________.RMC

3.10 Repeat steps 3.5 thru 3.9 to pack upper wood insert

______________.RMC

3.11 Install insert lid, place nuts on the threaded connecting rods and tighten.______________.RMC

3.12 Place styrofoam spacers to fill the drum. Should require five (5) spacers. Seal the drum liner ______________.RMC

3.13 Place the drum lid with gasket, ring and bolt on the drum

______________.RMC

3.14 Permission to remove the sample drum the the packaging area.

______________Rad-Con

3.15 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place the locknut on the bolt outside of the ring cleat and tighten______________.RMC

3.16 Using the torque wrench, check the nut and bolt to ensure that they are tightened to greater than 40 ft/lbs______________.RMC

3.17 Seal the drum with a lead seal______________.RMC

3.18 Perform a package survey consisting of a 3 point contact and 3 foot radiation levels plus Beta/Gamma and Alpha swipe surveys on the sample drum______________.RMC

3.19 Remove the drum to a transport vehicle and secure the drum for transport to the scales for weight______________.RMC

NOTE: Required only if drum is the outer shipping container.

3.20 Weigh the drum and mark the weight on the side of the drum in letters 1/2 inch high (minimum heightn) in a durable contrasting color______________.RMC

Record Weight__________

CAUTION: Maximum allowable weight for this package is 765 lbs for shipment of Radioactive Material in liquid form.

3.21 Place two (2) THIS END UP labels on the drum, one label each on the outer, opposite sides of the drum.______________.RMC

3.22 Place two (2) Cargo-Only Aircraft Labels on the drum. One label each on the outer opposite sides of the drum. (For air shipments only)______________.RMC

3.23 Place two (2) applicable Radioactive labels on the drum. One label each on the outer, opposite sides of the drum______________.RMC

NOTE: Ensure all labels are not obscured by any markings or attachments

3.24 Tie and secure the drum in the transport vehicle for transport.

______________.RMC

I certify that all of the above steps were taken in preparation of this sample for shipment.

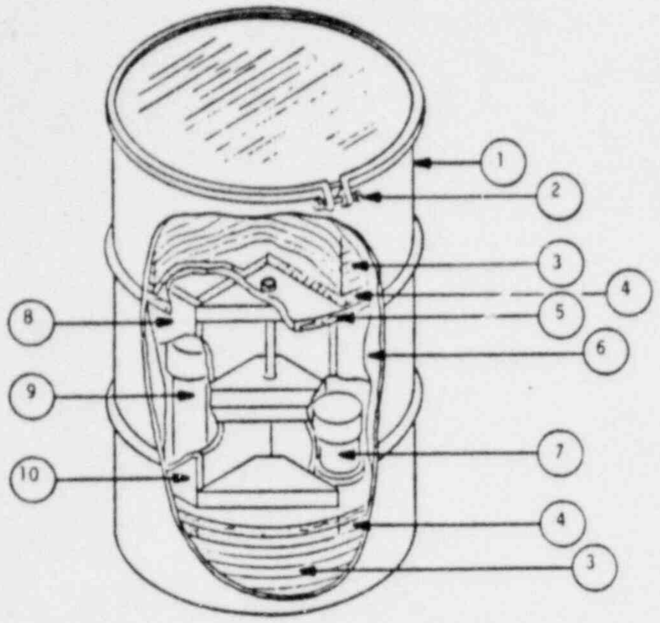
.RMC____________________________ DATE __________________

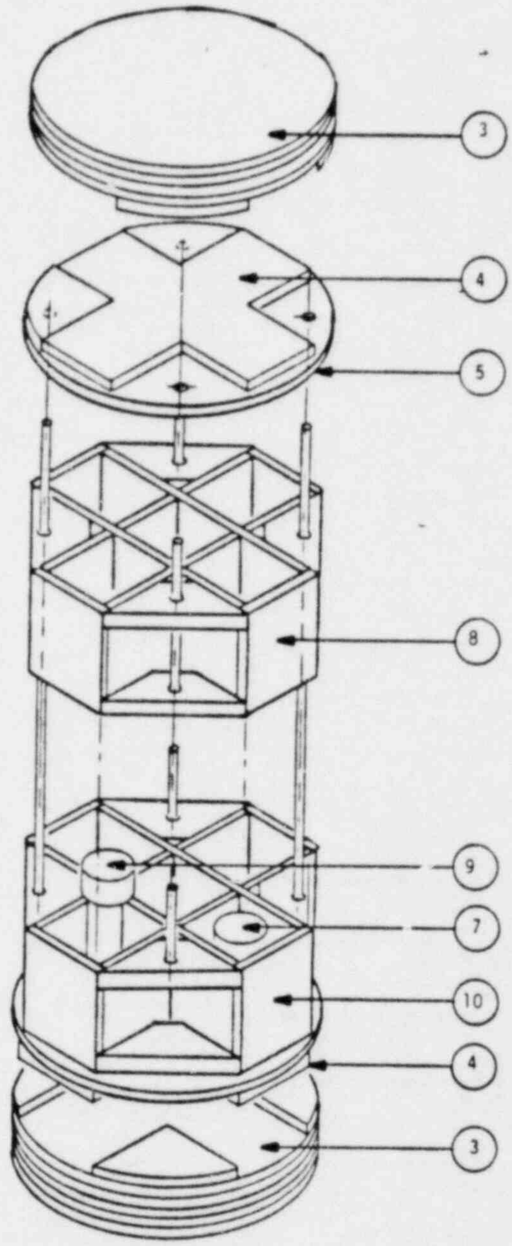
NOTE: This checklist, when completed, will be attached to and become part of the shipping document file.

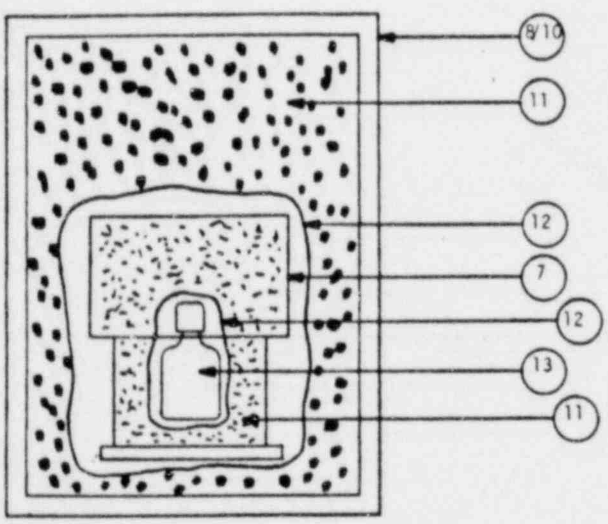
FOR USE IN UNIT II ONLY

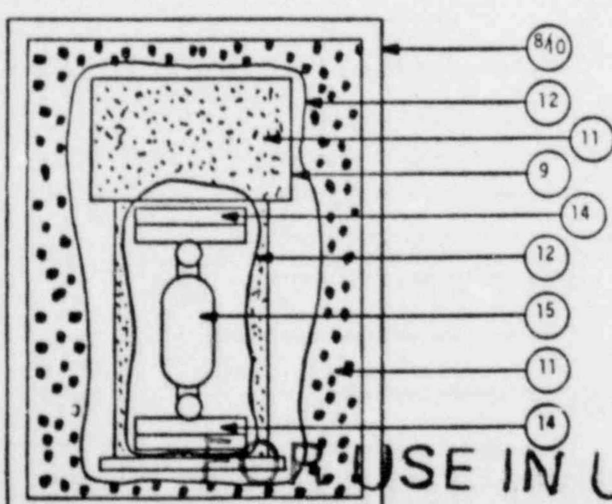
ATTACHMENT 2.3
PACKAGE CONFIGURATION AND PACKAGING CHECKLIST FOR FIVE SAMPLE SHIPPING CONTAINERS FOR RADIOACTIVE MATERIAL IN LIQUID FORM

1.0 PACKAGE CONFIGURATION









1. DOT 17-H, 55 gallon drum
2. Bolt and lock nut
3. Styrofoam spacers
4. Lead shield assembly
5. Insert lid
6. Poly drum liner
7. Small metal sample container
8. Upper wood insert
9. Large metal sample container
10. Lower wood insert
11. Absorbent material
12. Plastic bag
13. Poly sample bottle
14. Spacer
15. Sample flask

FOR USE IN UNIT II ONLY

2.0 PREREQUISITES

NOTE: These steps may be performed in any order providing they are completed prior to commencement of the packaging operation.

2.1 Initiate an RWP, if required, with specific dress requirements for both the Packager and the Packager-helper______________.RMC

2.2 Stage the following items at the sample packaging area, outside the RWP area.

NOTE: Some items may be omitted if samples were previously packaged.

2.2.1 One new, yellow, DOT-17H, 55 gallon drum, undamaged (except for superficial marks) with lid, ring, bolt and locknut and undamaged drum lid gasket. Ensure the drum has DOT specification markings in accordance with 40CFR 178.118-10 and 178.118-11.______________.RMC

2.2.2 Three (3) large heavy duty plastic bags suitable for lining the 55 gallon drum______________.RMC

2.2.3 Upper and lower wood inserts______________.RMC

2.2.4 Five (5) plastic bags suitable for lining wood insert ______________.RMC

2.2.5 Five (5) metal sample containers______________.RMC

2.2.6 Five (5) plastic bags suitable for wrapping samples. ______________.RMC

2.2.7 Nine (9) styrofoam spacers______________.RMC

2.2.8 Approved absorbent material______________.RMC

2.2.9 One (1) roll of duct tape______________.RMC

2.2.10 One (1) extra nut and bolt for the 55 gallon drum

______________.RMC

2.2.11 One (1) extra set of nuts for wood insert (4 nuts)

______________.RMC

2.2.12 One (1) hammer or mallet______________.RMC

2.2.13 One (1) crescent wrench (10 inch or greater)

______________.RMC

2.2.14 One (1) calibrated torque wrench (appropriate range for greater than 40 ft/lbs)______________.RMC

2.2.15 At least one (1) lead seal and the Met-Ed seal crimping tool______________.RMC

2.2.16 Two (2) lead shield assemblies______________.RMC

2.2.17 The RMC shall verify that all the materials used in this package are the same as those used in the cerification package for this Type 7A container______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2 inch high in a durable, contrasting color

______________.RMC

METROPOLITAN EDISON CO.
P.O. BOX 480
MIDDLETOWN, PA 17057

U.S. DOT 7A, TYPE A
RADIOACTIVE MATERIAL
N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce effectiveness.

2.4 Brief the Packager and Packager-helper on the provisions of the RWP and the function they are to perform______________.RMC

2.5 Brief the Rad-Con Tech. on the functions of the packaging operation.

_______________.RMC The functions of the packaging operation are understood_______________.Rad-Con Tech

CAUTION: A Rad-Con Tech. shall be present during all phases of the packaging operation, if required.

2.6 Place the metal sample containers in the RWP area adjacent to the sample packaging area. Inspect the general condition of the containers. All of the containers are satisfactory

_______________.RMC

2.7 Place two (2) of the large, heavy duty plastic bags on the floor. Set the new DOT-17H, 55 gallon drum on them and position a radiation boundry around the drum

_______________RMC _______________Rad-Con

3.0 PACKAGING OPERATION

3.1 Place a heavy duty plastic drum liner into the drum

_______________.RMC

3.2 Place five (5) styrofoam spacers into the bottom of the drum

_______________.RMC

3.3 Place one (1) lead shield assembly into the drum, if required. If not required, place one (1) additional styrofoam spacer into the drum_______________.RMC

3.4 Place lower wood insert into the drum. Line each section to be used with a plastic bag_______________.RMC

3.5 Place metal sample containers into the insert______________.RMC

NOTE: Steps 3.6 and 3.7 may be completed prior to commencement of the final packaging operation. Sign off the applicable steps that were used.

3.6 Sample Preparation

3.6.1 Tape bottle lids______________.RMC

3.6.2 Seal each bottle into a plastic bag______________.RMC

3.6.3 Remove or tape sample flask valve handles ______________.RMC

3.6.4 Ensure sample flask caps are installed______________.RMC

3.6.5 Install spacers on sample flask and seal into a plastic bag______________.RMC

3.7 Rad-Con shall survey packaged samples. Surveys completed. ______________Rad-Con

3.8 Place absorbent material into the bottom of each metal sample container. Insert prepared sample. Add additional absorbent and install cap______________.RMC

NOTE: If additional shielding is required, lead plugs are available for installation inside the metal sample containers both above and below the sample

3.9 Seal the plastic bag around each metal sample container ______________.RMC

3.10 Fill lower wood insert with absorbent material______________.RMC

3.11 Install upper wood insert and add absorbent material to fill all void spaces______________ C

3.12 Install insert lid, place nuts on the threaded connecting rods and tighten_______________.RMC

3.13 Place assembled insert into the drum, add styrofoam spacers to fill the drum. Should require (5) spacers. Seal the drum liner _______________.RMC

3.14 Place the drum lid with gasket, ring and bolt on the drum _______________.RMC

3.15 Permission to remove the sample drum from the packaging area _______________.RMC

3.16 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place the locknut on the bolt outside of the ring cleat and tighten_______________.RMC

3.17 Using the torque wrench, check the nut and bolt to ensure that they are greater than 40 ft/lbs_______________.RMC

3.18 Seal the drum with a lead seal_______________.RMC

3.19 Perform a package survey consisting of a 3-point contact and 3-foot radiation levels plus Beta/Gamma and Alpha swipe survey on the sample drum_______________Rad-Con

3.20 Remove the drum to a transport vehicle and secure the drum for transport to the scales for weighing_______________.RMC

3.21 Weigh the drum and mark on the side of the drum in letters 1/2-inch high (minimum height) in a durable contrasting color

_______________.RMC

Record weight________________

CAUTION: Maximum allowable weight for this package is 770 lbs for shipment of radioactive material in liquid form.

3.22 Place two (2) THIS END UP labels on the drum. One label each on the outer, opposite sides of the drum_______________.RMC

3.23 Place two (2) CARGO-ONLY AIRCRAFT labels on the drum. One label each on the outer opposite sides of the drum. (For air shipments only)_______________.RMC

3.24 Place two (2) applicable Radioactive labels on the drum. One label each on the outer opposite sides of the drum_______________.RMC

3.25 Tie and secure the drum in the transport vehicle for transport

_______________.RMC

I certify that all of above steps were taken in the preparation of this sample for shipment.

RMC_______________ DATE_______________

NOTE: This checklist, when completed, will be attached to and become part of the shipping document file.

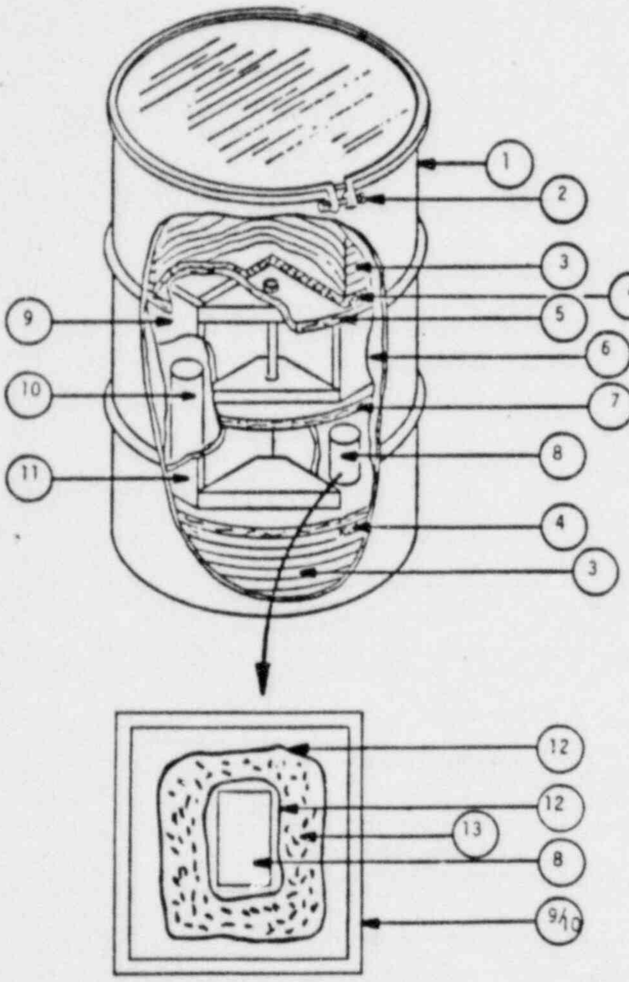
FOR USE IN UNIT II ONLY

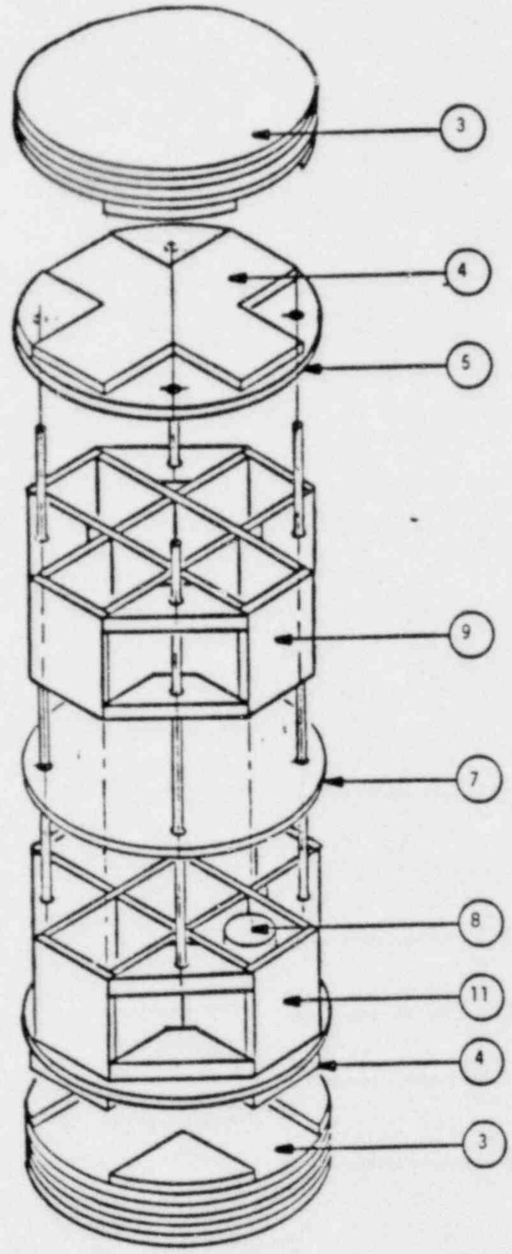
ATTACHMENT 2.4

PACKAGE CONFIGURATION AND PACKAGING CHECK LIST FOR 5 OR 10 SAMPLE

SHIPPING CONTAINERS FOR RADIOACTIVE MATERIAL IN SOLID FORM

1.0 PACKAGING CONFIGURATION





1. DOT 17-H, 55 gallon drum
2. Bolt and lock nut
3. Styrofoam spacers
4. Lead shield assembly
5. Insert lid
6. Poly drum liner
7. Insert divider (required for 10 sample shipment)
8. Small sample
9. Upper wood insert
10. Large sample
11. Lower wood insert
12. Plastic bag
13. Packing material

FOR USE IN UNIT II ONLY

2.0 PREREQUISITES

NOTE: These steps may be performed in any order providing they are completed prior to commencement of the packaging operation.

2.1 Initiate an RWP, if required, with specific dress requirements for both the Packager and the Packager-helper

_______________.RMC

2.2 Stage the following items at the sample packaging area, outside the RWP area.

NOTE: Some items may be omitted if samples were previously packaged.

2.2.1 One new, yellow, DOT-17H, 55 gallon drum, undamaged (except for superficial marks) with lid, ring, bolt and locknut and an undamaged drum lid gasket. Ensure the drum has DOT specification markings in accordance with 49CFR 178.118-10 and 178.118-11.

_______________.RMC

2.2.2 Three (3) heavy duty plastic bags suitable for lining the 55 gallon drum_______________.RMC

2.2.3 Upper and lower wood inserts_______________.RMC

2.2.4 Ten (10) plastic bags suitable for lining wood insert.

2.2.6 Eleven (11) styrofoam spacers_______________.RMC

2.2.7 Two (2) lead shield assemblies, if required

_______________.RMC

NOTE: Additional lead plates are available for interior shielding as required.

2.2.8 Approved absorbent material______________.RMC

2.2.9 One (1) roll of duct tape______________.RMC

2.2.10 One (1) extra nut and bolt for the 55 gallon drum

______________.RMC

2.2.11 One (1) extra set of nuts for wood insert (4 nuts)

______________.RMC

2.2.12 One (1) hammer or mallet______________.RMC

2.2.13 One (1) crescent wrench (10 inch or greater)

______________.RMC

2.2.14 One (1) calibrated torque wrench (appropriate range for greater than 40 ft/lbs)______________.RMC

Serial No.______________ Cal. Due Date______________

2.2.15 At least one (1) lead seal and the Met-Ed seal crimping tool______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2 inch high in a durable, contrasting color

______________.RMC

METROPOLITAN EDISON CO.
P.O. BOX 480
MIDDLETOWN, PA 17057

U.S. DOT 7A, TYPE A
RADIOACTIVE MATERIAL
N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce its effectiveness.

NOTE: Depending on the radiation levels of the sample(s) to be packaged steps 2.4 and 2.5 may be omitted, if not required.

2.4 Brief the Packager and Packager-helper on the provisions of the RWP and the function they are to perform_____________.RMC

The provisions of the RWP and functions of the packing operation are understood. Packager_____________

Packager-Helper_____________

2.5 Brief the Rad-Con Tech. on the functions of the packaging operation

RMC_____________ Rad-Con Tech._____________

CAUTION: A Rad-Con Tech shall be present during all phases of the packaging operation, if required.

2.6 Place two (2) of the large, heavy duty plastic bags on the floor. Set the new DOT-17H, 55 gallon drum on them and position a radiation boundry around the drum_____________.RMC

_____________Rad-Con

3.0 PACKAGING OPERATION

3.1 Place a heavy duty plastic drum liner into the drum.

_____________.RMC

3.2 Place six (6) styrofoam spacers into the bottom of the drum.

_____________.RMC

3.3 If required, install lead shield assembly into the drum. If added reduce 3.2 by one (1) spacer_____________.RMC

3.4 For five (5) sample shipments made assemble upper and lower wood inserts with insert divider removed_____________.RMC

3.5 Place a plastic bag into each section of the insert to be used

_____________.RMC

NOTE: Steps 3.6 and 3.7 may be accomplished prior to commencement of the final packaging operation. Sign off applicable steps used.

3.6 Prepare samples by wrapping in plastic. Seal the bag and tape all sharp edges or protrusions______________.RMC

3.7 Rad-Con will survey each packaged sample. Surveys completed ______________.RMC

3.8 Place prepared samples into insert. Fill with packing material and seal bag______________.RMC

3.9 For 10 sample shipment mode, assemble upper wood insert to the lower wood insert______________.RMC

3.10 Repeat steps 3.5 thru 3.8 to pack upper wood insert ______________.RMC

3.11 Install insert lid, place nuts on the threaded connecting rods and tighten. Place assembled insert into drum______________.RMC

3.12 Install lead shield assembly, if required. If not required, install one (1) styrofoam spacer______________.RMC

3.13 Add additional styrofoam spacers (4-5) to fill drum. Seal drum liner______________.RMC

3.14 Place the drum lid with gasket, ring and bolt on the drum. ______________.RMC

3.15 Permission to remove the sample drum from the packaging area. ______________.RMC

3.16 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place the locknut on the bolt outside of the ring cleat and tighten______________.RMC

3.17 Using the torque wrench, check the nut and bolt to ensure that they are tightened to greater than 40 ft/lbs.______________.RMC

3.18 Seal the drum with a lead seal______________.RMC

3.19 Perform a package survey consisting of a 3 point contact and 3 foot radiation levels plus Beta/Gamma and Alpha swipe surveys on the sample drum______________.RMC

3.20 Remove the drum to a transport vehicle and secure the drum for transport to the scales for weighing______________.RMC

3.21 Weigh the drum and mark the weight on the side of the drum in letters 1/2 inch high (minimum height) in a durable contrasting color______________.RMC

CAUTION: Maximum allowable weight for this package is 840 lbs. for shipment of Radioactive Material in solid form.

3.22 Place two (2) Cargo-Only Aircraft Labels on the drum. One label each on the outer opposite sides of the drum. (For Air Shipments Only)______________.RMC

NOTE: Ensure all labels not obscured by any markings or attachments.

3.24 Tie and secure the drum in the transport vehicle for transport.

______________.RMC

I certify that all of the above steps were taken in the preparation of this sample for shipment.

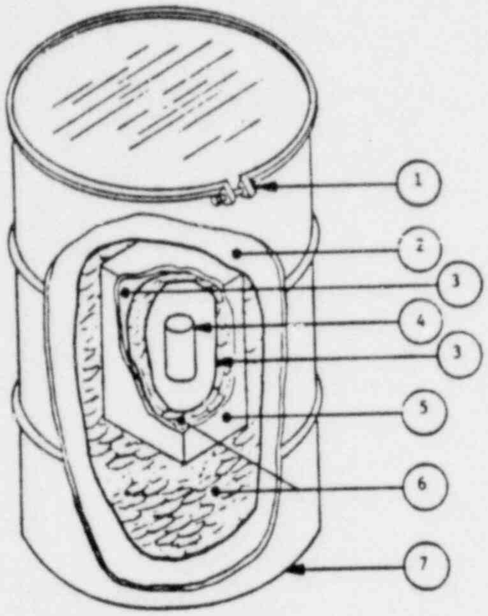
RMC______________ DATE______________

NOTE: This checklist, when completed, will be attached to and become part of the shipping document file.

FOR USE IN UNIT II ONLY

ATTACHMENT 2.5
PACKAGE CONFIGURATION AND PACKAGING CHECK LIST FOR LARGE SAMPLES OR SAMPLES THAT REQUIRE SPECIAL SHIELDING FOR RADIOACTIVE MATERIAL IN SOLID FORM

1.0 PACKAGING CONFIGURATION



1. Bolt and lock nut
2. Poly drum Liner
3. Plastic Bag
4. Sample
5. Box (optional) (cardboard or wood)
6. Packing Material
7. DOT 17-H, 55 gallon drum

2.0 PREREQUISITES

NOTE: These steps may be performed in any order providing they are completed prior to commencement of the packaging operation.

2.1 Initiate an RWP, if required, with specific dress requirements for both the Packager and the Packager-helper.

_______________.RMC

2.2 Stage the following items at the sample packaging area, outside the RWP area.

NOTE: Some items may be omitted if samples were previously packaged.

2.2.1 One new, yellow, DOT-17H, 55 gallon drum, undamaged (except for superficial marks) with lid, ring, bolt and locknut and an undamaged drum lid gasket. Ensure the drum has DOT specification markings in accordance with 49CFR 178.118-10 and 178.188-11______________.RMC

2.2.2 Three (3) large, heavy duty plastic bags suitable for lining the 55 gallon drum______________.RMC

2.2.3 Plastic bags for wrapping samples______________.RMC

2.2.4 Plastic bags for lining boxes______________.RMC

2.2.5 Box(s), cardboard or wood, shielding to be added as required.

NOTE: Items 2.2.4 and 2.2.5 are optional. Items dependent on packaging requirements. RMC to N/A, if not used.

2.2.6 One (1) roll of duct tape______________.RMC

2.2.7 One (1) extra nut and bolt for the 55 gallon drum ______________.RMC

2.2.8 One (1) hammer or mallet______________.RMC

2.2.9 One (1) crescent wrench (10) inch or greater) ______________.RMC

2.2.10 One (1) calibrated torque wrench (appropriate range for greater than 40 ft/lbs)______________.RMC

2.2.11 At least one (1) lead seal and the Met-Ed seal crimping tool______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2 inch high in durable, contrasting color______________.RMC

METROPOLITAN EDISON COMPANY	U.S. DOT 7A, TYPE A
P.O. BOX 480	RADIOACTIVE MATERIAL
MIDDLETOWN, PA 17057	N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce it's effectiveness.

NOTE: Depending on the size and/or radiation levels of the sample(s) to be packaged, steps 2.4 and 2.5 may be omitted if not required.

2.4 Brief the Packager and Packager-helper on the provisions of the RWP and the function they are to perform______________.RMC

The provisions of the RWP and functions of the packing operation are understood______________Packager ______________Packager-helper

2.5 Brief the Rad-Con Tech. on the functions of the packaging operation.

______________.RMC

The functions of the packaging operation are understood.

Rad-Con Tech.______________

CAUTION: A Rad-Con Tech. shall be present during all phases of the packaging operation, if required.

2.6 Place two (2) of the large, heavy duty plastic bags on the floor. Set the new DOT-17H, 55 gallon drum on them and position a radiation boundry around the drum______________.RMC

______________Rad-Con

3.0 PACKAGING OPERATION

3.1 Place a heavy duty plastic drum liner into the drum.

_______________.RMC

NOTE: Steps 3.2 - 3.4 may be accomplished prior to commencement of the final packaging operation. Sign off the applicable steps that were used.

3.2 Prepare sample(s) by wrapping in plastic bags. Seal bags and tape all sharp edges and protrustions_______________.RMC

3.3 Rad-Con will survey prepared samples. Survey completed

_______________.Rad-Con

3.4 Packaging of samples. Use one of the following methods.

NOTE: RMC is to N/A steps not used.

3.4.1 Large or unusual shape samples, prepare as in step 3.2.

_______________.RMC

3.4.2 Line a cardboard box(es) with a plastic bag. Place prepared sample(s) into the box(es). Add packing material to fill the box(es). Seal the liner, close and tape box shut_______________.RMC

3.4.3 Line previously constructed wood box(es) with a plastic bag. Place sample(s) into the box(es). Add packing material to fill box(es). Seal the bag, close box(es)

_______________.RMC

NOTE: Shielding may be added, as necessary, either inside or outside of the box(es). High activity samples may require special shielding to be constructed inside the drum. This method is not illustrated in para 1 of this attachment.

3.5 Add packing material to the drum. Place packaged samples, prepared in step 3.4, into the drum. Fill the drum with packing material and seal the drum liner.

______________.RMC

3.6 Place the drum lid with gasket, ring and bolt on the drum

______________.RMC

3.7 Permission to remove the sample drum from the packaging area.

______________Rad-Con

3.8 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place the locknut on the bolt outside of the ring cleat and tighten______________.RMC

3.9 Using the torque wrench, check the nut and bolt to ensure that they are tightened to greater than 40 ft-lbs.______________.RMC

3.10 Seal the drum with a lead seal______________.RMC

3.11 Perform a package survey consisting of a 3 point contact and 3 foot radiation levels plus Beta/Gamma and Alpha swipe surveys on the sample drum______________Rad-Con

3.12 Remove the drum to a transport vehicle and secure the drum for transport to the scales for weighing______________.RMC

3.13 Weigh the drum and mark the weight on the side of the drum in letters 1/2 inch high (minimum height) in a durable constrasting color______________RMC Record Weight______________

CAUTION: Maximum allowable weight for this package is 840 lbs for shipment of Radioactive Material in solid form.

3.14 Place two (2) Cargo-Only Aircraft Labels on the drum. One label each on the outer opposite sides of the drum. (For air shipment only)______________.RMC

3.15 Place two (2) applicable Radioactive labels on the drum. One label each on the outer, opposite sides of the drum_______________.RMC

NOTE: Ensure all labels are not obsured by any markings or attachments.

3.16 Tie and secure the drum in the transport vehicle for transport _______________.RMC

I certify that all of the above steps were taken in the preparation of this sample for shipment.

RMC_______________ DATE _______________

NOTE: This checklist, when completed, will be attached to and become part of the shipping document file.

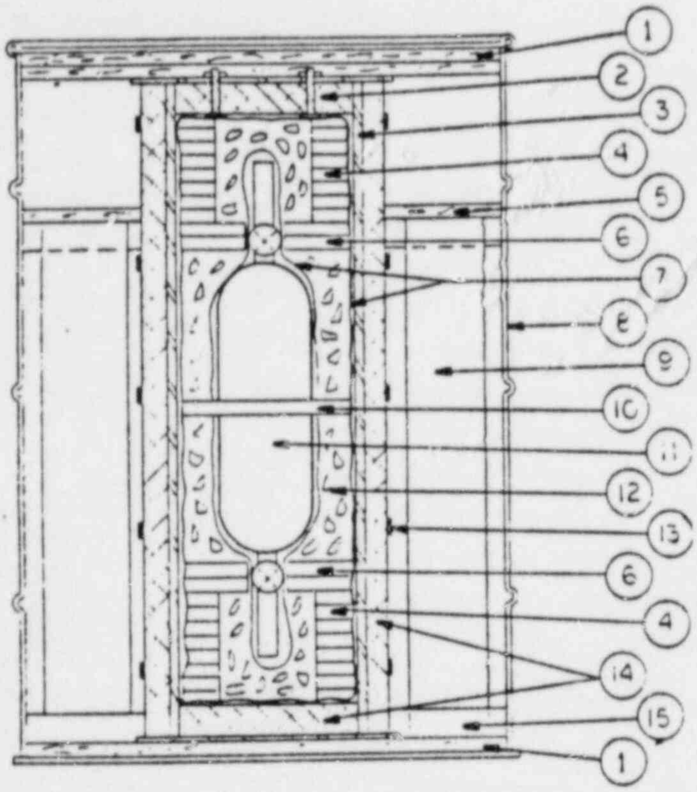
ATTACHMENT 2.6

PACKAGE CONFIGURATION AND PACKAGING CHECKLIST FOR RADIOACTIVE

LIQUID SAMPLES IN SHIELDED SAMPLE BOMBS

UP TO ONE (1) LITER

1.0 PACKAGE CONFIGURATION



1. Plywood Spacer D
2. Lid with 1" lead shield
3. Sch 10, SS Pipe, 8-inch
4. Plywood Spacer A
5. Plywood Support Disc
6. Plywood Spacer B
7. Plastic Bags
8. DOT 17-H Drum with Lid, Ring, Bolt, and Lock Nut
9. Support, 2" x 4"
10. Plywood Spacer C
11. Sample Bomb - Inner containment vessel
12. Approved Absorbent
13. Banding
14. Lead Shielding 1-inch
15. Support, 1" x 2"

2.0 PREREQUISITES

NOTE: These steps may be performed in any order providing they are completed prior to commencement of the packaging operation.

2.1 Initiate an RWP with specific dress requirements for both the Packager and the Packager-Helper_________________.RMC

2.2 Stage the following items at the Sample Packaging Area, outside the RWP area.

NOTE: Some items may be omitted if samples were previously packaged.

2.2.1 One new, yellow, DOT-17H, 55 gallon drum, with inner lead shield, undamaged (except for superficial marks) with lid, ring, bolt and locknut and an undamaged drum lid gasket. Ensure the drum has DOT specification markings in accordance with 49CFR 178.118-110 and 178.118-11.______________.RMC

2.2.2 Suitable material for floor covering______________.RMC

2.2.3 Support assembly for sample bomb.______________.RMC

2.2.4 Plastic bag suitable for lining shield pipe ______________.RMC

2.2.5 Three plastic bags suitable for wrapping sample bomb ______________.RMC

2.2.6 Approved absorbent material______________.RMC

2.2.7 One (1) roll of duct tape______________.RMC

2.2.8 One (1) extra nut and bolt for the 55 gallon drum ______________.RMC

2.2.9 One (1) hammer or mallet______________.RMC

2.2.10 One (1) crescent wrench (10 inch or greater) ______________.RMC

2.2.11 One (1) calibrated torque wrench (appropriate range for gerater than 40 ft/lbs)______________.RMC

2.2.12 At least one (1) lead seal and the Met-Ed seal crimping tool______________.RMC

2.2.13 The RMC shall verify that all the materials used in this package are the same as those used in the certification package for this Type 7A container______________.RMC

2.3 Stencil the drum with the following information using letters at least 1/2 inch high in a durable, contrasting color

______________.RMC

METROPOLITAN EDISON CO. P.O. BOX 480 MIDDLETOWN, PA 17057	U.S. DOT 7A, TYPE A RADIOACTIVE MATERIAL N.O.S.

NOTE: Marking must not be obscured by labels or attachments and must be located away from any other markings that could substantially reduce its effectiveness.

2.4 Brief the Packager and Packager-Helper on the provisions of the RWP and the function they are to perform ______________.RMC

The provisions of the RWP and functions of the packaging operation are understood:

________________________ ________________________

Packager Packager-Helper

2.5 Brief the Rad Con Tech. on the functions of the packaging operation

______________.RMC

The functions of the packaging operation are understood:

____

Rad Con Tech.

CAUTION: A Rad-Con Tech shall be present during all phases of the packaging operation, if required.

2.6 Place the 55 gallon shielded sample drum in the RWP area adjacent to the sample packaging area. Inspect the general condition of the container. The container is satisfactory

______________.RMC

2.7 Place the selected floor covering material on the floor of the packaging area. Set the DOT-17H, 55 gallon drum, containing the shield assembly, on the material and position a radiation boundary around the drum______________.RMC

3.0 PACKAGING OPERATION

3.1 Place eight (8) wood spacers (spacer A) into the bottom of the plastic liner for the shielded pipe______________.RMC

NOTE: The number of spacers is dependent on the size of the sample bomb. The above is for a one (1) liter sample.

3.2 Place the item prepared in step 3.1 into the 8-inch shielded pipe in the 55 gallon drum______________.RMC

3.3 Add absorbent material to fill the inner cavity of the wood spacers ______________.RMC

3.4 Sample Preparation

NOTE: Steps 3.4.1, 3.4.2, 3.4.3 and 3.4.4 may be signed off after these steps are accomplished provided there is verbal verification that these steps have been completed.

NOTE: Section 3.4 may be completed prior to starting of packaging operation.

3.4.1 Tape the valve handles securely to prevent movement.

______________.Sample Preparer

3.4.2 Place the sample bomb into a plastic bag and tape tightly around the fittings at each end.

______________.Sample Preparer

3.4.3 Rad-Con shall survey the sample bomb and record the results______________.Rad-Con

______________mR/hr ______________mRad/hr

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3.4.4 Place the sample bomb into a second bag and securely tape around fittings at each end______________.Rad-Con

3.4.5 Place the sample bomb into a third bag and securely tape around fittings at each end______________.RMC

3.5 Place two (2) slotted spacers (spacer B) over one end of the sample bomb and slide up to fit over valve handle______________.RMC

3.6 Place sample bomb, with spacers down, into the drum. The slotted spacers should rest against the top of the spacers added in step 3.1

______________.RMC

3.7 Add absorbent material to the middle of the sample bomb. Add center wood spacer (spacer C) and fill with absorbent up to the upper valve handle______________.RMC

3.8 Position the slotted spacers (spacer B) over the upper valve handle

______________.RMC

3.9 Add additional spacer(s) (spacer A) (8-9 for (1) liter sample) to fill the shielded pipe to within one (1) inch from the top of the pipe.

______________.RMC

3.10 Fill the center void of the spacers with absorbent material.

______________.RMC

3.11 Seal the plastic bag______________.RMC

3.12 Place metal plug into the shielded pipe. Add two (2) wood spacers (spacer D) to drum______________.RMC

3.13 Place the drum lid with gasket, ring and bolt on the drum.

______________.RMC

3.14 Permission to remove the sample drum from the packaging area

______________.Rad-Con

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3.15 Tighten the bolt on the drum ring. Tap the ring with a hammer or mallet to seat the ring and retighten. Place the locknut on the bolt outside of the ring cleat and tighten______________.RMC

3.16 Using the torque wrench, check the nut bolt to ensure that they are tightened to greater than 40 ft/lbs______________.RMC

3.17 Seal the drum with a lead seal______________.RMC

3.18 Perform a package survey consisting of a 3 point contact and 3 foot radiation levels plus Beta/Gamma and Alpha swipe surveys on the sample drum______________.Rad-Con

3.19 Remove the drum to a transport vehicle and secure the drum for transport to the scales for weighing______________.RMC

3.20 Weigh the drum and mark the weight on the side of the drum in letters 1/2 inch high (minimum height) in a durable contrasting color______________.RMC Record Weight______________

CAUTION: Maximum allowable weight for this package is 609 lbs for shipment of Radioactive Material in liquid form.

3.12 Place two (2) THIS END UP labels on the drum, one label each on the outer,opposite sides of the drum______________.RMC

3.22 Place two (2) Cargo-Only Aircraft labels on the drum. One label each on the outer, opposite sides of the drum. (For Air Shipments Only)______________.RMC

3.23 Place two (2) applicable Radioactive labels on the drum. One label each on the outer, opposite sides of the drum.______________.RMC

NOTE: Ensure all labels are not obscured by any markings or attachments.

3.24 Tie and secure the drum in the transport vehicle for transport.

______________.RMC

NOTE: Step 3.24 to be completed when transportation is available.

I certify that all of the above steps were taken in the preparation of this sample for shipment.

RMC ____________________ DATE ______________

NOTE: This checklist, when completed, will be attached to and become part of the shipping document file.

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ATTACHMENT 3

PACKAGING LIQUID SCINTILLATION VIALS

1. Liquid scintillation vials shall not be disposed of in compacted trash.

2. Liquid scintillation vials shall be packaged in yellow, 17-H 55 gallon steel drums as follows:

   2.1 The inside of the outer package, the 55 gallon drum, shall be lined with a 4 mil poly liner, and sealed at the top when the container is packed.

   NOTE: Place a layer (1-2 inches) of absorbent in the drum before the plactic liner is placed in the drum

   2.2 Place approximately 3 inches of absorbant at the bottom of the container.

   2.3 Vials and absorbant must be placed in the container in layers not exceeding 6 inches in depth.

   2.4 Between each layer at least 1 inch of absorbant must be placed.

   2.5 The top layer must be approximately 3 inches of absorbant.

3. The vials are not to be opened.

4. The container must be filled with enough absorbent to absorb at least twice the volume of liquid.

5. The following absorbents are authorized for use in packaging scintillation vials

   5.1 Florco - A maximum of 11.96 gallons of fluid per 55 gallon drum (905 vials)

   5.2 Florco - X- A maximum of 10.1 gallons of fluid per 55 gallon drum (764 vials)

   NOTE: The number of vials is based on 50 ml of fluid per vial.

6. The drum must be labeled "Flammable Liquid", in addition to the labels for the proper shipping category as determined in 5.2 of this procedure.

ATTACHMENT 4

PACKAGING OF CONTAMINATED OIL

1. Mix oil thoroughly and take a sample of the oil for analysis of the activity

2. Calculate the activity of the oil to be disposed of in each drum

   2.1 mCi/cc x volume (of oil per drum) = total activity per drum

   2.2 The volume of oil per drum is determined by the type of absorbent used. The following is a list of approved, tested absorbents and the amount of oil allowed per drum

      2.2.1 Florco 11.96 gallons of oil per 55 gallon drum

      2.2.2 Florco-X 10.10 gallons of oil per 55 gallon drum

3. Processing of single drum volumes

   3.1 Place a 4 mil plastic liner in a yellow 55 gallon 17H drum

   3.2 Add approximately 1 foot of absorbent material to the drum. Add 1/3 of the oil to be absorbed (volume dependent on absorbent used) and mix thoroughly. Repeat until full.

   3.3 Seal the plastic liner and install the drum lid and lock ring. Tighten the ring bolt and lock nut to greater than 40 ft/lbs.

4. Processing large volumes of oil using batch method

   4.1 Place sufficient absorbent into mixing trough for one or more drums (depending on size of trough)

   4.2 Add the amount of oil, as determined by the amount and type of absorbent used, to the trough and mix throughly

   4.3 Place a 4 mil plastic liner in a yellow 55 gallon 17H drum. Transfer mixture to drum(s)

   4.4 When a drum is full, close as per step 3.3

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ATTACHMENT 5

PACKAGING COMPACTIBLE TRASH

1. Compacted trash shall be packaged in yellow, 17-H 55 gallon steel drums.

   NOTE: There are some drums currently in storage that contain radioactive materials and do not satisfy the color coding requirement above. These drums existed prior to instituting the color coding program. In the circumstance where these non-yellow drums may need to be moved to the compacting room for compacting their contents, written permission of the Supervisor , Waste Disposal shall be obtained, no exceptions.

2. Containers shall be visually inspected prior to use to insure good sealing edge, no large dents or creases, no holes or cuts and no bung holes in the side or bottom of the drums.

3. After the drums have been filled and tops installed they shall be surveyed for removable surface contamination prior to movement to staging facility and surveyed for dose rate, contact (high and average) and three feet, prior to storage or shipment.

   NOTE: Filling and closure of drums shall be done in accordance with appropriate operating procedures for the compactor used.

4. Labeling shall be as per the proper shipping category (i.e. LSA, Type A, etc.) as determined in 5.2 of this procedure.

5. Drums shall contain NO LIQUIDS.

ATTACHMENT 6

PACKAGING DIRTY LAUNDRY

1. Dirty laundry shall be packaged in white 17-H 55 gallon steel drums.
2. A poly or cloth bag shall be inserted into the laundry drum prior to dirty laundry. The liner shall be rolled over the top edge of the drum to prevent the drum from being contaminated.
3. After the drum is filled with dirty laundry, seal the top of the poly liner, or cloth bag.
4. Inspect the drum sealing gasket and replace if damaged.
5. Install the drum top and locking ring, tighten the bolt and locknut to greater than 40 ft/lbs.
6. Laundry shall be labeled for the proper shipping category as determined in 5.2 of this procedure.

FOR USE IN UNIT II ONLY

8. Acceptance Tests and Maintenace Program

8.1 Acceptance Tests

This section is taken from the model SN-1 Licensing package and will also pertain to the proposed insert as the cask was originally manufactured and licensed in 1974, the cask has already been acceptance tested.

8.1.1 Visual Inspection

8.1.1.1 Check package for cracks, pinholes, or other breaches of the containment vessel.

8.1.1.2 Inspect all tie-down and lifting lugs/devices for damage.

8.1.1.3 Verify there are no defects which would impare package effectiveness.

8.1.1.4 All welds have been radiographed and dye penetrant tested.

8.1.2 Structural and Pressure Tests

8.1.2.1 If visual inspection of package (Section 8.1.1) shows no defects or separation of concrete from the SN-1 or carbon steel liner, structural integrity of the package is considered to be maintained.

8.1.2.2 Package was pneumatically tested to 38 psig.

8.1.3 Leak Tests

8.1.3.1 The cask was tested pneumatically at 38 psig upon completion with no detectable leakage.

8.1.4 Component Tests

8.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices

Not applicable.

8.1.4.2 Gaskets

The gasket used is a .375" diameter silicone rubber O-ring, Aeronautical Material Specification (AMS) #3302D, temperature range -70°F to 600°F.

8.1.4.3 Miscellaneous

The impact limiters and their respective hold-down devices must be inspected for any damage which may reduce package effectiveness.

8.1.5 Test for Shielding Integrity

The package shielding evaluation was performed by calculation, hence, if no structural defect or damage is found, the shielding integrity is assumed to be maintained. In addition, radiation and contamination surveys will be performed before each shipment to assure levels are within limits of 10 and 49 CFR.

8.1.6 Thermal Acceptance Tests

The package shall be inspected to assure construction is as designed, hence package will meet model specifications used in thermal evaluation model.

8.1.7 Acceptance Criteria

If any of the acceptance criteria (design criteria) are not met, the package will not be put into service until the items of noncompliance are corrected.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

8.2.1.1 Structural tests shall comprise 8.1.1.1 through 8.1.1.3, this will be conducted prior to each loading of the package for shipment.

8.2.1.2 Pressure tests will consist of pressurizing the package to 38 psig, and will be performed whenever any change to the package takes place or defects to the package warranting pressure testing occurs.

8.2.2 Leak Tests

Considering:
1) All radioactive material will be in a sealed inner container, and
2) There is no breach of package containment due to normal conditions of transport or hypothetical accident conditions,

we will assume a zero leakage rate is acceptable.

8.2.2.1 Gas Pressure Drop Test

The test shall be performed as specified in ANSI N14.5-1977, through use of the test header in Appendix 8.2.8.

1) The internal volume of the package will be reduced by inserting an actual liner, such as those to be shipped.

2) The test header shall be connected, and the package pressurized to 15 psig for 2 - 4 hours.

3) The leakage rate shall be determined using the following equation:

$$L = \frac{VT_s}{3600H} \quad \frac{P_1}{T_1} - \frac{P_2}{T_2}$$ Where:

L = Leakage rate atm. cm^3/s

H = Test duration

P_1= Gas pressure in package, test start, atm.

T_1= Gas pressure in package, test end, atm.

T_2= Gas temperature, test end, ^oK

T_s= Reference absolute temperature, 298K

V = Volume in package, Cm^3.

8.2.2.2 Sensitivity

The sensitivity for the gas pressure drop test is listed by ANSI as 10^{-2} $Pa.m^3/s$.

8.2.2.3 Frequency

Leak tests shall be performed before first usage; after any change to the containment, i.e., gasket replacement, and/or once during each 12 month period.

8.2.3 Subsystems Maintenance

The impact limiters and their respoective tie-down devices shall be inspected for integrity and damages/defects that may impare functional effectiveness.

8.2.4 Valves, Rupture Discs, and Gaskets on the Containment Vessel

The silicone O-ring closure head seal will be inspected before each usage, and will be replaced if any damage is found or any reduction of its effectiveness is suspected.

8.2.5 Shielding

If no structural damage or defects are found, the shielding effectiveness will be assumed to be unchanged. Furthermore, the radiation levels of the package shall be determined before each shipment to assure levels are within the limits specified in 10 and 49 CFR.

8.2.6 Thermal

If no damage or defect is found in the pre-shipment structural inspection, it will be assumed that the thermal effectiveness has not changed.

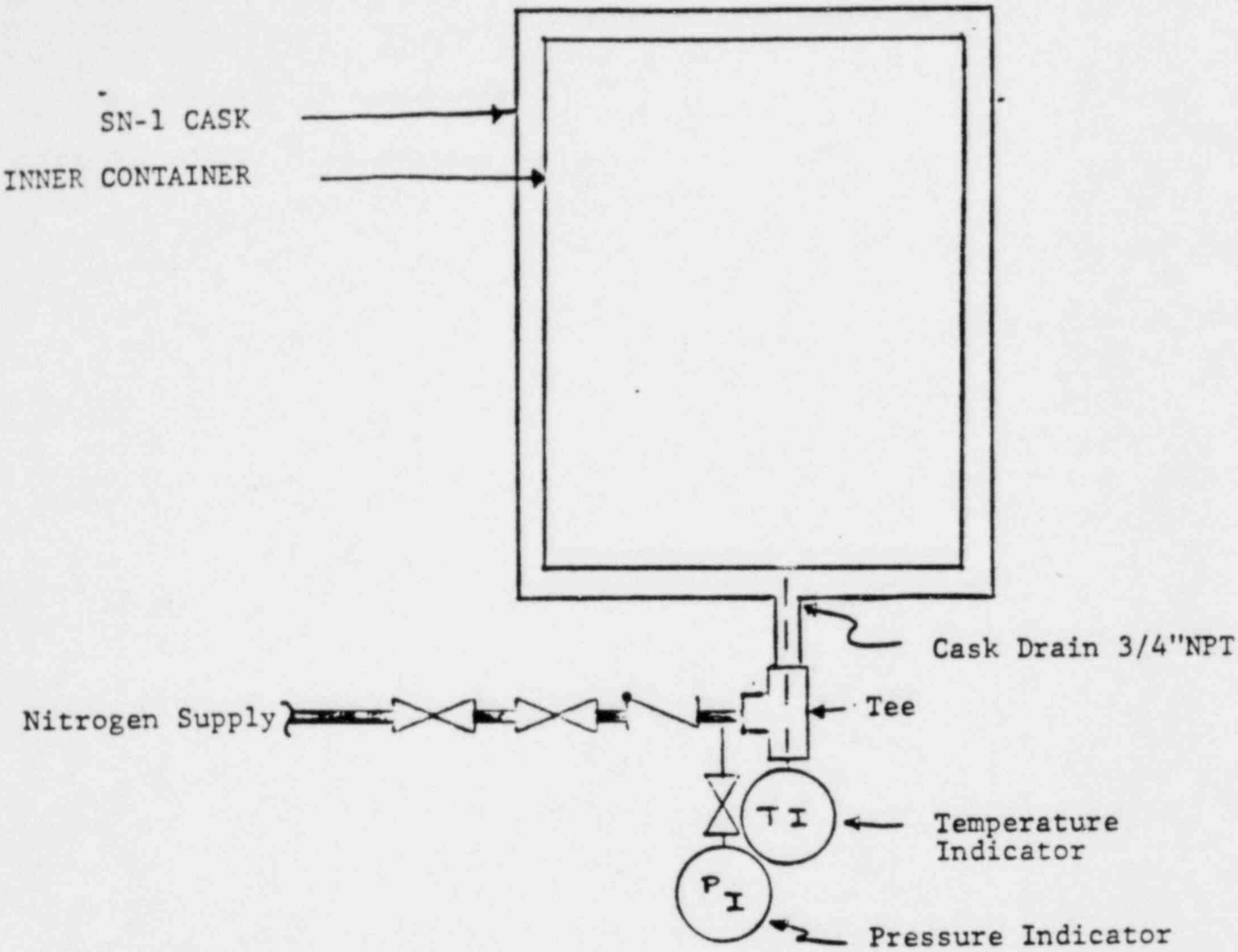
8.2.7 Miscellaneous

8.2.7.1 If any items of noncompliance are found, those items will be corrected and documented before the package is placed back into use.

8.2.7.2 In addition to the above criteria, all of the conditions in Station Health Physics Procedures HPP 1618 A and D and the requirements of OOA Checklist 1618 A, will be conformed to. These documents can be found in Appendix 7.4.

8.2.8 Appendix

PRESSURE TEST HEADER



Notes:

1. Temperature indication readable to $2^{o}F$ or $1^{o}C$.
2. Pressure indication, 0 - 25 psig, calibrated to maximum error of 1% of full scale.

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