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Shielding Design Evaluations of Concrete-Lined Drums for RH-TRU Waste

L. A. Rodgers

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Shielding Design Evaluations of Concrete-Lined
Drums for RH-TRU Waste

May 1996

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U. S. Department of Energy

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed WHC-SD-WM-TI-752

Author L. A. Rodgers

Yes No N/A

- ☒ [ ] [ ] Problem completely defined.
- ☒ [ ] [ ] Necessary assumptions explicitly stated and supported.
- ☒ [ ] [ ] Computer codes and data files documented.
See Note in page 2 of Kaiser's Calculation Identification and Index
- ☒ [ ] [ ] Data used in calculations explicitly stated in document.
- ☒ [ ] [ ] Data checked for consistency with original source information as applicable.
- ☒ [ ] [ ] Mathematical derivations checked including dimensional consistency of results.
- ☒ [ ] [ ] Models appropriate and used within range of validity or use outside range of established validity justified.
- ☒ [ ] [ ] Hand calculations checked for errors.
- ☒ [ ] [ ] Code run streams correct and consistent with analysis documentation.
- ☒ [ ] [ ] Code output consistent with input and with results reported in analysis documentation.
- ☒ [ ] [ ] Acceptability limits on analytical results applicable and supported. Limits checked against sources.
- ☒ [ ] [ ] Safety margins consistent with good engineering practices.
- ☒ [ ] [ ] Conclusions consistent with analytical results and applicable limits.
- ☒ [ ] [ ] Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number N/A

C. T. Li
Reviewer

Charles T. Li

5/16/96
Date

	CALCULATION IDENTIFICATION AND INDEX	Page 1 of
		Date 5/16/96

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline **Mechanism**   WO/Job No.   Calculation No.

Project No. & Name   **Shielding Design Evaluations of Concrete-Lined Drums for RH-TRU Waste**

Calculation Item   **Drum**

These calculations apply to:

Dwg. No.   **H-3-3045 41**   Rev. No.   **0**

Dwg. No.   Rev. No.

Other (Study, CDR)   Rev. No.

The status of these calculations is:

☐ Preliminary Calculations

☒ Final Calculations

☐ Check Calculations (On Calculation Dated)

☐ Void Calculation (Reason Voided)

Incorporated in Final Drawings?   ☒ Yes   ☒ No

This calculation verified by independent "check" calculations?   ☐ Yes   ☒ No

Original and Revised Calculation Approvals:

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Approved by	<i>R.B. Papp 6/12/96</i>		
Checked Against Approved Vendor Data			

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15	Model Geometry Cal.

[illegible]

CALCULATION CROSS INDEX (Typical)

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Shielding Design Evaluations of Concrete-Lined Drums for RH-TRU Waste

1.0 INTRODUCTION

Transuranic (TRU) waste from the "hot cells" of Pacific Northwest National Laboratory's (PNNL's) 327 Building is to be shipped on site to the Transuranic Storage and Assay Facility (TRUSAF) for storage. This is to be accomplished through the use of a new waste package consisting of a concrete-lined drum design. The TRU waste will have been placed in 1-gallon paint cans, which may be crushed by a compactor to maximize storage in the waste package. Three to six of these cans will be placed into a 17.8-cm (7-in.) diameter sleeve, which in turn will be loaded into the waste package (e.g., a concrete-lined, 208-liter [55-gallon] drum).

This new design is to take advantage of features of an existing design that has already been used by PNNL.

The purpose of these scoping calculations is to provide a gross comparison of the radiation shielding afforded by the existing design to that of possible new design configurations. That is, parameters for the new design were varied (e.g., concrete thickness, inner steel pipe size, lead linings, etc.) as inputs to the Microshield analytical shielding program (Reference 1) to provide a general comparison against the existing design and provide an indication of those design parameters that might improve the effective shielding capacity of the new design.

Once a drum configuration is selected and fabricated, it will be loaded with various types of TRU waste and radiologically surveyed per administrative controls to ensure dose rates fall within acceptable levels. If dose rates from a drum exceed these levels, the waste contents will be removed and replaced with contents that result in acceptable rates. These surveys will ensure acceptability of each waste package. Therefore, these calculations and the associated results are for information only. They should not be used for extrapolation of quantitative results.

2.0 DISCUSSION

The existing waste package is constructed of a D.O.T. 17H 208 liter (55 gallon) drum. It has a concrete liner around a 14-in., schedule 80, carbon steel pipe located at the center of the drum. The top and bottom shield plugs are 2.54 cm (1-in.) thick carbon steel plates. The new waste packages are to be shipped in accordance with SD-RE-SAP-033 entitled, "Transuranic Radioactive Material in the 55-Gallon Drum, HCS-042-002, Safety Analysis Report for Packaging (Onsite)" (Reference 2), which states that the weight is to be limited to 658 kg (1450 lb) per drum. Design improvements of the new waste package considered using a smaller pipe for loading the waste, adding lead around the pipe or the drum, and using lead or thicker steel shield plugs. Comparisons of the resulting dose rates calculated from each design (assuming a given source) are discussed below according to the primary parameters investigated.

The shielding calculations were performed using the "Microshield 4.10" analytical software (Reference 1) (Attachment A) and later with hand calculations (Appendix B). The same source strength was assumed to exist in each case analyzed and included Cs-137, Co-60, and Ba-137m. Parameters from each design needed for the

Microshield¹ calculations are distance to detector, source length, dose point height from base, source cylinder radius, and thicknesses of all shields (steel, lead, concrete, and air). The investigation considered both radial and longitudinal shielding. Variation of these parameters to represent different package configurations produced results that were compared to help select parameters for the new design.

Five waste package drum wall configurations were modeled: two models simulated the existing waste package, and three models simulated the new waste package. For the comparison, the weight of each waste package configuration was estimated. All configurations used for the models had a dead weight of less than 658 kg (1450 lb). The two models for the existing waste package used the same concrete thickness. However, in one model the source was assumed at the center of the 14-in. pipe, whereas in the other model the source was assumed to be in contact with the pipe. The model with the source assumed in contact with the pipe had the higher dose rate. The three new waste package models all used an 8-in. schedule 40 pipe: one with a concrete sidewall only, one with a lead wrap around the pipe, and one with lead wrap against the inside of the drum.

When compared to the existing waste package, the weights of the new waste packages increased by 5 percent for sidewalls with concrete only and 12 and 23 percent for sidewalls employing lead wraps. The dose rate was decreased by 36 percent for the concrete-only model and by 64 percent for the lead wrap models. The lead wrap models' weights come very close to the weight limits in SD-RE-SAP-033.

The end shields for the top and bottom were also modeled using lead, steel, and combinations of both. Those shields employing lead thicknesses of 2.54 cm (1 in.) or more were found to have a shielding capacity equal to or greater than that of the radial model with sidewalls of only concrete. The 5.04-cm (2-in.) thick steel shields provided less longitudinal shielding than the radial shielding provided by the concrete sidewalls. One model considered a shield made of 2.54 cm (1 in.) of lead and 2.54 cm (1 in.) of steel. This combination produced a shielding capacity equivalent to almost six times what was calculated for the sidewalls of the new design shielded only by concrete. Other configurations indicated shielding capacities that were either less than that of the concrete sidewalls or even greater than that of the lead-steel combination. No smaller thicknesses of lead or steel were considered in these scoping Microshield calculations.

However, because of additional handling requirements, manufacturing processes, and disposal concerns associated with the use of lead in the design, thicker steel end shields (without lead) were given further consideration. To do this, hand calculations were performed by PNNL radiological control personnel (Appendix B). These calculations used the source term information and selected results from the foregoing Microshield calculations. They determined (1) that a 8.9-cm (3.5-in.) thickness of steel (iron) would provide shielding equivalent to the combination of 2.54 cm (1 in.) of lead and 2.54 cm (1 in.) of steel and (2) that a 5.7-cm (2.25-in.) thickness of steel (iron) would be necessary to attenuate the same source energy through the ends of the drum to the level calculated by Microshield as passing through the sidewalls.

3.0 CONCLUSIONS

Scoping calculations were performed to provide a gross assessment of the shielding capacity achievable by modifying an existing waste package design. They are presented herewith (Appendix A) for information only. The design was dictated by the requirement that a 208 liter (55-gallon) D.O.T. drum be used and that the waste paint cans it would receive would fit into a pipe smaller than the existing design.

The weight limit was the major factor in eliminating radial lead shielding from the design. It was decided that the added weight did not reduce the dose rate sufficiently to warrant its use. In addition, lead adds manufacturing and disposal problems that would need to be considered. Therefore, it was concluded that the new waste package would be constructed using the 8-in. pipe and a sidewall of concrete only.

A limited number of end shield configurations was considered in the scoping calculations performed using Microshield. Of those considered, the configuration that most closely matched the shielding provided by the sidewalls was composed of a combination employing 2.54 cm (1 in.) of lead and 2.54 cm (1 in.) of steel. This configuration provided shielding greater than--but nearest in equivalence to--the radial shielding afforded by the concrete sidewalls. Hand calculations took this one step further to eliminate the use of lead by using thicker steel end shields. They determined that a 5.7-cm (2.25-in.) thickness of steel (iron) would be adequate to reduce the dose rate through the ends to levels equivalent to that calculated by Microshield as passing through the sidewalls.

4.0 REFERENCES

1. Microshield, Version 4.10, Grove Engineering, Inc, Rockville, Maryland, 1993.
2. "Transuranic Radioactive Material in the 55-Gallon Drum, HCS-042-002, Safety Analysis Report for Packaging (Onsite)," SD-RE-SAP-033, Westinghouse Hanford Company, Richland, WA 99352.

Appendix A
Calculation Results for Drum Shielding

ANALYTICAL CALCULATIONS

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Subject DRUM SHIELDING
Originator J. H. Hays Date 3/13/96
Checker Charles T. Li Date 4/3/96

THE 325 BUILDING HAS USED A CONCRETE DRUM FOR SITE SHIPMENTS OF WAST FROM THEIR CELLS. THE 327 BUILDING HAS A NEED TO SHIP SOME WAST FROM THEIR CELLS FOR DISPOSAL. THE DRUM TO BE USED IS TO BE OF A SIMILAR DESIGN. THE ORIGINAL DRUM DESIGN WAS NEVER FORMULIZED, BUT THE NEW 327 BUILDING DRUM IS TO BE.

THE BASIC DESIGN AND METHODOLOGY FOR THE DRUMS AND WAST IS THE SAME. THE WAST FROM THE CELLS IS IN SEAL PAINT CANS, 1 GALLON. THE WAST VARIES AND CAN CONTAIN SOME FUEL ELEMENT MATERIAL. THE PAINT CANS ARE TO BE LOADED INTO A SLEEVE

CONSTRUCTED OF 22 GAGE S.S. STEEL. IT IS TO HAVE A CABLE BAIL FOR IN-CELL HANDLING. THE SLEEVE IS TAKEN INTO CELL AND UP TO THREE, UN-COMPACTED, PAINT CANS PLACE INSIDED IT. A RIGID FOAM, LIKE CELOTEX, PLUG IS PUSHED INTO THE SLEEVE, TO HOLD THE PAINT CANS IN PLACE DURING HANDLING. THE SLEEVE (PAINT CANS) IS THEN PUSHED OUT A CELL PLUG INTO THE DRUMS INTER PIPE CAVITY. THE DRUM'S OPEN TOP IS ROTATED UPWARD TO APPROXIMATELY 45° IN PLACE SO THAT THE CELL ACTS AS A SHIELD. A SHIELD PLUG IS PLACED ON THE PIPE AND A

ANALYTICAL CALCULATIONS

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Subject DRUM SHIELDING
Originator JAL Date 3/13/96
Checker Charles T. Li Date 4/3/96

RIGID FOAM, LIKE CELOTEX, PLUG IS PUSHED INTO THE DRUM TO HOLD THE SHIELD PLUG IN PLACE. THE DRUM IS ROTATED TO UP A RIGHT POSITION AND THE DRUM LID IS INSTALLED.

THE SLEEVE IS CONSTRUCTED OF 22 GAGE CARBON STEEL SIDES AND BOTTOM WELDED TOGETHER. A CABLE BAIL IS ATTACHED WITH SUFFICIENT LENGTH TO BE PUSHED OVER THE SIDE OF THE SLEEVE. SLEEVE IS APPROX 27½" LONG AND 7" Ø OD.

THE EXISTING DRUM IS CONSTRUCTED WITH OF D.O.T. 17H 55 GALLON DRUM, CONCRETE LINER AND A 14" SCH 80 CARBON STEEL PIPE FOR THE CAVITY AT THE CENTER OF THE DRUM. THE TOP AND BOTTOM SHIELD PLUGS ARE 1" CARBON STEEL.

THE 325 BUILDING HAS HAD FOUND THE 1" BOTTOM PLUG TO BE INSUFFICIENT SHIELDING AT TIMES AND HAS ADD A SECOND 1" PLATE.

THE SOURCE LOAD FROM THE 327 LAB CELLS WAST PAINT CANS IS QUESTIONABLE. THEREFORE IT WAS DESIDED TO USE C_3 137 @ 140 Ci AND C_6 60 @ 0.198 Ci FOR DOSE CALCULATIONS. THESE ELEMENTS ARE EXPECTED TO BE IN SOME OF THE WAST. C_{213m} IS ADD TO SOURCE ASSUMPTION AT ~94.6% OF C_6 FOR 132 Ci.

ANALYTICAL CALCULATIONS

Subject DRUM
Originator JAR Date 3/14/96
Checker Charles T. Xi Date 4/3/96

SEVERAL DESIGN CHANGES ARE TO BE INCORPORATED FOR THE 327 DRUMS.

- THE PAINT CANS AND DRUM CAN DO NOT NEED A 14" Ø CAVITY AND IT IS DESIRABLE TO HAVE ADDITIONAL SHIELDING. THEREFORE A 8" SCH 40 PIPE IS USED IN THE NEW DRUMS
- THE USE OF A LEAD WRAP IS EVALUATED FOR TWO LOCATIONS. ONE AROUND THE PIPE AND TWO ON THE INSIDE OF THE DRUM.
- THE EFFECTIVE SHIELDING OF THE TOP AND BOTTOM PIPE SHIELD PLUGS WILL BE DESIGNED TO BE EQUAL OR GREATER THAN THE SIDES.
- THE DRUMS ARE TO BE SHIPPED USING SD-RE-SAP-033 SECTION 4.3.2#6, THEREFORE A MAXIMUM WEIGHT IS 1450 LB TO BE USED.

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator RAE Date 3/14/96
Checker Charles T. Xi Date 4/3/96

THE SHIELDING CALCULATIONS ARE PERFORMED TO APPROXIMATE THE PERCENT OF DOSE RATE REDUCTION THE NEW DRUM DESIGN(S) WILL HAVE. ALSO, THE TOP & BOTTOM OF THE NEW DRUM DESIGN ARE TO HAVE EQUALANT SHIELDING TO MATCH THE SIDES.

IN MODELING THE SOURCE IT IS ASSUMED TO BE AIR. (TO BE CONSERVATIVE) MICROSHIELD 3.23 IS USED.

EVALUATION OF RESULTS

(SEE THE NEXT PAGES FOR TABLES)

- 1.) CHANGING TO THE 8" PIPE, THE WEIGHT INCREASED ONLY ~5% BUT THE DOSE RATE IS ONLY 64% & 48% OF THE 325 DRUM DESIGN.
  - 2.) THE USE OF LEAD WRAP ON THE PIPE OR INSIDE OF DRUM INCREASED THE WEIGHT 18% & 73% AND IT CAME VERY CLOSE TO THE LIMIT OF 1450 LB. THE DECREASE OF DOSE RATE OVER THE CONCRETE WAS LESS THAN ANOTHER 70%.
- THE CONCLUSION IS THAT: THAT THE ADD WEIGHT OF THE LEAD DID NOT REDUCE THE DOSE RATE SUFFICIENTLY TO JUSTIFY IT'S USE.

- 3.) THE MODEL FOR THE TOP & BOTTOM SHIELD PLUGS SHOWED THAT 2" OF STEEL WAS INSUFFICIENT TO EQUAL THE CONCRETE SIDES 1" OF STEEL + LEAD OR 3" OF LEAD HAS SUFFICIENT SHIELD.

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator JAM Date 3/12/96
Checker Charles T. Li Date 4/3/96

BOTH ARE EQUIVALENT WITH THE CALCULATED
SIDE DOSE RATE.

THE CONCLUSION IS THAT: THE TOP AND
BOTTOM CAN BE 1" OF STEEL AND LEAD OR
2" OF LEAD

ANALYTICAL CALCULATIONS

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Subject DRUM
 Originator HR Date 3/14/96
 Checker Charles T. Li Date 4/3/96

COMPARISON TABLE

MODEL	WEIGHT UNLOADED (lb)	INCREASE IN WEIGHT (lb / %)	DOSE (m / hr)	% OF 'RDRUMOLD'	% 'OLD DRUM'
'RDRUMOLD' SOURCE IN CENTER	1085	-	55140		40.00%
'OLD DRUM' SOURCE ON SIDE (MODIFIED) SEA			73340		
'RDRUM NEW' 8" PIPE	1140	5%	35390	64%	48%
'RNEW 14LD' 1/4" LD ON PIPE	1211	12%	18980	34%	26%
'RINNEW 10' 1/4" LEAD ON INSIDE OF DRUM	1336	23%	19880	36%	29%

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator APL Date 3/14/96
Checker Charles T. Li Date 4/2/96

COMPARISON OF TOP & BOTTOM MODELS

MODEL	DOSE m/hr	% OVER ST	% OVER NEW DRUM
R207-S7 2" STEEL	110800		313%
R207L0-S 1" LEAD 1" STEEL	6028	54%	12%
R207L0-S 2" LEAD	1102	10%	3%
R207-S7 2" STEEL	68090	~	192%
R207-L0 2" LEAD	769	~	2%
R3307L0-S 2" LEAD 1/2" STEEL	528	5%	1%

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator SKR Date 3/13/96
Checker Charles T. Li Date 4/3/96

THE DRUM USED BY 327 IS SHOWN
BELOW.

THERE IS NO DRAWINGS OR OTHER
FORMAL DESIGN DATA AVAILABLE.

ANALYTICAL CALCULATIONS

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Subject WEIGHT DRUM
 Originator ML Date 3/14/96
 Checker Charles T. Li Date 4/3/96

DRUM WEIGHT CALCULATIONS

STEEL DRUM 22½" ID, 18 GAGE by 35" H (INSIDE)
 (0.0478")

$$VOL = \pi (r_o - r_i)^2 H$$

$$= \pi \left[\left(\frac{22\frac{1}{2} + 2(0.0478)}{2} \right)^2 - \left(\frac{22\frac{1}{2}}{2} \right)^2 \right] (35)$$

$$= 118,509 \text{ in}^3$$

LIDS) 22½" Ø 18 GAGE (0.0478")

$$VOL = \pi r^2 H = \pi (11\frac{1}{4})^2 (0.0478)$$

$$= 19,006 \text{ in}^3$$

$$TOTAL VOL = 118,509 \text{ in}^3 + 2(19,006 \text{ in}^3)$$

$$= 156,521 \text{ in}^3$$

STEEL 490 16/FF 3

$$WEIGHT = \frac{490 \text{ lb}}{\text{FF 3}} \cdot 156,521 \text{ in}^3 \frac{\text{FF}^3}{(12 \text{ in})^3} \cdot (1.10) \quad \begin{matrix} 3\% \text{ Form loss} \\ \uparrow \end{matrix}$$

$$= 49 \text{ lb}$$

STEEL PIPE

8" SCH 40

PIPE 28.55 16/FF 27.25"

$$LENGTH = (33\frac{1}{4} - 2(2)) \cdot \frac{\text{FF}}{12 \text{ in}} = 2.438 \text{ FF}$$

$$WEIGHT = 28.55 \frac{\text{lb}}{\text{FF}} (2.438 \text{ FF}) =$$

$$= 70 \text{ lb}$$

ANALYTICAL CALCULATIONS

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Subject DRUM
 Originator APL Date 3/14/96
 Checker Charles T. Li Date 4/3/96

2' R PIPE SHIELD ENDS

BOTTOM R 2" x 9" SQ

TOP R 2" x 8.625" SQ

$$\text{VOL} = 2 \text{ hwt} = 2" [(9")^2 + (8.625")^2] \\ = 310.78 \text{ in}^3$$

$$\text{WEIGHT} = 490 \text{ lb/ft}^3 \cdot 310.78 \text{ in}^3 \frac{\text{ft}^3}{(12 \text{ in})^3} \\ = 88 \text{ lb}$$

FOAM PLUGS ~ 0 lbCONCRETE OD 22 1/2 H = 33 1/4

$$\text{VOL} = \pi r^2 H = \pi (11 1/4")^2 (33.25") = 13720 \text{ in}^3$$

$$\text{Less VOL of pipe} = \pi r^2 H = \pi \left(\frac{8.625"}{2} \right)^2 (29.25") = 1709 \text{ in}^3$$

$$\text{Less R PIPE ENDS} = 310.78 \text{ in}^3 \\ \text{CON. VOL.} \sim 11200 \text{ in}^3$$

CONCRETE 144 lb/ft³

$$\text{WEIGHT} = 144 \text{ lb/ft}^3 \cdot 11200 \text{ in}^3 \frac{\text{ft}^3}{(12 \text{ in})^3} = 933 \text{ lb}$$

$$\text{TOTAL WEIGHT} = \underline{1140 \text{ lb}} \quad \text{'NEW DRUM' MODEL}$$

ADD 1/4" LEAD PIPE WRAP + END CAPSEND CAPS 1/4" = t 2.981 in OD

$$\text{VOL} = \pi r^2 H = \pi \left(\frac{2.981 \text{ in}}{2} \right)^2 (0.25 \text{ in}) \\ = 12.509 \text{ in}^3$$

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator JAR Date 3/14/96
Checker Charles T. Li Date 4/3/96

LEAD $710 \frac{16}{\text{F}^3}$

$$\text{WEIGHT} = \frac{710 \frac{16}{\text{F}^3}}{\frac{\text{F}^3}{(12 \text{ in})^3}} \cdot 12.507 \text{ in}^3 \frac{\text{F}^3}{(12 \text{ in})^3}$$

$$= 5 \frac{16}{\text{each}}$$

PIPE WRAP $L = 29.25 \text{ in}$ $20 = 8.625 \text{ in}$ $\frac{1}{4}'' t$

$$\text{VOL} = \pi r^2 h = \pi \left[\left(\frac{8.625'' + 2(\frac{1}{4}'')}{2} \right)^2 - \left(\frac{8.625''}{2} \right)^2 \right] 29.25''$$

$$= 203.883 \text{ in}^3$$

$$\text{WEIGHT} = \frac{710 \frac{16}{\text{F}^3}}{\frac{\text{F}^3}{(12 \text{ in})^3}} \cdot 203.883 \text{ in}^3 \frac{\text{F}^3}{(12 \text{ in})^3}$$

$$= 84 \frac{16}{\text{each}}$$

CHANGE IN CONCRETE WEIGHT

$$\text{WEIGHT} = \left(11200 \text{ in}^3 - 203.883 \text{ in}^3 \right) \frac{144 \frac{16}{\text{F}^3}}{\frac{\text{F}^3}{(12 \text{ in})^3}}$$

$$= 916 \frac{16}{\text{each}}$$

TOTAL WEIGHT = 1217 16 'NEW 1420' MOD

ADD 1/4" LEAD DRUM WRAP & PIPE END CAPS

DRUM WRAP $\text{OD} = 22 \frac{1}{2}''$ $t = \frac{1}{4}'' \Rightarrow 22'' \text{ ID}$

$$H = 33 \frac{3}{4}'' - 1 \frac{1}{2}'' = 31.75''$$

$$\text{VOL} = \pi r^2 H = \pi \left(\left(\frac{22 \frac{1}{2}''}{2} \right)^2 - \left(\frac{22''}{2} \right)^2 \right) 31.75 \text{ in}$$

$$= 581.047 \text{ in}^3$$

$$\text{WEIGHT} = \frac{710 \frac{16}{\text{F}^3}}{\frac{\text{F}^3}{(12 \text{ in})^3}} \cdot 581.047 \text{ in}^3 \frac{\text{F}^3}{(12 \text{ in})^3}$$

$$= 239 \frac{16}{\text{each}}$$

ANALYTICAL CALCULATIONS

PAGE A-13 OF A-33

Subject DRUM
Originator JH Date 3/14/96
Checker Charles T. Xi Date 4/3/96

CHANGE IN CONCRETE WEIGHT

$$\text{WEIGHT} = (11200 \text{ in}^3 - 581047 \text{ in}^3) \frac{144 \text{ lb}}{\text{ft}^3} \frac{\text{ft}^3}{(12 \text{ in})^3} \\ = \underline{885 \text{ lb}}$$

$$\text{TOTAL WEIGHT} = \underline{1336 \text{ lb}} \quad \text{'14 NEW LO' MODEL}$$

FINAL DESIGN WEIGHT

STEEL DRUM $\sim 49 \text{ lb}$
STEEL PIPE $(28.55 \text{ lb/ft})(27 \text{ ft})(\text{ft}/12 \text{ in}) = 64 \text{ lb}$
STEEL PLATE $490 \text{ lb/ft}^3 (12 \text{ in} \times 11 \frac{5}{8} \text{ in}^2) (\text{ft}^3/12 \text{ in})^3 = 19 \text{ lb}$
STEEL PLATE $490 \text{ lb/ft}^3 (12 \text{ in} \times 11 \frac{5}{8} \text{ in} \times 3 \frac{1}{2} \text{ in}) (\text{ft}^3/12 \text{ in})^3 = 17 \text{ lb}$
LEG PLATE $710 \text{ lb/ft}^3 (2 \text{ in} \times 11 \frac{5}{8} \text{ in}) (\text{ft}^3/12 \text{ in})^3 = 11 \text{ lb}$
LEG PLATE $710 \text{ lb/ft}^3 (2 \text{ in} \times 11 \frac{5}{8} \text{ in} \times 10 \frac{3}{8} \text{ in}) (\text{ft}^3/12 \text{ in})^3 = 97 \text{ lb}$

CONCRETE $33 \frac{1}{4} \text{ in} \times 22 \frac{1}{2} \text{ in} \text{ } \phi$

$$\text{Vol} = \pi r^2 h = \pi \left(\frac{22.5 \text{ in}}{2} \right)^2 (33 \frac{1}{4} \text{ in}) \left(\frac{\text{ft}^3}{12 \text{ in}} \right)^3 = 7.65 \text{ ft}^3$$

$$\pi r^2 h + \pm b d + \pm b d$$

$$\left[\pi \left(\frac{8 \frac{3}{8} \text{ in}}{2} \right)^2 27 \text{ in} + 2 \frac{1}{2} \text{ in} (11 \frac{5}{8} \text{ in})^2 + 2 \text{ in} (11 \frac{5}{8} \text{ in}) 10 \frac{3}{8} \text{ in} \right] \frac{\text{ft}^3}{12 \text{ in}}^3 = 1.25 \text{ ft}^3$$

$$144 \text{ lb/ft}^3 (7.65 \text{ ft}^3 - 1.25 \text{ ft}^3) = \underline{922 \text{ lb}}$$

$$\text{APPROX WEIGHT} = 49 + 64 + 19 + 17 + 11 + 97 + 922 \\ = \underline{1279 \text{ lb}} < 1450 \text{ lb}$$

ANALYTICAL CALCULATIONS

PAGE A-14 OF A-33

Subject DRUM
Originator AMR Date 3/14/96
Checker Charles T. Zi Date 4/3/96

WEIGHT OF ORIGINAL DESIGN DRUM

STEEL DRUM

46 lb

STEEL PIPE

14" SCH 80 PIPE - 106.13 16/ft

LENGTH 33 1/4"

$$\begin{aligned} \text{WEIGHT} &= 33.25 (106.13 \text{ 16/ft}) \left(\frac{\text{ft}}{12 \text{ in}} \right) \\ &= \underline{294 \text{ lb}} \end{aligned}$$

1" PLATE ENDS

20 14" SCH PIPE = 12.5 in

$$\begin{aligned} \text{VOL.} &= \pi r^2 h = 2 \left(\pi \left(\frac{12.5}{2} \right)^2 (1") \right) = 245.43 \text{ in}^3 \\ &\quad \# \nearrow \\ &\quad \text{(ONE Ea. End)} \end{aligned}$$

$$\begin{aligned} \text{WEIGHT} &= 245.43 \text{ in}^3 (490 \text{ 16/ft}^3) \frac{\text{ft}^3}{(12 \text{ in})^3} \\ &= \underline{70 \text{ lb}} \end{aligned}$$

FOAM PLUGS

~0 lb

CONCRETE

DRUM VOL = 13220 in³

$$\text{1/2" pipe Vol} = \pi r^2 h = \pi (7")^2 (33.25) = 5118 \text{ in}^3$$

$$\text{CON. Vol} = 13220 \text{ in}^3 - 5118 \text{ in}^3 = 8102 \text{ in}^3$$

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator JAL Date 3/14/96
Checker Charles T. Li Date 4/3/96

$$\begin{aligned} \text{WEIGHT} &= 8102 \text{ in}^3 \cdot 144 \text{ lb/ft}^3 \cdot \frac{\text{ft}^3}{(12 \text{ in})^3} \\ &= \underline{675 \text{ lb}} \end{aligned}$$

$$\text{TOTAL WEIGHT} = \underline{\underline{1085 \text{ lb}}}$$

LEAD BOTTOM

$$8" \text{ PIPE } I O = 7.981 \text{ in } \quad L = 2" \text{ LEAD}$$

$$\begin{aligned} \text{VOL} &= \pi r^2 L = \pi \left(\frac{7.981}{2} \right)^2 (2") \\ &= 100.05 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{WEIGHT} &= 710 \text{ lb/ft}^3 \cdot (100.05 \text{ in}^3) \cdot \frac{\text{ft}^3}{(12 \text{ in})^3} \\ &= 41 \text{ lb} \end{aligned}$$

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator LLH Date 3/14/96
Checker Charles T. Li Date 4/3/96

MODEL GEOMETRY CAL.

MODEL DIM. FOR DRUM DESIGN

INSIDE $22\frac{1}{4}"$ ϕ HEIGHT 35" OVERALL
 $33\frac{1}{4}"$ USABLE

TOP MODEL "TOP-ST"

$33\frac{1}{4}"$

$-1\frac{3}{4}"$ FOAM

$-2"$ TOP PLUG

$-7"$ BOTTOM PLUG

$-1"$ FOAM

$T_1 = 26.50$ in (67.31cm)

$T_2 = 1"$ FOAM (AIR)
(2.54cm)

$T_3 = 2"$ STEEL
(5.08cm)

$T_4 = 1\frac{3}{4}"$ FOAM (AIR)
(4.445cm)

$T_5 = 0.0495"$ STEEL
(0.126cm)

DENSITY FOAM $\sim$ AIR 0.0122

g/cc STEEL 2

CONCRETE 2.35

LEAD 11.3

$X = T_1 + T_5 = 31\frac{1}{4}"$ 79.506 cm

8" SCH 40 $LO = 7.981$ in

$R = [7.981 \text{ in} / 2] 2.54 \text{ cm} = 10.136 \text{ cm}$

MODEL "TOP-LO" SAME DIM BUT LEAD
IN PLACE OF STEEL PLUG.

ANALYTICAL CALCULATIONS

PAGE A-17 OF A-33

Subject DRUM
 Originator Jpe Date 3/14/96
 Checker Charles T. Li Date 4/3/96

MODEL 'DRUM OLD' DRUM 22 1/2" ID

14" Ø PIPE SCH 80

$$OD = 14"$$

$$ID = 12.5"$$

$$t = 0.75"$$

$$8" \text{ Ø PIPE SCH 40 } \xrightarrow{ID} T_1 = [7.981 \text{ in}] \frac{1}{2} 2.54 \frac{\text{cm}}{\text{in}} = 10.136 \text{ cm (AIR)}$$

$$T_2 = 12.5" - 7.981" \frac{1}{2} (2.54 \frac{\text{cm}}{\text{in}}) = 5.739 \text{ cm AIR}$$

$$T_3 = 0.75" \text{ STEEL (1.905 cm)}$$

$$T_4 = [22 \frac{1}{2}" - 14"] \frac{1}{2} (2.54) = 10.795 \text{ cm CONCRETE}$$

$$T_5 = 0.126 \text{ cm}$$

$$L \quad X = 28.70 \text{ km}$$

$$L = 67.31 \text{ cm} \quad Y = \frac{1}{2} L = 33.655 \text{ cm}$$

MODEL 'DRUM NEW'

8" Ø PIPE SCH 40

$$OD = 8.625 \text{ in}$$

$$ID = 7.981 \text{ in}$$

$$t = 0.322 \text{ in}$$

$$T_1 = [7.981 \text{ in} / 2] 2.54 = 10.136 \text{ cm AIR}$$

$$T_2 = 0.322 \text{ in} (2.54 \frac{\text{cm}}{\text{in}}) = 0.818 \text{ cm STEEL}$$

$$T_3 = [22 \frac{1}{2}" - 8.625"] \frac{1}{2} (2.54 \frac{\text{cm}}{\text{in}}) = 17.621 \text{ cm CONCRETE}$$

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator HAL Date 3/14/96
Checker Charles T. Li Date 4/3/96

(18 gage) $T_4 = 0.0495 \text{ in } (0.126 \text{ cm})$ STEEL

$X = 28.701 \text{ cm}$

$L = 67.31 \text{ cm} \quad Y = 33.655 \text{ cm}$

MODEL 'NEW 1/4' X_4 LEAD AROUND PIPE

$T_1 = 10.136 \text{ cm (AIR)}$

$T_2 = 0.818 \text{ cm (STEEL)}$

$T_3 = X_4 \cdot 2.54 = 0.635 \text{ cm (LEAD)}$

$T_4 = 17.621 \text{ cm} - 0.635 \text{ cm}$

$= 16.986 \text{ cm (CONCRETE)}$

$T_5 = 0.126 \text{ cm}$

$X, L \neq Y$ SAME

MODEL '1/4 NEW 20'

$T_4 = 16.986 \text{ cm}$

$T_3 = 0.635 \text{ cm}$

MODEL 'OLD DRUM'

MODIFIED GEO. USING EFFECTIVE THICKNESS
AND REDUCED DIA., THE AIR GAP BETWEEN
PAINT LANS & PIPE IS NOT USED

$L = 67.310 \text{ cm} \quad T_1 = T_1 = 10.136 \text{ cm air}$
 $Y = 33.655 \text{ cm} \quad T_2 = T_3 = 1.905 \text{ cm STEEL}$
 $T_3 = T_4 = 10.785 \text{ cm concrete}$
 $T_4 = T_5 = 0.126 \text{ cm ST.}$

} $= X = 22.962 \text{ cm}$

ANALYTICAL CALCULATIONS

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Subject DRUM
Originator ZAL Date 3/14/96
Checker Charles T. Li Date 4/3/96

MODEL 'BOT-ST'

$$T_1 = 26.50 \text{ in } (67.31 \text{ cm})$$

$$T_2 = 2 \text{ " STEEL } (5.08 \text{ cm})$$

$$T_3 = 0.0495 \text{ " STEEL } (0.126 \text{ cm})$$

$$\Sigma X = 72.516 \text{ cm}$$

MODEL 'BOT-LD-ST'

$$T_1 = 26.50 \text{ in } (67.31 \text{ cm})$$

$$T_2 = 1 \text{ " LEAD } (2.54 \text{ cm})$$

$$T_3 = 1 \text{ " STEEL } (2.54 \text{ cm})$$

$$T_4 = 0.126 \text{ cm (STEEL)}$$

$$\Sigma X = 72.516 \text{ cm}$$

MODEL 'BOT-LD-ST'

$$T_1 = 67.31 \text{ cm}$$

$$T_2 = 2 \text{ " LEAD } (5.08 \text{ cm})$$

$$T_3 = 0.126 \text{ cm}$$

$$\Sigma X = 72.516$$

MODEL 'BOT-LD-ST'

ADD $\frac{1}{2}$ " STEEL PLATE TO 2" LEAD

$$R = 10.136$$

$$T_2 = \frac{1}{2} \text{ " } (1.27 \text{ cm}) = 1.270 \text{ cm STEEL}$$

$$T_1 = 67.31 - 1.77 \text{ cm} = 66.40 \text{ cm AIR}$$

$$T_3 = 5.08 \text{ cm LD}$$

$$X = 72.516$$

MicroShield 4.10 - Serial #4.10-00508
Kaiser Engineers/Hanford

WHC-SD-WM-TI-752
REV. 0

Page : 1
DOS File: OLDDRUM.MS4
Run Date: May 13, 1996
Run Time: 2:42 p.m. Monday
Duration: 0:00:09

File Ref: _____
Date: _____
By: _____
Checked: _____

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Case Title: Case: rrumold with modified configuration

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	inches
Dose point coordinate X:	22.962	0.0	9.0
Dose point coordinate Y:	33.655	1.0	1.3
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	67.31	2.0	2.5
Cylinder radius:	10.136	0.0	4.0
Shield 2:	1.905	0.0	.8
Shield 3:	10.795	0.0	4.2
Shield 4:	0.126	0.0	.0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Cylinder	Shield 3 Cylinder	Shield 4 Cylinder	Transition Shield
Air	0.00122				0.00122
Concrete			2.35		
Iron		7.86		7.86	

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	8
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	$\mu\text{Ci/cm}^3$	Nuclide	curies	$\mu\text{Ci/cm}^3$
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	4.739e+006	3.720e+007	9.249e+003	7.260e+004
1.0	7.326e+009	2.998e+004	1.454e+005	5.527e+001	2.680e+002
1.5	7.326e+009	7.955e+004	2.759e+005	1.338e+002	4.642e+002
TOTAL:	4.409e+012	4.848e+006	3.762e+007	9.438e+003	7.334e+004

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

File Ref:

DOS File: R2DRUMOL.MS4

Date:

Run Date: May 13, 1996

By:

Run Time: 2:43 p.m. Monday

Checked:

Duration: 0:00:12

Case Title: Case: Zdrumold

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	28.701	0.0	11.3
Dose point coordinate Y:	33.655	1.0	1.3
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	67.31	2.0	2.5
Cylinder radius:	15.875	0.0	6.3
Shield 2:	1.905	0.0	.8
Shield 3:	10.795	0.0	4.2
Shield 4:	0.126	0.0	.0

Source Volume: 53291.4 cm³ 1.88197 cu ft. 3252.04 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Cylinder	Shield 3 Cylinder	Shield 4 Cylinder	Transition Shield
Air	0.00122				0.00122
Concrete			2.35		
Iron		7.86		7.86	

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	2.4769e+003	Co-60	1.9800e-001	3.7154e+000
Cs-137	1.4000e+002	2.6271e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	3.572e+006	2.797e+007	6.971e+003	5.459e+004
1.0	7.326e+009	2.256e+004	1.091e+005	4.158e+001	2.011e+002
1.5	7.326e+009	5.975e+004	2.066e+005	1.005e+002	3.476e+002
TOTAL:	4.409e+012	3.654e+006	2.828e+007	7.113e+003	5.514e+004

ANALYTICAL CALCULATIONS

WHC-SD-WM-TI-752

REV. 0

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Subject _____

Originator A. HedgesDate 2/14/96Checker Charles T. E.Date 4/3/96

'DRUMNEW' MODEL

MicroShield 4.10 - Serial #4.10-00508
Kaiser Engineers/Hanford

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Page : 1
DOS File: RDRUMMEW.MS4
Run Date: May 13, 1996
Run Time: 2:45 p.m. Monday
Duration: 0:00:12

File Ref: _____
Date:
By:
Checked:

Case Title: drumnew

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and inches
Dose point coordinate X:	28.701	0.0 11.3
Dose point coordinate Y:	33.655	1.0 1.3
Dose point coordinate Z:	0.0	0.0 .0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	0.818	0.0 .3
Shield 3:	17.621	0.0 6.9
Shield 4:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

Material	Source Shield	MATERIAL DENSITIES (g/cm ³)			Transition Shield
		Shield 2 Cylinder	Shield 3 Cylinder	Shield 4 Cylinder	
Air	0.0012		2.35		0.00122
Concrete		7.86		7.86	
Iron					

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

Nuclide	SOURCE		NUCLIDES	
	curies	μCi/cm ³	Nuclide	curies μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001 9.1139e+000
Cs-137	1.4000e+002	6.4441e+003		

RESULTS					
Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	1.884e+006	1.793e+007	3.677e+003	3.499e+004
1.0	7.326e+009	1.350e+004	7.635e+004	2.489e+001	1.407e+002
1.5	7.326e+009	3.922e+004	1.538e+005	6.598e+001	2.587e+002
TOTAL:	4.409e+012	1.936e+006	1.816e+007	3.767e+003	3.539e+004

BD-6400-060.1 (07/93)

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1
DOS File: RNEW14LD.MS4
Run Date: May 13, 1996
Run Time: 2:47 p.m. Monday
Duration: 0:00:12

File Ref: _____
Date: 1/1
By: AT
Checked: CTL

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Case Title: new/4ld

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and inches
Dose point coordinate X:	28.701	0.0 11.3
Dose point coordinate Y:	33.655	1.0 1.3
Dose point coordinate Z:	0.0	0.0 .0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	0.818	0.0 .3
Shield 3:	0.635	0.0 .3
Shield 4:	16.986	0.0 6.7
Shield 5:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Cylinder	Shield 3 Cylinder	Shield 4 Cylinder	Shield 5 Cylinder
Air	0.00122				
Concrete				2.35	
Iron		7.86			7.86
Lead			11.3		

Material Transition Shield
Air 0.00122

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 4

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	7.972e+005	9.471e+006	1.556e+003	1.849e+004
1.0	7.326e+009	8.353e+003	5.376e+004	1.540e+001	9.910e+001
1.5	7.326e+009	2.747e+004	1.188e+005	4.622e+001	1.998e+002
TOTAL:	4.409e+012	8.331e+005	9.643e+006	1.618e+003	1.878e+004

'14 NEW 10' MODEL

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

DOS File: R14NEWLD.MS4

Run Date: May 13, 1996

Run Time: 2:56 p.m. Monday

Duration: 0:00:12

File Ref: _____

Date: 1/11/97

By: AK

Checked: CTL

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Case Title: <None> *% new wild*

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet and inches
Dose point coordinate X:	28.701	0.0 11.3
Dose point coordinate Y:	33.655	1.0 1.3
Dose point coordinate Z:	0.0	0.0 .0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	0.818	0.0 .3
Shield 3:	16.986	0.0 6.7
Shield 4:	0.635	0.0 .3
Shield 5:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Cylinder	Shield 3 Cylinder	Shield 4 Cylinder	Shield 5 Cylinder
Air	0.00122				
Concrete		7.86	2.35		7.86
Iron				11.3	
Lead					

Material	Transition Shield
Air	0.00122

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)	Exposure Rate In Air (mR/hr)
		No Buildup	With Buildup
0.6	4.395e+012	8.523e+005	1.003e+007
1.0	7.326e+009	8.708e+003	5.564e+004
1.5	7.326e+009	2.840e+004	1.220e+005
TOTAL:	4.409e+012	8.894e+005	1.021e+007

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

File Ref:

DOS File: RBOT-ST.MS4

Date:

Run Date: May 13, 1996

By:

Run Time: 2:49 p.m. Monday

Checked:

Duration: 0:00:02

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Case Title: Case:bot-st

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet	and inches
Dose point coordinate X:	0.0	0.0	.0
Dose point coordinate Y:	72.516	2.0	4.5
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	67.31	2.0	2.5
Cylinder radius:	10.136	0.0	4.0
Shield 2:	5.08	0.0	2.0
Shield 3:	0.126	0.0	.0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Slab	Shield 3 Slab
Air	0.00122		
Iron		7.86	7.86

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 2

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	8
Y Direction (axial)	8

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	1.118e+007	5.616e+007	2.182e+004	1.096e+005
1.0	7.326e+009	6.562e+004	2.400e+005	1.210e+002	4.424e+002
1.5	7.326e+009	1.623e+005	4.605e+005	2.731e+002	7.748e+002
TOTAL:	4.409e+012	1.141e+007	5.686e+007	2.221e+004	1.108e+005

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

DOS File: RBOTLE-S.MS4

Run Date: May 13, 1996

Run Time: 2:59 p.m. Monday

Duration: 0:00:03

File Ref:

Date:

By:

Checked:

Case Title: Case: botld-st

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet and inches
Dose point coordinate X:	0.0	0.0 .0
Dose point coordinate Y:	72.516	2.0 4.5
Dose point coordinate Z:	0.0	0.0 .0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	2.54	0.0 1.0
Shield 3:	2.54	0.0 1.0
Shield 4:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab
Air	0.00122			
Iron			7.86	7.86
Lead		11.3		

BUILDUP

Method: Buildup Factor Tables

The material reference is Shield 2

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	8

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6	4.395e+012	1.497e+006	2.871e+006	2.922e+003	5.603e+003
1.0	7.326e+009	2.821e+004	5.870e+004	5.199e+001	1.082e+002
1.5	7.326e+009	9.459e+004	1.879e+005	1.591e+002	3.161e+002
TOTAL:	4.409e+012	1.620e+006	3.117e+006	3.133e+003	6.028e+003

MicroShield 4.10 - Serial #4.10-00508

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PAGE A-30 OF A-33

Page : 1

DOS File: R2BTLd-S.MS4

Run Date: May 13, 1996

Run Time: 2:52 p.m. Monday

Duration: 0:00:03

File Ref: _____

Date: _____

By: _____

Checked: CTC

Case Title: 2btld-st

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet and inches
Dose point coordinate X:	0.0	0.0
Dose point coordinate Y:	72.516	2.0 4.5
Dose point coordinate Z:	0.0	0.0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	5.08	0.0 2.0
Shield 3:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Slab	Shield 3 Slab
Air	0.00122		
Iron		7.86	
Lead		11.3	

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 2

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	μCi/cm ³	Nuclide	curies	μCi/cm ³
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)	Exposure Rate In Air (mR/hr)
0.6	4.395e+012	2.048e+005	3.998e+002
1.0	7.326e+009	1.211e+004	2.231e+001
1.5	7.326e+009	5.483e+004	9.225e+001
TOTAL:	4.409e+012	2.718e+005	5.144e+002

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

DOS File: R38TLD-S.MS4

Run Date: May 13, 1996

Run Time: 2:53 p.m. Monday

Duration: 0:00:03

File Ref:

Date:

By:

Checked:

Case Title: 3btld-st

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet and inches
Dose point coordinate X:	0.0	0.0
Dose point coordinate Y:	72.516	2.0 4.5
Dose point coordinate Z:	0.0	0.0 0.0
Cylinder height:	66.04	2.0 2.0
Cylinder radius:	10.136	0.0 4.0
Shield 2:	1.27	0.0 .5
Shield 3:	5.08	0.0 2.0
Shield 4:	0.126	0.0 .0

Source Volume: 21315.2 cm³ .75274 cu ft. 1300.74 cu in.

Material	Source Shield	MATERIAL DENSITIES (g/cm ³)		
		Shield 2 Slab	Shield 3 Slab	Shield 4 Slab
Air	0.00122			
Iron		7.86		7.86
Lead			11.3	

BUILDUP

Method: Buildup Factor Tables

The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

Nuclide	curies	SOURCE NUCLIDES		Nuclide	curies	μCi/cm ³
		μCi/cm ³				
Ba-137m	1.3200e+002	6.1928e+003		Co-60	1.9800e-001	9.2891e+000
Cs-137	1.4000e+002	6.5681e+003				

===== RESULTS =====						
Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)		
		No Buildup	With Buildup	No Buildup	With Buildup	
0.6	4.395e+012	8.892e+004	1.959e+005	1.736e+002	3.823e+002	
1.0	7.326e+009	6.084e+003	1.466e+004	1.122e+001	2.701e+001	
1.5	7.326e+009	3.052e+004	7.077e+004	5.135e+001	1.191e+002	
TOTAL:	4.409e+012	1.255e+005	2.813e+005	2.361e+002	5.284e+002	

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

File Ref:

DOS File: RTOP-ST.MS4

Date:

Run Date: May 16, 1996

By:

Run Time: 8:20 a.m. Thursday

Checked:

Duration: 0:00:03

Case Title: Case: top-st

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet and inches
Dose point coordinate X:	0.0	0.0 .0
Dose point coordinate Y:	79.501	2.0 7.3
Dose point coordinate Z:	0.0	0.0 .0
Cylinder height:	67.31	2.0 2.5
Cylinder radius:	10.136	0.0 4.0
Shield 2:	2.54	0.0 1.0
Shield 3:	5.08	0.0 2.0
Shield 4:	4.445	0.0 1.7
Shield 5:	0.126	0.0 .0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122	0.00122		0.00122	
Iron			7.86		7.86

BUILDUP

Method: Buildup Factor Tables
The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	$\mu\text{Ci/cm}^3$	Nuclide	curies	$\mu\text{Ci/cm}^3$
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)	Exposure Rate In Air (mR/hr)
		No Buildup	With Buildup
0.6	4.395e+012	7.226e+006	3.452e+007
1.0	7.326e+009	4.085e+004	1.410e+004
1.5	7.326e+009	9.814e+004	7.530e+001
		2.655e+005	1.651e+002
TOTAL:	4.409e+012	7.365e+006	3.493e+007
			1.434e+004
			6.809e+004

MicroShield 4.10 - Serial #4.10-00508

Kaiser Engineers/Hanford

Page : 1

DOS File: RTOP-LD.MS4

Run Date: May 13, 1996

Run Time: 3:39 p.m. Monday

Duration: 0:00:03

File Ref:

Date:

By:

Checked:

Case Title: Case:top-ld

GEOMETRY 8 - Cylinder Volume - End Shields

	centimeters	feet	and inches
Dose point coordinate X:	0.0	0.0	.0
Dose point coordinate Y:	79.506	2.0	7.3
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	67.31	2.0	2.5
Cylinder radius:	10.136	0.0	4.0
Shield 2:	2.54	0.0	1.0
Shield 3:	5.08	0.0	2.0
Shield 4:	4.445	0.0	1.7
Shield 5:	0.126	0.0	.0
Air Gap:	5.0e-003	0.0	.0

Source Volume: 21725.1 cm³ .767216 cu ft. 1325.75 cu in.

MATERIAL DENSITIES (g/cm³)

Material	Source Shield	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122	0.00122		0.00122	
Iron					7.86
Lead			11.3		

Material Air Gap

Air 0.00122

BUILDUP

Method: Buildup Factor Tables

The material reference is Shield 3

INTEGRATION PARAMETERS

	Quadrature Order
Radial	11
Circumferential	11
Y Direction (axial)	11

SOURCE NUCLIDES

Nuclide	curies	$\mu\text{Ci/cm}^3$	Nuclide	curies	$\mu\text{Ci/cm}^3$
Ba-137m	1.3200e+002	6.0759e+003	Co-60	1.9800e-001	9.1139e+000
Cs-137	1.4000e+002	6.4441e+003			

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)	Exposure Rate In Air (mR/hr)
		No Buildup	With Buildup
0.6	4.395e+012	1.484e+005	3.138e+005
1.0	7.326e+009	8.048e+003	1.799e+004
1.5	7.326e+009	3.480e+004	7.345e+004
TOTAL:	4.409e+012	1.912e+005	4.053e+005

Appendix B

PNNL Hand Calculations for Equivalent Drum Shielding

Prepared By: ANDREW P. MILLER Date: 06-05-96 Project: WASTE DRUM SHIELDING CALCULATION
Title/Subject:

INFORMATION GIVEN: ON STEEL WASTE DRUM
WITH CONCRETE SHIELDING
EXPOSURE RATE AT 5102 = 35.4 R/HR

ON STEEL WASTE DRUM
BOTTOM WITH 1" STEEL
AND 1" LEAD SHIELDING
EXPOSURE RATE AT CENTER = 6.0 R/HR

RADIOACTIVE CONTENT OF
OF CONTAINERS 140 Ci: ^{137}Cs
AND 0.198 Ci: ^{60}Co

INFORMATION FROM RHM (RADIOLOGICAL HAZARD HANDBOOK):

DENSITY OF STEEL (Iron) = 7.86 g/cm^3

DENSITY OF LEAD = 11.35 g/cm^3

DENSITY OF CONCRETE = 2.25 g/cm^3

μ_{Fe} FOR IRON AT 0.662 MeV = $0.076 \text{ cm}^2/\text{g}$

μ_{Fe} FOR ^{LEAD} AT 0.662 MeV = $0.125 \text{ cm}^2/\text{g}$

μ_{Fe} FOR CONCRETE AT 0.662 MeV = $0.081 \text{ cm}^2/\text{g}$

ASSUMPTIONS MADE: A. PRIMARY ENERGY OF ^{137}Cs IS
0.662 MeV

B. CONTRIBUTION OF EXPOSURE RATE
FROM 0.198 Ci ^{60}Co IN THE
PRESENCE OF 140 Ci OF ^{137}Cs
IS INSIGNIFICANT.

C. SHIELDING CALCULATIONS USING
IRON AND STEEL ARE
ESSENTIALLY THE SAME.

Prepared By:

Date:

Project:

Title/Subject:

QUESTION #1 HOW MUCH STEEL PROVIDES AS MUCH STIFFNESS AS 1" L2AD?
A) 1" STEEL AND 1" L2AD?

1" STEEL $I = I_0 e^{-u_{eff} P x}$ (ASSUME I_0 IS UNITY)

$$\frac{I}{I_0} = e^{-(0.0769 \text{ cm}^2/\text{gm} \times 7.86 \text{ g/cm}^3 \times 2.54 \text{ cm})}$$

$$\frac{I}{I_0} = \underline{0.2153 \text{ STEEL}}$$

1" L2AD $I = I_0 e^{-u_{eff} P x}$ (ASSUME I_0 IS UNITY)

$$\frac{I}{I_0} = e^{-(0.125 \text{ cm}^2/\text{gm} \times 11.35 \text{ g/cm}^3 \times 2.54 \text{ cm})}$$

$$\frac{I}{I_0} = \underline{0.02722 \text{ L2AD}}$$

1" STEEL $\neq$ 1" L2AD = $0.2153 \times 0.02722 = 0.005864$

$$\frac{I}{I_0} = 5.864 \times 10^{-3}$$

$$\frac{I}{I_0} = e^{-u_{eff} P x}$$

$$\ln \frac{I}{I_0} = -u_{eff} P x$$

$$x = \frac{\ln \frac{I}{I_0}}{u_{eff} P} = \frac{\ln 5.864 \times 10^{-3}}{(-0.0769 \text{ cm}^2/\text{g} \times 7.86 \text{ g/cm}^3)}$$

$$x = 8.502 \text{ cm}$$

$$x = 3.347 \text{ INCHES}$$

ROUND UP TO 3.5 INCHES

Prepared By:

Date:

Project:

Title/Subject:

QUESTION #3.

 IF CONCRETE ON SIDE OF WASTE DRUM
RESULTS IN 35.4 R/HR EXPOSURE RATE

 AND IF 1" LAG & 1" IRON ON BOTTOM OF
WASTE DRUM RESULTS IN 6.0 R/HR EXPOSURE RATE

 GIVING 3.5" IRON (STEEL) RESULTS IN
6.0 R/HR EXPOSURE RATE

 THEN HOW MUCH IRON (STEEL) IS NEEDED TO
HAVE 35.4 R/HR AT SIDE OF WASTE DRUM?

$$\frac{I}{I_0} = .005864 \quad \text{FOR 3.5" STEEL} \quad I = 6 \text{ R/HR}$$

$$\left(\frac{I}{I_0}\right) = \frac{6 \text{ R/HR}}{.005864} = I_0 = 1023.2 \text{ R/HR}$$

$$\begin{aligned} I_{\text{DESIRABLE}} &= 35.4 \text{ R/HR} \\ \frac{35.4 \text{ R/HR}}{1023.2 \text{ R/HR}} &= \frac{I}{I_0} = 3.4597 \times 10^{-2} \end{aligned}$$

$$\text{LN} \frac{I}{I_0} = \text{CONST} \times$$

$$X = \frac{\text{LN} \frac{I}{I_0}}{-\text{CONST}}$$

$$X = \frac{\text{LN}(3.4597 \times 10^{-2})}{(-.0769 \text{ cm}^{-1}) \times 7.86 \text{ g/cm}^2}$$

$$X = 5.565 \text{ cm}$$

$$X = 2.19 \text{ INCHES}$$

ROUND UP TO 2 1/4 INCHES

 ANDER DZ MILLER ^{CHP} 06-06-96

 DPA ^{CHP} 6/6/96

DISTRIBUTION SHEET

To	From	Page 1 of 1
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327 Legacy Waste Removal/ BE1267		ECN No.

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