MOL.19980216.0260

CRWMS/M&O

Non-Q Design Analysis Cover Sheet

Complete only applicable items.

(1.) QA: N/A

Page: 1 Of: 58

2. DESIGN ANALYSIS TITLE Criticality Analysis of Pu and U Accumulations in a Tuff Fracture Network			
3. DOCUMENT IDENTIFIER (Including Rev. No.) A00000000-01717-0200-00050 REV 00		4. REV. NO. REV 00	5. TOTAL PAGES ~~56~~ 58 SG 11/13/97
6. TOTAL ATTACHMENTS 7	7. ATTACHMENT NUMBERS - NO. OF PAGES IN EACH See Section 9 - Total Attachment pages 30		8. SYSTEM ELEMENT N/A

	Print Name	Signature	Date
9. Originator	E. Tuttle	EB Tuttle	11-19-97
10. Checker	S. Goluoglu	[signature]	11/13/97
11. Lead Design Engineer	P. Gottlieb	P. Gottlieb	11/19/97
12. Department Manager	H.A. Benton	[signature] For	1.29.98

13. Remarks

NAP-MG-013 (Effective 09/08/95)

0642 (Rev. 08/16/95)

2. DESIGN ANALYSIS TITLE	
Criticality Analysis of Pu and U Accumulations in a Tuff Fracture Network	
3. DOCUMENT IDENTIFIER (Including Rev. No.)	
A00000000-01717-0200-00050 REV 00	
4. Revision No.	**5. Description of Revision**
00	Issued for initial release

Table of Contents

Section **Page**

1. Purpose

The objective of this analysis is to evaluate accumulations within the thermally altered tuff surrounding a drift. The evaluation examines accumulation of uranium minerals (soddyite), plutonium oxide (PuO_2), and combinations of these materials. A hypothetical model of the tuff is used to provide insight into the factors that affect criticality for this near-field scenario. The factors examined include: the size of the accumulation, the fissile composition of the accumulation, the water or clayey material fraction in the accumulation and the water fraction in the tuff.

2. Quality Assurance

The Quality Assurance (QA) program does not apply to this analysis. The Waste Package Development Department responsible manager has evaluated this activity in accordance with QAP-2-0, *Conduct of Activities*. The *Studies Not Supported by OCRWM* (Ref. 5.1) activity evaluation has determined that work associated with the immobilized Pu task is not subject to *Quality Assurance Requirements and Description* (QARD; Ref 5.2) requirements.

3. Method

The solution method is to use the MCNP4A computer program (CSCI:30006 V4A) to calculate k-effective for criticality safety evaluations.

4. Design Inputs

4.1 Material Properties

The five materials considered in this evaluation are Topopah Spring Welded tuff, soddyite, plutonium oxide, clayey material from degraded HLW glass, and water. The physical parameters of these materials are listed in Table 4-1. It is noted that the weight percents for the tuff do not sum to 1.0. However, the difference is small and will have no significant effect on calculational results.

Table 4-1 Material Properties

Compound	Wt %
Topopah Spring Welded Tuff (Ref. 5.3, p. I-9) Dry, $\rho = 2.247$ g/cm^3	
SiO_2	76.827
Al_2O_3	12.740
Fe0	0.842
CaO	0.560
MgO	0.245
TiO_2	0.098
Na_2O	3.593
K_2O	4.930
P_2O_5	0.015
MnO	0.067
Total	99.917
Soddyite (Ref. 5.4) $\rho = 4.7$ g/cm^3	
$(^{235}UO_2)_2(SiO_4){:}2H_2O$	100.00
Plutonium Oxide (Ref. 5.5) $\rho = 11.46$ g/cm^3	
$^{239}PuO_2$	100.00
Clayey Material (Ref. 5.3, p. I-21) $\rho = 2.62$ g/cm^3	
See Attachments VI and VII	
Water $\rho = 1.00$ g/cm^3	
H_2O	100.00

4.2 Criteria

The *Engineered Barrier Design Requirements Document* (EBDRD; Ref. 5.10) contains several criteria which relate to criticality control. The "TBD" (to be determined) items identified in these criteria will not be carried to the conclusions of this analysis based on the rationale that the conclusions are for preliminary design, and will not be used as input to design documents supporting construction, fabrication, or procurement. A review of the EBDRD identified the following relevant requirements:

The EBDRD requirements 3.2.2.6 and 3.7.1.3.A both indicate that a WP criticality shall not be possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. These requirements also indicate that the design must provide for criticality safety under normal and accident conditions, and, that the calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a five percent margin after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the methods of calculation. The latter requirement contains a "TBD" at the end.

Controlled Design Assumptions document (CDA) assumption EBDRD 3.7.1.3.A (Ref. 5.11, p. 4-32) clarifies that the above requirement is applicable to only the preclosure phase of the MGDS, in accordance with the current DOE position on postclosure criticality. This assumption also indicates that for postclosure, the probability and consequences of a criticality provide reasonable assurance that the performance objective of 10CFR60.112 is met. While the Nuclear Regulatory Commission (NRC) has not yet endorsed any specific change for postclosure, they have indicated that they agree that one is necessary.

Finally, EBDRD 3.3.1.G indicates that "The Engineered Barrier Segment design shall meet all relevant requirements imposed by 10CFR60." The NRC has recently revised several parts of 10CFR60 which relate to the identification and analysis of design basis events (Ref. 5.12) including the criticality control requirement, which was moved to 60.131(h). These changes are not reflected in the current versions of the EBDRD or the CDA. The change to the criticality requirement simply replaces the phrase "criticality safety under normal and accident conditions" with "criticality safety assuming design basis events."

This analysis contributes to satisfying the above requirements by providing k_{eff} of degraded MIT and ORR fuel This analysis provides information which will be used in probabilistic analyses of postclosure criticality as part of Total System Performance Assessment (TSPA)-Viability Assessment (VA) to demonstrate compliance with the performance objective of §60.112 (or, as appropriate, other applicable performance objectives in effect or proposed by the NRC at the time the TSPA-VA analysis is performed).

4.3 Assumptions

4.3.1 Based on the inspection of ESF by P. Gottlieb, W. Davis and P. Cloke on July 23, 1997, the worst case fracture density in the walls of an emplacement drift is assumed to be the equivalent of parallel plane spacings of ~3cm in three dimensions. The entire model volume is one meter cube.

4.3.2 Only the principle fissile isotopes ^{235}U and ^{239}Pu are considered in the composition of the accumulation due to the scoping nature of this evaluation.

4.4 Codes and Standards

Not Applicable. Neutronic design of the waste package is not controlled by codes and standards.

5. References

5.1 *QAP-2-0 Activity Evaluations*, ID No. WP-30, Perform Criticality, Thermal, Structural, and Shielding Analyses as Required for DOE Spent Fuel Characterization, Dated 8/3/97, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

5.2 *Quality Assurance Requirements and Description*, DOE/RW-0333P REV 7, U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM).

5.3 *Evaluation of the Potential for Deposition of Uranium/Plutonium from Repository Waste Packages*, DI Number: BBA000000-01717-0200-00050 REV. 00, CRWMS M&O.

5.4 Roberts, W.L., Rapp, G.R., Jr., and Weber, J., *Encyclopedia of Minerals*, van Nostrad, New York, 1974.

5.5 *Handbook of Chemistry and Physics*, 66th Edition, CRC Press, 1985

5.6 *Material Compositions and Number Densities For Neutronics Calculations*, DI Number: BBA000000-01717-0200-00002 REV 00, CRWMS M&O.

5.7 Wilson, M.L., et al., *Total-System Performance Assessment for Yucca Mountain - SNL Second Iteration (TSPA-1993)*, Volume 1, SAND93-2675, April, 1994.

5.8 MCNP-A General Monte Carlo N-Particle Transport Code, Version 4A, LA-12625-M, Los Alamos National Laboratory, November 1993.

5.9 *Software Qualification Report for MCNP4A*, CSCI: 30006 V4A, DI Number: 30006-2003 REV 02, CRWMS M&O.

5.10 *Engineered Barrier Design Requirements Document*, YMP/CM-0024, REV 0, ICN 1, Yucca Mountain Site Characterization Project.

5.11 *Controlled Design Assumptions Document*, Document Identifier (DI) Number: B00000000-01717-4600-00032 REV 04, ICN 01, CRWMS M&O.

5.12 *10 CFR Part 60; Disposal of High-Level Radioactive Wastes in Geologic Repositories; Design Basis Events; Final Rule,* U.S. Nuclear Regulatory Commission, Federal Register, Volume 61, Number 234, pp. 64257-64270, December 4, 1996.

5.13 *Electronic Attachments for A00000000-01717-0200-00050 REV 00, Criticality Analysis of Pu and U Accumulations in a Tuff Fracture Network*, Colorado Backup Tape, RPC Batch Number MOY-980129-02, CRWMS M&O.

6. Use of Computer Software

The calculation of effective multiplication factor was performed with the MCNP4A (Ref. 5.8) computer code, CSCI: 30006 V4A. MCNP4A calculates k_{eff} for a variety of geometric configurations with neutron cross sections for elements and isotopes described in the Evaluated Nuclear Data File version B-V (ENDF-B/V). MCNP4A is appropriate for the geometries and materials required for these analyses. The calculations using the MCNP4A software were executed on a Hewlett-Packard 9000 Series 735 workstation. The software qualification of the MCNP4A software, including problems related to calculation of k-effective for fissile systems, is summarized in the Software Qualification Report for the Monte Carlo N-Particle code (Ref. 5.9). The MCNP4A evaluations performed for this design are fully within the range of the validation for the MCNP4A software used. Access to and use of the MCNP4A software for this analysis was granted by Software Configuration Management and performed in accordance with the QAP-SI series procedures. Inputs and outputs for the MCNP4A software are included as attachments (see Section 9.2) as described in the following design analysis.

The computation of number densities was performed with Microsoft Excel Version 7.0. Microsoft Excel 7.0 was executed on an IBM PC compatible personal computer. Microsoft Excel 7.0 was used simply to provide data manipulation for the analyses and is considered Computational Support Software. These files are included as attachments (see Section 9.3).

7. Design Analysis

7.1 MCNP Model Description

Investigations of the thermally altered tuff around a drift indicate fracture spacings of ~3 cm (center-to-center) in three dimensions. The maximum fracture aperture is expected to be about 0.1 cm. This fracture scenario is approximated with a cubical representation of the fractured tuff. A three-dimensional array of cubes, 3 cm on a side, will represent the fracture area. The inner cube (a minimum of 2.900 cm on a side) is filled with porous tuff. The outer cubic shell represents the fracture filled with an aqueous or clayey material mixture of soddyite, PuO_2, or a 50/50 mixture of soddyite and PuO_2. The total fracture region is modeled as a one meter cube of cubic fractures surrounded by a one meter thick, cubic shell reflector of tuff with the same porosity and water content as the inner fractured tuff. The MCNP geometry is shown in Figure 7.1-1.

The evaluation examines material composition effects related to the moderator fraction in both the tuff and the fissile material. The evaluation also determines the effects of the size of the fracture aperture which range from 0.001 to 0.100 cm thick.

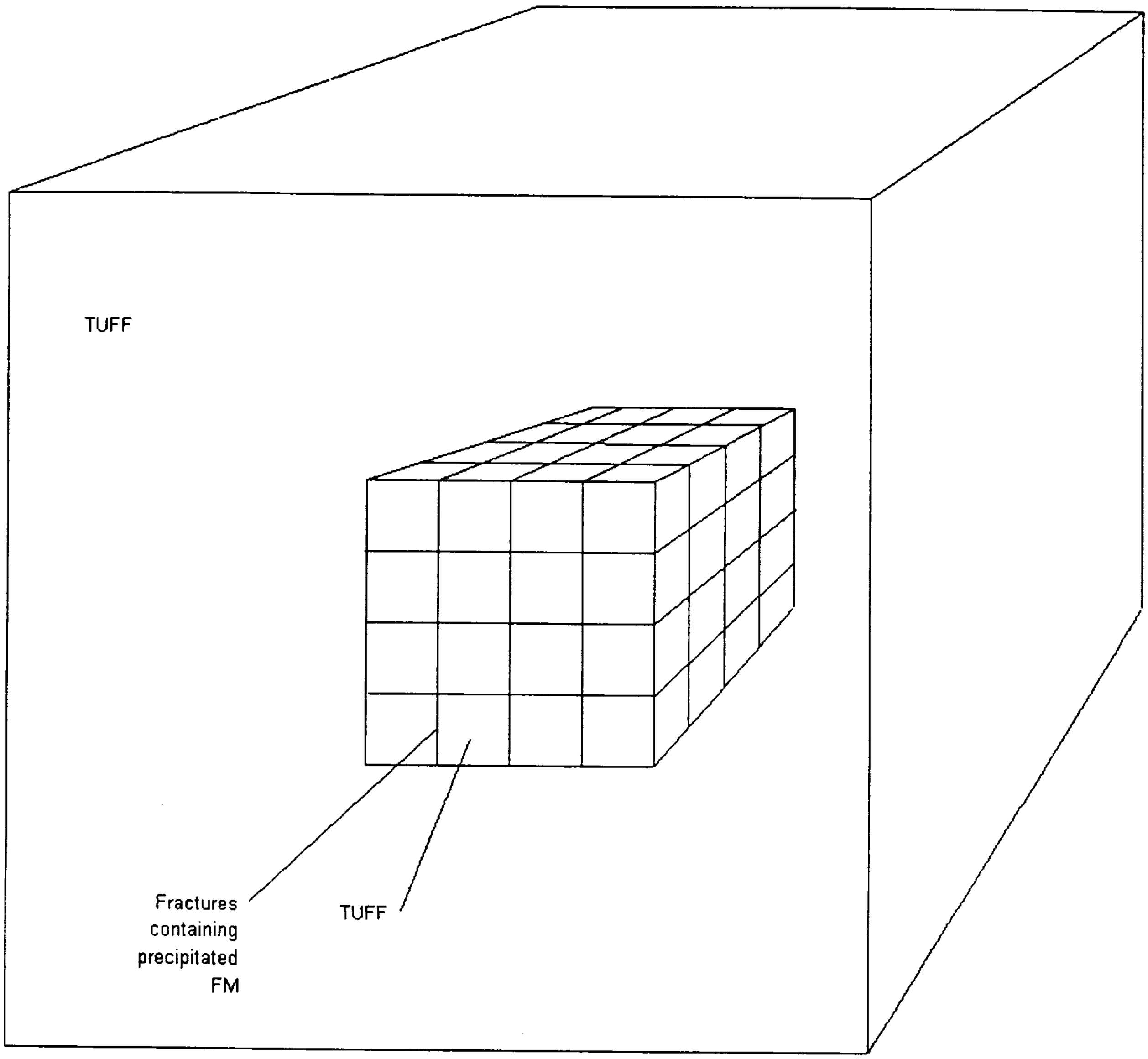

Figure 7.1-1. Illustration of Fracture Matrix Model

7.2 Material Composition Description

The MCNP model used for this analysis assumes that the material specifications are in terms of elemental mass densities. Thus, the data in Table 4-1 must be manipulated into the correct format to characterize the addition of moderating material, i.e., water or clayey material, in various proportions. The generation of the elemental mass densities follows the methodology described in "Material Compositions and Number Densities for Neutronics Calculations" (Ref. 5.6). Table 7.2-1 lists the elemental mass densities for the compounds listed in Table 4-1, as well as their elemental weight fraction. The elemental densities in Table 7.2-1 are listed by compound for each material for both primary elements and oxide components. The elemental densities are obtained with the following formula:

$$(\rho_e)_i = \frac{(\rho_m)(w_c)(N_i * amu_i)}{\sum_{\rho_e \in c} \rho_e}$$

where,

$(\rho_e)_I$ is the elemental density of element I in the compound, g/cm^3,
ρ_m is the material density, g/cm^3,
w_c is the weight fraction of the compound in the material,
N_i is the number of atoms of the element I in the compound,
amu_i is the atomic mass of the element I, and
$\Sigma(\rho_e)$ is the summation of all the elemental densities in the compound c.

For example, for the compound SiO_2 in tuff (see Table 7.2-1), the elemental densities are:

$$(\rho_e)_{Si} = \frac{(2.247)(0.76827)(1*28.086)}{1*28.086+2*15.994915} = 0.807062$$

$$(\rho_e)_O = \frac{(2.247)(0.76827)(2*15.994915)}{1*28.086+2*15.994915} = 0.919240$$

The elemental weight fractions for a material are obtained by dividing the elemental density by the sum of the elemental densities of all compounds in the material, i.e.,

$$(W_e)_i = \frac{(\rho_e)_i}{\sum_{\rho_e \in m} \rho_e},$$

where W_e is the elemental weight fraction in the material m for element I. For example, the element weight fraction of silicon and oxygen in tuff is:

$$W_{Si} = \frac{0.807062}{2.245135} = 0.359472$$
$$W_O = \frac{1.105025}{2.245135} = 0.492186,$$

where the values are obtained from Table 7.2-1. The elemental densities given in Table 7.2-1 are for pure quantities of the materials listed. For the MCNP evaluation, elemental densities of water contained in, or mixed with, the materials are desired. These quantities are obtained from the product of the elemental densities and the volume fractions of the components in the mixture. Results for tuff are listed in Table 7.2-2. It is noted that tuff is a porous material with a porosity of 0.139 (Ref. 5.7). The water that is mixed with the tuff is assumed to reside in the pores of the material. Thus, the elemental densities of the tuff remain at a volume fraction of 1.0 and water, up to a volume fraction of 0.139, can reside in the pores of the tuff. This increases the density of the tuff to the sum of the densities of tuff and the interstitial water in the pores. For this evaluation four volume fractions of water are examined: 0.13, 0.08, 0.04, and 0.00, i.e., dry tuff. For tuff and other materials, the elemental density is found from:

$$(\rho_{e,i})_m = (\rho_e)_i \ (V_f)_c$$

where,

$(\rho_{e,i})_c$ is the elemental density of element I for compound c in the mixture,
$(\rho_e)_I$ is the elemental density of the I-th element of compound c,
$(V_f)_c$ is the volume fraction of compound c in the mixture.

The elemental densities are used in the input file for MCNP to characterize the material composition. It is noted that MCNP sums the elemental densities and normalizes the values to a total sum of 1.0 to obtain an elemental weight fraction. In addition, MCNP requires the specification of the density of the material. The density of the mixture, ρ_m, is just the sum of the elemental densities, i.e.,

$$\rho_m = \sum_i (\rho_{e,i})_m$$

Elemental densities for the mixtures of soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide with water or clayey material were determined using Excel spreadsheets Tuff.Xls and Clay.Xls, respectively. The elemental densities for some configurations are shown in

Tables 7.2-2 thru 7.2.4.

Description of Tuff.Xls (spreadsheet for fissile mixtures in water)

1) determine no. of atoms of each element in each compound (soddyite, water and PuO_2)

2) multiply no. of atoms of each element by the atomic weight

3) determine atomic weight for each compound

4) determine volume fraction and density for each compound

5) calculate fractional density for each element in each compound:
vol. fraction x density x weight percent of element in compound

6) sum fractional densities for each element - Note - MCNP input is in g/cc

Description of Clay.Xls (spreadsheet for fissile mixtures in clayey material)

1) determine no. of atoms of each element in clayey material

2) determine mass of each compound in clayey material

3) determine total volume of clayey material

4) determine atomic weight of each compound in clayey material

5) determine fractional density for each element in clayey material:
(no. of atoms x mass of compound / total vol. / atomic weight of compound x Avogadros number) for each compound containing that element

6) using Tuff.Xls, determine fractional densities for each element in 100% volume fraction soddyite and PuO_2 (no. of atoms x Avogadros number x density / atomic weight)

7) determine volume fraction for clayey material, soddyite and PuO_2

8) multiply volume fractions by fractional densities for each element - Note - MCNP input is in atomic units

In addition to the base fissile fractions of 0.1, 0.5. and 0.9, additional fractions are included that were necessary to estimate the fraction that would result in a k_{eff} of 0.93 for various mixtures.

Table 7.2-1 Elemental Weight Percents

Compound	Compound Wt %	Primary Element Density (g/cm^3)	Oxygen Element Density (g/cm^3)	Element	Elemental Weight Fraction
Tuff, ρ=2.247					
SiO_2	76.827	0.807062	0.919240	Si	0.359472
Al_2O_3	12.740	0.151527	0.134740	Al	0.067491
FeO	0.842	0.014707	0.004212	Fe	0.006551
CaO	0.560	0.008994	0.003589	Ca	0.004006
MgO	0.245	0.003321	0.002185	Mg	0.001479
TiO_2	0.098	0.001320	0.000882	Ti	0.000588
Na_2O	3.593	0.059898	0.020837	Na	0.026679
K_2O	4.930	0.091967	0.018810	K	0.040963
P_2O_5	0.015	0.000147	0.000190	P	0.000066
MnO	0.067	0.001166	0.000339	Mn	0.000519
total	99.917	1.140109	1.105025	O	0.492186
		sum = 2.245135		total	1.000000
Water, ρ=1.000					
H_2O	100	0.111915	0.888085	H	0.111915
total	100	0.111915	0.888085	O	0.888085
		sum = 1.0		total	1.0
Soddyite, ρ=4.7					
$((^{235}UO_2)_2 SiO_4):2H_2O$	100	3.336704	0.454130	^{235}U	0.709937
		0.199356	0.454130	Si	0.042416
		0.028614	0.227065	H	0.006088
total	100	3.564674	1.135326	O	0.241559
		sum = 4.7		total	1.0
PuO_2, ρ=11.46					
$^{239}PuO_2$	100	10.107429	1.352571	^{239}Pu	0.881975
total	100	10.107429	1.352571	O	0.118025
		sum = 11.46		total	1.0

Table 7.2-2 Soddyite/Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3					
Soddyite volume fraction =		1.0	0.1	0.5	0.9	0.35	0.36
^{235}U	92235.50C	3.336704	0.333670	1.668352	3.003034	1.167846	1.201213
Si	14000.50C	0.199356	0.019936	0.099678	0.179420	0.069774	0.071768
H	1001.50C	0.028614	0.002861	0.014307	0.025753	0.010015	0.010301
O	8016.50C	1.135326	0.113533	0.567663	1.021793	0.397364	0.408717
Water volume fraction =		1.0	0.9	0.5	0.1	0.65	0.64
H	1001.50C	0.111915	0.100723	0.055957	0.011191	0.072745	0.071626
O	8016.50C	0.888085	0.799277	0.444043	0.088809	0.577255	0.568374
H(total)	1001.50C		0.103585	0.070265	0.036944	0.082760	0.081927
O(total)	8016.50C		0.912809	1.011706	1.110602	0.974619	0.977092
Density =			1.370	2.850	4.330	2.295	2.332

Table 7.2-2 (cont.) Soddyite/Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3				
Soddyite volume fraction=		0.44	0.46	0.71	0.72	0.98
^{235}U	92235.50C	1.468150	1.534884	2.369060	2.402427	3.269970
Si	14000.50C	0.087716	0.091704	0.141543	0.143536	0.195369
H	1001.50C	0.012590	0.013163	0.020316	0.020602	0.028042
O	8016.50C	0.499543	0.522250	0.806081	0.817435	1.112620
Water volume fraction =		0.56	0.54	0.29	0.28	0.02
H	1001.50C	0.062672	0.060434	0.032455	0.031336	0.002238
O	8016.50C	0.497328	0.479566	0.257545	0.248664	0.017762
H(total)	1001.50C	0.075263	0.073597	0.052772	0.051938	0.030280
O(total)	8016.50C	0.996871	1.001816	1.063626	1.066099	1.130381
Density =		2.628	2.702	3.627	3.664	4.626

Table 7.2-3 Plutonium Oxide/Water Mixture Elemental Densities								
Element	MCNP.ID	Elemental Density, g/cm^3						
PuO_2 volume fraction =		1.0	0.1	0.5	0.9	0.06	0.07
^{239}Pu	94239.55C	10.107429	1.010743	5.053715	9.096686	0.606446	0.707520
O	8016.50C	1.352571	0.135257	0.676285	1.217314	0.081154	0.094680
H_2O volume fraction =		1.0	0.9	0.5	0.1	0.94	0.93
H	1001.50C	0.111915	0.100723	0.055957	0.011191	0.105200	0.104081
O	8016.50C	0.888085	0.799277	0.444043	0.088809	0.834800	0.825919
O(total)	8016.50C		0.934534	1.120328	1.306122	0.915954	0.920599
Density =			2.046	6.230	10.414	1.6276	1.7322

Table 7.2-3 (cont.) Plutonium Oxide/Water Mixture Elemental Densities							
Element	MCNP.ID	Elemental Density, g/cm^3					
PuO_2 volume fraction =		0.08	0.11	0.12	0.13	0.15	0.16
^{239}Pu	94239.55C	0.808594	1.111817	1.212892	1.313966	1.516114	1.617189
O	8016.50C	0.108206	0.148783	0.162308	0.175834	0.202886	0.216411
H_2O volume fraction =		0.92	0.89	0.88	0.87	0.85	0.84
H	1001.50C	0.102962	0.099604	0.098485	0.097366	0.095128	0.094009
O	8016.50C	0.817038	0.790396	0.781515	0.772634	0.754872	0.745991
O(total)	8016.50C	0.925244	0.939179	0.943823	0.948468	0.957758	0.962403
Density =		1.8368	2.1506	2.2552	2.3598	2.569	2.6736

Table 7.2-3 (cont.) Plutonium Oxide/Water Mixture Elemental Densities							
Element	MCNP.ID		Elemental Density, g/cm^3				
PuO_2 volume fraction =		0.31	0.32	0.38	0.39	0.63	0.64
^{239}Pu	94239.55C	3.133303	3.234377	3.840823	3.941897	6.367680	6.468755
O	8016.50C	0.419297	0.432823	0.513977	0.527503	0.852120	0.865645
H_2O volume fraction =		0.69	0.68	0.62	0.61	0.37	0.36
H	1001.50C	0.077221	0.076102	0.069387	0.068268	0.041409	0.040289
O	8016.50C	0.612779	0.603898	0.550613	0.541732	0.328591	0.319711
O(total)	8016.50C	1.032076	1.036721	1.064590	1.069235	1.180711	1.185356
Density =		4.2426	4.3472	4.9748	5.0794	7.5898	7.6944

Table 7.2-3 (cont.) Plutonium Oxide/Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3					
PuO_2 volume fraction =		0.78	0.79	0.91	0.92	0.1162	0.1446
^{239}Pu	94239.55C	7.883795	7.984869	9.197761	9.298835	1.174520	1.461477
O	8016.50C	1.055005	1.068531	1.230839	1.244365	0.157174	0.195574
H_2O volume fraction =		0.22	0.21	0.09	0.08	0.8837964	0.8554057
H	1001.50C	0.024621	0.023502	0.010072	0.008953	0.098910	0.095733
O	8016.50C	0.195379	0.186498	0.079928	0.071047	0.784886	0.759673
O(total)	8016.50C	1.250384	1.255029	1.310767	1.315412	0.942060	0.955247
Density =		9.1588	9.2634	10.5186	10.6232	2.2155	2.5125

Table 7.2-4 Soddyite, Plutonium Oxide, Water Mixture Elemental Densities

Element	MCNP ID	Elemental Density, g/cm^3					
Soddyite volume fraction =		1.0	0.05	0.25	0.45	0.055	0.06
^{235}U	92235.50C	3.336704	0.166835	0.834176	1.501517	0.183519	0.200202
Si	14000.50C	0.199356	0.009968	0.049839	0.089710	0.010965	0.011961
H	1001.50C	0.028614	0.001431	0.007154	0.012876	0.001574	0.001717
O	8016.50C	1.135326	0.056766	0.283832	0.510897	0.062443	0.068120
PuO_2 volume fraction =		1.0	0.05	0.25	0.45	0.055	0.06
^{239}Pu	94239.55C	10.107429	0.505371	2.526857	4.548343	0.555909	0.606446
O	8016.50C	1.352571	0.067629	0.338143	0.608657	0.074391	0.081154
Water volume fraction =		1.0	0.90	0.50	0.10	0.89	0.88
H	1001.50C	0.111915	0.100723	0.055957	0.011191	0.099604	0.098485
O	8016.50C	0.888085	0.799277	0.444043	0.088809	0.790396	0.781515
H(total)	1001.50C		0.102154	0.063111	0.024068	0.101178	0.100202
O(total)	8016.50C		0.923671	1.066017	1.208362	0.927230	0.930789
Density =			1.708	4.540	7.372	1.779	1.850

Table 7.2-4 (cont.) Soddyite, Plutonium Oxide, Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3					
Soddyite volume fraction =		0.065	0.105	0.11	0.125	0.13	0.27
^{235}U	92235.50C	0.216886	0.350354	0.367037	0.417088	0.433772	0.900910
Si	14000.50C	0.012958	0.020932	0.021929	0.024919	0.025916	0.053826
H	1001.50C	0.001860	0.003005	0.003148	0.003577	0.003720	0.007726
O	8016.50C	0.073796	0.119209	0.124886	0.141916	0.147592	0.306538
PuO_2 volume fraction =		0.065	0.105	0.11	0.125	0.13	0.27
^{239}Pu	94239.55C	0.656983	1.061280	1.111817	1.263429	1.313966	2.729006
O	8016.50C	0.087917	0.142020	0.148783	0.169071	0.175834	0.365194
Water volume fraction =		0.87	0.79	0.78	0.75	0.74	0.46
H	1001.50C	0.097366	0.088413	0.087294	0.083936	0.082817	0.051481
O	8016.50C	0.772634	0.701587	0.692706	0.666064	0.657183	0.408519
H(total)	1001.50C	0.099226	0.091417	0.090441	0.087513	0.086537	0.059207
O(total)	8016.50C	0.934347	0.962816	0.966375	0.977051	0.980610	1.080251
Density =		1.920	2.487	2.558	2.770	2.841	4.823

Table 7.2-4 (cont.) Soddyite, Plutonium Oxide, Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3					
Soddyite volume fraction =		0.275	0.33	0.335	0.39	0.395	0.49
^{235}U	92235.50C	0.917594	1.101112	1.117796	1.301315	1.317998	1.634985
Si	14000.50C	0.054823	0.065787	0.066784	0.077749	0.078745	0.097684
H	1001.50C	0.007869	0.009443	0.009586	0.011160	0.011303	0.014021
O	8016.50C	0.312215	0.374658	0.380334	0.442777	0.448454	0.556310
PuO_2 volume fraction =		0.275	0.33	0.335	0.39	0.395	0.49
^{239}Pu	94239.55C	2.779543	3.335452	3.385989	3.941897	3.992435	4.952640
O	8016.50C	0.371957	0.446348	0.453111	0.527503	0.534265	0.662760
Water volume fraction =		0.45	0.34	0.33	0.22	0.21	0.02
H	1001.50C	0.050362	0.038051	0.036932	0.024621	0.023502	0.002238
O	8016.50C	0.399638	0.301949	0.293068	0.195379	0.186498	0.017762
H(total)	1001.50C	0.058231	0.047494	0.046518	0.035781	0.034805	0.016259
O(total)	8016.50C	1.083810	1.122955	1.126514	1.165658	1.169217	1.236831
Density =		4.894	5.673	5.744	6.522	6.593	7.938

Table 7.2-4 (cont.) Soddyite, Plutonium Oxide, Water Mixture Elemental Densities

Element	MCNP.ID	Elemental Density, g/cm^3	
Soddyite volume fraction =		0.087425	0.10875
^{235}U	92235.50C	0.291711	0.362867
Si	14000.50C	0.017429	0.021680
H	1001.50C	0.002502	0.003112
O	8016.50C	0.099256	0.123467
PuO_2 volume fraction =		0.087425	0.10875
^{239}Pu	94239.55C	0.883642	1.099183
O	8016.50C	0.118248	0.147092
Water volume fraction =		0.82515	0.7825
H	1001.50C	0.092347	0.087573
O	8016.50C	0.732803	0.694927
H(total)	1001.50C	0.094848	0.090685
O(total)	8016.50C	0.950308	0.965485
density =		2.238	2.540

7.3 MCNP Results for Fissile Mixtures with Water

The results for various fracture contents and widths are provided in this section for fissile mixtures with water. The results are categorized by fracture width and fracture content.

7.3.1 Results for 0.1 cm Fracture Width

Tables 7.3-1, 7.3-2, and 7.3-3 list the results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide for fracture widths of 0.1 cm. The evaluation of the 50/50 mixture of soddyite and plutonium oxide in water provides results bracketed by those of soddyite and plutonium oxide. The tables cover a range of water volume fractions in the tuff for the fissile volume fractions required for a k_{eff} of 0.93. The results are fairly consistent for each fissile material with the volume fraction increasing as the amount of water in the tuff decreases. For soddyite they range from 3.1% to 3.8%, for plutonium oxide they range from .57% to .64% and for the 50/50 mixture of soddyite and plutonium oxide they range from .96% to 1.08%.

Table 7.3-1 Soddyite MCNP Results in 0.1 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.030	9.68	p87s03.o	0.9164	0.0021	0.0036	571.1
0.031	10.00	p87s031.o	0.9270	0.0014	0.0036	553.9
0.0312	10.07	**linear interpolation**	**0.9300**	-	-	-
0.032	10.33	p87s032.o	0.9398	0.0018	0.0037	535.7
0.040	12.91	p87s04.o	1.0266	0.0015	0.0044	426.8
8 Volume Percent Interstitial Water in Tuff						
0.030	9.68	p92s03.o	0.9023	0.0020	0.0039	449.2
0.0322	10.39	**linear interpolation**	**0.9300**	-	-	-
0.034	10.97	p92s034.o	0.9536	0.0020	0.0042	395.3
0.035	11.29	p92s035.o	0.9571	0.0020	0.0046	384.8
0.040	12.91	p92s04.o	1.0089	0.0017	0.0051	335.4
4 Volume Percent Interstitial Water in Tuff						
0.030	9.68	p96s03.o	0.8817	0.0019	0.0048	351.9
0.0347	11.20	**linear interpolation**	**0.9300**	-	-	-
0.035	11.29	p96s035.o	0.9322	0.0018	0.0053	301.2
0.040	12.91	p96s04.o	0.9818	0.0026	0.0054	262.4
0.050	16.13	p96s05.o	1.0592	0.0026	0.0064	209.0
0 Volume Percent Interstitial Water in Tuff						
0.030	9.68	p100s03.o	0.8527	0.0019	0.0054	254.7
0.0380	12.26	**linear interpolation**	**0.9300**	-	-	-
0.040	12.91	p100s04.o	0.9491	0.0021	0.0060	189.6
0.050	16.13	p100s05.o	1.0157	0.0020	0.0070	150.7

Table 7.3-2 Plutonium Oxide MCNP Results in 0.1 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.005	4.89	p87p005.o	0.8783	0.0016	0.0032	1161.0
0.0057	5.57	**linear interpolation**	**0.9300**			
0.006	5.86	p87p006.o	0.9522	0.0020	0.0038	963.5
0.010	9.77	p87p01.o	1.1388	0.0018	0.0056	579.9
8 Volume Percent Interstitial Water in Tuff						
0.005	4.89	p92p005.o	0.8719	0.0020	0.0039	915.2
0.0058	5.67	**linear interpolation**	**0.9300**			
0.006	5.86	p92p006.o	0.9434	0.0019	0.0042	759.5
0.010	9.77	p92p01.o	1.1184	0.0020	0.0057	456.9
4 Volume Percent Interstitial Water in Tuff						
0.005	4.89	p96p005.o	0.8631	0.0018	0.0043	718.9
0.006	5.86	p96p006.o	0.9279	0.0023	0.0049	596.4
0.00604	5.90	**linear interpolation**	**0.9300**			
0.007	6.84	p96p007.o	0.9793	0.0025	0.0048	512.4
0.010	9.77	p96p01.o	1.0927	0.0020	0.0066	358.6
0 Volume Percent Interstitial Water in Tuff						
0.005	4.89	p100p005.o	0.8491	0.0016	0.0046	522.9
0.006	5.86	p100p006.o	0.9129	0.0016	0.0054	433.7
0.0064	6.26	**linear interpolation**	**0.9300**			
0.007	6.84	p100p007.o	0.9584	0.0017	0.0060	372.5
0.010	9.77	p100p01.o	1.0634	0.0016	0.0070	260.5

Table 7.3-3 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.1 cm Wide Fracture						
Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.009	5.85	p87sp009.o	0.9061	0.0025	0.0034	969.8
0.0096	6.24	**linear interpolation**	**0.9300**	-	-	-
0.010	6.50	p87sp01.o	0.9483	0.0013	0.0038	867.0
0.020	13.00	p87sp02.o	1.1945	0.0024	0.0061	431.7
8 Volume Percent Interstitial Water in Tuff						
0.009	5.85	p92sp009.o	0.8989	0.0020	0.0036	764.2
0.0099	6.44	**linear interpolation**	**0.9300**	-	-	-
0.010	6.50	p92sp01.o	0.9329	0.0018	0.0041	683.2
0.020	13.00	p92sp02.o	1.1641	0.0015	0.0071	339.8
4 Volume Percent Interstitial Water in Tuff						
0.010	6.50	p96sp01.o	0.9207	0.0022	0.0043	536.3
0.0102	6.63	**linear interpolation**	**0.9300**	-	-	-
0.011	7.15	p96sp011.o	0.9590	0.0019	0.0049	487.4
0.012	7.80	p96sp012.o	0.9856	0.0018	0.0051	446.6
0.020	13.00	p96sp02.o	1.1336	0.0017	0.0075	266.4
0 Volume Percent Interstitial Water in Tuff						
0.010	6.50	p100sp01.o	0.9042	0.0022	0.0051	389.7
0.0108	7.02	**linear interpolation**	**0.9300**	-	-	-
0.011	7.15	p100sp0a.o	0.9351	0.0021	0.0060	354.1
0.016	10.40	p100sp0f.o	1.0467	0.0020	0.0073	242.7

7.3.2 Results for 0.01 cm Fracture Width

Tables 7.3-4, 7.3-5, and 7.3-6 list the results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide for fracture widths of 0.01 cm. The tables cover a range of fissile mixtures with water and water in the tuff matrix.

The results for soddyite, Table 7.3-4, show a range of k_{eff} values from about 0.48 to 1.20 as the amount of soddyite increase from a volume fraction of 10% to 90% for a water volume fraction of 13% in the tuff. A similar range is seen for 8% and 4% water volume in the tuff with slightly lower k_{eff} values. For no water in the tuff, the k_{eff}'s are considerably lower, but the general trend is the same. To obtain a value of k_{eff} of 0.93, volume fractions about 0.355, 0.438 and 0.722 are required for tuff with 13%, 8% and 4% volume fraction water, respectively. For no water in the tuff, the maximum value of k_{eff} is about 0.705.

For plutonium oxide, the general trend is the same (see Table 7.3-5); however, the values of k_{eff} are significantly higher. They range from about 0.92 to 1.37 for 13% water, 0.91 to 1.28 for 8% water and 0.90 to 1.15 for 4% water. For no water in the tuff, the results are significantly lower. Volume fractions of about 0.062, 0.074 and 0.113 are required to produce a k_{eff} of about 0.93 for tuff water volume fractions of 13%, 8% and 4%, respectively. The case with no water in the tuff has a k_{eff} below 0.93 with a maximum k_{eff} of about 0.923 for 92% plutonium oxide volume fraction in the fracture.

For 50/50 mixture of soddyite and plutonium oxide (see Table 7.3-6) the k_{eff} values range from about 0.91 to 1.34 for a tuff water volume percent of 13% with slightly smaller values for 8% and 4%. For no water in the tuff, the k_{eff} is significantly lower. The fissile mixture volume percent required for a 0.93 k_{eff} are about 0.105, 0.125 and 0.195 for 13%, 8% and 4% tuff water volume fractions, respectively. Without water in the tuff, no values approaching 0.93 are possible.

The trend of decreasing k_{eff} with decreasing water in the tuff could be caused by leakage through the reflector in the model. To assess this possibility, an additional evaluation examined the effect of water in the reflector. Models with a 50/50 mixture of soddyite and PuO_2 fissile volume fraction of 11% and a tuff water volume fraction of 13% in the reflector were evaluated. The results are shown in Table 7.3-7. As is noted, there is no significant k_{eff} change over the cases with 8% and 0% water in the reflector. The small change is about what would be expected for the slight change in fissile volume fraction for the 8% and 0% tuff water fractions. Thus, the trend is controlled by the water content of the tuff within the fracture zone rather than leakage from the region.

Table 7.3-4 Soddyite MCNP Results in 0.01 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	3.33	t87s10.o	0.4757	0.0010	0.0028	1082.4
0.35	11.64	t87s35.o	0.9228	0.0016	0.0051	305.0
0.355	11.81	**linear interpolation**	**0.9300**	-	-	-
0.36	11.97	t87s36.o	0.9363	0.0013	0.0053	296.3
0.50	16.63	t87s50.o	1.0438	0.0019	0.0067	211.7
0.90	29.93	t87s90.o	1.2018	0.0022	0.0105	115.0
8 Volume Percent Interstitial Water in Tuff						
0.10	3.33	t92s10.o	0.4496	0.0014	0.0033	693.5
0.438	14.57	**linear extrapolation**	**0.9300**	-	-	-
0.44	14.63	t92s44.o	0.9316	0.0020	0.0079	153.0
0.46	15.30	t92s46.o	0.9463	0.0025	0.0086	146.1
0.50	16.63	t92s50.o	0.9694	0.0021	0.0085	134.0
0.90	29.93	t92s90.o	1.1059	0.0024	0.0135	71.8
4 Volume Percent Interstitial Water in Tuff						
0.10	3.33	t96s10.o	0.4007	0.0010	0.0043	382.6
0.50	16.63	t96s50.o	0.8540	0.0020	0.0110	71.8
0.72	23.94	t96s72.o	0.9276	0.0027	0.0140	48.1
0.722	24.01	**linear interpolation**	**0.9300**	-	-	-
0.73	24.28	t96s73.o	0.9375	0.0026	0.0138	47.4
0.90	29.93	t96s90.o	0.9689	0.0023	0.0168	37.3
0 Volume Percent Interstitial Water in Tuff						
0.10	3.33	t100s10.o	0.2823	0.0010	0.0068	72.4
0.50	16.63	t100s50.o	0.6129	0.0019	0.0175	9.8
0.90	29.93	t100s90.o	0.7022	0.0018	0.0266	2.9
0.98	32.59	t100s98.o	0.7046	0.0024	0.0293	2.2

Table 7.3-5 Plutonium Oxide MCNP Results in 0.01 cm Wide Fracture						
Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.06	6.04	t87p06.o	0.9196	0.0020	0.0047	606.1
0.062	6.25	**linear interpolation**	**0.9300**	-	-	-
0.07	7.05	t87p07.o	0.9727	0.0017	0.0052	519.1
0.10	10.07	t87p10.o	1.0807	0.0024	0.0068	362.6
0.50	50.37	t87p50.o	1.3393	0.0023	0.0277	70.4
0.90	90.66	t87p90.o	1.3747	0.0024	0.0483	38.0
8 Volume Percent Interstitial Water in Tuff						
0.07	7.05	t92p07.o	0.9149	0.0023	0.0066	332.6
0.074	7.45	**linear interpolation**	**0.9300**	-	-	-
0.08	8.06	t92p08.o	0.9556	0.0017	0.0073	290.7
0.10	10.07	t92p10.o	1.0118	0.0026	0.0081	232.1
0.50	50.37	t92p50.o	1.2381	0.0029	0.0331	44.3
0.90	90.66	t92p90.o	1.2805	0.0017	0.0602	23.4
4 Volume Percent Interstitial Water in Tuff						
0.10	10.07	t96p10.o	0.9034	0.0027	0.0109	127.8
0.11	11.08	t96p11.o	0.9257	0.0023	0.0113	115.9
0.113	11.38	**linear interpolation**	**0.9300**	-	-	-
0.12	12.09	t96p12.o	0.9419	0.0023	0.0123	106.0
0.50	50.37	t96p50.o	1.1080	0.0021	0.0410	23.4
0.90	90.66	t96p90.o	1.1533	0.0025	0.0738	11.9
0 Volume Percent Interstitial Water in Tuff						
0.10	10.07	t100p10.o	0.6697	0.0022	0.0162	23.6
0.50	50.37	t100p50.o	0.8625	0.0030	0.0630	2.6
0.90	90.66	t100p90.o	0.9162	0.0029	0.1054	0.3
0.91	91.67	t100p91.o	0.9230	0.0022	0.1074	0.3
0.92	92.68	t100p92.o	0.9234	0.0023	0.1081	0.2

Table 7.3-6 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.01 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	6.70	t87sp10.o	0.9111	0.0018	0.0047	543.4
0.105	7.03	**linear interpolation**	**0.9300**	-	-	-
0.11	7.37	t87sp11.o	0.9483	0.0019	0.0049	493.7
0.50	33.50	t87sp50.o	1.2907	0.0030	0.0173	105.9
0.90	60.30	t87sp90.o	1.3351	0.0023	0.0295	57.3
8 Volume Percent Interstitial Water in Tuff						
0.10	6.70	t92sp10.o	0.8589	0.0020	0.0054	348.0
0.12	8.04	t92sp12.o	0.9187	0.0024	0.0063	289.4
0.125	8.37	**linear interpolation**	**0.9300**	-	-	-
0.13	8.71	t92sp13.o	0.9427	0.0025	0.0070	266.9
0.50	33.50	t92sp50.o	1.1922	0.0023	0.0213	66.8
0.90	60.30	t92sp90.o	1.2339	0.0022	0.0375	35.6
4 Volume Percent Interstitial Water in Tuff						
0.10	6.70	t96sp10.o	0.7765	0.0021	0.0071	191.8
0.19	12.73	t96sp19.o	0.9247	0.0024	0.0116	99.3
0.195	13.06	**linear interpolation**	**0.9300**	-	-	-
0.20	13.40	t96sp20.o	0.9348	0.0020	0.0119	94.2
0.50	33.50	t96sp50.o	1.0561	0.0021	0.0266	35.6
0.90	60.30	t96sp90.o	1.0943	0.0039	0.0463	18.3
0 Volume Percent Interstitial Water in Tuff						
0.10	6.70	t100sp10.o	0.5819	0.0020	0.0112	35.9
0.50	33.50	t100sp50.o	0.7937	0.0028	0.0418	4.4
0.90	60.30	t100sp90.o	0.8419	0.0020	0.0692	94.0
0.94	62.98	t100sp94.o	0.8527	0.0016	0.0712	0.8
0.98	65.66	t100sp98.o	0.8533	0.0021	0.0732	0.6

Table 7.3-7 50/50 Mixture of Soddyite and Plutonium Oxide in 0.01 cm Wide Fracture with 11% Fissile Volume Fraction (7.37 kg Fissile Material)

Reflector H_2O Vol %	MCNP Case ID	Vol % H_2O Central Region	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
0	t87spy.o	13	0.9741	0.0019	0.0051	493.7
8	t87spx.o	13	0.9533	0.0019	0.0049	493.7
13	t87sp11.o	13	0.9483	0.0019	0.0049	493.7
0	t92spx.o	8	0.9210	0.0020	0.0061	316.4
8	t92sp11.o	8	0.8903	0.0020	0.0056	316.4
13	t92spy.o	8	0.8886	0.0022	0.0062	316.4

7.3.3 Results for 0.005 cm Fracture Width

The results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide mixtures filling a 0.005 cm fracture are listed in Tables 7.3-8, 7.3-9, and 7.3-10. The general trend of the data is similar to that for the 0.01 cm wide fracture with higher fissile volume fractions for the same k_{eff}.

Table 7.3-8 Soddyite MCNP Results in 0.005 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.50	8.33	n87s50.o	0.8008	0.0014	0.0048	415.3
0.71	11.83	n87s71.o	0.9283	0.0015	0.0057	290.7
0.714	11.89	**linear interpolation**	**0.9300**	-	-	-
0.72	11.99	n87s72.o	0.9325	0.0018	0.0055	286.6
0.90	14.99	n87s90.o	1.0087	0.0021	0.0064	228.1
8 Volume Percent Interstitial Water in Tuff						
0.50	8.33	n92s50.o	0.7427	0.0019	0.0055	259.1
0.899	14.97	**linear interpolation**	**0.9300**	-	-	-
0.90	14.99	n92s90.o	0.9305	0.0021	0.0078	141.4
4 Volume Percent Interstitial Water in Tuff						
0.50	8.33	n96s50.o	0.6475	0.0016	0.0071	134.4
0.90	14.99	n96s90.o	0.8085	0.0028	0.0102	72.1
0.98	16.32	n96s98.o	0.8227	0.0021	0.0106	65.7
0 Volume Percent Interstitial Water in Tuff						
0.50	8.33	n100s50.o	0.4266	0.0018	0.0132	9.8
0.90	14.99	n100s90.o	0.5390	0.0020	0.0180	2.9

Table 7.3-9 Plutonium Oxide MCNP Results in 0.005 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	5.05	n87p10.o	0.8479	0.0017	0.0046	704.4
0.12	6.05	n87p12.o	0.9143	0.0015	0.0051	586.4
0.125	6.31	**linear interpolation**	**0.9300**	-	-	-
0.13	6.56	n87p13.o	0.9448	0.0018	0.0055	541.2
0.50	25.23	n87p50.o	1.2646	0.0019	0.0149	138.8
0.90	45.41	n87p90.o	1.3231	0.0022	0.0252	75.9
8 Volume Percent Interstitial Water in Tuff						
0.10	5.05	n92p10.o	0.8006	0.0018	0.0051	442.2
0.15	7.57	n92p15.o	0.9259	0.0024	0.0075	293.9
0.152	7.67	**linear interpolation**	**0.9300**	-	-	-
0.16	8.07	n92p16.o	0.9484	0.0019	0.0074	275.4
0.50	25.23	n92p50.o	1.1598	0.0026	0.0172	86.3
0.90	45.41	n92p90.o	1.2151	0.0029	0.0306	46.8
4 Volume Percent Interstitial Water in Tuff						
0.10	5.05	n96p10.o	0.7194	0.0017	0.0067	232.7
0.26	13.12	n96p26.o	0.9289	0.0020	0.0137	87.9
0.262	13.22	**linear interpolation**	**0.9300**	-	-	-
0.27	13.62	n96p27.o	0.9342	0.0019	0.0140	84.5
0.50	25.23	n96p50.o	1.0176	0.0023	0.0230	44.4
0.90	45.41	n96p90.o	1.0716	0.0024	0.0397	23.5
0 Volume Percent Interstitial Water in Tuff						
0.50	25.23	n100p50.o	0.7207	0.0021	0.0372	2.6
0.90	45.41	n100p90.o	0.7892	0.0028	0.0624	0.3

Table 7.3-10 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.005 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	3.36	n87sp10.o	0.6478	0.0014	0.0034	1055.0
0.21	7.05	n87sp21.o	0.92319	0.00184	0.0052	500.6
0.214	7.18	**linear interpolation**	**0.93**	-	-	-
0.22	7.38	n87sp22.o	0.94253	0.00200	0.0051	477.6
0.50	16.78	n87sp50.o	1.17436	0.00234	0.0098	208.3
0.90	30.20	n87sp90.o	1.27168	0.00221	0.0160	114.2
8 Volume Percent Interstitial Water in Tuff						
0.10	3.36	n92sp10.o	0.62067	0.00173	0.0037	662.5
0.25	8.39	n92sp25.o	0.91879	0.00166	0.0073	263.1
0.258	8.66	**linear interpolation**	**0.93**	-	-	-
0.26	8.72	n92sp26.o	0.93330	0.00216	0.0082	252.7
0.50	16.78	n92sp50.o	1.08224	0.00283	0.0118	129.8
0.90	30.20	n92sp90.o	1.16276	0.00260	0.0202	70.6
4 Volume Percent Interstitial Water in Tuff						
0.10	3.36	n96sp10.o	0.56314	0.00160	0.0053	348.9
0.44	14.76	n96sp44.o	0.92732	0.00220	0.0137	76.6
0.444	14.90	**linear interpolation**	**0.93**	-	-	-
0.45	15.10	n96sp45.o	0.93410	0.00231	0.0135	74.9
0.50	16.78	n96sp50.o	0.95194	0.00228	0.0151	67.0
0.90	30.20	n96sp90.o	1.01926	0.00224	0.0257	35.7
0 Volume Percent Interstitial Water in Tuff						
0.50	16.78	n100sp50.o	0.65109	0.00194	0.0262	4.4
0.90	30.20	n100sp90.o	0.72542	0.00147	0.0407	0.9

7.3.4 Results for 0.002 cm Fracture Width

For the 0.002 cm fracture width only plutonium oxide and a 50/50 mixture of soddyite and plutonium oxide cases were evaluated. Further, for these cases only the conditions for a tuff water fraction of 0.13, 0.08 and 0.04 and fissile volume fractions of 0.5 and 0.9 were evaluated. Results for these cases are listed in Tables 7.3-11 and 7.3-12. Due to lower possible fissile mass in the fracture, a significant reduction in k_{eff} is noted.

Table 7.3-11 Plutonium Oxide MCNP Results in 0.002 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.31	6.26	h87p31.o	0.9204	0.0018	0.0050	555.3
0.317	6.40	**linear interpolation**	**0.9300**	-	-	-
0.32	6.46	h87p32.o	0.9341	0.0021	0.0055	537.9
0.50	10.10	h87p50.o	1.0684	0.0018	0.0072	343.3
0.90	18.18	h87p90.o	1.2098	0.0023	0.0109	189.6
8 Volume Percent Interstitial Water in Tuff						
0.38	7.68	h92p38.o	0.9232	0.0021	0.0074	279.9
0.388	7.84	**linear interpolation**	**0.9300**	-	-	-
0.39	7.88	h92p39.o	0.9320	0.0022	0.0078	272.6
0.50	10.10	h92p50.o	0.9938	0.0026	0.0093	212.1
0.90	18.18	h92p90.o	1.1073	0.0022	0.0144	116.7
4 Volume Percent Interstitial Water in Tuff						
0.50	10.10	h96p50.o	0.8719	0.0022	0.0121	107.3
0.72	14.54	h96p72.o	0.9273	0.0027	0.0151	73.7
0.723	14.61	**linear interpolation**	**0.9300**	-	-	-
0.73	14.75	h96p73.o	0.9358	0.0025	0.0151	72.6
0.90	18.18	h96p90.o	0.9575	0.0021	0.0174	58.4

Table 7.3-12 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.002 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.50	6.72	h87sp50.o	0.9055	0.0019	0.0049	514.5
0.54	7.25	h87sp54.o	0.9285	0.0017	0.0048	476.1
0.541	7.27	**linear interpolation**	**0.9300**	-	-	-
0.55	7.39	h87sp55.o	0.9404	0.0023	0.0050	467.4
0.90	12.09	h87sp90.o	1.0869	0.0021	0.0073	284.3
8 Volume Percent Interstitial Water in Tuff						
0.50	6.72	h92sp50.o	0.8511	0.0021	0.0064	318.0
0.66	8.87	h92sp66.o	0.9290	0.0028	0.0078	240.1
0.662	8.89	**linear interpolation**	**0.9300**	-	-	-
0.67	9.00	h92sp67.o	0.9345	0.0021	0.0078	236.5
0.90	12.09	h92sp90.o	1.0055	0.0023	0.0093	175.2
4 Volume Percent Interstitial Water in Tuff						
0.50	6.72	h96sp50.o	0.7514	0.0024	0.0078	161.1
0.90	12.09	h96sp90.o	0.8775	0.0025	0.0121	88.0
0.98	13.17	h96sp98.o	0.8960	0.0031	0.0126	80.5

7.3.5 Results for 0.001 cm Fracture Width

For a further reduction in the fracture width, 0.001 cm, with 13%, 8% and 4% water in the tuff a further reduction in k_{eff} is noted as shown in Tables 7.3-13 and 7.3-14.

Table 7.3-13 Plutonium Oxide MCNP Results in 0.001 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.63	6.37	k87p63.o	0.9234	0.0020	0.0053	542.8
0.638	6.45	**linear interpolation**	**0.9300**	-	-	-
0.64	6.47	k87p64.o	0.9323	0.0020	0.0052	534.3
0.90	9.09	k87p90.o	1.0399	0.0023	0.0069	379.2
8 Volume Percent Interstitial Water in Tuff						
0.78	7.88	k92p78.o	0.9258	0.0022	0.0075	269.6
0.784	7.92	**linear interpolation**	**0.9300**	-	-	-
0.79	7.98	k92p79.o	0.9350	0.0019	0.0071	266.1
0.90	9.09	k92p90.o	0.9646	0.0019	0.0084	233.3
4 Volume Percent Interstitial Water in Tuff						
0.90	9.09	k96p90.o	0.8464	0.0020	0.0106	116.7
0.98	9.90	k96p98.o	0.8601	0.0023	0.0111	106.9

Table 7.3-14 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.001 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.90	6.05	k87sp90.o	0.8640	0.0017	0.0047	568.3
0.98	6.59	k87sp98.o	0.8999	0.0020	0.0051	521.6
8 Volume Percent Interstitial Water in Tuff						
0.90	6.05	k92sp90.o	0.8115	0.0020	0.0065	349.8
0.98	6.59	k92sp98.o	0.8417	0.0016	0.0059	320.9
4 Volume Percent Interstitial Water in Tuff						
0.90	6.05	k96sp90.o	0.7145	0.0017	0.0077	175.2
0.98	6.59	k96sp98.o	0.7392	0.0024	0.0086	160.6

7.3.6 K_{eff} as a Function of Fracture Width

The results listed in the previous tables allow trending of the k_{eff} as a function of fracture width for plutonium oxide and a 50/50 mixture of soddyite and plutonium oxide for 90 volume percent fissile material in water and 13 volume percent water in the tuff. Table 7.3-15 lists the k_{eff} as a function of the fracture width. The trend of the data is illustrated in Figure 7.3-1. For the 50/50 mixture of soddyite and plutonium oxide, a fracture width of about 0.0013 cm is required to obtain a k_{eff} of 0.93. Due to the slope of the PuO_2 curve no estimate is made for the thickness required for a k_{eff} of 0.93 for plutonium oxide.

Table 7.3-15 Plutonium Oxide and 50/50 Mixture of Soddyite/PuO_2 MCNP Results As a Function of Fracture Width for 90 Volume Percent Fissile Material and 13 Volume Percent Water in Tuff

Fracture Width (cm)	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ
		Plutonium Oxide		
0.001	9.09	k87p90.o	1.03986	0.00230
0.002	18.18	h87p90.o	1.20977	0.00228
0.005	45.41	n87p90.o	1.32308	0.00218
0.010	90.66	t87p90.o	1.37472	0.00238
		50/50 Mixture of Soddyite/Plutonium Oxide		
0.001	6.05	k87sp90.o	0.86399	0.00166
0.0013	-	**linear interpolation**	**0.93**	-
0.002	12.09	h87sp90.o	1.08692	0.00208
0.005	30.20	n87sp90.o	1.27168	0.00221
0.010	60.30	t87sp90.o	1.33505	0.00232

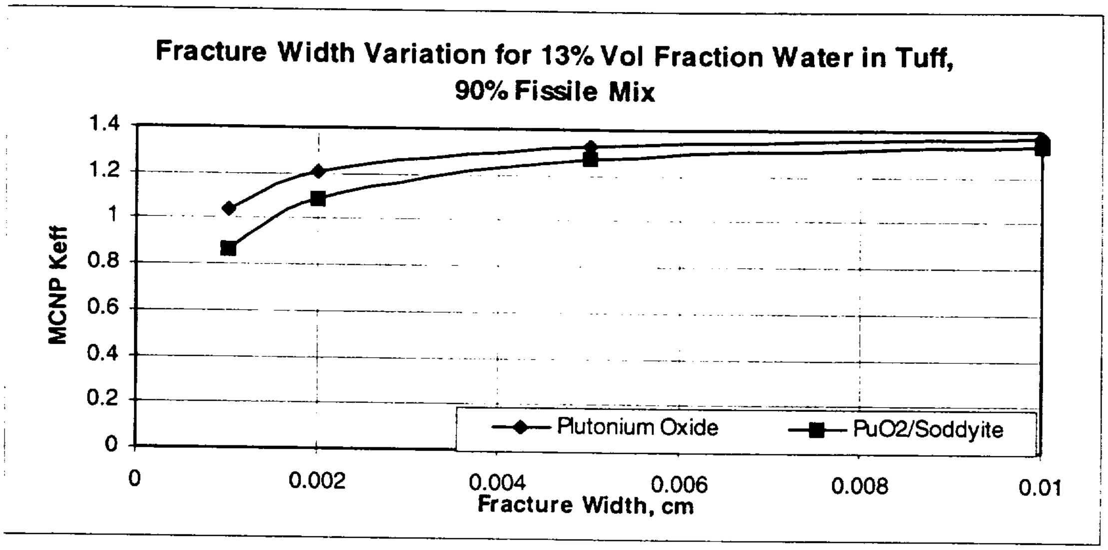

Figure 7.3-1 K_{eff} as a Function of Fracture Width

7.3.7 Fissile Weight Evaluations for a k_{eff} of 0.93

The criticality safety criterion can be satisfied with a maximum k_{eff} from MCNP of about 0.93. This section presents an evaluation that determines the k_{eff} of fissile masses of both plutonium oxide and a 50/50 mixture of soddyite and plutonium oxide for a total fissile mass equal to the mass of soddyite that produces a k_{eff} of 0.93.

Table 7.3-16 lists results from a series of cases that examined an equivalent mass of fissile material. The fissile mass of plutonium oxide and the 50/50 mixture of soddyite and plutonium oxide was set equal to the mass of ^{235}U required to give a k_{eff} of 0.93 (from linear interpolation) in tuff with both 13 and 8 volume percent interstitial water. As seen from the table, the equivalent mass of plutonium oxide is more reactive by about 19% or 16% Δk_{eff} for tuff with 13 and 8 volume fraction interstitial water, respectively. The 50/50 mixture of soddyite and plutonium oxide has Δk_{eff} values about 3% less than for the plutonium oxide mixture. Based upon these results, plutonium oxide mixtures provide the bounding material for the three fissile mixtures examined in this evaluation.

Table 7.3-16 K_{eff} for Equal Fissile Masses, 0.01 cm Fracture Width

Material	Fissile Volume Fraction	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ
13 Volume Percent Interstitial Water in Tuff					
Soddyite	0.3520	11.71	Estimated	0.93	-
Plutonium	0.1162	11.71	t87pue.o	1.12427	0.00192
Mixture	0.17485	11.71	t87spue.o	1.09043	0.00174
8 Volume Percent Interstitial Water in Tuff					
Soddyite	0.4380	14.57	Estimated	0.93	-
Plutonium	0.1446	14.57	t92pue.o	1.09287	0.00231
Mixture	0.2175	14.57	t92spue.o	1.06700	0.00222

7.4 MCNP Results for Fissile Mixtures with Clayey Material

The results for various fracture contents and widths are provided in this section for fissile mixtures with clayey material. The results are categorized by fracture width and fracture content.

7.4.1 Results for 0.1 cm Fracture Width

Tables 7.4-1, 7.4-2, and 7.4-3 list the results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide for fracture widths of 0.1 cm. The tables cover a range of water volume fractions in the tuff for the fissile volume fractions required for a k_{eff} of 0.93. The results for each fissile material show the volume fraction increasing as the amount of water in the tuff decreases. For soddyite they range from 3.89% to 27.1%, for plutonium oxide they range from .67% to 9.7% and for the 50/50 mixture of soddyite and plutonium oxide they range from 1.15% to 14.3%.

Table 7.4-1 Soddyite Results in 0.1 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.030	9.68	e87s03.o	0.8440	0.0020	0.0050	323.8
0.0389	12.55	**linear interpolation**	**0.9300**	-	-	-
0.039	12.58	e87s039.o	0.9310	0.0022	0.0056	249.1
0.040	12.91	e87s04.o	0.9428	0.0025	0.0058	243.5
0.100	32.27	e87s10.o	1.2023	0.0021	0.0111	98.0
8 Volume Percent Interstitial Water in Tuff						
0.040	12.91	e92s04.o	0.8716	0.0017	0.0071	150.9
0.0498	16.07	**linear interpolation**	**0.9300**	-	-	-
0.050	16.13	e92s05.o	0.9312	0.0018	0.0084	121.2
0.100	32.27	e92s10.o	1.1036	0.0022	0.0136	61.2
4 Volume Percent Interstitial Water in Tuff						
0.070	22.59	e96s07.o	0.8917	0.0021	0.0136	44.3
0.080	25.81	e96s08.o	0.9258	0.0028	0.0140	39.1
0.082	26.46	**linear interpolation**	**0.9300**	-	-	-
0.090	29.04	e96s09.o	0.9497	0.0027	0.0157	35.0
0.100	32.27	e96s10.o	0.9641	0.0020	0.0171	31.8
0.500	161.34	e96s50.o	1.2021	0.0024	0.0674	7.9
0 Volume Percent Interstitial Water in Tuff						
0.27	87.12	e100s27.o	0.9283	0.0023	0.0557	2.1
0.271	87.44	**linear interpolation**	**0.9300**	-	-	-
0.28	90.35	e100s28.o	0.9409	0.0026	0.0569	2.1
0.29	93.57	e100s29.o	0.9475	0.0020	0.0591	2.1
0.34	109.71	e100s34.o	0.9807	0.0024	0.0667	2.1
0.50	161.34	e100s50.o	1.0670	0.0031	0.0873	2.0

Table 7.4-2 Plutonium Oxide MCNP Results in 0.1 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.006	5.86	e87p006.o	0.8906	0.002	0.0049	558.0
0.0067	6.55	**linear interpolation**	**0.9300**	-	-	-
0.007	6.84	e87p007.o	0.9437	0.0017	0.0051	461.0
0.010	9.77	e87p01.o	1.0475	0.0024	0.0064	321.3
8 Volume Percent Interstitial Water in Tuff						
0.007	6.84	e92p007.o	0.8755	0.0027	0.0063	284.2
0.008	7.82	e92p008.o	0.9143	0.0022	0.0070	251.4
0.0085	8.31	**linear interpolation**	**0.9300**	-	-	-
0.009	8.80	e92p009.o	0.9434	0.0024	0.0082	225.4
0.010	9.77	e92p01.o	0.9664	0.0023	0.0086	198.1
0.020	19.55	e92p02.o	1.0993	0.0023	0.0152	99.0
4 Volume Percent Interstitial Water in Tuff						
0.010	9.77	e96p01.o	0.8446	0.0017	0.0106	99.7
0.016	15.64	e96p016.o	0.9286	0.0021	0.0153	62.1
0.0162	15.83	**linear interpolation**	**0.9300**	-	-	-
0.017	16.62	e96p017.o	0.9364	0.0028	0.0161	58.7
0.020	19.55	e96p02.o	0.9621	0.0021	0.0183	49.8
0.030	29.33	e96p03.o	1.0091	0.0024	0.0263	33.2
0 Volume Percent Interstitial Water in Tuff						
0.090	87.97	e100p09.o	0.9115	0.0023	0.1005	0.1
0.097	94.81	**linear interpolation**	**0.9300**	-	-	-
0.100	97.74	e100p10.o	0.9380	0.0022	0.1097	0.1
0.200	195.49	e100p20.o	1.0866	0.0028	0.1827	0.1

Table 7.4-3 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.1 cm Wide Fracture						
Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.010	6.50	e87sp01.o	0.8812	0.0017	0.0050	491.5
0.011	7.15	e87sp011.o	0.9145	0.0019	0.0050	438.8
0.0115	7.48	**linear interpolation**	**0.9300**	-	-	-
0.012	7.80	e87sp012.o	0.9422	0.0017	0.0051	410.0
0.020	13.00	e87sp02.o	1.0946	0.0023	0.0077	241.0
8 Volume Percent Interstitial Water in Tuff						
0.014	9.10	e92sp014.o	0.9225	0.0022	0.0068	217.1
0.0144	9.36	**linear interpolation**	**0.9300**	-	-	-
0.015	9.75	e92sp015.o	0.9407	0.0025	0.0080	199.9
0.020	13.00	e92sp02.o	1.0075	0.0020	0.0096	148.8
4 Volume Percent Interstitial Water in Tuff						
0.024	15.60	e96sp024.o	0.9114	0.0021	0.0143	62.8
0.0273	17.75	**linear interpolation**	**0.9300**	-	-	-
0.028	18.20	e96sp028.o	0.9339	0.0027	0.0171	54.1
0.030	19.50	e96sp03.o	0.9470	0.0024	0.0171	50.6
0.100	65.00	e96sp10.o	1.0908	0.0031	0.0487	15.4
0.200	130.01	e96sp20.o	1.1759	0.0026	0.0880	7.9
0 Volume Percent Interstitial Water in Tuff						
0.100	65.00	e100sp10.o	0.8668	0.0024	0.0703	0.7
0.140	91.01	e100sp14.o	0.9248	0.0027	0.0910	0.6
0.143	96.48	**linear interpolation**	**0.9300**	-	-	-
0.150	97.51	e100sp15.o	0.9397	0.0022	0.0947	0.6
0.160	104.01	e100sp16.o	0.9515	0.0024	0.0994	0.6

7.4.2 Results for 0.01 cm Fracture Width

Tables 7.4-4, 7.4-5, and 7.4-6 list the results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide for fracture widths of 0.01 cm. The tables cover a range of fissile mixtures with clayey material and water in the tuff matrix.

The results for soddyite (Table 7.4-4) show a range of k_{eff} values from about 0.47 to 1.20 as the amount of soddyite increases from a volume fraction of 10% to 90% for a water volume fraction of 13% in the tuff. A similar range is seen for 8% and 4% water volume in the tuff with slightly lower k_{eff} values. For no water in the tuff, the k_{eff}'s are considerably lower, but the general trend is the same. To obtain a value of k_{eff} of 0.93, volume fractions about 0.359, 0.455 and 0.7598 are required for tuff with 13%, 8% and 4% volume fraction water, respectively. For no water in the tuff, the maximum value of k_{eff} is about 0.703.

For plutonium oxide, the general trend is the same (see Table 7.4-5); however, the values of k_{eff} are significantly higher. They range from about .91 to 1.37 for 13% water, 0.90 to 1.28 for 8% water and 0.86 to 1.15 for 4% water. For no water in the tuff, the results are significantly lower. Volume fractions of about 0.064, 0.079 and 0.143 are required to produce a k_{eff} of about 0.93 for tuff water volume fractions of 13%, 8% and 4%, respectively. The case with no water in the tuff has a k_{eff} below 0.93 with a maximum k_{eff} of about 0.928 for 98% plutonium oxide volume fraction in the fracture.

The evaluation of the 50/50 mixture of soddyite and plutonium oxide in clayey material provides results bracketed by those of soddyite and plutonium oxide (see Table 7.4-6). The k_{eff} values range from about 0.90 to 1.34 for a tuff water volume percent of 13% with slightly smaller values for 8% and 4%. For no water in the tuff, the k_{eff} is significantly lower. The fissile mixture volume percent required for a 0.93 k_{eff} are about 0.109, 0.134 and 0.2403 for 13%, 8% and 4% tuff water volume fractions, respectively. Without water in the tuff, no values approaching 0.93 are possible.

Table 7.4-4 Soddyite MCNP Results in 0.01 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	3.33	a87s10.o	0.4674	0.0012	0.0029	1018.8
0.35	11.64	a87s35.o	0.9152	0.0022	0.0049	291.0
0.359	11.94	**linear interpolation**	**0.9300**	-	-	-
0.36	11.97	a87s36.o	0.9323	0.0015	0.0054	282.7
0.50	16.63	a87s50.o	1.0397	0.0021	0.0071	204.1
0.90	29.93	a87s90.o	1.1977	0.0018	0.0108	114.2
8 Volume Percent Interstitial Water in Tuff						
0.10	3.33	a92s10.o	0.4387	0.0012	0.0035	627.4
0.45	14.97	a92s45.o	0.9248	0.0022	0.0077	140.2
0.455	15.13	**linear interpolation**	**0.9300**	-	-	-
0.46	15.30	a92s46.o	0.9354	0.0030	0.0087	137.1
0.50	16.63	a92s50.o	0.9553	0.0021	0.0082	126.3
0.90	29.93	a92s90.o	1.1013	0.0026	0.0132	71.0
4 Volume Percent Interstitial Water in Tuff						
0.10	3.33	a96s10.o	0.3783	0.0010	0.0045	314.6
0.50	16.63	a96s50.o	0.8305	0.0024	0.0111	64.1
0.75	24.94	a96s75.o	0.9231	0.0031	0.0147	43.4
0.7598	25.27	**linear interpolation**	**0.9300**	-	-	-
0.76	25.27	a96s76.o	0.9301	0.0026	0.0151	42.8
0.90	29.93	a96s90.o	0.9627	0.0025	0.0166	36.5
0 Volume Percent Interstitial Water in Tuff						
0.10	3.33	a100s10.o	0.2281	0.0007	0.0092	2.4
0.50	16.63	a100s50.o	0.5570	0.0015	0.0195	2.0
0.90	29.93	a100s90.o	0.6876	0.0017	0.0284	2.0
0.98	32.59	a100s98.o	0.7034	0.0020	0.0297	2.0

Table 7.4-5 Plutonium Oxide MCNP Results in 0.01 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.06	6.04	a87p06.o	0.9068	0.0016	0.0050	567.1
0.064	6.45	**linear interpolation**	**0.9300**	-	-	-
0.07	7.05	a87p07.o	0.9603	0.0020	0.0061	486.1
0.10	10.07	a87p10.o	1.0706	0.0018	0.0079	339.3
0.50	50.37	a87p50.o	1.3301	0.0023	0.0280	67.8
0.90	90.66	a87p90.o	1.3731	0.0020	0.0495	37.7
8 Volume Percent Interstitial Water in Tuff						
0.07	7.05	a92p07.o	0.8960	0.0017	0.0066	299.0
0.079	7.96	**linear interpolation**	**0.9300**	-	-	-
0.08	8.06	a92p08.o	0.9330	0.0022	0.0075	260.6
0.10	10.07	a92p10.o	0.9916	0.0024	0.0088	208.7
0.50	50.37	a92p50.o	1.2239	0.0018	0.0342	41.7
0.90	90.66	a92p90.o	1.2755	0.0027	0.0601	23.3
4 Volume Percent Interstitial Water in Tuff						
0.10	10.07	a96p10.o	0.8625	0.0025	0.0114	104.3
0.14	14.10	a96p14.o	0.9253	0.0023	0.0146	74.6
0.143	14.41	**linear interpolation**	**0.9300**	-	-	-
0.15	15.11	a96p15.o	0.9391	0.0016	0.0150	69.5
0.50	50.37	a96p50.o	1.0807	0.0024	0.0432	20.8
0.90	90.66	a96p90.o	1.1519	0.0024	0.0730	11.6
0 Volume Percent Interstitial Water in Tuff						
0.10	10.07	a100p10.o	0.5524	0.0020	0.0202	0.1
0.50	50.37	a100p50.o	0.8018	0.0027	0.0665	0.0
0.90	90.66	a100p90.o	0.9094	0.0032	0.1085	0.0
0.98	98.72	a100p98.o	0.9278	0.0020	0.1126	0.0

Table 7.4-6 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.01 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	6.70	a87sp10.o	0.9019	0.0020	0.0050	510.0
0.109	7.30	**linear interpolation**	**0.9300**	-	-	-
0.11	7.37	a87sp11.o	0.9345	0.0016	0.0056	462.7
0.50	33.50	a87sp50.o	1.2837	0.0027	0.0174	102.0
0.90	60.30	a87sp90.o	1.3386	0.0024	0.0300	56.9
8 Volume Percent Interstitial Water in Tuff						
0.10	6.70	a92sp10.o	0.8441	0.0020	0.0062	313.8
0.13	8.71	a92sp13.o	0.9241	0.0021	0.0078	241.1
0.134	8.98	**linear interpolation**	**0.9300**	-	-	-
0.14	9.38	a92sp14.o	0.9404	0.0024	0.0079	223.6
0.50	33.50	a92sp50.o	1.1723	0.0025	0.0220	62.9
0.90	60.30	a92sp90.o	1.2326	0.0029	0.0366	35.2
4 Volume Percent Interstitial Water in Tuff						
0.10	6.70	a96sp10.o	0.7411	0.0016	0.0083	157.1
0.24	16.08	a96sp24.o	0.9297	0.0024	0.0153	65.6
0.2403	16.10	**linear interpolation**	**0.9300**	-	-	-
0.25	16.75	a96sp25.o	0.9383	0.0024	0.0152	62.9
0.50	33.50	a96sp50.o	1.0298	0.0024	0.0286	31.7
0.90	60.30	a96sp90.o	1.0942	0.0022	0.0458	17.8
0 Volume Percent Interstitial Water in Tuff						
0.10	6.70	a100sp10.o	0.4780	0.0014	0.0144	0.7
0.50	33.50	a100sp50.o	0.7353	0.0021	0.0456	0.5
0.90	60.30	a100sp90.o	0.8323	0.0024	0.0690	0.5
0.98	65.66	a100sp98.o	0.8507	0.0019	0.0720	0.5

7.4.3 Results for 0.005 cm Fracture Width

The results for soddyite, plutonium oxide, and a 50/50 mixture of soddyite and plutonium oxide mixtures with clayey material filling a 0.005 cm fracture are listed in Tables 7.4-7, 7.4-8, and 7.4-9. The general trend of the data is similar to that for the 0.01 cm wide fracture with lower k_{eff} values, as expected due to smaller possible masses of fissile material.

Table 7.4-7 Soddyite MCNP Results in 0.005 cm Wide Fracture

Fissile Vol Frac.	^{235}U Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.50	8.33	b87s50.o	0.7951	0.0017	0.0048	407.8
0.72	11.99	b87s72.o	0.9277	0.0021	0.0054	283.7
0.724	12.06	**linear interpolation**	**0.9300**	-	-	-
0.73	12.16	b87s73.o	0.9340	0.0019	0.0055	279.8
0.90	14.99	b87s90.o	1.0023	0.0021	0.0073	227.4
8 Volume Percent Interstitial Water in Tuff						
0.50	8.33	b92s50.o	0.7366	0.0015	0.0055	251.5
0.90	14.99	b92s90.o	0.9257	0.0024	0.0081	140.6
0.906	15.09	**linear interpolation**	**0.9300**	-	-	-
0.91	15.16	b92s91.o	0.9329	0.0021	0.0080	139.0
4 Volume Percent Interstitial Water in Tuff						
0.50	8.33	b96s50.o	0.6374	0.0015	0.0072	126.7
0.90	14.99	b96s90.o	0.8042	0.0023	0.0102	71.2
0.98	16.32	b96s98.o	0.8261	0.0021	0.0109	65.6
0 Volume Percent Interstitial Water in Tuff						
0.50	8.33	b100s50.o	0.4017	0.0014	0.0140	2.0
0.90	14.99	b100s90.o	0.5345	0.0017	0.0183	2.0

Table 7.4-8 Plutonium Oxide MCNP Results in 0.005 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	5.05	b87p10.o	0.8441	0.0018	0.0044	681.3
0.12	6.05	b87p12.o	0.9097	0.0020	0.0053	568.1
0.127	6.41	**linear interpolation**	**0.9300**	-	-	-
0.13	6.56	b87p13.o	0.9371	0.0022	0.0057	524.5
0.50	25.23	b87p50.o	1.2597	0.0024	0.0158	136.2
0.90	45.41	b87p90.o	1.3209	0.0021	0.0258	75.6
8 Volume Percent Interstitial Water in Tuff						
0.10	5.05	b92p10.o	0.7946	0.0023	0.0056	418.9
0.15	7.57	b92p15.o	0.9149	0.0017	0.0078	279.1
0.158	7.97	**linear interpolation**	**0.9300**	-	-	-
0.16	8.07	b92p16.o	0.9332	0.0024	0.0084	261.7
0.50	25.23	b92p50.o	1.1569	0.0021	0.0178	83.8
0.90	45.41	b92p90.o	1.2150	0.0024	0.0321	46.5
4 Volume Percent Interstitial Water in Tuff						
0.10	5.05	b96p10.o	0.7045	0.0022	0.0070	209.3
0.29	14.63	b96p29.o	0.9290	0.0021	0.0153	72.2
0.292	14.73	**linear interpolation**	**0.9300**	-	-	-
0.30	15.14	b96p30.o	0.9357	0.0020	0.0158	69.7
0.50	25.23	b96p50.o	1.0034	0.0024	0.0247	41.8
0.90	45.41	b96p90.o	1.0722	0.0026	0.0401	23.2
0 Volume Percent Interstitial Water in Tuff						
0.50	25.23	b100p50.o	0.6884	0.0018	0.0421	0.0
0.90	45.41	b100p90.o	0.7861	0.0019	0.0625	0.0

Table 7.4-9 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.005 cm Wide Fracture						
Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.10	3.36	b87sp10.o	0.6446	0.0015	0.0038	1023.3
0.21	7.05	b87sp21.o	0.9222	0.0023	0.0054	486.3
0.214	7.18	**linear interpolation**	**0.9300**	-	-	-
0.22	7.38	b87sp22.o	0.9402	0.0019	0.0054	463.9
0.50	16.78	b87sp50.o	1.1656	0.0021	0.0100	204.4
0.90	30.20	b87sp90.o	1.2679	0.0022	0.0162	113.8
8 Volume Percent Interstitial Water in Tuff						
0.10	3.36	b92sp10.o	0.6130	0.0015	0.0044	629.5
0.26	8.72	b92sp26.o	0.9226	0.0022	0.0074	241.8
0.267	8.96	**linear interpolation**	**0.9300**	-	-	-
0.27	9.06	b92sp27.o	0.9332	0.0020	0.0073	232.7
0.50	16.78	b92sp50.o	1.0727	0.0020	0.0129	125.9
0.90	30.20	b92sp90.o	1.1652	0.0025	0.0207	70.1
4 Volume Percent Interstitial Water in Tuff						
0.10	3.36	b96sp10.o	0.5496	0.0016	0.0054	314.8
0.47	15.77	b96sp47.o	0.9231	0.0023	0.0149	67.1
0.479	16.07	**linear interpolation**	**0.9300**	-	-	-
0.48	16.11	b96sp48.o	0.9307	0.0023	0.0146	65.8
0.50	16.78	b96sp50.o	0.9389	0.0021	0.0157	63.1
0.90	30.20	b96sp90.o	1.0166	0.0025	0.0262	35.3
0 Volume Percent Interstitial Water in Tuff						
0.50	16.78	b100sp50.o	0.6225	0.0016	0.0273	0.5
0.90	30.20	b100sp90.o	0.7189	0.0020	0.0415	0.5

7.4.4 Results for 0.002 cm Fracture Width

For the 0.002 cm fracture width only plutonium oxide and a 50/50 mixture of soddyite and plutonium oxide cases were evaluated. Further, for these cases only the conditions for a tuff water fraction of 0.13, 0.08 and 0.04 were evaluated. Results for these cases are listed in Tables 7.4-10 and 7.4-11. Due to lower possible fissile mass in the fracture, a significant reduction in k_{eff} is noted.

Table 7.4-10 Plutonium Oxide MCNP Results in 0.002 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.31	6.26	c87p31.o	0.9192	0.0021	0.0052	549.7
0.319	6.44	**linear interpolation**	**0.9300**	-	-	-
0.32	6.46	c87p32.o	0.9311	0.0018	0.0054	532.6
0.50	10.10	c87p50.o	1.0736	0.0021	0.0073	340.8
0.90	18.18	c87p90.o	1.2078	0.0017	0.0121	189.2
8 Volume Percent Interstitial Water in Tuff						
0.40	8.08	c92p40.o	0.9295	0.0026	0.0071	262.0
0.4004	8.09	**linear interpolation**	**0.9300**	-	-	-
0.41	8.28	c92p41.o	0.9410	0.0020	0.0076	255.5
0.50	10.10	c92p50.o	0.9928	0.0023	0.0085	209.6
0.90	18.18	c92p90.o	1.1064	0.0020	0.0143	116.4
4 Volume Percent Interstitial Water in Tuff						
0.50	10.10	c96p50.o	0.8637	0.0024	0.0118	104.7
0.72	14.54	c96p72.o	0.9285	0.0035	0.0150	72.7
0.722	14.59	**linear interpolation**	**0.9300**	-	-	-
0.73	14.75	c96p73.o	0.9372	0.0018	0.0156	71.7
0.90	18.18	c96p90.o	0.9583	0.0021	0.0190	58.1

Table 7.4-11 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.002 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.50	6.72	c87sp50.o	0.9027	0.0016	0.0053	510.6
0.53	7.12	c87sp53.o	0.9278	0.0016	0.0054	481.9
0.533	7.16	**linear interpolation**	**0.9300**	-	-	-
0.54	7.25	c87sp54.o	0.9348	0.0018	0.0050	472.8
0.90	12.09	c87sp90.o	1.0892	0.0022	0.0078	283.9
8 Volume Percent Interstitial Water in Tuff						
0.50	6.72	c92sp50.o	0.8463	0.0023	0.0061	314.2
0.65	8.73	c92sp65.o	0.9269	0.0022	0.0073	241.9
0.658	8.84	**linear interpolation**	**0.9300**	-	-	-
0.66	8.87	c92sp66.o	0.9309	0.0018	0.0073	238.2
0.90	12.09	c92sp90.o	1.0047	0.0021	0.0090	174.8
4 Volume Percent Interstitial Water in Tuff						
0.50	6.72	c96sp50.o	0.7416	0.0024	0.0085	157.2
0.90	12.09	c96sp90.o	0.8761	0.0018	0.0127	87.6
0.98	13.17	c96sp98.o	0.8936	0.0026	0.0124	80.4

7.4.5 Results for 0.001 cm Fracture Width

For a further reduction in the fracture width, 0.001 cm, with 13%, 8% and 4% water in the tuff, a further reduction in k_{eff} is noted as shown in Tables 7.4-12 and 7.4-13 for these cases.

Table 7.4-12 Plutonium Oxide MCNP Results in 0.001 cm Wide Fracture

Fissile Vol Frac.	^{239}Pu Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.64	6.47	d87p64.o	0.9288	0.0017	0.0054	532.8
0.641	6.48	**linear interpolation**	**0.9300**	-	-	-
0.65	6.57	d87p65.o	0.9387	0.0018	0.0051	524.7
0.90	9.09	d87p90.o	1.0494	0.0017	0.0069	378.9
8 Volume Percent Interstitial Water in Tuff						
0.70	7.07	d92p78.o	0.9005	0.0024	0.0074	299.7
0.785	7.93	**linear interpolation**	**0.9300**	-	-	-
0.79	7.98	d92p79.o	0.9318	0.0023	0.0073	265.4
0.90	9.09	d92p90.0	0.9685	0.0022	0.0087	232.9
4 Volume Percent Interstitial Water in Tuff						
0.90	9.09	d96p90.o	0.8462	0.0024	0.0103	116.4
0.98	9.90	d96p98.o	0.8631	0.0020	0.0112	106.9

Table 7.4-13 50/50 Mixture of Soddyite and Plutonium Oxide MCNP Results in 0.001 cm Wide Fracture

Fissile Vol Frac.	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ	Average Energy of Fission (MeV)	H/X Ratio
13 Volume Percent Interstitial Water in Tuff						
0.90	6.05	d87sp90.o	0.8645	0.0018	0.0052	567.9
0.98	6.59	d87sp98.o	0.8946	0.0015	0.0050	521.6
8 Volume Percent Interstitial Water in Tuff						
0.90	6.05	d92sp90.o	0.8097	0.0017	0.0057	349.4
0.98	6.59	d92sp98.o	0.8387	0.0020	0.0062	320.9
4 Volume Percent Interstitial Water in Tuff						
0.90	6.05	d96sp90.o	0.7180	0.0017	0.0074	174.8
0.98	6.59	d96sp98.o	0.7393	0.0018	0.0078	160.6

7.4.6 K_{eff} as a Function of Fracture Width

The results listed in the previous tables allow trending of the k_{eff} as a function of fracture width for plutonium oxide and a 50/50 mixture of soddyite and plutonium oxide for 90 volume percent fissile material in clayey material and 13 volume percent water in the tuff. Table 7.4-14 lists the k_{eff} as a function of the fracture width. For the 50/50 mixture of soddyite and plutonium oxide, a fracture width of about 0.0013 cm is required to obtain a k_{eff} of 0.93. Due to the slope of the PuO_2 curve no estimate is made for the thickness required for a k_{eff} of 0.93 for plutonium oxide.

Table 7.4-14 Plutonium Oxide and 50/50 of Mixture Soddyite/PuO_2 MCNP Results As a Function of Fracture Width for 90 Volume Percent Fissile Material and 13 Volume Percent Water in Tuff

Fracture Width	Fissile Mass, Kg	MCNP Case ID	k_{eff}	σ
Plutonium Oxide				
0.001	9.09	d87p90.o	1.04943	0.00166
0.002	18.18	c87p90.o	1.20775	0.00168
0.005	45.41	b87p90.o	1.32091	0.00211
0.010	90.66	a87p90.o	1.37312	0.00201
50/50 Mixture of Soddyite and Plutonium Oxide				
0.001	6.05	d87sp90.o	0.86451	0.00184
0.0013	-	**linear interpolation**	**0.93**	-
0.002	12.09	c87sp90.o	1.08915	0.00224
0.005	30.20	b87sp90.o	1.26786	0.00219
0.010	60.30	a87sp90.o	1.33863	0.00242

8. Conclusions

The tables in the previous sections provide the k_{eff} results for the fissile material as a function of fracture width or fissile concentration. In addition, an estimate of the fissile volume fraction and weight that would produce a k_{eff} of 0.93 is tabulated based on linear interpolation. These interpolated values are gathered and listed in Tables 8-1 and 8-2 as a function of spacing and material. The trend of the data indicates that the volume fraction of fissile material is inversely proportional to the fracture width by almost a constant factor, i.e. the volume fraction approximately doubles for a reduction in the width by a factor of 2. Stated another way, the fissile mass to produce a k_{eff} of 0.93 essentially remains constant for a given material. For uranium, the required weight seems almost constant with small deviations probably due to the statistical nature of the results and linear interpolation. However, for the materials containing plutonium, there seems to be a slight increase in mass as the fissile volume fraction increases. This may also be due to statistics and interpolation. However, since the trend is followed for four sets of data, it is probably related to either the fissile mass increase or the decrease in the hydrogen content of the fissile material.

Other observations that can be made from this data are:

1) soddyite is the least reactive fissile material and plutonium oxide is the most reactive
2) the results for fissile mixtures with water and fissile mixtures with clayey material are very similar
3) the fissile volume fraction increases as the amount of water in the tuff decreases

Table 8-1 0.93 K_{eff} Fissile Volume Fractions and Weights MCNP Results for Fissile Mixtures with Water

Fracture Width, cm	13% Water VF in Tuff			8% Water VF in Tuff			4% Water VF in Tuff		
	Soddyite	PuO_2	Mixture	Soddyite	PuO_2	Mixture	Soddyite	PuO_2	Mixture
	Fissile Volume Fraction			Fissile Volume Fraction			Fissile Volume Fraction		
0.100	0.0312	0.0057	0.0096	0.0322	0.0058	0.0099	0.0347	0.00604	0.0102
0.010	0.355	0.062	0.105	0.438	0.074	0.125	0.722	0.113	0.195
0.005	0.714	0.125	0.214	0.899	0.152	0.258	-	0.262	0.444
0.002	-	0.317	0.541	-	0.388	0.662	-	0.723	-
0.001	-	0.638	-	-	0.784	-	-	-	-
	Fissile Weight, Kg			Fissile Weight, Kg			Fissile Weight, Kg		
0.100	10.07	5.57	6.24	10.39	5.67	6.44	11.20	5.90	6.63
0.010	11.81	6.25	7.03	14.57	7.45	8.37	24.01	11.38	13.06
0.005	11.89	6.31	7.18	14.97	7.67	8.66	-	13.22	14.90
0.002	-	6.40	7.27	-	7.84	8.89	-	14.61	-
0.001	-	6.45	-	-	7.92	-	-	-	-

Table 8-2 0.93 K_{eff} Fissile Volume Fractions and Weights
MCNP Results for Fissile Mixtures with Clayey Material

Fracture Width, cm	13% Water VF in Tuff			8% Water VF in Tuff			4% Water VF in Tuff		
	Soddyite	PuO_2	Mixture	Soddyite	PuO_2	Mixture	Soddyite	PuO_2	Mixture
	Fissile Volume Fraction			Fissile Volume Fraction			Fissile Volume Fraction		
0.100	0.0389	0.0067	0.0115	0.0498	0.0085	0.0144	0.082	0.0162	0.0273
0.010	0.359	0.064	0.109	0.455	0.079	0.134	0.7598	0.143	0.2403
0.005	0.724	0.127	0.214	0.906	0.158	0.267	-	0.292	0.479
0.002	-	0.319	0.533	-	0.4004	0.658	-	0.722	-
0.001	-	0.641	-	-	0.789	-	-	-	-
	Fissile Weight, Kg			Fissile Weight, Kg			Fissile Weight, Kg		
0.100	12.55	6.55	7.48	16.07	8.31	9.36	26.46	15.83	17.75
0.010	11.94	6.45	7.30	15.13	7.96	8.98	25.27	14.41	16.10
0.005	12.06	6.41	7.18	15.09	7.97	8.96	-	14.73	16.07
0.002	-	6.44	7.16	-	8.09	8.84	-	14.59	-
0.001	-	6.48	-	-	7.97	-	-	-	-

9. Attachments

The following is a list of attachments. Electronic attachments are provided on Colorado DT-350 backup tapes (Ref. 5. 13) and listed in Attachment II.

Attachment	Description	Number of Pages	Date
I	Sample MCNP input file listings	6	11/17/97
II	List of MCNP output files supporting results	10	11/17/97
III	Listing of EXCEL spreadsheet Tuff.xls,Sheet1	4	11/17/97
IV	Listing of EXCEL spreadsheet Tuff.xls,Sheet2	2	11/17/97
V	Listing of EXCEL spreadsheet Tuff.xls,Sheet3	1	11/17/97
VI	Listing of EXCEL spreadsheet Clay.xls,Sheet1	6	11/17/97
VII	Listing of EXCEL spreadsheet Clay.xls,Sheet2	1	11/17/97

A listing of three typical MCNP input files is provided in this section. The files represent a fracture width of 0.01 cm for 10% soddyite, plutonium oxide, and soddyite/PuO_2 mixtures in tuff with 8%, 13%, and 0% interstitial water, respectively. Note that the titles in the input files refer to the fracture thickness at the edge of a fracture cube. The fracture width, twice this value, is used in previous sections to distinguish among the fracture width evaluations.

```
NEAR-FIELD CRITICALITY ANALYSIS
C  t92s10: .005 cm, 8% water, 10% soddyite
C   CELL SPECIFICATIONS
C  inner region
1  1 -2.325135  -1   2  -3   4  -5   6          U=1  IMP:N=1
2  2 -1.37      1:  -2:  3:  -4:  5:  -6       U=1  IMP:N=1
C  3 cm cube
3  0        -11  12  -13  14  -15  16  LAT=1  FILL=1  U=2  IMP:N=1
C  1 meter cube
4  0        -21  22  -23  24  -25  26     FILL=2  U=3  IMP:N=1
5  1 -2.325135  21: -22: 23: -24: 25: -26          U=3  IMP:N=1
C  3 meter cube
6  0        -31  32  -33  34  -35  36     FILL=3     IMP:N=1

C   SURFACE SPECIFICATIONS
C  inner region - tuff
1     PX   1.495
2     PX  -1.495
3     PY   1.495
4     PY  -1.495
5     PZ   1.495
6     PZ  -1.495
C  outer region - soddyite
11     PX   1.5
12     PX  -1.5
13     PY   1.5
14     PY  -1.5
15     PZ   1.5
16     PZ  -1.5
C  1 meter cube
21     PX   50.
22     PX  -50.
23     PY   50.
24     PY  -50.
25     PZ   50.
```

```
26    PZ  -50.
C  reflector
*31    PX   150.
*32    PX  -150.
*33    PY   150.
*34    PY  -150.
*35    PZ   150.
*36    PZ  -150.

MODE    N            $ neutron transport
KCODE   4000  1.  7  37  $ criticality source
SDEF  RAD=D1  ERG=D2     $ general source
SI1  50              $ source information
SP2  -3              $ source probability, watt fission spectrum
C    MATERIAL SPECIFICATIONS
C  100% tuff, 8% water, density  2.325135 g/cc
M1   8016.50c  -1.176071     $ oxygen
   14000.50c  -.807062     $ silicon
   13027.50c  -.151527     $ aluminum
   26000.55c  -.014707     $ iron
   20000.50c  -.008994     $ calcium
   12000.50c  -.003321     $ magnesium
   22000.50c  -.001320     $ titanium
   11023.50c  -.059898     $ sodium
   19000.50c  -.091967     $ potassium
   15031.50c  -.000147     $ phosphorus
   25055.50c  -.001166     $ manganese
    1001.50c  -.008953     $ hydrogen
MT1   LWTR.01T
C  10% soddyite, 90% water, density 1.37 g/cc
M2  92235.50c    -.333670    $ uraniun
    8016.50c   -.912809    $ oxygen
   14000.50c    -.019936    $ silicon
    1001.50c   -.103585    $ hydrogen
MT2  LWTR.01T
PRINT

NEAR-FIELD CRITICALITY ANALYSIS
C   t87p10: .005 cm, 13% water, 10% PuO2
C    CELL SPECIFICATIONS
C   inner region
1   1 -2.375135  -1   2  -3   4  -5   6          U=1  IMP:N=1
```

```
2  2 -2.046     1: -2: 3: -4: 5: -6          U=1 IMP:N=1
C  3 cm cube
3  0         -11 12 -13 14 -15 16 LAT=1 FILL=1 U=2 IMP:N=1
C  1 meter cube
4  0         -21 22 -23 24 -25 26     FILL=2 U=3 IMP:N=1
5  1 -2.375135  21: -22: 23: -24: 25: -26       U=3 IMP:N=1
C  3 meter cube
6  0         -31 32 -33 34 -35 36     FILL=3    IMP:N=1

C   SURFACE SPECIFICATIONS
C  inner region - tuff
1     PX   1.495
2     PX  -1.495
3     PY   1.495
4     PY  -1.495
5     PZ   1.495
6     PZ  -1.495
C  outer region - soddyite
11     PX   1.5
12     PX  -1.5
13     PY   1.5
14     PY  -1.5
15     PZ   1.5
16     PZ  -1.5
C  1 meter cube
21     PX   50.
22     PX  -50.
23     PY   50.
24     PY  -50.
25     PZ   50.
26     PZ  -50.
C  reflector
*31    PX   150.
*32    PX  -150.
*33    PY   150.
*34    PY  -150.
*35    PZ   150.
*36    PZ  -150.

MODE    N            $ neutron transport
KCODE   4000  1.  7  37  $ criticality source
SDEF  RAD=D1  ERG=D2     $ general source
```

```
SI1  50            $ source information
SP2  -3            $ source probability, watt fission spectrum
C    MATERIAL SPECIFICATIONS
C  100% tuff, 13% water, density  2.375135 g/cc
M1    8016.50c   -1.220476    $ oxygen
    14000.50c    -.807062    $ silicon
    13027.50c    -.151527    $ aluminum
    26000.55c    -.014707    $ iron
    20000.50c    -.008994    $ calcium
    12000.50c    -.003321    $ magnesium
    22000.50c    -.001320    $ titanium
    11023.50c    -.059898    $ sodium
    19000.50c    -.091967    $ potassium
    15031.50c    -.000147    $ phosphorus
    25055.50c    -.001166    $ manganese
     1001.50c   -.014549    $ hydrogen
MT1  LWTR.01T
C  10% PuO2, 90% water, density 2.046 g/cc
M2   94239.55c    -1.010743    $ plutonium
     8016.50c   -.934534    $ oxygen
     1001.50c   -.100723    $ hydrogen
MT2  LWTR.01T
PRINT

NEAR-FIELD CRITICALITY ANALYSIS
C    CELL SPECIFICATIONS        (T100sp10: .005 cm, 0%water, 10% Soddyite/PuO2)
C  inner region
1   1 -2.245135  -1   2  -3   4  -5   6           U=1  IMP:N=1
2   2 -1.708     1:  -2:  3:  -4:  5:  -6          U=1  IMP:N=1
C  3 cm cube
3   0         -11   12  -13   14  -15   16  LAT=1  FILL=1  U=2  IMP:N=1
C  1 meter cube
4   0         -21   22  -23   24  -25   26      FILL=2  U=3  IMP:N=1
5   1 -2.245135  21: -22:  23: -24:  25: -26            U=3  IMP:N=1
C  3 meter cube
6   0         -31   32  -33   34  -35   36      FILL=3     IMP:N=1

C    SURFACE SPECIFICATIONS
C  inner region - tuff
1     PX   1.495
2     PX  -1.495
3     PY   1.495
```

```
4     PY  -1.495
5     PZ   1.495
6     PZ  -1.495
C  outer region - soddyite
11     PX   1.5
12     PX  -1.5
13     PY   1.5
14     PY  -1.5
15     PZ   1.5
16     PZ  -1.5
C  1 meter cube
21     PX   50.
22     PX  -50.
23     PY   50.
24     PY  -50.
25     PZ   50.
26     PZ  -50.
C  reflector
*31    PX   150.
*32    PX  -150.
*33    PY   150.
*34    PY  -150.
*35    PZ   150.
*36    PZ  -150.

MODE    N             $ neutron transport
KCODE   4000  1.  7  37  $ criticality source
SDEF  RAD=D1  ERG=D2     $ general source
SI1  50              $ source information
SP2  -3              $ source probability, watt fission spectrum
C    MATERIAL SPECIFICATIONS
C  100% tuff, no water, density  2.245135 g/cc
M1    8016.50c   -1.105025    $ oxygen
     14000.50c   -.807062    $ silicon
     13027.50c   -.151527    $ aluminum
     26000.55c   -.014707    $ iron
     20000.50c   -.008994    $ calcium
     12000.50c   -.003321    $ magnesium
     22000.50c   -.001320    $ titanium
     11023.50c   -.059898    $ sodium
     19000.50c   -.091967    $ potassium
     15031.50c   -.000147    $ phosphorus
```

```
   25055.50c    -.001166    $ manganese
C  5% soddyite, 5% plutonium, 90% water, density 1.708 g/cc
M2  92235.50c    -.166835    $ uraniun
     8016.50c   -.923671    $ oxygen
    14000.50c    -.009968    $ silicon
     1001.50c   -.102154    $ hydrogen
    94239.55c    -.505371    $ plutonium
MT2  LWTR.01T
PRINT
```

A list of the MCNP output cases that are referenced in this document are listed in the following sub-sections.

Results for 0.1 cm Fracture Width

```
Directory of C:\Work\tuttle\transoct\pluto5
HEADOUT        3,696  11-06-97  2:54p headout
HXAVE   OUT   63,081  11-06-97  2:55p hxave.out
P100P005       2,194  11-06-97  2:55p p100p005
P100P005 O   116,899  11-06-97  2:56p p100p005.o
P100P006       2,195  11-06-97  2:55p p100p006
P100P006 O   118,002  11-06-97  2:56p p100p006.o
P100P007       2,195  11-06-97  2:55p p100p007
P100P007 O   116,899  11-06-97  2:56p p100p007.o
P100P01        2,189  11-06-97  2:55p p100p01
P100P01  O   116,900  11-06-97  2:56p p100p01.o
P100S03        2,236  11-06-97  2:55p p100s03
P100S03  O   117,143  11-06-97  2:56p p100s03.o
P100S04        2,236  11-06-97  2:55p p100s04
P100S04  O   118,117  11-06-97  2:56p p100s04.o
P100S05        2,236  11-06-97  2:55p p100s05
P100S05  O   117,116  11-06-97  2:56p p100s05.o
P100SP01       2,299  11-06-97  2:55p p100sp01
P100SP01 O   118,592  11-06-97  2:56p p100sp01.o
P100SP0A       2,306  11-06-97  2:55p p100sp0a
P100SP0A O   118,589  11-06-97  2:56p p100sp0a.o
P100SP0F       2,304  11-06-97  2:55p p100sp0f
P100SP0F O   118,375  11-06-97  2:56p p100sp0f.o
P87P005        2,252  11-06-97  2:55p p87p005
P87P005  O   118,029  11-06-97  2:56p p87p005.o
P87P006        2,253  11-06-97  2:55p p87p006
P87P006  O   116,286  11-06-97  2:56p p87p006.o
P87P01         2,247  11-06-97  2:55p p87p01
P87P01   O   117,953  11-06-97  2:56p p87p01.o
P87S03         2,294  11-06-97  2:55p p87s03
P87S03   O   118,414  11-06-97  2:56p p87s03.o
P87S031        2,302  11-06-97  2:55p p87s031
P87S031  O   118,082  11-06-97  2:56p p87s031.o
P87S032        2,302  11-06-97  2:55p p87s032
P87S032  O   117,503  11-06-97  2:56p p87s032.o
P87S04         2,294  11-06-97  2:55p p87s04
P87S04   O   118,329  11-06-97  2:56p p87s04.o
P87SP009       2,366  11-06-97  2:55p p87sp009
P87SP009 O   118,188  11-06-97  2:56p p87sp009.o
P87SP01        2,359  11-06-97  2:55p p87sp01
P87SP01  O   118,583  11-06-97  2:56p p87sp01.o
P87SP02        2,357  11-06-97  2:55p p87sp02
P87SP02  O   117,138  11-06-97  2:56p p87sp02.o
P92P005        2,250  11-06-97  2:54p p92p005
P92P005  O   118,329  11-06-97  2:56p p92p005.o
P92P006        2,251  11-06-97  2:55p p92p006
P92P006  O   118,199  11-06-97  2:57p p92p006.o
P92P01         2,245  11-06-97  2:55p p92p01
P92P01   O   116,423  11-06-97  2:57p p92p01.o
P92S03         2,293  11-06-97  2:55p p92s03
P92S03   O   117,684  11-06-97  2:57p p92s03.o
P92S034        2,301  11-06-97  2:55p p92s034
P92S034  O   118,443  11-06-97  2:57p p92s034.o
P92S035        2,301  11-06-97  2:55p p92s035
P92S035  O   117,442  11-06-97  2:57p p92s035.o
P92S04         2,293  11-06-97  2:55p p92s04
P92S04   O   117,838  11-06-97  2:57p p92s04.o
P92SP009       2,362  11-06-97  2:55p p92sp009
P92SP009 O   117,916  11-06-97  2:57p p92sp009.o
P92SP01        2,355  11-06-97  2:55p p92sp01
P92SP01  O   118,189  11-06-97  2:57p p92sp01.o
P92SP02        2,353  11-06-97  2:55p p92sp02
P92SP02  O   116,872  11-06-97  2:57p p92sp02.o
P96P005        2,250  11-06-97  2:55p p96p005
P96P005  O   117,469  11-06-97  2:57p p96p005.o
P96P006        2,251  11-06-97  2:55p p96p006
P96P006  O   118,142  11-06-97  2:57p p96p006.o
P96P007        2,251  11-06-97  2:55p p96p007
P96P007  O   117,924  11-06-97  2:57p p96p007.o
P96P01         2,245  11-06-97  2:55p p96p01
P96P01   O   117,928  11-06-97  2:57p p96p01.o
P96S03         2,293  11-06-97  2:55p p96s03
P96S03   O   118,416  11-06-97  2:57p p96s03.o
P96S035        2,301  11-06-97  2:55p p96s035
P96S035  O   118,573  11-06-97  2:57p p96s035.o
P96S04         2,293  11-06-97  2:55p p96s04
P96S04   O   118,412  11-06-97  2:57p p96s04.o
P96S05         2,293  11-06-97  2:55p p96s05
P96S05   O   118,169  11-06-97  2:57p p96s05.o
P96SP01        2,355  11-06-97  2:55p p96sp01
P96SP01  O   118,945  11-06-97  2:57p p96sp01.o
P96SP011       2,363  11-06-97  2:55p p96sp011
P96SP011 O   119,074  11-06-97  2:57p p96sp011.o
```

```
P96SP012        2,361  11-06-97  2:55p p96sp012
P96SP012 O      119,048  11-06-97  2:57p p96sp012.o
P96SP02         2,353  11-06-97  2:55p p96sp02
P96SP02  O      118,699  11-06-97  2:57p p96sp02.o
PLUTO5   HX       5,350  11-06-97  2:55p pluto5.hx
PLUTO5~1 KEF      3,364  11-06-97  2:54p pluto5.keff
SUMRY~1  OUT  3,093,492  11-06-97  2:55p sumry.outlst
TEMP            6,025  11-06-97  2:54p temp
```

Results for 0.01 cm Fracture Width

```
Directory of C:\Work\tuttle\transoct\pluto
HEADING           133  10-24-97  1:26p heading
HEADOUT         5,605  10-24-97  1:26p headout
HXAVE    OUT   55,044  10-24-97  1:26p hxave.out
PLUTO1~1 KEF    2,936  10-24-97  1:27p pluto1.keff
SUMRY~1  OUT  1,037,057  10-24-97  1:27p sumry.outlst
T0SP11R         2,933  10-24-97  1:27p t0sp11r
T0SP11R  O    119,675  10-24-97  1:27p t0sp11r.o
T100P10         2,154  10-24-97  1:27p t100p10
T100P10  O    118,511  10-24-97  1:27p t100p10.o
T100P50         2,153  10-24-97  1:27p t100p50
T100P50  O    117,966  10-24-97  1:27p t100p50.o
T100P90         2,155  10-24-97  1:27p t100p90
T100P90  O    117,993  10-24-97  1:27p t100p90.o
T100P91         2,155  10-24-97  1:27p t100p91
T100P91  O    117,965  10-24-97  1:27p t100p91.o
T100P92         2,155  10-24-97  1:27p t100p92
T100P92  O    117,294  10-24-97  1:27p t100p92.o
T100S10         2,198  10-24-97  1:27p t100s10
T100S10  O    118,755  10-24-97  1:27p t100s10.o
T100S50         2,198  10-24-97  1:27p t100s50
T100S50  O    117,540  10-24-97  1:27p t100s50.o
T100S90         2,198  10-24-97  1:27p t100s90
T100S90  O    117,669  10-24-97  1:27p t100s90.o
T100S98         2,198  10-24-97  1:27p t100s98
T100S98  O    118,755  10-24-97  1:27p t100s98.o
T100SP10        2,257  10-24-97  1:27p t100sp10
T100SP10 O    118,957  10-24-97  1:27p t100sp10.o
T100SP50        2,258  10-24-97  1:27p t100sp50
T100SP50 O    118,011  10-24-97  1:27p t100sp50.o
T100SP90        2,259  10-24-97  1:27p t100sp90
T100SP90 O    118,041  10-24-97  1:27p t100sp90.o
T100SP94        2,259  10-24-97  1:27p t100sp94
T100SP94 O    121,454  10-24-97  1:27p t100sp94.o
T100SP98        2,259  10-24-97  1:27p t100sp98
T100SP98 O    119,226  10-24-97  1:27p t100sp98.o
T87P06          2,215  10-24-97  1:27p t87p06
T87P06   O    118,105  10-24-97  1:27p t87p06.o
T87P07          2,215  10-24-97  1:27p t87p07
T87P07   O    116,530  10-24-97  1:27p t87p07.o
T87P10          2,255  10-24-97  1:27p t87p10
T87P10   O    116,420  10-24-97  1:27p t87p10.o
T87P50          2,254  10-24-97  1:27p t87p50
T87P50   O    116,174  10-24-97  1:27p t87p50.o
T87P90          2,256  10-24-97  1:27p t87p90
T87P90   O    116,146  10-24-97  1:27p t87p90.o
T87PUE          2,286  10-24-97  1:27p t87pue
T87PUE   O    116,648  10-24-97  1:27p t87pue.o
T87S10          2,302  10-24-97  1:27p t87s10
T87S10   O    117,957  10-24-97  1:27p t87s10.o
T87S35          2,297  10-24-97  1:27p t87s35
T87S35   O    117,841  10-24-97  1:27p t87s35.o
T87S36          2,305  10-24-97  1:27p t87s36
T87S36   O    117,842  10-24-97  1:27p t87s36.o
T87S50          2,304  10-24-97  1:27p t87s50
T87S50   O    120,225  10-24-97  1:27p t87s50.o
T87S90          2,304  10-24-97  1:27p t87s90
T87S90   O    119,390  10-24-97  1:27p t87s90.o
T87SP10         2,317  10-24-97  1:27p t87sp10
T87SP10  O    117,952  10-24-97  1:27p t87sp10.o
T87SP11         2,322  10-24-97  1:27p t87sp11
T87SP11  O    118,121  10-24-97  1:27p t87sp11.o
T87SP50         2,363  10-24-97  1:27p t87sp50
T87SP50  O    116,921  10-24-97  1:27p t87sp50.o
T87SP90         2,364  10-24-97  1:27p t87sp90
T87SP90  O    116,920  10-24-97  1:27p t87sp90.o
T87SPUE         2,385  10-24-97  1:27p t87spue
T87SPUE  O    118,402  10-24-97  1:27p t87spue.o
T87SPUE  OO   118,670  10-24-97  1:27p t87spue.oo
T8SP11R         2,998  10-24-97  1:27p t8sp11r
T8SP11R  O    120,484  10-24-97  1:27p t8sp11r.o
T92P07          2,212  10-24-97  1:27p t92p07
T92P07   O    118,075  10-24-97  1:27p t92p07.o
T92P08          2,212  10-24-97  1:27p t92p08
T92P08   O    118,104  10-24-97  1:27p t92p08.o
T92P10          2,253  10-24-97  1:27p t92p10
```

T92P10 O	118,169	10-24-97	1:27p	t92p10.o
T92P50	2,252	10-24-97	1:27p	t92p50
T92P50 O	117,925	10-24-97	1:28p	t92p50.o
T92P90	2,254	10-24-97	1:27p	t92p90
T92P90 O	117,923	10-24-97	1:28p	t92p90.o
T92PUE	2,285	10-24-97	1:27p	t92pue
T92PUE O	116,549	10-24-97	1:28p	t92pue.o
T92S10	2,301	10-24-97	1:27p	t92s10
T92S10 O	117,930	10-24-97	1:28p	t92s10.o
T92S44	2,257	10-24-97	1:27p	t92s44
T92S44 O	118,318	10-24-97	1:28p	t92s44.o
T92S46	2,257	10-24-97	1:27p	t92s46
T92S46 O	118,348	10-24-97	1:28p	t92s46.o
T92S50	2,301	10-24-97	1:27p	t92s50
T92S50 O	117,712	10-24-97	1:28p	t92s50.o
T92S90	2,301	10-24-97	1:27p	t92s90
T92S90 O	118,546	10-24-97	1:28p	t92s90.o
T92SP10	2,360	10-24-97	1:27p	t92sp10
T92SP10 O	118,994	10-24-97	1:28p	t92sp10.o
T92SP12	2,361	10-24-97	1:27p	t92sp12
T92SP12 O	118,184	10-24-97	1:28p	t92sp12.o
T92SP13	2,320	10-24-97	1:27p	t92sp13
T92SP13 O	118,851	10-24-97	1:28p	t92sp13.o
T92SP50	2,361	10-24-97	1:27p	t92sp50
T92SP50 O	120,624	10-24-97	1:28p	t92sp50.o
T92SP90	2,362	10-24-97	1:27p	t92sp90
T92SP90 O	120,050	10-24-97	1:28p	t92sp90.o
T92SPUE	2,388	10-24-97	1:27p	t92spue
T92SPUE O	118,918	10-24-97	1:28p	t92spue.o
T96P10	2,253	10-24-97	1:27p	t96p10
T96P10 O	118,385	10-24-97	1:28p	t96p10.o
T96P11	2,254	10-24-97	1:27p	t96p11
T96P11 O	117,470	10-24-97	1:28p	t96p11.o
T96P12	2,254	10-24-97	1:27p	t96p12
T96P12 O	117,470	10-24-97	1:28p	t96p12.o
T96P50	2,252	10-24-97	1:27p	t96p50
T96P50 O	118,329	10-24-97	1:28p	t96p50.o
T96P90	2,254	10-24-97	1:27p	t96p90
T96P90 O	117,470	10-24-97	1:28p	t96p90.o
T96S10	2,301	10-24-97	1:27p	t96s10
T96S10 O	118,246	10-24-97	1:28p	t96s10.o
T96S50	2,301	10-24-97	1:27p	t96s50
T96S50 O	118,759	10-24-97	1:28p	t96s50.o
T96S72	2,302	10-24-97	1:27p	t96s72
T96S72 O	118,660	10-24-97	1:28p	t96s72.o
T96S73	2,302	10-24-97	1:27p	t96s73
T96S73 O	118,630	10-24-97	1:28p	t96s73.o
T96S90	2,301	10-24-97	1:27p	t96s90
T96S90 O	118,687	10-24-97	1:28p	t96s90.o
T96SP10	2,360	10-24-97	1:27p	t96sp10
T96SP10 O	121,115	10-24-97	1:28p	t96sp10.o
T96SP19	2,365	10-24-97	1:27p	t96sp19
T96SP19 O	118,432	10-24-97	1:28p	t96sp19.o
T96SP20	2,363	10-24-97	1:27p	t96sp20
T96SP20 O	119,189	10-24-97	1:28p	t96sp20.o
T96SP50	2,361	10-24-97	1:27p	t96sp50
T96SP50 O	118,158	10-24-97	1:28p	t96sp50.o
T96SP90	2,362	10-24-97	1:27p	t96sp90
T96SP90 O	118,888	10-24-97	1:28p	t96sp90.o

Results from new runs

Directory of C:\Work\tuttle\transect\newruns

T0SP11R	3,019	01-28-98	3:37p	t0sp11r
T0SP11RO	121,160	01-28-98	3:37p	t0sp11ro
T87SPX	2,993	01-28-98	3:37p	t87spx
T87SPXO	121,186	01-28-98	3:37p	t87spxo
T87SPY	2,994	01-28-98	3:37p	t87spy
T87SPYO	121,234	01-28-98	3:37p	t87spyo
T8SP11R	3,086	01-28-98	3:37p	t8sp11r
T8SP11RO	121,481	01-28-98	3:37p	t8sp11ro
T92SP11	2,392	01-28-98	3:37p	t92sp11
T92SP11O	119,151	01-28-98	3:37p	t92sp11o
T92SPX	2,947	01-28-98	3:37p	t92spx
T92SPXO	121,112	01-28-98	3:37p	t92spxo
T92SPY	2,993	01-28-98	3:37p	t92spy
T92SPYO	121,291	01-28-98	3:37p	t92spyo

Results for 0.005 cm Fracture Width

Directory of C:\Work\tuttle\transect\pluto2

HEADING	133	10-24-97	1:28p	heading
HEADOUT	3,938	10-24-97	1:28p	headout

HXAVE	OUT	46,286	10-24-97	1:28p	hxave.out
N100P50		2,159	10-24-97	1:28p	n100p50
N100P50	O	120,708	10-24-97	1:28p	n100p50.o
N100P90		2,161	10-24-97	1:28p	n100p90
N100P90	O	117,398	10-24-97	1:28p	n100p90.o
N100S50		2,204	10-24-97	1:28p	n100s50
N100S50	O	117,574	10-24-97	1:28p	n100s50.o
N100S90		2,204	10-24-97	1:28p	n100s90
N100S90	O	117,316	10-24-97	1:28p	n100s90.o
N100SP50		2,264	10-24-97	1:28p	n100sp50
N100SP50	O	118,042	10-24-97	1:28p	n100sp50.o
N100SP90		2,265	10-24-97	1:28p	n100sp90
N100SP90	O	119,257	10-24-97	1:28p	n100sp90.o
N87P10		2,262	10-24-97	1:28p	n87p10
N87P10	O	118,058	10-24-97	1:28p	n87p10.o
N87P12		2,263	10-24-97	1:28p	n87p12
N87P12	O	117,599	10-24-97	1:28p	n87p12.o
N87P13		2,263	10-24-97	1:28p	n87p13
N87P13	O	118,199	10-24-97	1:28p	n87p13.o
N87P50		2,261	10-24-97	1:28p	n87p50
N87P50	O	116,204	10-24-97	1:28p	n87p50.o
N87P90		2,263	10-24-97	1:28p	n87p90
N87P90	O	117,679	10-24-97	1:28p	n87p90.o
N87S50		2,311	10-24-97	1:28p	n87s50
N87S50	O	118,415	10-24-97	1:28p	n87s50.o
N87S71		2,312	10-24-97	1:28p	n87s71
N87S71	O	117,816	10-24-97	1:28p	n87s71.o
N87S72		2,312	10-24-97	1:28p	n87s72
N87S72	O	117,683	10-24-97	1:28p	n87s72.o
N87S90		2,311	10-24-97	1:28p	n87s90
N87S90	O	118,416	10-24-97	1:28p	n87s90.o
N87SP10		2,370	10-24-97	1:28p	n87sp10
N87SP10	O	118,136	10-24-97	1:28p	n87sp10.o
N87SP21		2,376	10-24-97	1:28p	n87sp21
N87SP21	O	118,158	10-24-97	1:28p	n87sp21.o
N87SP22		2,372	10-24-97	1:28p	n87sp22
N87SP22	O	118,214	10-24-97	1:28p	n87sp22.o
N87SP50		2,370	10-24-97	1:28p	n87sp50
N87SP50	O	118,671	10-24-97	1:28p	n87sp50.o
N87SP90		2,371	10-24-97	1:28p	n87sp90
N87SP90	O	116,893	10-24-97	1:29p	n87sp90.o
N92P10		2,260	10-24-97	1:28p	n92p10
N92P10	O	118,411	10-24-97	1:29p	n92p10.o
N92P15		2,261	10-24-97	1:28p	n92p15
N92P15	O	118,168	10-24-97	1:29p	n92p15.o
N92P16		2,261	10-24-97	1:28p	n92p16
N92P16	O	118,200	10-24-97	1:29p	n92p16.o
N92P50		2,259	10-24-97	1:28p	n92p50
N92P50	O	117,954	10-24-97	1:29p	n92p50.o
N92P90		2,261	10-24-97	1:28p	n92p90
N92P90	O	118,058	10-24-97	1:29p	n92p90.o
N92S50		2,308	10-24-97	1:28p	n92s50
N92S50	O	117,930	10-24-97	1:29p	n92s50.o
N92S90		2,308	10-24-97	1:28p	n92s90
N92S90	O	117,713	10-24-97	1:29p	n92s90.o
N92SP10		2,368	10-24-97	1:28p	n92sp10
N92SP10	O	118,431	10-24-97	1:29p	n92sp10.o
N92SP25		2,372	10-24-97	1:28p	n92sp25
N92SP25	O	118,376	10-24-97	1:29p	n92sp25.o
N92SP26		2,370	10-24-97	1:28p	n92sp26
N92SP26	O	118,749	10-24-97	1:29p	n92sp26.o
N92SP50		2,368	10-24-97	1:28p	n92sp50
N92SP50	O	118,888	10-24-97	1:29p	n92sp50.o
N92SP90		2,369	10-24-97	1:28p	n92sp90
N92SP90	O	118,831	10-24-97	1:29p	n92sp90.o
N96P10		2,260	10-24-97	1:28p	n96p10
N96P10	O	117,413	10-24-97	1:29p	n96p10.o
N96P26		2,261	10-24-97	1:28p	n96p26
N96P26	O	118,415	10-24-97	1:29p	n96p26.o
N96P27		2,261	10-24-97	1:28p	n96p27
N96P27	O	120,123	10-24-97	1:29p	n96p27.o
N96P50		2,259	10-24-97	1:28p	n96p50
N96P50	O	117,441	10-24-97	1:29p	n96p50.o
N96P90		2,261	10-24-97	1:28p	n96p90
N96P90	O	117,413	10-24-97	1:29p	n96p90.o
N96S50		2,308	10-24-97	1:28p	n96s50
N96S50	O	118,604	10-24-97	1:29p	n96s50.o
N96S90		2,308	10-24-97	1:28p	n96s90
N96S90	O	117,957	10-24-97	1:29p	n96s90.o
N96S98		2,309	10-24-97	1:28p	n96s98
N96S98	O	118,687	10-24-97	1:29p	n96s98.o
N96SP10		2,368	10-24-97	1:28p	n96sp10
N96SP10	O	119,431	10-24-97	1:29p	n96sp10.o
N96SP44		2,370	10-24-97	1:28p	n96sp44
N96SP44	O	119,131	10-24-97	1:29p	n96sp44.o
N96SP45		2,374	10-24-97	1:28p	n96sp45
N96SP45	O	119,189	10-24-97	1:29p	n96sp45.o
N96SP50		2,368	10-24-97	1:28p	n96sp50
N96SP50	O	119,189	10-24-97	1:29p	n96sp50.o
N96SP90		2,369	10-24-97	1:28p	n96sp90

N96SP90 O	119,132	10-24-97	1:29p	n96sp90.o
PLUTO2~1 KEF	2,478	10-24-97	1:28p	pluto2.keff
SUMRY~1 OUT	910,315	10-24-97	1:28p	sumry.outlst

Results for 0.002 cm Fracture Width

Directory of C:\Work\tuttle\transoct\pluto3

H87P31	2,256	10-24-97	1:14p	h87p31
H87P31 O	118,172	10-24-97	1:29p	h87p31.o
H87P32	2,256	10-24-97	1:14p	h87p32
H87P32 O	117,543	10-24-97	1:29p	h87p32.o
H87P50	2,254	10-24-97	1:14p	h87p50
H87P50 O	116,449	10-24-97	1:29p	h87p50.o
H87P90	2,256	10-24-97	1:14p	h87p90
H87P90 O	116,448	10-24-97	1:29p	h87p90.o
H87SP50	2,363	10-24-97	1:14p	h87sp50
H87SP50 O	118,159	10-24-97	1:29p	h87sp50.o
H87SP54	2,365	10-24-97	1:14p	h87sp54
H87SP54 O	117,532	10-24-97	1:29p	h87sp54.o
H87SP55	2,368	10-24-97	1:14p	h87sp55
H87SP55 O	118,319	10-24-97	1:29p	h87sp55.o
H87SP90	2,364	10-24-97	1:14p	h87sp90
H87SP90 O	118,831	10-24-97	1:29p	h87sp90.o
H92P38	2,254	10-24-97	1:14p	h92p38
H92P38 O	117,439	10-24-97	1:29p	h92p38.o
H92P39	2,254	10-24-97	1:14p	h92p39
H92P39 O	117,300	10-24-97	1:29p	h92p39.o
H92P50	2,252	10-24-97	1:14p	h92p50
H92P50 O	117,443	10-24-97	1:29p	h92p50.o
H92P90	2,254	10-24-97	1:14p	h92p90
H92P90 O	118,299	10-24-97	1:29p	h92p90.o
H92SP50	2,361	10-24-97	1:14p	h92sp50
H92SP50 O	118,215	10-24-97	1:29p	h92sp50.o
H92SP66	2,363	10-24-97	1:14p	h92sp66
H92SP66 O	118,918	10-24-97	1:29p	h92sp66.o
H92SP67	2,367	10-24-97	1:14p	h92sp67
H92SP67 O	119,074	10-24-97	1:29p	h92sp67.o
H92SP90	2,362	10-24-97	1:14p	h92sp90
H92SP90 O	118,918	10-24-97	1:29p	h92sp90.o
H96P50	2,252	10-24-97	1:14p	h96p50
H96P50 O	117,817	10-24-97	1:29p	h96p50.o
H96P72	2,254	10-24-97	1:14p	h96p72
H96P72 O	117,431	10-24-97	1:29p	h96p72.o
H96P73	2,254	10-24-97	1:14p	h96p73
H96P73 O	118,416	10-24-97	1:29p	h96p73.o
H96P90	2,254	10-24-97	1:14p	h96p90
H96P90 O	118,443	10-24-97	1:29p	h96p90.o
H96SP50	2,361	10-24-97	1:14p	h96sp50
H96SP50 O	119,406	10-24-97	1:29p	h96sp50.o
H96SP90	2,362	10-24-97	1:14p	h96sp90
H96SP90 O	120,727	10-24-97	1:29p	h96sp90.o
H96SP98	2,362	10-24-97	1:14p	h96sp98
H96SP98 O	119,262	10-24-97	1:29p	h96sp98.o
HEADING	133	10-24-97	1:14p	heading
HEADOUT	2,012	10-24-97	1:14p	headout
HXAVE OUT	23,637	10-24-97	1:14p	hxave.out
PLUTO3~1 KEF	1,315	10-24-97	1:14p	pluto3.keff
SUMRY~1 OUT	397,453	10-24-97	1:29p	sumry.outlst

Results for 0.001 cm Fracture Width

Directory of C:\Work\tuttle\transoct\pluto4

HEADING	133	10-24-97	1:14p	heading
HEADOUT	1,224	10-24-97	1:14p	headout
HXAVE OUT	17,034	10-24-97	1:14p	hxave.out
K87P63	2,263	10-24-97	1:14p	k87p63
K87P63 O	117,371	10-24-97	1:29p	k87p63.o
K87P64	2,263	10-24-97	1:14p	k87p64
K87P64 O	117,470	10-24-97	1:29p	k87p64.o
K87P90	2,263	10-24-97	1:14p	k87p90
K87P90 O	117,955	10-24-97	1:29p	k87p90.o
K87SP90	2,371	10-24-97	1:14p	k87sp90
K87SP90 O	118,805	10-24-97	1:29p	k87sp90.o
K87SP98	2,371	10-24-97	1:14p	k87sp98
K87SP98 O	121,387	10-24-97	1:29p	k87sp98.o
K92P78	2,261	10-24-97	1:14p	k92p78
K92P78 O	118,169	10-24-97	1:29p	k92p78.o
K92P79	2,261	10-24-97	1:14p	k92p79
K92P79 O	118,299	10-24-97	1:29p	k92p79.o
K92P90	2,261	10-24-97	1:14p	k92p90
K92P90 O	118,199	10-24-97	1:29p	k92p90.o
K92SP90	2,369	10-24-97	1:14p	k92sp90
K92SP90 O	118,919	10-24-97	1:30p	k92sp90.o
K92SP98	2,369	10-24-97	1:14p	k92sp98

```
K92SP98  O      118,918  10-24-97  1:30p k92sp98.o
K96P90            2,261  10-24-97  1:14p k96p90
K96P90   O      117,714  10-24-97  1:30p k96p90.o
K96P98            2,261  10-24-97  1:14p k96p98
K96P98   O      117,714  10-24-97  1:30p k96p98.o
K96SP90           2,369  10-24-97  1:14p k96sp90
K96SP90  O      119,072  10-24-97  1:30p k96sp90.o
K96SP98           2,369  10-24-97  1:14p k96sp98
K96SP98  O      119,404  10-24-97  1:30p k96sp98.o
PLUTO4~1 KEF        976  10-24-97  1:14p pluto4.keff
SUMRY~1  OUT    229,080  10-24-97  1:29p sumry.outlst
```

Results for 0.1 cm Fracture Width

```
Directory of C:\Work\tuttle\transect\clay5
CLAY5    HX       4,812  11-06-97  2:56p clay5.hx
CLAY5~1  KEF      3,024  11-06-97  2:55p clay5.keff
E100P09           2,960  11-06-97  2:55p e100p09
E100P09  O      122,661  11-06-97  2:58p e100p09.o
E100P10           2,962  11-06-97  2:55p e100p10
E100P10  O      121,471  11-06-97  2:58p e100p10.o
E100P20           2,962  11-06-97  2:56p e100p20
E100P20  O      121,069  11-06-97  2:58p e100p20.o
E100S27           2,968  11-06-97  2:56p e100s27
E100S27  O      121,315  11-06-97  2:58p e100s27.o
E100S28           2,968  11-06-97  2:56p e100s28
E100S28  O      121,444  11-06-97  2:58p e100s28.o
E100S29           2,968  11-06-97  2:56p e100s29
E100S29  O      121,501  11-06-97  2:58p e100s29.o
E100S34           2,968  11-06-97  2:56p e100s34
E100S34  O      121,096  11-06-97  2:58p e100s34.o
E100S50           2,968  11-06-97  2:55p e100s50
E100S50  O      121,067  11-06-97  2:58p e100s50.o
E100SP10          3,039  11-06-97  2:55p e100sp10
E100SP10 O      121,976  11-06-97  2:58p e100sp10.o
E100SP14          3,039  11-06-97  2:56p e100sp14
E100SP14 O      123,003  11-06-97  2:58p e100sp14.o
E100SP15          3,043  11-06-97  2:56p e100sp15
E100SP15 O      123,059  11-06-97  2:58p e100sp15.o
E100SP16          3,039  11-06-97  2:56p e100sp16
E100SP16 O      123,060  11-06-97  2:58p e100sp16.o
E87P006           3,023  11-06-97  2:56p e87p006
E87P006  O      123,859  11-06-97  2:58p e87p006.o
E87P007           3,023  11-06-97  2:56p e87p007
E87P007  O      123,863  11-06-97  2:58p e87p007.o
E87P01            3,019  11-06-97  2:55p e87p01
E87P01   O      121,337  11-06-97  2:58p e87p01.o
E87S03            3,026  11-06-97  2:56p e87s03
E87S03   O      122,396  11-06-97  2:58p e87s03.o
E87S039           3,033  11-06-97  2:56p e87s039
E87S039  O      123,805  11-06-97  2:58p e87s039.o
E87S04            3,026  11-06-97  2:56p e87s04
E87S04   O      122,285  11-06-97  2:58p e87s04.o
E87S10            3,028  11-06-97  2:55p e87s10
E87S10   O      120,372  11-06-97  2:58p e87s10.o
E87SP01           3,100  11-06-97  2:55p e87sp01
E87SP01  O      121,925  11-06-97  2:58p e87sp01.o
E87SP011          3,107  11-06-97  2:56p e87sp011
E87SP011 O      122,994  11-06-97  2:58p e87sp011.o
E87SP012          3,105  11-06-97  2:56p e87sp012
E87SP012 O      122,028  11-06-97  2:58p e87sp012.o
E87SP02           3,098  11-06-97  2:56p e87sp02
E87SP02  O      122,595  11-06-97  2:58p e87sp02.o
E92P007           3,021  11-06-97  2:55p e92p007
E92P007  O      122,366  11-06-97  2:58p e92p007.o
E92P008           3,021  11-06-97  2:56p e92p008
E92P008  O      121,494  11-06-97  2:58p e92p008.o
E92P009           3,021  11-06-97  2:56p e92p009
E92P009  O      122,396  11-06-97  2:58p e92p009.o
E92P01            3,017  11-06-97  2:56p e92p01
E92P01   O      122,394  11-06-97  2:58p e92p01.o
E92P02            3,017  11-06-97  2:56p e92p02
E92P02   O      121,423  11-06-97  2:58p e92p02.o
E92S04            3,023  11-06-97  2:56p e92s04
E92S04   O      121,797  11-06-97  2:58p e92s04.o
E92S05            3,023  11-06-97  2:56p e92s05
E92S05   O      123,992  11-06-97  2:58p e92s05.o
E92S10            3,025  11-06-97  2:55p e92s10
E92S10   O      121,366  11-06-97  2:58p e92s10.o
E92SP014          3,102  11-06-97  2:56p e92sp014
E92SP014 O      121,784  11-06-97  2:58p e92sp014.o
E92SP015          3,104  11-06-97  2:56p e92sp015
E92SP015 O      122,870  11-06-97  2:58p e92sp015.o
E92SP02           3,095  11-06-97  2:56p e92sp02
E92SP02  O      121,896  11-06-97  2:58p e92sp02.o
E96P01            3,017  11-06-97  2:55p e96p01
E96P01   O      122,369  11-06-97  2:58p e96p01.o
```

```
E96P016        3,024  11-06-97  2:56p e96p016
E96P016 O      121,827  11-06-97  2:58p e96p016.o
E96P017        3,024  11-06-97  2:56p e96p017
E96P017 O      121,667  11-06-97  2:58p e96p017.o
E96P02         3,017  11-06-97  2:56p e96p02
E96P02  O      122,395  11-06-97  2:58p e96p02.o
E96P03         3,017  11-06-97  2:56p e96p03
E96P03  O      123,834  11-06-97  2:58p e96p03.o
E96S07         3,023  11-06-97  2:56p e96s07
E96S07  O      121,640  11-06-97  2:58p e96s07.o
E96S08         3,023  11-06-97  2:56p e96s08
E96S08  O      122,339  11-06-97  2:58p e96s08.o
E96S09         3,023  11-06-97  2:56p e96s09
E96S09  O      121,667  11-06-97  2:58p e96s09.o
E96S10         3,025  11-06-97  2:55p e96s10
E96S10  O      122,396  11-06-97  2:58p e96s10.o
E96S50         3,025  11-06-97  2:55p e96s50
E96S50  O      122,121  11-06-97  2:58p e96s50.o
E96SP024       3,104  11-06-97  2:56p e96sp024
E96SP024 O     123,270  11-06-97  2:58p e96sp024.o
E96SP028       3,104  11-06-97  2:56p e96sp028
E96SP028 O     122,955  11-06-97  2:58p e96sp028.o
E96SP03        3,099  11-06-97  2:56p e96sp03
E96SP03  O     123,057  11-06-97  2:58p e96sp03.o
E96SP10        3,096  11-06-97  2:55p e96sp10
E96SP10  O     122,057  11-06-97  2:59p e96sp10.o
E96SP20        3,098  11-06-97  2:56p e96sp20
E96SP20  O     121,925  11-06-97  2:59p e96sp20.o
HEADING          133  11-06-97  2:55p heading
HEADOUT        4,305  11-06-97  2:55p headout
HXAVE   OUT    56,499  11-06-97  2:56p hxave.out
SUMRY~1 OUT    3,419,208  11-06-97  2:56p sumry.outlst
TEMP           6,968  11-06-97  2:55p temp
```

Results for 0.01 cm Fracture Width

```
Directory of C:\Work\tuttle\transoct\clay1
A100P10        2,969  10-24-97  1:18p a100p10
A100P10 O      121,390  10-24-97  1:21p a100p10.o
A100P50        2,969  10-24-97  1:18p a100p50
A100P50 O      121,285  10-24-97  1:21p a100p50.o
A100P90        2,969  10-24-97  1:18p a100p90
A100P90 O      121,285  10-24-97  1:21p a100p90.o
A100P98        2,968  10-24-97  1:18p a100p98
A100P98 O      121,315  10-24-97  1:21p a100p98.o
A100S10        2,975  10-24-97  1:18p a100s10
A100S10 O      121,393  10-24-97  1:21p a100s10.o
A100S50        2,975  10-24-97  1:18p a100s50
A100S50 O      121,715  10-24-97  1:21p a100s50.o
A100S90        2,975  10-24-97  1:18p a100s90
A100S90 O      122,329  10-24-97  1:21p a100s90.o
A100S98        2,974  10-24-97  1:18p a100s98
A100S98 O      122,328  10-24-97  1:21p a100s98.o
A100SP10       3,046  10-24-97  1:18p a100sp10
A100SP10 O     121,949  10-24-97  1:21p a100sp10.o
A100SP50       3,048  10-24-97  1:18p a100sp50
A100SP50 O     121,975  10-24-97  1:21p a100sp50.o
A100SP90       3,048  10-24-97  1:18p a100sp90
A100SP90 O     123,060  10-24-97  1:21p a100sp90.o
A100SP98       3,047  10-24-97  1:18p a100sp98
A100SP98 O     121,521  10-24-97  1:21p a100sp98.o
A87P06         3,026  10-24-97  1:18p a87p06
A87P06  O      121,423  10-24-97  1:21p a87p06.o
A87P07         3,026  10-24-97  1:18p a87p07
A87P07  O      121,982  10-24-97  1:21p a87p07.o
A87P10         3,028  10-24-97  1:18p a87p10
A87P10  O      121,189  10-24-97  1:21p a87p10.o
A87P50         3,028  10-24-97  1:18p a87p50
A87P50  O      121,879  10-24-97  1:21p a87p50.o
A87P90         3,028  10-24-97  1:18p a87p90
A87P90  O      122,006  10-24-97  1:21p a87p90.o
A87S10         3,033  10-24-97  1:18p a87s10
A87S10  O      122,339  10-24-97  1:21p a87s10.o
A87S35         3,034  10-24-97  1:18p a87s35
A87S35  O      121,392  10-24-97  1:21p a87s35.o
A87S36         3,034  10-24-97  1:18p a87s36
A87S36  O      121,366  10-24-97  1:21p a87s36.o
A87S50         3,035  10-24-97  1:18p a87s50
A87S50  O      122,151  10-24-97  1:21p a87s50.o
A87S90         3,035  10-24-97  1:18p a87s90
A87S90  O      122,041  10-24-97  1:21p a87s90.o
A87SP10        3,106  10-24-97  1:18p a87sp10
A87SP10 O      122,085  10-24-97  1:21p a87sp10.o
A87SP11        3,110  10-24-97  1:18p a87sp11
A87SP11 O      122,628  10-24-97  1:21p a87sp11.o
A87SP50        3,107  10-24-97  1:18p a87sp50
A87SP50 O      121,008  10-24-97  1:21p a87sp50.o
```

A87SP90	3,107	10-24-97	1:18p	a87sp90
A87SP90 O	120,734	10-24-97	1:21p	a87sp90.o
A92P07	3,024	10-24-97	1:18p	a92p07
A92P07 O	122,368	10-24-97	1:22p	a92p07.o
A92P08	3,024	10-24-97	1:18p	a92p08
A92P08 O	121,392	10-24-97	1:22p	a92p08.o
A92P10	3,026	10-24-97	1:18p	a92p10
A92P10 O	122,366	10-24-97	1:22p	a92p10.o
A92P50	3,026	10-24-97	1:18p	a92p50
A92P50 O	123,862	10-24-97	1:22p	a92p50.o
A92P90	3,026	10-24-97	1:18p	a92p90
A92P90 O	123,831	10-24-97	1:22p	a92p90.o
A92S10	3,032	10-24-97	1:18p	a92s10
A92S10 O	122,369	10-24-97	1:22p	a92s10.o
A92S45	3,032	10-24-97	1:18p	a92s45
A92S45 O	122,369	10-24-97	1:22p	a92s45.o
A92S46	3,032	10-24-97	1:18p	a92s46
A92S46 O	122,366	10-24-97	1:22p	a92s46.o
A92S50	3,032	10-24-97	1:18p	a92s50
A92S50 O	123,862	10-24-97	1:22p	a92s50.o
A92S90	3,032	10-24-97	1:18p	a92s90
A92S90 O	123,963	10-24-97	1:22p	a92s90.o
A92SP10	3,103	10-24-97	1:18p	a92sp10
A92SP10 O	123,302	10-24-97	1:22p	a92sp10.o
A92SP13	3,107	10-24-97	1:18p	a92sp13
A92SP13 O	122,868	10-24-97	1:22p	a92sp13.o
A92SP14	3,103	10-24-97	1:18p	a92sp14
A92SP14 O	123,028	10-24-97	1:22p	a92sp14.o
A92SP50	3,105	10-24-97	1:18p	a92sp50
A92SP50 O	122,785	10-24-97	1:22p	a92sp50.o
A92SP90	3,105	10-24-97	1:18p	a92sp90
A92SP90 O	122,598	10-24-97	1:22p	a92sp90.o
A96P10	3,026	10-24-97	1:18p	a96p10
A96P10 O	121,610	10-24-97	1:22p	a96p10.o
A96P14	3,026	10-24-97	1:18p	a96p14
A96P14 O	122,171	10-24-97	1:22p	a96p14.o
A96P15	3,026	10-24-97	1:18p	a96p15
A96P15 O	122,397	10-24-97	1:22p	a96p15.o
A96P50	3,026	10-24-97	1:18p	a96p50
A96P50 O	121,521	10-24-97	1:22p	a96p50.o
A96P90	3,026	10-24-97	1:18p	a96p90
A96P90 O	122,151	10-24-97	1:22p	a96p90.o
A96S10	3,032	10-24-97	1:18p	a96s10
A96S10 O	122,653	10-24-97	1:22p	a96s10.o
A96S50	3,032	10-24-97	1:18p	a96s50
A96S50 O	122,640	10-24-97	1:22p	a96s50.o
A96S75	3,032	10-24-97	1:18p	a96s75
A96S75 O	121,640	10-24-97	1:22p	a96s75.o
A96S76	3,032	10-24-97	1:18p	a96s76
A96S76 O	121,639	10-24-97	1:22p	a96s76.o
A96S90	3,032	10-24-97	1:18p	a96s90
A96S90 O	122,686	10-24-97	1:22p	a96s90.o
A96SP10	3,103	10-24-97	1:18p	a96sp10
A96SP10 O	122,327	10-24-97	1:22p	a96sp10.o
A96SP24	3,105	10-24-97	1:18p	a96sp24
A96SP24 O	122,169	10-24-97	1:22p	a96sp24.o
A96SP25	3,109	10-24-97	1:18p	a96sp25
A96SP25 O	122,867	10-24-97	1:22p	a96sp25.o
A96SP50	3,105	10-24-97	1:18p	a96sp50
A96SP50 O	122,329	10-24-97	1:22p	a96sp50.o
A96SP90	3,105	10-24-97	1:18p	a96sp90
A96SP90 O	124,363	10-24-97	1:22p	a96sp90.o
CLAY1~1 KEF	2,892	10-24-97	1:18p	clay1.keff
HEADING	133	10-24-97	1:18p	heading
HEADOUT	4,902	10-24-97	1:18p	headout
HXAVE OUT	54,271	10-24-97	1:18p	hxave.out
SUMRY~1 OUT	1,133,538	10-24-97	1:23p	sumry.outlst

Results for 0.005 cm Fracture Width

Directory of C:\Work\tuttle\transect\clay2

B100P50	2,976	10-24-97	1:18p	b100p50
B100P50 O	121,343	10-24-97	1:23p	b100p50.o
B100P90	2,976	10-24-97	1:18p	b100p90
B100P90 O	122,532	10-24-97	1:23p	b100p90.o
B100S50	2,982	10-24-97	1:18p	b100s50
B100S50 O	121,227	10-24-97	1:23p	b100s50.o
B100S90	2,982	10-24-97	1:18p	b100s90
B100S90 O	121,720	10-24-97	1:23p	b100s90.o
B100SP50	3,055	10-24-97	1:18p	b100sp50
B100SP50 O	122,596	10-24-97	1:23p	b100sp50.o
B100SP90	3,055	10-24-97	1:18p	b100sp90
B100SP90 O	123,059	10-24-97	1:23p	b100sp90.o
B87P10	3,035	10-24-97	1:18p	b87p10
B87P10 O	121,423	10-24-97	1:23p	b87p10.o
B87P12	3,035	10-24-97	1:18p	b87p12
B87P12 O	121,395	10-24-97	1:23p	b87p12.o

```
B87P13       3,035  10-24-97  1:18p b87p13
B87P13  O    121,553  10-24-97  1:23p b87p13.o
B87P50       3,035  10-24-97  1:18p b87p50
B87P50  O    121,908  10-24-97  1:23p b87p50.o
B87P90       3,035  10-24-97  1:18p b87p90
B87P90  O    121,878  10-24-97  1:23p b87p90.o
B87S50       3,042  10-24-97  1:18p b87s50
B87S50  O    122,338  10-24-97  1:23p b87s50.o
B87S72       3,042  10-24-97  1:18p b87s72
B87S72  O    122,124  10-24-97  1:24p b87s72.o
B87S73       3,042  10-24-97  1:18p b87s73
B87S73  O    121,253  10-24-97  1:24p b87s73.o
B87S90       3,042  10-24-97  1:18p b87s90
B87S90  O    123,991  10-24-97  1:24p b87s90.o
B87SP10      3,113  10-24-97  1:18p b87sp10
B87SP10 O    122,002  10-24-97  1:24p b87sp10.o
B87SP21      3,118  10-24-97  1:18p b87sp21
B87SP21 O    121,868  10-24-97  1:24p b87sp21.o
B87SP22      3,114  10-24-97  1:18p b87sp22
B87SP22 O    122,654  10-24-97  1:24p b87sp22.o
B87SP50      3,114  10-24-97  1:18p b87sp50
B87SP50 O    121,064  10-24-97  1:24p b87sp50.o
B87SP90      3,114  10-24-97  1:18p b87sp90
B87SP90 O    122,383  10-24-97  1:24p b87sp90.o
B92P10       3,033  10-24-97  1:18p b92p10
B92P10  O    122,339  10-24-97  1:24p b92p10.o
B92P15       3,033  10-24-97  1:18p b92p15
B92P15  O    121,553  10-24-97  1:24p b92p15.o
B92P16       3,033  10-24-97  1:18p b92p16
B92P16  O    121,366  10-24-97  1:24p b92p16.o
B92P50       3,033  10-24-97  1:18p b92p50
B92P50  O    122,281  10-24-97  1:24p b92p50.o
B92P90       3,033  10-24-97  1:18p b92p90
B92P90  O    121,881  10-24-97  1:24p b92p90.o
B92S50       3,039  10-24-97  1:18p b92s50
B92S50  O    122,640  10-24-97  1:24p b92s50.o
B92S90       3,039  10-24-97  1:18p b92s90
B92S90  O    123,964  10-24-97  1:24p b92s90.o
B92S91       3,038  10-24-97  1:18p b92s91
B92S91  O    122,496  10-24-97  1:24p b92s91.o
B92SP10      3,110  10-24-97  1:18p b92sp10
B92SP10 O    123,395  10-24-97  1:24p b92sp10.o
B92SP26      3,112  10-24-97  1:18p b92sp26
B92SP26 O    121,866  10-24-97  1:24p b92sp26.o
B92SP27      3,116  10-24-97  1:18p b92sp27
B92SP27 O    121,923  10-24-97  1:24p b92sp27.o
B92SP50      3,112  10-24-97  1:18p b92sp50
B92SP50 O    122,141  10-24-97  1:24p b92sp50.o
B92SP90      3,112  10-24-97  1:18p b92sp90
B92SP90 O    121,783  10-24-97  1:24p b92sp90.o
B96P10       3,033  10-24-97  1:18p b96p10
B96P10  O    122,369  10-24-97  1:24p b96p10.o
B96P29       3,033  10-24-97  1:18p b96p29
B96P29  O    121,639  10-24-97  1:24p b96p29.o
B96P30       3,033  10-24-97  1:18p b96p30
B96P30  O    122,369  10-24-97  1:24p b96p30.o
B96P50       3,033  10-24-97  1:18p b96p50
B96P50  O    123,834  10-24-97  1:24p b96p50.o
B96P90       3,033  10-24-97  1:18p b96p90
B96P90  O    122,339  10-24-97  1:24p b96p90.o
B96S50       3,039  10-24-97  1:18p b96s50
B96S50  O    121,343  10-24-97  1:24p b96s50.o
B96S90       3,039  10-24-97  1:18p b96s90
B96S90  O    122,743  10-24-97  1:24p b96s90.o
B96S98       3,038  10-24-97  1:18p b96s98
B96S98  O    121,667  10-24-97  1:24p b96s98.o
B96SP10      3,110  10-24-97  1:18p b96sp10
B96SP10 O    123,301  10-24-97  1:24p b96sp10.o
B96SP47      3,116  10-24-97  1:18p b96sp47
B96SP47 O    124,336  10-24-97  1:24p b96sp47.o
B96SP48      3,112  10-24-97  1:18p b96sp48
B96SP48 O    123,031  10-24-97  1:24p b96sp48.o
B96SP50      3,112  10-24-97  1:18p b96sp50
B96SP50 O    122,459  10-24-97  1:24p b96sp50.o
B96SP90      3,112  10-24-97  1:18p b96sp90
B96SP90 O    122,112  10-24-97  1:24p b96sp90.o
CLAY2~1 KEF      2,441  10-24-97  1:18p clay2.keff
HEADING          133  10-24-97  1:18p heading
HEADOUT          4,025  10-24-97  1:18p headout
HXAVE   OUT      45,533  10-24-97  1:18p hxave.out
SUMRY~1 OUT      847,910  10-24-97  1:24p sumry.outlst
```

Results for 0.002 cm Fracture Width

```
Directory of C:\Work\tuttle\transect\clay3
C87P31       3,028  10-24-97  1:18p c87p31
C87P31  O    121,556  10-24-97  1:24p c87p31.o
```

```
C87P32        3,028  10-24-97  1:18p c87p32
C87P32  O     122,125  10-24-97  1:24p c87p32.o
C87P50        3,028  10-24-97  1:18p c87p50
C87P50  O     121,365  10-24-97  1:24p c87p50.o
C87P90        3,028  10-24-97  1:18p c87p90
C87P90  O     120,402  10-24-97  1:24p c87p90.o
C87SP50       3,107  10-24-97  1:18p c87sp50
C87SP50 O     121,761  10-24-97  1:24p c87sp50.o
C87SP53       3,111  10-24-97  1:18p c87sp53
C87SP53 O     121,925  10-24-97  1:24p c87sp53.o
C87SP54       3,107  10-24-97  1:18p c87sp54
C87SP54 O     122,872  10-24-97  1:24p c87sp54.o
C87SP90       3,107  10-24-97  1:18p c87sp90
C87SP90 O     121,924  10-24-97  1:24p c87sp90.o
C92P40        3,026  10-24-97  1:18p c92p40
C92P40  O     122,379  10-24-97  1:24p c92p40.o
C92P41        3,026  10-24-97  1:18p c92p41
C92P41  O     121,422  10-24-97  1:24p c92p41.o
C92P50        3,026  10-24-97  1:18p c92p50
C92P50  O     122,340  10-24-97  1:24p c92p50.o
C92P90        3,026  10-24-97  1:18p c92p90
C92P90  O     122,096  10-24-97  1:25p c92p90.o
C92SP50       3,105  10-24-97  1:18p c92sp50
C92SP50 O     123,058  10-24-97  1:25p c92sp50.o
C92SP65       3,109  10-24-97  1:18p c92sp65
C92SP65 O     122,024  10-24-97  1:25p c92sp65.o
C92SP66       3,105  10-24-97  1:18p c92sp66
C92SP66 O     121,898  10-24-97  1:25p c92sp66.o
C92SP90       3,105  10-24-97  1:18p c92sp90
C92SP90 O     122,868  10-24-97  1:25p c92sp90.o
C96P50        3,026  10-24-97  1:18p c96p50
C96P50  O     121,610  10-24-97  1:25p c96p50.o
C96P72        3,026  10-24-97  1:18p c96p72
C96P72  O     121,610  10-24-97  1:25p c96p72.o
C96P73        3,026  10-24-97  1:18p c96p73
C96P73  O     121,666  10-24-97  1:25p c96p73.o
C96P90        3,026  10-24-97  1:18p c96p90
C96P90  O     121,667  10-24-97  1:25p c96p90.o
C96SP50       3,105  10-24-97  1:18p c96sp50
C96SP50 O     123,274  10-24-97  1:25p c96sp50.o
C96SP90       3,105  10-24-97  1:18p c96sp90
C96SP90 O     123,142  10-24-97  1:25p c96sp90.o
C96SP98       3,104  10-24-97  1:18p c96sp98
C96SP98 O     123,086  10-24-97  1:25p c96sp98.o
CLAY3~1 KEF     1,316  10-24-97  1:18p clay3.keff
HEADING          133  10-24-97  1:18p heading
HEADOUT         2,012  10-24-97  1:18p headout
HXAVE   OUT    23,627  10-24-97  1:18p hxave.out
SUMRY~1 OUT   904,963  10-24-97  1:18p sumry.outlst
```

Results for 0.001 cm Fracture Width

```
Directory of C:\Work\tuttle\transoct\clay4
CLAY4~1 KEF       789  10-24-97  1:18p clay4.keff
D87P64        3,035  10-24-97  1:18p d87p64
D87P64  O     121,227  10-24-97  1:25p d87p64.o
D87P65        3,035  10-24-97  1:18p d87p65
D87P65  O     121,423  10-24-97  1:25p d87p65.o
D87P90        3,035  10-24-97  1:18p d87p90
D87P90  O     121,423  10-24-97  1:25p d87p90.o
D87SP90       3,114  10-24-97  1:18p d87sp90
D87SP90 O     122,597  10-24-97  1:25p d87sp90.o
D87SP98       3,113  10-24-97  1:18p d87sp98
D87SP98 O     121,925  10-24-97  1:25p d87sp98.o
D92P78        3,033  10-24-97  1:18p d92p78
D92P78  O     121,769  10-24-97  1:25p d92p78.o
D92P79        3,033  10-24-97  1:18p d92p79
D92P79  O     121,396  10-24-97  1:25p d92p79.o
D92P90        3,033  10-24-97  1:18p d92p90
D92P90  O     121,396  10-24-97  1:25p d92p90.o
D92SP90       3,112  10-24-97  1:18p d92sp90
D92SP90 O     122,627  10-24-97  1:25p d92sp90.o
D92SP98       3,111  10-24-97  1:18p d92sp98
D92SP98 O     122,898  10-24-97  1:25p d92sp98.o
D96P90        3,033  10-24-97  1:18p d96p90
D96P90  O     121,666  10-24-97  1:25p d96p90.o
D96P98        3,032  10-24-97  1:18p d96p98
D96P98  O     121,667  10-24-97  1:25p d96p98.o
D96SP90       3,112  10-24-97  1:18p d96sp90
D96SP90 O     122,168  10-24-97  1:25p d96sp90.o
D96SP98       3,111  10-24-97  1:18p d96sp98
D96SP98 O     122,272  10-24-97  1:25p d96sp98.o
HEADING          133  10-24-97  1:18p heading
HEADOUT         1,224  10-24-97  1:18p headout
HXAVE   OUT    13,363  10-24-97  1:18p hxave.out
SUMRY~1 OUT   522,358  10-24-97  1:25p sumry.outlst
```

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	From DAT-TUFF.WK3															Element	O	Si	Al
2																At. Wt.	15.995	28.086	26.982
3																			
4																			
5				Number of Atoms per Compound													Number of Atoms * Atomic Weigh		
6																			
7	Compound	Wt %		O	Si	Al	Fe	Ca	Mg	Ti	Na	K	P	Mn	H		O	Si	Al
8																			
9	SiO2	78.900		2	1												31.99	28.086	
10	Al2O3	12.300		3		2											47.985		53.964
11	Fe2O3	0.973		3			2										47.985		
12	CaO	0.451		1				1									15.995		
13	MgO	0.128		1					1								15.995		
14	TiO2	0.093		2						1							31.99		
15	Na2O	3.920		1							2						15.995		
16	K2O	3.180		1								2					15.995		
17	P2O5	0.010		5									2				79.975		
18	MnO	0.046		1										1			15.995		
19																			
20	H2O	100.000		1											2		15.995		
21																			
22																			
23																Fractional Densities per Compound and Ele			
24																			
25		Vol. Fract.	Dens.													SiO2	0.466351	0.409439	
26	Dry Tuff	0.5	2.22													Al2O3	0.064261		0.072269
27	Water	0.5	1													FeO	0.003246		
28																CaO	0.001428		
29																MgO	0.000564		
30																TiO2	0.000413		
31																Na2O	0.011230		
32																K2O	0.005994		
33																P2O5	0.000063		
34																MnO	0.000115		
35																			
36																H2O	0.444034		
37																			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
38																Total	0.997699	0.409439	0.072269
39																			
40																Wt. Fract.	0.619684	0.254308	0.044887

	T	U	V	W	X	Y	Z	AA	AB	AC
1	Fe	Ca	Mg	Ti	Na	K	P	Mn	H	
2	55.847	40.080	24.312	47.900	22.990	39.102	30.974	54.938	1.008	
3										
4										
5										
6										
7	Fe	Ca	Mg	Ti	Na	K	P	Mn	H	Total
8										
9										60.076
10										101.949
11	111.694									159.679
12		40.08								56.075
13			24.312							40.307
14				47.9						79.890
15					45.98					61.975
16						78.204				94.199
17							61.948			141.923
18								54.938		70.933
19										
20									2.016	18.011
21										
22										
23	nt									
24										
25										
26										
27	0.007555									
28		0.003578								
29			0.000857							
30				0.000619						
31					0.032282					
32						0.029304				
33							0.000048			
34								0.000395		
35										
36									0.055966	
37										

	T	U	V	W	X	Y	Z	AA	AB	AC
38	0.007555	0.003578	0.000857	0.000619	0.032282	0.029304	0.000048	0.000395	0.055966	1.610011
39										
40	0.004692	0.002222	0.000532	0.000384	0.020051	0.018201	0.000030	0.000246	0.034761	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	From FAX	Aug. 4														Element	O	Si	Al	Fe	Ca
2																At. Wt.	15.994915	28.086000	26.9815389	55.847000	40.080000
3																					
4																					
5				Number of Atoms per Compound													Number of Atoms * Atomic Weight				
6																					
7	Compoun	Wt %		O	Si	Al	Fe	Ca	Mg	Ti	Na	K	P	Mn	H		O	Si	Al	Fe	Ca
8																					
9	SiO2	76.827		2	1												31.989830	28.086000			
10	Al2O3	12.740		3		2											47.984745		53.963078		
11	Fe0	0.842		1			1										15.994915			55.847000	
12	CaO	0.560		1				1									15.994915				40.080000
13	MgO	0.245		1					1								15.994915				
14	TiO2	0.098		2						1							31.989830				
15	Na2O	3.593		1							2						15.994915				
16	K2O	4.930		1								2					15.994915				
17	P2O5	0.015		5									2				79.974575				
18	MnO	0.067		1										1			15.994915				
19																					
20	H2O	100.000		1											2		15.994915				
21																					
22																					
23																Fractional Densities per Compound and Element					
24																					
25		Vol. Fract.	Dens.													SiO2	0.919240	0.807062			
26	Dry Tuff	1	2.247													Al2O3	0.134740		0.151527		
27	Water	0.13	1													FeO	0.004212			0.014707	
28																CaO	0.003589				0.008994
29																MgO	0.002185				
30																TiO2	0.000882				
31																Na2O	0.020837				
32																K2O	0.018810				
33																P2O5	0.000190				
34																MnO	0.000339				
35																					
36																H2O	0.115451				
37																					
38																Total	1.220476	0.807062	0.151527	0.014707	0.008994
39																					
40																Wt. Fract.	0.513855	0.339796	0.063797	0.006192	0.003787

	V	W	X	Y	Z	AA	AB	AC
1	Mg	Ti	Na	K	P	Mn	H	
2	24.312000	47.900000	22.9897707	39.102000	30.9737647	54.9380503	1.00782519	
3								
4								
5								
6								
7	Mg	Ti	Na	K	P	Mn	H	Total
8								
9								60.075830
10								101.947823
11								71.841915
12								56.074915
13	24.312000							40.306915
14		47.900000						79.889830
15			45.979541					61.974456
16				78.204000				94.198915
17					61.947529			141.922104
18						54.938050		70.932965
19								
20							2.015650	18.010565
21								
22								
23								
24								
25								
26								
27								
28								
29	0.003321							
30		0.001320						
31			0.059898					
32				0.091967				
33					0.000147			
34						0.001166		
35								
36							0.014549	
37								
38	0.003321	0.001320	0.059898	0.091967	0.000147	0.001166	0.014549	2.375135
39								
40	0.001398	0.000556	0.025219	0.038721	0.000062	0.000491	0.006126	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Soddyite/Plutonium								Element	O	Si	H	U	Pu	
2									At. Wt.	15.994915	28.086000	1.00782519	235.043915	239.052146	
3															
4															
5				Number of Atoms per Compound						Number of Atoms * Atomic Weight					
6															
7	Compoun	Wt %		O	Si	H	U	Pu		O	Si	H	U	Pu	Total
8															
9	Soddyite	100.000	0.004275	10	1	4	2			159.949150	28.086000	4.031301	470.087830		662.154281
10				0.04	0	0.02	0.01								
11	H2O	100.000	0.033439	1		2				15.994915		2.015650			18.010565
12				0.03		0.07									
13	PuO2	100.000	0.025464	2				1		31.989830				239.052146	271.041976
14				0.05				0.03							
15															
16															
17															
18															
19															
20		Vol. Fract.	Dens.						Fractional Densities per Compound and Element						
21	Soddyite	0	4.7												
22	Water	0.73	1						Soddyite	0.000000	0.000000	0.000000	0.000000	0.000000	
23	PuO2	0.27	11.46												
24									H2O	0.648302	0.000000	0.081698	0.000000	0.000000	
25															
26									PuO2	0.365194	0.000000	0.000000	0.000000	2.729006	
27															
28									Total	1.013496	0.000000	0.081698	0.000000	2.729006	3.824200
29															
30									Wt. Fract.	0.265022	0.000000	0.021363	0.000000	0.713615	

	A	B	C	D	E	F	G	H	I	J	K	L	M
1									Solids produced at the end of cell 4, pass 0-Large Area Tuff reaction				
2		**Number Density Work**			Isotope List				Phase/End-member	Log moles	Moles	Mass, g	Volume cc
3													
4									Albite_low, NaAlSi3O8	0.4603	2.8863	756.86	288.84
5		Element	Symbol	Isotope	MCNP ID	Atomic Weight	Isotopic Fraction		Borax, Na2B4O7*10(H2O)	-1.8373	0.014544	5.5467	3.2384
6	1	Hydrogen	H	H-1	1001.50C	1.00782519			Celadonite, KMgAlSi4O(10)(OH)2	-0.9122	0.12241	48.563	19.23
7			D	H-2	1002.55C	2.01410222			Fluorapatite, Ca5F(PO4)3	-2.839	0.001449	0.73062	0.22831875
8			T	H-3	1003.50C	3.01604971			Maximum_Microcline, KAlSi3O8	0.3221	2.0996	584.4	228.32
9	2	Helium	He	nat.	2000.01C	4.0026			Na4UO2(CO3)3	-2.513	0.003069	1.6634	0.4505292
10			He	He-4	2004.50C	4.00260312			PuO2	-3.4514	0.000354	0.09761	0.0084277
11	3	Lithium	Li	Li-6	3006.50C	6.0151247			Pyrolusite, MnO2	-1.7122	0.0194	1.6866	0.333320158
12			Li	Li-7	3007.55C	7.0160039			Quartz, SiO2	1.0195	10.46	628.5	237.32
13	4	Beryllium	Be	Be-9	4009.50C	9.0121855			Rutile, TiO2	-1.5969	0.0253	2.0209	0.47615
14	5	Boron	B	B-10	5010.50C	10.0129388	0.199		Tenorite, CuO	-4.5819	2.62E-05	0.002083	0.00032
15			B	B-11	5011.56C	11.0093053	0.801						
16	6	Carbon	C	nat.	6000.50C	12.01115			Carbonate-Calcite	-0.6963	0.20122		
17			C	C-12	6012.50C	12			Calcite, CaCO3	-0.7024	0.19843	19.86	7.3288
18	7	Nitrogen	N	N-14	7014.50C	14.00307439			Magnesite, MgCO3	-2.5549	0.002787	0.23498	0.078085
19	8	Oxygen	O	O-16	8016.50C	15.994915			Rhodochrosite, MnCO3	-11.4657	3.42E-12	3.9333E-10	1.0633E-10
20	9	Fluorine	F	F-19	9019.50C	18.9984046			Siderite, FeCO3	-20.262	5.47E-21	6.3368E-19	1.6068E-19
21	11	Sodium	Na	Na-23	11023.50	22.9897707			Smithsonite, ZnCO3	-15.8471	1.42E-16	1.7832E-14	4.0208E-15
22	12	Magnesiu	Mg	nat.	12000.50	24.312			Strontianite, SrCO3	-8.8731	1.34E-09	1.9772E-07	5.2246E-08
23	13	Aluminum	Al	Al-27	13027.50	26.9815389							
24	14	Silicon	Si	nat.	14000.50	28.086			Smectite-di	-0.9185	0.12065		
25	15	Phosphoru	P	P-31	15031.50	30.9737647			Beidellite-Ca,	-19.8784	1.32E-20	4.8498E-18	1.7137E-18
26	16	Sulfur	S	S-32	16032.50	31.9720737			Beidellite-K	-18.9681	1.08E-19	4.0126E-17	1.4389E-17
27	17	Chlorine	Cl	nat.	17000.50	35.452			Beidellite-Mg	-20.4681	3.4E-21	1.2388E-18	4.193E-19
28	19	Potasium	K	nat.	19000.50	39.102			Beidellite-Na	-16.9541	1.11E-17	4.0854E-15	1.451E-15
29	20	Calcium	Ca	nat.	20000.50	40.08			Montmor-Ca	-12.9278	1.18E-13	4.3221E-11	5.9038E-11
30	22	Titanium	Ti	nat.	22000.50	47.9			Montmor-K	-11.8045	1.57E-12	5.8405E-10	7.8431E-10
31	23	Vanadium	V	nat.	23000.50	50.942			Montmor-Mg	-13.3066	4.94E-14	1.7942E-11	2.4684E-11
32	24	Chromium	Cr	nat.	24000.50	51.996			Montmor-Na	-9.8013	1.58E-10	5.7988E-08	7.8999E-08
33	25	Manganes	Mn	Mn-55	25055.50	54.9380503			Nontronite-Ca, Ca(0.165)Fe2Al(0.33)Si(3.67)O(10)(OH)2	-3.8541	0.00014	0.059377	0.018346
34	26	Iron	Fe	nat.	26000.55	55.847			Nontronite-K, K(0.33)Fe2Al(0.33)Si(3.67)O(10)(OH)2	-2.8351	0.001462	0.62947	0.19775
35	27	Cobalt	Co	Co-59	27059.50	58.933189			Nontronite-Mg, Mg(0.165)Fe2Al(0.33)Si(3.67)O(10)(OH)2	-4.4433	3.6E-05	0.015193	0.0046752
36	28	Nickel	Ni	nat.	28000.50	58.71			Nontronite-Na, Na(0.33)Fe2Al(0.33)Si(3.67)O(10)(OH)2	-0.9244	0.11901	50.612	15.723
37	29	Copper	Cu	nat.	29000.50	63.54							
38	30	Zinc	Zn	nat.		65.37			Rhabdophane-ss	-5.6277	2.36E-06		
39	33	Arsenic	As	As-75	33075.35	74.9215964			LaPO4:H2O	-6.402	3.96E-07	0.000099819	
40	38	Strontium	Sr	nat.		87.62			CePO4:H2O	-19.9869	1.03E-20	2.6087E-18	
41	40	Zirconium	Zr	nat.	40000.50	91.22			NdPO4:H2O	-6.3886	4.09E-07	0.00010513	
42	41	Niobium	Nb	Nb-93	41093.50	92.906382			GdPO4:H2O	-6.0807	8.3E-07	0.0002244	5.25527E-05
43	42	Molybden	Mo	nat.	42000.50	95.94			SmPO4:H2O	-6.142	7.21E-07	0.0001899	
44			Mo	Mo-95		94.905839						2101.482553	801.7961747
45	43	Technetiu	Tc	Tc-99*		98.90627501							
46	44	Ruthenium	Ru	Ru-101		100.905576							
47	45	Rhodium	Rh	Rh-103	45103.50	102.905511							
48	47	Silver	Ag	Ag-109	47109.50	108.904756							
49	48	Cadmium	Cd	nat.	48000.50	112.4							

	A	B	C	D	E	F	G	H	I	J	K	L	M
50	49	Indium	In	nat.		114.82							
51	50	Tin	Sn	nat.	50000.35	118.69							
52	55	Cesium	Cs	Cs-133		132.905355							
53			Cs	Cs-135		134.90577							
54	56	Barium	Ba	nat.		137.34							
55	57	Lanthanu	La	nat.		138.91							
56	58	Cerium	Ce	nat.		140.12							
57	60	Neodymiu	Nd	Nd-143		142.909779							
58			Nd	Nd-145		144.912538							
59													
60													
61													
62													
63		**Number Density Work**			Isotope List (Continued)								
64													
65													
66		Element	Symbol	Isotope	MCNP ID	Atomic Weight							
67	62	Samarium	Sm	Sm-147		146.914867							
68			Sm	Sm-149	62149.50	148.91718							
69			Sm	Sm-150		149.917276							
70			Sm	Sm-151		150.919919							
71			Sm	Sm-152		151.919756							
72	63	Europium	Eu	Eu-151	63151.55	150.919838							
73			Eu	Eu-153	63153.55	152.921242							
74			Eu	Eu-154	63154.50	153.923053							
75	64	Gadoliniu	Gd	nat.	64000.35	157.25							
76			Gd	Gd-155	64155.50	154.922664							
77			Gd	Gd-157	64157.50	156.924025							
78	72	Hafnium	Hf	nat.	72000.50	178.49							
79	73	Tantalum	Ta	Ta-181	73181.50	180.948007							
80	74	Tungsten	W	nat.	74000.55	183.85							
81	82	Lead	Pb	nat.	82000.50	207.19							
82	92	Uranium	U	U-233	92233.50	233.039522							
83			U	U-234	92234.50	234.040904							
84			U	U-235	92235.50	235.043915							
85			U	U-236	92236.50	236.045637							
86			U	U-238	92238.50	238.05077							
87	93	Neptunium	Np	Np-237	93237.55	237.048056							
88	94	Plutonium	Pu	Pu-238	94238.50	238.049511							
89			Pu	Pu-239	94239.55	239.052146							
90			Pu	Pu-240	94240.50	240.053882							
91			Pu	Pu-241	94241.50	241.056737							
92			Pu	Pu-242	94242.50	242.058725							
93			Pu	Pu-243	94243.35	243.061972							
94	95	Americium	Am	Am-241	95241.50	241.056714							
95			Am	Am-242m	95242.50	242.059502							
96			Am	Am-243	95243.50	243.061367							
97	96	Curium	Cm	Cm-243	96243.35	243.06137							
98			Cm	Cm-245	96245.35	245.065371							

	A	B	C	D	E	F	G	H	I	J	K	L	M
99			Cm	Cm-248	96248.35	248.0722							
100													
101													
102		**Number Density Worksheet:**											
103													
104		Number Density = (Weight %) * (Density) * (Na) / (Aw)											
105		Avogadro's Number [		0.602252									
106		Atomic Weight [Aw]											
107													

	N	O	P	Q	R	S	T	U	V
1									
2	Density g/cc		Atomic Weight	Atom Density			MCNP ID	Isotopic Atom Density for MCNP	
3				mass/(total volume)/AW*Av					
4	2.620343443		262.1886296	2.1683E-03			1001.50C	3.6517E-04	
5	1.712790267		381.2937137	1.0927E-05	***		6012.50C	1.5117E-04	
6	2.525377015		396.6941693	9.1953E-05			8016.50C	4.8406E-02	
7	3.2		504.2586787	1.0883E-06			9019.50C	1.0883E-06	
8	2.559565522		278.3008589	1.5773E-03			11023.50C	2.1978E-03	
9	3.692102532		538.9470628	2.3183E-06	***		12000.50C	9.4051E-05	
10	11.58204492		271.041976	2.7050E-07	***		13027.50C	3.8674E-03	
11	5.06		86.9278803	1.4574E-05			14000.50C	1.9795E-02	
12	2.648322939		60.07583	7.8581E-03			15031.50C	3.2649E-06	
13	4.244250761		79.88983	1.9001E-05			19000.50C	1.6696E-03	
14	6.509375		79.534915	1.9672E-08			20000.50C	1.5454E-04	
15							22000.50C	1.9001E-05	
16							25055.50C	1.4574E-05	
17	2.709857003		100.064745	1.4908E-04			26000.55C	1.8127E-04	
18	3.009284754		84.296745	2.0938E-06			29000.50C	1.9672E-08	
19	3.699144174		114.9227953	2.5708E-15					
20	3.943739109		115.831745	4.1092E-24			TOTAL	7.6920E-02	
21	4.434938321		125.365895	1.0684E-19	***				
22	3.784404548		147.615895	1.0061E-12	***				
23									
24									
25	2.830016922								
26	2.788658003								
27	2.954447889								
28	2.815575465								
29	0.732087808								
30	0.744667287								
31	0.726867607								
32	0.734034608								
33	3.236509321		424.2413582	1.0513E-07					
34	3.183160556		430.5318182	1.0982E-06					
35	3.249700548		421.6396382	2.7066E-08					
36	3.218978566		425.2147825	8.9405E-05					
37					*** indicates not included in total or isotopic number densities				
38			TOTAL	1.1972E-02					
39									
40									
41									
42	4.27								
43									
44									
45									
46									
47									
48									
49									

	N	O	P	Q	R	S	T	U	V
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									
68									
69									
70									
71									
72									
73									
74									
75									
76									
77									
78									
79									
80									
81									
82									
83									
84									
85									
86									
87									
88									
89									
90									
91									
92									
93									
94									
95									
96									
97									
98									

	N	O	P	Q	R	S	T	U	V
99									
100									
101									
102									
103									
104									
105									
106									
107									

	A	B	C	D	E	F	G	H	I	J	K	L
1			0.76	0.12	0.12							
2												
3	Element	MCNP ID	Clayey	Soddyite	PuO2	Total		MCNP ID	Total	$	Element	
4												
5	Hydrogen	1001.50C	3.6517E-04	0.0171		2.3295E-03	M2	1001.50C	2.3295E-03	$	Hydrogen	
6	Carbon	6012.50C	1.5117E-04			1.1489E-04		6012.50C	1.1489E-04	$	Carbon	
7	Oxygen	8016.50C	4.8406E-02	0.04275	0.050928	4.8030E-02		8016.50C	4.8030E-02	$	Oxygen	
8	Fluorine	9019.50C	1.0883E-06			8.2712E-07		9019.50C	8.2712E-07	$	Fluorine	
9	Sodium	11023.50C	2.1978E-03			1.6703E-03		11023.50	1.6703E-03	$	Sodium	
10	Magnesium	12000.50C	9.4051E-05			7.1479E-05		12000.50	7.1479E-05	$	Magnesium	
11	Aluminum	13027.50C	3.8674E-03			2.9392E-03		13027.50	2.9392E-03	$	Aluminum	
12	Silicon	14000.50C	1.9795E-02	0.004275		1.5557E-02		14000.50	1.5557E-02	$	Silicon	
13	Phosphorus	15031.50C	3.2649E-06			2.4813E-06		15031.50	2.4813E-06	$	Phosphorus	
14	Potasium	19000.50C	1.6696E-03			1.2689E-03		19000.50	1.2689E-03	$	Potasium	
15	Calcium	20000.50C	1.5454E-04			1.1745E-04		20000.50	1.1745E-04	$	Calcium	
16	Titanium	22000.50C	1.9001E-05			1.4440E-05		22000.50	1.4440E-05	$	Titanium	
17	Manganese	25055.50C	1.4574E-05			1.1076E-05		25055.50	1.1076E-05	$	Manganese	
18	Iron	26000.55C	1.8127E-04			1.3777E-04		26000.55	1.3777E-04	$	Iron	
19	Copper	29000.50C	1.9672E-08			1.4951E-08		29000.50	1.4951E-08	$	Copper	
20	Uranium	92235.50C		0.00855		1.0260E-03		92235.50	1.0260E-03	$	Uranium	
21	Plutonium	94239.55C			0.025464	3.0557E-03		94239.55	3.0557E-03	$	Plutonium	
22												
23		TOTAL	7.6920E-02	0.072675	0.076392	7.6347E-02						