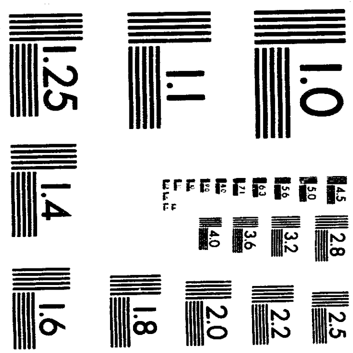
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

2

SRT-CMA-930068

SRTC CRITICALITY TECHNICAL REVIEW OF NCSE 93-04

by
Roy Rathbun

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

DOE Contract No. **DE-AC09-89SR18035**

DISCLAIMER

NRTSC
Technology
On Time
On Target

SAVANNAH RIVER TECHNOLOGY CENTER
Applied Technology Section
Applied Physics Group

SRT-CMA-930068

SRTC CRITICALITY SAFETY TECHNICAL REVIEW:

NUCLEAR CRITICALITY SAFETY EVALUATION 93-04
ENRICHED URANIUM RECEIPT (U)

October 13, 1993

Reviewer: Roy Rathbun
Roy Rathbun, ext. 58232
Applied Physics Group/Criticality Analysis

Approvals:

Task Leader, APG
Criticality Analysis and Training — J. F. Mincey 10/13/93
J. F. Mincey

Manager, Applied Physics Group (APG) — C. E. Apperson/M. R. Buckner
C. E. Apperson

UNCLASSIFIED

DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION

Reviewing Official: C. E. Apperson/M. R. Buckner
C. E. Apperson, Manager APG

Date: 10/14/93

Distribution:

M. J. Crouse	707-F	P. J. Vescovi	773-22A
R. L. Reed	773-42A	J. F. Zino	773-22A
M. R. Buckner,	773-42A	C. E. Apperson	773-42A
J. F. Mincey	773-22A	T. G. Williamson	773-42A
T. A. Reilly	707-F	E. F. Trumble	786-1A
APG Files/Kaye Summers	773-42A	Technical Information Mgmt	703-43A

SUMMARY

Review of NMP-NCS-930087, "Nuclear Criticality Safety Evaluation 93-04 Enriched Uranium Receipt (U), July 30, 1993," was requested of SRTC Applied Physics Group. The NCSE is a criticality assessment to determine the mass limit for Engineered Low Level Trench (ELLT) waste uranium burial. The intent is to bury uranium in pits that would be separated by a specified amount of undisturbed soil.

The NCSE under review concludes that a 500 gram limit per burial position is acceptable to ensure the burial site remains in a critically safe configuration for all normal and single credible abnormal conditions. The ability to make this conclusion is highly dependent on a double verification of mass content per package as well as a double verification that the intended burial position has not been previously filled. Furthermore, the evaluation shows that the specified 3 feet of soil separating the surface of each buried package could suffer about a 2 foot reduction in spacing (leaving about 1 foot to 13" of separation) and remain in a critically safe configuration. Also addressed was the inclusion of small relative fractions of Pu-239, Pu-241 and Am-242m with the uranium mass. The rules of fractions from ANSI/ANS 8.15 were conservatively applied to account for these actinides. ***It should be emphasized that these results rely heavily on administrative controls and on burial of uranium with small fractions of Pu-239, Pu-241 and Am-242m isotopes only.*** After a thorough review of the NCSE and independent calculations, this reviewer agrees with that conclusion.

SCOPE OF TECHNICAL REVIEW

This technical review consisted of:
- ☒ an independent check of the methods and models employed,
- ☒ independent HRXN/KENO-V.a calculations of alternate configurations,
- ☒ application of ANSI/ANS 8.1,
- ☒ verification of WSRC Nuclear Criticality Safety Manual(1) procedures.

DOCUMENTATION

Issuance of this memorandum transmits this technical review as critical data.

METHOD AND MODEL REVIEW

Method:

Cross-Sections

The 16-Group Hansen-Roach cross-section data libraries were employed. The Hansen-Roach Library is an extensively employed database for criticality safety analysis.

Computer Codes

Cross-section preparation and processing was performed with the Joshua 70 version of HRXN[2]. This is a validated code developed at SRS.

The system keff is predicted with KENO-IV, an SRS validated criticality calculational code developed at Oak Ridge National Laboratory as part of the SCALE[3] package and included in the Joshua 70 system at SRS. This code is widely used throughout the industry.

Model:

The materials used in the HRXN calculations are given in Attachment 1. The KENO-IV model is given in the NCSE, attached.

Status: model was checked and verified

EVALUATION

Data to perform this evaluation were derived from the NCSE under review, from a previous technical review by this reviewer[4], and from private communications with the author. One important compromise resulting from these conversations was the agreement to apply a mass penalty on the calculated result from the basic uniform uranium KENO model. Because a mass limit is being set for uncontrolled moderation and reflection configurations, special care must be taken in setting this limit. Based on reference 5 (Clark), the direct result from uniform fissile mass unit modeling will over-estimate the mass limit, i. e., the minimum mass will result from non-uniform fissile distribution. According to that study, the result predicted by a uniform uranium model needs to be reduced by about 6% to yield a more accurate minimum mass (for Pu-239 and U-233 these reductions would be 4% and 5%, respectively). The 6% penalty was applied in this evaluation.

NCSE CONTENT EVALUATION

Bias Applied, Subcritical Margin and K-Safe:

Bias: The bias applied is 0.011 and reflects the bias for an H/U ratio of 500. This ratio is in the range of optimum moderation and is applicable for U235-water mixture systems predicted with the HRXN/KENO criticality method[6].

Subcritical Margin: The subcritical margin applied for both normal and accident conditions is 0.05 Δk, which is the commonly used value for criticality evaluations. However, since this is a minimum mass determination and deals with optimally moderated fissile units, an additional margin needs to be imposed to address fissile content non-uniformity concerns[5]. If the non-uniformity were modeled then the 0.05 Δk margin is appropriate. However, this is a much more rigorous modeling evaluation requiring considerable time and effort. In lieu of adding additional margin or attempting the explicit modeling, a 6% mass penalty was applied, as explained previously.

K-safe: The K-safe used for the NCSE is 1.000-0.011(bias)-0.050(margin) = 0.939. Additional margin is built-in with the 6% mass penalty discussed.

Review of NCSE Conclusions:

The NCSE recommends a limit of 500 grams of U-235 per burial position in a single planar array, to ensure the burial site remains in a critically safe configuration for all normal and single credible abnormal conditions. The ability to make this conclusion is highly dependent on a double verification of mass content per package as well as a double verification that the intended burial position has not been previously filled. The evaluation also concluded that a significant redistribution of the buried packages could occur (3 feet separation reduced to about 1 foot separation) before k-safe is breached. *It should be emphasized that these results rely heavily on administrative controls.*

The rules of fractions from ANSI/ANS 8.15 were invoked to address the issue of small amounts of Pu-239, Pu-241 and Am-242m mixed with the uranium shipment. Conservative factors were applied to arrive at uranium gram equivalents, with the sum of all constituents being less than 500 grams, given consideration for the mass conversion factors. After a thorough review of the NCSE and independent calculations *with uranium only,* this reviewer agrees with that conclusion. Details of this conclusion are given below.

Normal conditions:

Under normal conditions, 500 grams of U-235 will be buried per position. Separation of buried packages is specified as 3 feet of soil between package surfaces, which qualified the units as being isolated. The fissile unit is modeled as a 535 gm (recall that a 6% penalty is applied for a net 500 gm limit) U-235 sphere @ 52 g/l, with a H/U ratio of 500. This set of values yields the most reactive configuration. Application of ANSI/ANS 8.1 endorses this conclusion, stating that the limit for isolated units is 700 grams (the greater mass limit is attributable to less subcritical margin). The NCSE quotes the maximum k-eff for this configuration, with consideration for optimum moderation and a wide variety of possible water/soil combinations as reflectors, is 0.930, which is below k-safe.

In-transit units are included in the evaluation by basis that the model employed is reflected on all 6 faces. Many in-transit units could be within 13" of the buried units and each other without exceeding k-safe.

Accident conditions:

Double batching was not evaluated. The NCSE quotes that two, independent mass checks will be instituted to preclude a double batching accident due to a single control failure.

Burial of two packages in the same position was also not evaluated. The NCSE quotes that the double contingency principle will be instituted to preclude an accident due to a single control failure.

Mass redistribution was addressed. The NCSE used the most optimum moderating water/soil mixture to evaluate the proximity limitation for the buried packages. The conclusion reached was that a 13 inch separation was sufficient for the configuration to remain below k-safe. It would require a serious flooding or explosion accident to cause that sort of uncontrolled package redistribution. Presumably, these situations are precluded in the ELLT.

꧁꧁꧁ INDEPENDENT KENO-V.a CALCULATIONS ꧂꧂꧂

Modeling and Spacing Sensitivity:

The normal configuration was modeled as a U-235 sphere @55g/l and a 485 H/U ratio, placing it in the range of the most reactive configuration. This was slightly different from that used in the NCSE because it is based on a previous technical review[4] by this reviewer and also provides a sensitivity check on the parameters. Both wide and narrow separation was calculated. The first set of calculations are based on 500 grams of U-235 and is intended mainly to evaluate the effect of separation distance. Additionally, the NCSE uses a 0.866 factor to convert from hex to square modeling, claiming an equivalency. This was also checked (It should be noted that the factor is applied to the sum of the separation distance and the sphere diameter).

TABLE 1
Separation Sensitivity

KENO-V.a Predictions (500 gm @ 55 gm/l)		
Condition:	**keff±1σ**	**keff+3σ**
Square Model 81.18 cm Separation	0.9011±0.0060	0.9191
Square Model 25 cm Separation	0.9058±0.0047	0.9199
Hex Model 32.817 cm Separation	0.9089±0.0050	0.9238

Limiting Case:

An additional case was calculated in the attempt to reproduce the conclusion reached in the NCSE. The modeled used only a 33 cm (13 inch) separation in hex geometry, and loaded 535 grams of U-235 per unit @ 55g/l. This result is given in Table 2.

TABLE 2
Close Proximity, 535 Gram U-235 Case

KENO-V.a Prediction (535 gm @ 55 gm/l)		
Condition:	**keff±1σ**	**keff+3σ**
Hex Model 33 cm Separation	0.92036±0.00526	0.9361

Double Batching Evaluation:

A series of hex model calculations were performed to predict the effects of several double batching levels. Spacing employed is the ELLT 3 feet specification. Normal batches contain 535 grams, while the double batch contains 1070 gms of U-235. Results are given in Table 3.

TABLE 3
Double Batching Evaluation

KENO-V.a Prediction (55 gm/l)			
Condition	**Control Failure Rate**	**keff±1σ**	**keff+3σ**
No double Batching	0%	0.9129±0.0052	0.9285
1 in 100	1%	0.9129±0.0052	0.9285
1 in 36	2.8%	0.9195±0.0058	0.9369
1 in 12	8.3%	1.0604±0.0053	1.0763
1 in 2	50%	1.0685±0.006	1.0865

Conclusions from independent calculations:

1. The conversion factor for hex to square modeling is valid.
2. Buried packages can be displaced to the extent that only 13 inches of separation exist.
3. Criticality for a 3% or greater double batching control failure rate exceeds k-safe.
4. A 500 gram limit is permissible based on the uniform distribution KENO model with 535 grams of U-235 at optimum moderation and reflection. This implies a 6% penalty is imposed on the uniform model prediction. This conclusion is based on ***uranium only*** calculations. Applying the mass conversion factors described previously, to the Pu-239, Pu-241 and Am-242m actinides, conservatively envelopes the effect of these separate isotopes on the system criticality.

SAFETY MANUAL FORMAT AND PROCEDURES

The WSRC Nuclear Criticality Safety Manual spells out certain requirements that are to be included in a specifically formatted NCSE. This section reviews the compliance with that document.

SECTION	REMARKS
1.0 Introduction:	Included with appropriate contents
2.0 Description:	Included with appropriate contents
3.0 Requirements Documentation	Included with appropriate contents
4.0 Methodology	Included with appropriate contents
5.0 Discussion of Contingencies	Included with appropriate contents
6.0 Evaluation of Results	Included with appropriate contents
7.0 Design Features (entered as Administratively Controlled Limits and Requirements)	Included with appropriate contents
8.0 Summary and Conclusions	Included with appropriate contents
9.0 References	Included with appropriate contents

REFERENCES

1. WSRC Nuclear Criticality Safety Manual (U), WSRC-IM-93-13, Rev.1, 7/1/93.

2. DPSTM-86-700-3; H. K. Clark, "JOSHUA Nuclear Criticality Safety Modules," March 1987.

3. NUREG/CR-0200;ORNL/NUREG/CSD-2/R1; "SCALE, A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," Oct., 1981.

4. SRT-CMA-930063, R. W. Rathbun, SRTC Criticality Safety Technical Review: Nuclear Criticality Safety Evaluation 93-18, Uranium Solidification Facility's Waste Handling Facility (U)," October 1, 1993.

5. H. K. Clark, "Effect of Distribution of Fissile Mass on Critical Mass," Nuclear Science and Engineering, Vol. 24, 1966.

6. H. K. Clark, "Subcritical Limits for U-235 Systems," Nuclear Science and Engineering, Vol. 81, 1982.

Attachment 1:NMP-NCS-930087

NMP-NCS-93-0087
10/12/93

INTRODUCTION

This analysis is the result of a request by the Solid Waste and Environmental Restoration group (SW & ER). SW & ER expects to receive a shipment of enriched Uranium in the near future. The intent is to bury the Uranium in pits that would be separated by a specified amount of undisturbed soil.

The purpose of this analysis is to evaluate the separation of 3 feet of soil for Nuclear Safety concerns and to identify a mass limit on ^{235}U for each pit. Several types of material that could separate the pits are examined; including various mixtures of a typical soil and water.

DESCRIPTION

The model utilized for this analysis considers a single planar array of optimally moderated spheres composed of a mixture of ^{235}U and water at optimum concentration. (Optimum here refers to the concentration and amount of moderation which produces the highest k-eff for a given system). The model examines a single sphere as well as an array that is infinitely large.

In reality, the ^{235}U will be present in boxes of various sizes. By examining the limit that would be required for an array of ^{235}U spheres, there will be no need to investigate the box size and shape. The reason behind this is that the sphere is the shape that has the least amount of leakage for a given amount of material. Thus, the mass limit imposed on the optimally moderated sphere will be conservative to use for any size box.

The spheres are then separated by three feet of a mixture of soil and water. The composition of the soil in the vicinity of the Burial Ground is modeled as a combination of Al_2O_3 (kaolanite), SiO_2 (sand), and water. This was determined from conversations with SRTC ⁄ ' scientist Virgil Rogers and from the SRS Soil Survey (1). The amount of each componen ' varied to determine the most reactive mixture. Details of the soil mixtures are given in appendix C.

REQUIREMENTS DOCUMENTATION

The American National Standard ANS-8.7 recommends that each cell in storage of fissionable material be subcritical if submerged in water. For this case, a single unit (13.5 cm radius sphere, 52 g $^{235}U/l$) reflected by more than 12" of water has a k-eff = 0.896 ± 0.003.

Other concerns such as fire, earthquake, or flooding have no significance in this evaluation. The configuration examined here of the reflected and optimally moderated spheres of material covers any concerns that might be raised due to a fire or a flood. The

Attachment 1:NMP-NCS-930087

consequences due to an earthquake would be minimal if any. (i.e. how catastrophic would the earthquake be to displace a container of material three feet?)

The above discussion assumes that the pits of material will be separated by at least three feet edge to edge by soil or a mixture of soil and water. This separation will be maintained by administrative controls. Currently, there are four procedures that involve the burial of enriched uranium in the burial ground. They are: (1) DPSOL 643-G-2013-Q Rev. 15 "Burying Waste Containing Enriched Uranium", (2) SOP 643-E-2042 T-NCSC "SWDF Radionuclide Inventory (U)", (3) SOP 643-E-2042A-NCSC "SWDF Radionuclide Inventory Data Sheet (U)", (4) SOP 643-E-2044-NCSC "ELLT #4 EU Disposal (U)".

A practical passive engineering control to prevent the pits from ever coming together would be difficult if not impossible. Possible controls to prevent this are discussed in the section of this evaluation entitled Discussion of Contingencies.

METHODOLOGY

The results given later in this analysis are based on three validated computer codes: ANISN, HRXN and KENO-IV. These codes are modules in the SRTC Joshua System (J70).

HRXN computes atom densities given mixture composition data and utilizes 16 group Hansen-Roach cross sections to compute macroscopic cross sections to be used with either ANISN or KENO. Sample output from the HRXN data used in the current analysis is given in appendix C.

ANISN solves the transport equation utilizing a discrete ordinates method in which the angular neutron flux is assumed to have a linear dependence over selected angular segments. ANISN provides a solution for spheres, infinite cylinders, and infinite slabs, utilizing only one position variable. (2) ANISN, which requires little computer time (when compared to Monte Carlo techniques such as KENO), is often utilized to determine a good starting point for the NCSE.

KENO solves the transport equation utilizing Monte Carlo techniques. It provides a multiplication factor (k-effective) for the system being modeled and an associated margin of error due to the statistical nature of Monte Carlo. It is necessary to allow a margin of safety sufficient to cover any uncertainties associated with the model (computational, experimental, etc.) This is done by reproducing results obtained from critical experiments.

Critical experiments relative to ^{235}U in solution are well documented by Clark (3). Clark documents several experiments involving aqueous solutions of Uranium. Clark suggests when using HRXN and a transport computer code like KENO-IV, a critical spherical aqueous solution of uranium with a H/U ratio of ~ 500 would have a minimum calculated k-eff of 0.989. Allowing a margin of safety of 0.05 yields a conservative value for k-eff of 0.939 which will be safe.

Attachment 1:NMP-NCS-930087

DISCUSSION OF CONTINGENCIES

The WSRC Site Criticality Safety Manual requires a double contingency element in all evaluations for Criticality Safety (4). This requires that for those processes in which a criticality cannot be proven incredible, a double contingency statement must be made in the NCSE which governs that process.

The double contingency requirement requires that if a criticality accident is judged to be credible, that there be at least two unlikely, independent, and concurrent changes in the process conditions before a criticality accident is possible (4). The Burial Ground SAR states that the estimated frequency of a criticality accident in the Burial Ground is less than one per million years (5). According to the Site Criticality Safety Manual, this would be judged incredible and thus not require a statement concerning the double contingency principle.

Under normal conditions, there will be no more than 500 g of ^{235}U in a single unit. Also, each unit will be seperated by at least 91.44 cm (36") of undisturbed soil.

Abnormal conditions to be considered include:
① Greater than 500 g of ^{235}U in a single unit
② The units may be closer than 91.44 cm (36")
③ The array may be more than one unit high.

The first concern is that more than 500 g of ^{235}U may be in a single unit. This could happen if more than 500 g of U^{235} is placed in a single unit or if two units are placed too closely together. While there is a control on the mass of ^{235}U in a single burial highlighted as a Nuclear Safety Control in the current procedure (6), there is not a second independent control on the ^{235}U mass. This should be considered in the revision to the current burial procedure..

The second concern is that the units may be closer than 91.44 cm (36") edge to edge. The units could in reality be closer than 20 cm apart before there would be any effect from adjacent units. Due to the constraints of the soil excavation equipment, it would be difficult to place two unit closer than three feet apart. In addition, there are procedural limits to prevent two units from being placed in the same position. The controls to prevent a second unit from being buried at or near the location of another unit at some later time should also be considered when the current procedures are revised.

The third concern is that the array may be more than one unit high. The Burial Ground procedure that currently covers burial of enriched uranium considers only the x and y coordinates of the location of a particular unit (6). The procedure does not consider the possibility of an array that is more than one unit high. This evaluation considers an array of units that is infinite in all directions. Provided that there is at least 8" of soil between the individual units, any concern for arrays that are more than one unit high is eliminated..

Attachment 1:NMP-NCS-930087

All of the concerns addressed in this section have dealt with the location of the unit to be buried. These controls need to be looked at as the procedures are revised to include a higher mass limit for ^{235}U.

EVALUATION & RESULTS

A single sphere was modeled in ANISN to determine the maximum diameter at optimum concentration that would remain subcritical. Results from several ANISN calculations indicate that the optimum concentration is 52 g ^{235}U/l of solution. A sphere of this ^{235}U concentration with a radius of 14.5 cm has a k-eff of 0.95 when reflected by 30.48 cm (12") of water. However, since the safe upper limit on k-eff was determined in the Methodology section of this evaluation to be 0.939, a sphere of 13.5 cm radius is used for additional calculations.

This value of 52 g/l ^{235}U concentration agrees well with work done by Paxton and Pruvost concerning critical dimensions of ^{235}U, ^{239}Pu, and ^{233}U (7). In figure 10 of reference 6, it is indicated that the minimum critical mass for a sphere of ^{235}U and water occurs at or near 50 g ^{235}U/l. This concentration served as a starting point for the ANISN calculations.

Spheres of ^{235}U at the optimum concentration of 52 g/l are represented in table 1. An array of spheres is modeled having an edge to edge separation of 70.31 cm (27.7") in a triangular pitched array. This is equivalent to a square pitched array with a separation of 0.866 times the triangular separation or 81.19 cm (32"). These results are obtained from KENO-IV calculations. They represent an infinite planar array of the ^{235}U spheres, as described above, having a radius of 13.5 cm utilizing amounts of reflection. The worst case occurs when there is a mixture of 70 weight percent water and 30 weight percent soil.

Table 1: Effect of Various Reflectors on K-eff

Job #	Reflector Material	K-eff ± σ
5194	Dry Soil	0.911 ± 0.003
4449	Soil @ 10% Water	0.877 ± 0.003
4449	Soil @ 20% Water	0.899 ± 0.003
4449	Soil @ 30% Water	0.905 ±0.003
4449	Soil @ 40% Water	0.901 ± 0.003
4449	Soil @ 50% Water	0.913 ± 0.003
4449	Soil @ 60% Water	0.908 ± 0.003
4449 (Max.)	Soil @ 70% Water	0.921 ± 0.003
4449	Soil @ 80% Water	0.919 ± 0.003
4313	30.48 cm (12") H_2O	0.891 ± 0.003

Note: All spheres in table 1 have a 13.5 cm sphere radius.

Attachment 1:NMP-NCS-930087

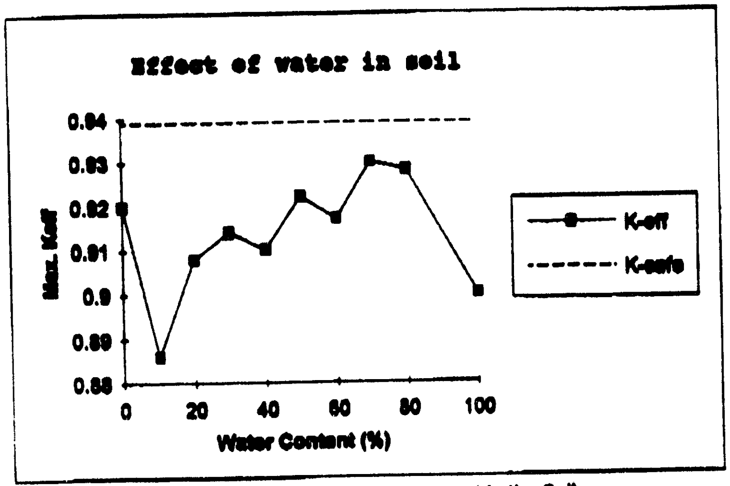

Figure 1: Effect of Water Content in the Soil
(Note: Max Keff is equivalent to Keff + 3σ)

Table 2 represents the effects of a reduced soil thickness surrounding and separating the spheres. The spheres are again 13.5 cm in radius with 52 g/l ^{235}U concentration and are surrounded by soil containing 70% water (which was found to be the case with the highest k-eff in table 1)

As shown in table 2, an edge to edge separation of as low as 20 cm (7.87") is necessary before any significant effect is seen in K-eff. This shows that the spheres are effectively isolated at any amount of soil thicker than 20 cm (7.87")

Table 2: Effect of soil separation on K-eff
* Separation is measured surface to surface.

Job #	Hex Pitch Separation* (cm)	Square Pitch Separation* (cm)	K-eff ± σ
4388	70.31	81.19	0.921 ± 0.003
4388	63.22	73.0	0.925 ± 0.003
4388	54.56	63.0	0.922 ± 0.003
4388	45.90	53.0	0.918 ± 0.003
4388	37.24	43.0	0.918 ± 0.003
4388	28.59	33.0	0.920 ± 0.003
4388	19.92	23.0	0.920 ± 0.003
4388 (Max)	11.26	13.0	0.931 ± 0.003

Attachment 1:NMP-NCS-930087

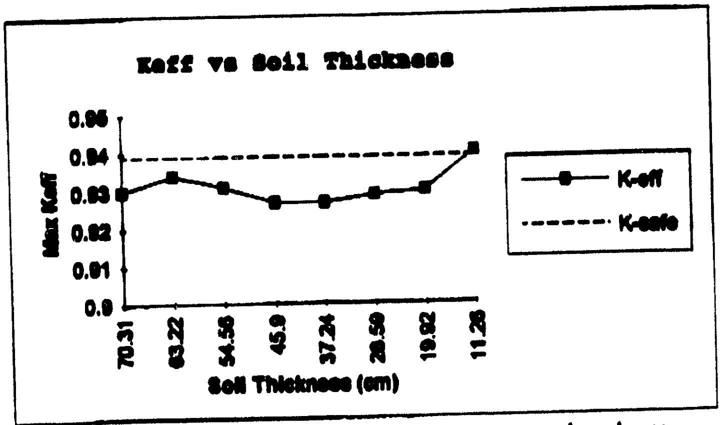

Figure 2: Effect of soil thickness between the spheres.
(Note: Max Keff is equivalent to Keff + 3σ)

Limits due to these results

The limit on the amount of ^{235}U in any single unit to be buried results from the cases cited in the above tables. Specifically, from a sphere with a 13.5 cm radius and a solution concentration of 52 g ^{235}U/l of solution. This results in a limit of 535 grams of ^{235}U. However, due to possible effects from the distribution of the ^{235}U in the sphere, this limit is reduced by approximately 6% to 500 grams (8).

Presence of other fissile isotopes

The possibility exists for additional isotopes to ~~be present in material that~~ is to be buried by Waste Management. Isotopes of concern are ^{239}Pu, ^{241}Pu, and ^{242m}Am. The ANS Standards (9) give some guidance for the storage of these isotopes when they are stored as a mixture.

One approach is to equate the number of grams of each isotope to the number of grams of ^{235}U through the use of a multiplication factor. This factor is determined by taking a ratio of the ^{235}U subcritical limit to the subcritical limit for each additional isotope. For ^{239}Pu the ratio is 700 / 450 or 1.6. The ratios for ^{241}Pu, and ^{242m}Am are 3.5 and 54 respectively. When one of these isotopes is present in a shipment, the amount of the additional isotope (^{239}Pu, ^{241}Pu, or ^{242m}Am) would be multiplied by the appropriate multiplication factor. These numbers would then be added to the amount of ^{235}U present and would have to be less than 500 grams.

The only concern with this method is that the subcritical limits used in the standard are determined using water reflection. For example, the Standards limit ^{235}U to 700 grams,

Attachment 1:NMP-NCS-930087

while this NCSE limits ^{235}U to 500 grams. To conservatively address the concerns that gave the 500 gram limit in this NCSE, the multiplication factors shall be doubled. This results in a factor of 3.2 for ^{239}Pu, 7.0 for ^{241}Pu, and 108 for ^{242m}Am.

ADMINISTRATIVELY CONTROLLED LIMITS AND REQUIREMENTS

As a requirement of this analysis, the amount of ^{235}U in any one unit shall be no more than 500 g. The controls on this limit should follow the guidance of the double contingency principle; with a minimum of two independent administrative checks of the ^{235}U mass in a single unit. In addition, the location of each burial should be controlled with guidance of the double contingency principle.

The presence of ^{239}Pu, ^{241}Pu, or ^{242m}Am are counted as an equivalent amount of ^{235}U using the multiplication factors given in the Evaluation and Results section of this NCSE. Administrative controls are the only way of ensuring that these calculations are made correctly.

SUMMARY AND CONCLUSIONS

This analysis has shown that three feet of soil (when measured edge to edge between units) effectively isolates the proposed units from each other. The mass limit of 500 g ^{235}U in any single unit is necessary due to the reflection provided by the soil and not from any interaction due to surrounding units.

Any additional isotopes of ^{239}Pu, ^{241}Pu, or ^{242m}Am are counted as gram equivalents of ^{235}U utilizing the multiplication factors of 3.2 for ^{239}Pu, 7.0 for ^{241}Pu, and 108 for ^{242m}Am. These limits are very conservative in their derivation. Due to the imposed limits on the specific activity of the fissile material that Waste Management is allowed to bury, these limits should not be restrictive to the operation.

This analysis has been conservative in establishing a mass limit. The ^{235}U was assumed to be in the shape of a sphere and present at an optimally moderated concentration of 52 g/l.

Several contingencies concerning a departure from normal operation have also been considered. The results of this analysis indicate a need for a secondary control on the permitted mass of ^{235}U in each unit to be buried. This could be in the form of an independent verification of the mass in the unit before burial. However, this may not be the only possible secondary mass control. In addition, there should be two or more controls concerning the location of each unit to prevent the burial of additional units at or near the same location.

Attachment 1:NMP-NCS-930087

SPHR4064.INPUT.KENO.SPHR4064

```
:SPHR     DESIGNATION FOR STUDY (NAME)
  : 1  NUMBER OF PROBLEMS IN STUDY
   :1  > 0 TO PRINT INPUT RECORDS
GENERAL INPUT          INPUT.KENO.GNRL.?NAME.?NPROB
GEOMETRY DESCRIPTION   INPUT.KENO.GEOM.?NAME.?NPROB
GENERAL GEOMETRY       INPUT.KENO.GNGM.?NAME.?NPROB
COMBINATORIAL GEOMETRY INPUT.KENO.CMGM.?NAME.?NPROB
PICTURE                INPUT.KENO.PCTR.?NAME.?NPROB
BOX LOCATION           INPUT.KENO.BXLN.?NAME.?NPROB
SEARCH PRESCRIPTION    INPUT.KENO.GEOM.?NAME.?NPROB*1000
CROSS SECTIONS         OUTPUT.XSEC.?NAME.?K
```

SPHR4064.INPUT.KENO.SPHR4064

```
RECORD IDENTIFICATIONS (MUST NOT EXCEED 50 UNLESS SEQUENTIAL)
 1: 1
```

WMER4064.INPUT.KENO.GNRL.SPHR.1

```
| TITLE FOR |  :WM & ER ENRICHED URANIUM RECEIPT        |
| PROBLEM   |  :JULY 27, 1992                   |
    : 60.0  MAXIMUM TIME (CPU IN MINUTES)
     : 303  NUMBER OF BATCHES OR GENERATIONS
     : 300  "  " NEUTRONS PER BATCH
       : 3  "  " BATCHES TO SKIP IN COMPUTING KEFF
       : 0  NO LONGER USED
       : 0  "  "  "
:000000000000  RANDOM NUMBER SEED (KENOCJ ONLY)
       : 0  NO LONGER USED
       : 1  NUMBER OF UNITS IN X DIRECTION
       : 1  "  "  "  " Y  "
       : 1  "  "     " Z  "
       : 0  PRINT OPTIONS (SEE INSTRUCTIONS)
       : 0  NUMBER OF BATCHES BETWEEN WRITING RESTART DATA
       : 0  "  " DUMMY RANDOM NUMBER CALLS (KENO ONLY)
       :1  >0 FOR PICTURE, >1 FOR GEOMETRY CHECK ONLY
       :0  >0 TO CALCULATE FLUX
       :0  >0 "    "  FISSION DENSITIES
       :0  0/1/2/3=NO/MATRIX KEFF BY ARRAY/BY BOX TYPE/BOTH
```

Attachment 1:NMP-NCS-930087

WMER4064.INPUT.KENO.GNRL.SPHR.1

```
   :0  >0 FOR ADJOINT RATHER THAN STANDARD CALCULATION
   :0  0/1/2=NO/SPECULAR ALBEDOS/DIFERENTIAL AND SPECULAR
-----------------ALBEDOS-----------------
     (MINUS FOR SPECULAR, I.D. FOR DIFFERENTIAL)
       :-1.0000  +X FACE    :-1.0000  -X FACE
       :-1.0000  +Y "       :-1.0000  -Y "
       :-1.0000  +Z "       :-1.0000  -Z "
----------------SEARCH PARAMETERS----------------
   :0  0/1/2/3=NO SEARCH/DIMENSIONS/UNITS/COARSE CONVERGENCE
:0.0000  KEFF FOR SEARCH IF SEARCH REQUESTED
   :0  NUMBER OF STD DEVIATIONS FOR CONVERGENCE TO THIS KEFF
  : 0  MAXIMUM ITERATIONS FOR 1 OR 2/ COARSE ITERATIONS FOR 3
  : 0   "   UNITS IN X FOR 2/ NUMBER COARSE BATCHES FOR 3
  : 0   "    " " Y " 2/ "  FINE ITERATIONS FOR 3
  : 0   "    " " Z " 2
--------STARTING DISTRIBUTION/SOURCE SAMPLING VOLUME--------
   :0  0-6 START TYPE (SEE INSTRUCTIONS)
:0.0000  FRACTION STARTED (TYPE 2 ONLY)
   : 0  BOX TYPE (START TYPE 4 OR 5 ONLY)
   : 0  NO. DATA LINES (2-4 = 1, 6 >,= 1/ EXTERNAL COMJOM = 2)
```

WMER4064.INPUT.KENO.GEOM.SPHR.1

```
: 0  NUMBER OF WEIGHTS
:0  NO LONGER USED
: 2  NUMBER OF GEOMETRY SPECIFICATIONS (1/2 NUMBER OF LINES)
:21  NUMBER OF MIXTURES
          MIXTURE IDENTIFICATIONS
  1: 0    2: 0    3: 0    4: 0    5: 0
  6: 0    7: 0    8: 0    9: 0   10: 0
 11: 0   12: 0   13: 0   14: 0   15: 0
 16: 0   17: 0   18: 0   19: 0   20: 0
 21: 0
```

WMER4064.INPUT.KENO.GEOM.SPHR.1

```
 1 :SPHERE        GEOMETRY/  : 2 MIXTURE/  : 0 WEIGHT/
:  13.500:  0.000:  0.000:  0.000:  0.000:  0.000
 2 :CUBOID        GEOMETRY/  : 7 MIXTURE/  : 0 WEIGHT/
:  54.094: -54.094: 54.094: -54.094: 54.094: -54.094
```

Attachment 1:NMP-NCS-930087

HRXN PROGRAM
JOB NAME: SPHR4064 DATA DESIGNATION: SPHR

COMPUTES ATOM DENSITIES AND CROSS SECTIONS FOR MIXTURES FROM HANSEN-ROACH 16-GROUP SETS
—> 50 G/L U235 MIXTURE NO. 1 DENSITY = 1.0456E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.2811E-04	5.0000E+01	4.7821E+00
H	1	6.6560E-02	1.1141E+02	1.0655E+01
O	10	3.3280E-02	8.8416E+02	8.4563E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 5.196E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 5.196E+02

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 5.000E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 5.000E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48582E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 5 ITERATIONS, B**2 = 2.09041E-02 CM-2, M**2 = 3.02408E+01 CM2, K = 1.6322
—> 52 G/L U235 MIXTURE NO. 2 DENSITY = 1.0475E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.3323E-04	5.2000E+01	4.9644E+00
H	1	6.6553E-02	1.1139E+02	1.0635E+01
O	10	3.3276E-02	8.8407E+02	8.4401E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 4.995E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 4.995E+02

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 5.200E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 5.200E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48572E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 5 ITERATIONS, B**2 = 2.13259E-02 CM-2, M**2 = 3.02027E+01 CM2, K = 1.6441
—> 54 G/L U235 MIXTURE NO. 3 DENSITY = 1.0494E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.3836E-04	5.4000E+01	5.1460E+00
H	1	6.6545E-02	1.1138E+02	1.0614E+01
O	10	3.3273E-02	8.8397E+02	8.4240E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 4.810E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 4.810E+02

Attachment 1:NMP-NCS-930087

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 5.400E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 5.400E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48562E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 5 ITERATIONS, B**2 = 2.17227E-02 CM-2, M**2 = 3.01658E+01 CM2, K = 1.6553
—> 56 G/L U235 MIXTURE NO. 4 DENSITY = 1.0512E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.4348E-04	5.6000E+01	5.3270E+00
H	1	6.6538E-02	1.1137E+02	1.0594E+01
O	10	3.3269E-02	8.8388E+02	8.4079E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 4.637E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 4.637E+02

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 5.600E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 5.600E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48552E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 5 ITERATIONS, B**2 = 2.20969E-02 CM-2, M**2 = 3.01297E+01 CM2, K = 1.6658
—> 58 G/L U235 MIXTURE NO. 5 DENSITY = 1.0531E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.4860E-04	5.8000E+01	5.5073E+00
H	1	6.6531E-02	1.1136E+02	1.0574E+01
O	10	3.3266E-02	8.8378E+02	8.3919E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 4.477E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 4.477E+02

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 5.800E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 5.800E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48542E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 5 ITERATIONS, B**2 = 2.24504E-02 CM-2, M**2 = 3.00943E+01 CM2, K = 1.6756
—> 60 G/L U235 MIXTURE NO. 6 DENSITY = 1.0550E+00 G/CC AT 20.0 DEG C
DENSITIES OF U AND PU COMPOUNDS ARE: 1.8663E+01

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
U235	45	1.5373E-04	6.0000E+01	5.6870E+00
H	1	6.6524E-02	1.1135E+02	1.0554E+01
O	10	3.3262E-02	8.8369E+02	8.3759E+01

WT % U233, U234, U235, U236, U238 IN U: 0.0 0.0 100.0000 0.0 0.0

Attachment 1:NMP-NCS-930087

RATIO OF HYDROGEN ATOMS TO FISSIONABLE ATOMS = 4.327E+02
RATIO OF HYDROGEN ATOMS TO FISSILE ATOMS = 4.327E+02

TOTAL CONCENTRATION OF FISSIONABLE NUCLIDES = 6.000E+01 G/L
TOTAL CONCENTRATION OF FISSILE NUCLIDES = 6.000E+01 G/L
MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48533E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 1.0000, AFTER 4 ITERATIONS, B**2 = 2.27830E-02 CM-2, M**2 = 3.00597E+01 CM2, K = 1.6849
---> WATER MIXTURE NO. 7 DENSITY = 9.9823E-01 G/CC AT 20.0 DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	6.6738E-02	1.1170E+02	1.1190E+01
O	10	3.3369E-02	8.8653E+02	8.8810E+01

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.48825E+00 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 3.48398E+01 CM2, K = 0.0
---> OAK RIDGE CONCRETE MIXTURE NO. 8 DENSITY = 2.2994E+00 G/CC AT 20.0 DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	8.5000E-03	1.4227E+01	6.1872E-01
C	8	2.0200E-02	4.0289E+02	1.7521E+01
O	10	3.5500E-02	9.4315E+02	4.1017E+01
CA	19	1.1100E-02	7.3875E+02	3.2128E+01
SI	15	1.7000E-03	7.9284E+01	3.4480E+00
MG	13	1.8600E-03	7.5090E+01	3.2656E+00
FE	24	1.9300E-04	1.7898E+01	7.7837E-01
AL	14	5.5600E-04	2.4911E+01	1.0833E+00
K	18	4.0300E-05	2.6167E+00	1.1380E-01
NA	12	1.6300E-05	6.2226E-01	2.7061E-02

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 4.33044E-01 CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 2.43340E+02 CM2, K = 0.0
---> ORDINARY CONCRETE MIXTURE NO. 9 DENSITY = 2.3433E+00 G/CC AT 20.0 DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	1.4868E-02	2.4886E+01	1.0620E+00
C	8	3.8140E-03	7.6070E+01	3.2463E+00
O	10	4.1519E-02	1.1031E+03	4.7073E+01
CA	19	1.1588E-02	7.7123E+02	3.2912E+01
SI	15	6.0370E-03	2.8155E+02	1.2015E+01
MG	13	5.8700E-04	2.3698E+01	1.0113E+00
FE	24	1.9680E-04	1.8250E+01	7.7884E-01
AL	14	7.3500E-04	3.2931E+01	1.4053E+00
NA	12	3.0400E-04	1.1605E+01	4.9526E-01

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 5.15859E-01 CM**-1

Attachment 1:NMP-NCS-930087

FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 1.62721E+02
CM2, K = 0.0
—> MAGNUSON CONCRETE MIXTURE NO. 10 DENSITY = 2.3299E+00 G/CC AT 20.0
DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	4.2400E-03	7.0968E+00	3.0460E-01
C	8	1.1300E-02	2.2538E+02	9.6734E+00
O	10	4.0200E-02	1.0680E+03	4.5840E+01
CA	19	7.2700E-03	4.8385E+02	2.0767E+01
SI	15	1.9300E-03	9.0011E+01	3.8633E+00
MG	13	4.9900E-03	2.0145E+02	8.6464E+00
FE	24	1.2900E-04	1.1963E+01	5.1345E-01
AL	14	3.7500E-04	1.6801E+01	7.2112E-01
K	18	3.1100E-03	2.0193E+02	8.6671E+00
NA	12	7.9000E-05	3.0158E+00	1.2944E-01
S	16	1.0000E-04	5.3243E+00	2.2852E-01
CL	17	1.9000E-05	1.1185E+00	4.8009E-02
TI	20	4.0000E-05	3.1816E+00	1.3656E-01
ZN	28	8.9000E-05	9.6623E+00	4.1471E-01
MN	23	1.2000E-05	1.0947E+00	4.6986E-02

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 3.33886E-01
CM**-1

FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 3.54121E+02
CM2, K = 0.0
—> BORATED CONCRETE MIXTURE NO. 11 DENSITY = 2.3079E+00 G/CC AT 20.0
DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	8.5000E-03	1.4227E+01	6.1646E-01
B	7	4.7000E-04	8.4374E+00	3.6559E-01
C	8	2.0200E-02	4.0289E+02	1.7457E+01
O	10	3.5500E-02	9.4315E+02	4.0867E+01
NA	12	1.6300E-05	6.2226E-01	2.6962E-02
MG	13	1.8600E-03	7.5090E+01	3.2536E+00
AL	14	5.5600E-04	2.4911E+01	1.0794E+00
SI	15	1.7000E-03	7.9284E+01	3.4354E+00
K	18	4.0300E-05	2.6167E+00	1.1338E-01
CA	19	1.1100E-02	7.3875E+02	3.2010E+01
FE	24	1.9300E-04	1.7898E+01	7.7552E-01

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 4.34783E-01
CM**-1

FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 1.53001E+02
CM2, K = 0.0
—> PORTLAND CONCRETE MIXTURE NO. 12 DENSITY = 2.3000E+00 G/CC AT 20.0
DEG C

NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
H	1	1.3741E-02	2.2999E+01	9.9995E-01
O	10	4.5797E-02	1.2167E+03	5.2900E+01
SI	15	1.6620E-02	7.7512E+02	3.3700E+01
AL	14	1.7454E-03	7.8200E+01	3.4000E+00

Attachment 1:NMP-NCS-930087

FE	24	3.4722E-04	3.2200E+01	1.4000E+00
CA	19	1.5206E-03	1.0120E+02	4.4000E+00
MG	13	1.1394E-04	4.5999E+00	1.9999E-01
C	8	1.1532E-04	2.3001E+00	1.0000E-01
NA	12	9.6397E-04	3.6800E+01	1.6000E+00
K	18	4.6049E-04	2.9900E+01	1.3000E+00

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 5.04395E-01
CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 1.77154E+02
CM2, K = 0.0
---> SOIL @ MIXTURE NO. 13 DENSITY = 1.6000E+00 G/CC AT 20.0 DEG C

	NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
20% WATER					
40% SAND	SI	15	6.4146E-03	2.9916E+02	1.8698E+01
40% KAOLANITE	O	10	3.4866E-02	9.2631E+02	5.7894E+01
	AL	14	7.5601E-03	3.3872E+02	2.1170E+01
	H	1	2.1394E-02	3.5808E+01	2.2380E+00

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 5.93623E-01
CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 1.51308E+02
CM2, K = 0.0
---> SOIL @ MIXTURE NO. 14 DENSITY = 1.6000E+00 G/CC AT 20.0 DEG C

	NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
80% WATER					
10% SAND	SI	15	1.6036E-03	7.4790E+01	4.6744E+00
10% KAOLANITE	O	10	4.8830E-02	1.2973E+03	8.1081E+01
	AL	14	1.8900E-03	8.4680E+01	5.2925E+00
	H	1	8.5576E-02	1.4323E+02	8.9521E+00

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.93747E+00
CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 1.96816E+01
CM2, K = 0.0
---> SOIL @ MIXTURE NO. 15 DENSITY = 1.6000E+00 G/CC AT 20.0 DEG C

	NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
70% WATER					
15% SAND	SI	15	2.4055E-03	1.1219E+02	7.0116E+00
15% KAOLANITE	O	10	4.6503E-02	1.2355E+03	7.7217E+01
	AL	14	2.8350E-03	1.2702E+02	7.9388E+00
	H	1	7.4879E-02	1.2533E+02	7.8331E+00

MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION = 1.71349E+00
CM**-1
FISSION SPECTRUM 100.0 % U235, 0.0 % PU239
@ KEFF = 0.0 , AFTER 0 ITERATIONS, B**2 = 0.0 CM-2, M**2 = 2.44652E+01
CM2, K = 0.0
---> SOIL @ MIXTURE NO. 16 DENSITY = 1.6000E+00 G/CC AT 20.0 DEG C

	NUCLIDE	ID	ATOM DENSITY	CONC(G/L)	WT %
60% WATER					
20% SAND	SI	15	3.2073E-03	1.4958E+02	9.3488E+00
20% KAOLANITE	O	10	4.4175E-02	1.1736E+03	7.3352E+01
	AL	14	3.7801E-03	1.6936E+02	1.0585E+01
	H	1	6.4182E-02	1.0743E+02	6.7141E+00

DATE FILMED

2/24/94

END