BWXT Nuclear Operations Group – Lynchburg

BWX Technologies, Inc.

To	NCS File		
From	Larry Wetzel	File No. or Ref. -	NCS-2018-005
Subj.	Calculations for U and Pu for License Amendment	Date	January 17, 2018

Introduction

In Section 5.2.8, the table (histogram) of the mass limits to Pu wt% is replaced by an equation that is more commonly used. The equation is the sum of fractions of fissile uranium mass over 350 grams and the plutonium mass over 220 grams.

This document provides the justification for the change.

Methodology

Calculational studies on the mixture of uranium metal and plutonium metal mixed with water in a sphere and water reflected were performed to attain an understanding of the relationship to the mixtures and k_{eff}. The current validation does not include plutonium, but for the sake of this study, the bias for HEU will be applied to plutonium and mixtures of uranium and plutonium.

The calculations were performed using NCSE-02 as guidance. The methodology to be applied is SCALE6.1/KENO-V.a calculations of k_{eff} with appropriate margin of subcriticality, bias, and limits. Reference calculations and evaluations are applied where applicable.

Calculations are performed using the SCALE 6.1 package running CSAS5 with the 238-group ENDF/B-VII cross section library (designated as "v7-238"). The calculations were run on ESH-468[1],

The calculation margin applied to all calculations is 0.010[2].

Reported k_{adj} values are given by the following equation:

$$k_{adj} = k_{calc} + 2\sigma + \text{calculation margin}$$

Discussion

The sum of fractions approach was described in ANSI/ANS-8.15-1981. Section 5.2 states the limits in Table 2 may be applied to mixtures of fissile units provided the sum of the ratios of the

[1] NCS-2017-154, "SCALE 6.1 Verification for Windows 7 Workstation ESH-468," L. L. Wetzel, dated September 21, 2017.

[2] NCS-TR-00007, Rev. 2, "Validation Report for SCALE 6.1 on Windows 7-Based PC's," L. L. Wetzel, August 20, 2014.

mass of each fissile nuclide to its limit (Table 2) does not exceed unity. For ^{235}U, the subcritical limit used 350 grams. ^{233}U is rarely handled at our facility (and per the license is limited to 1 gram). In Table 2, the subcritical limit for ^{239}Pu is 450 grams, and for ^{241}Pu is 200 grams. While the 220 value is slightly higher than the subcritical limit for ^{241}Pu, it is adequate considering is much lower than the ^{239}Pu subcritical limit and ^{239}Pu is more common. The use of this equation would result in a fraction critical in terms of mass of less than 0.5.

The current license limits the amount of ^{233}U to 1 gram and unencapsulated plutonium to 50 grams. The 1 gram of ^{233}U would make very little difference in the k_{eff} of the system. With 50 grams of Pu, the amount of ^{235}U that could be present is 270.4 grams.

The uranium density was set at 18.81 g/cm^3 and the plutonium density was set at 19.85 g/cm^3. The uranium was assumed to be 100 percent enriched in ^{235}U. The principle fissile forms of plutonium (^{239}Pu and ^{241}Pu) were investigated. The radius of the sphere was increased to increase the H/(U+Pu) until the optimum was established.

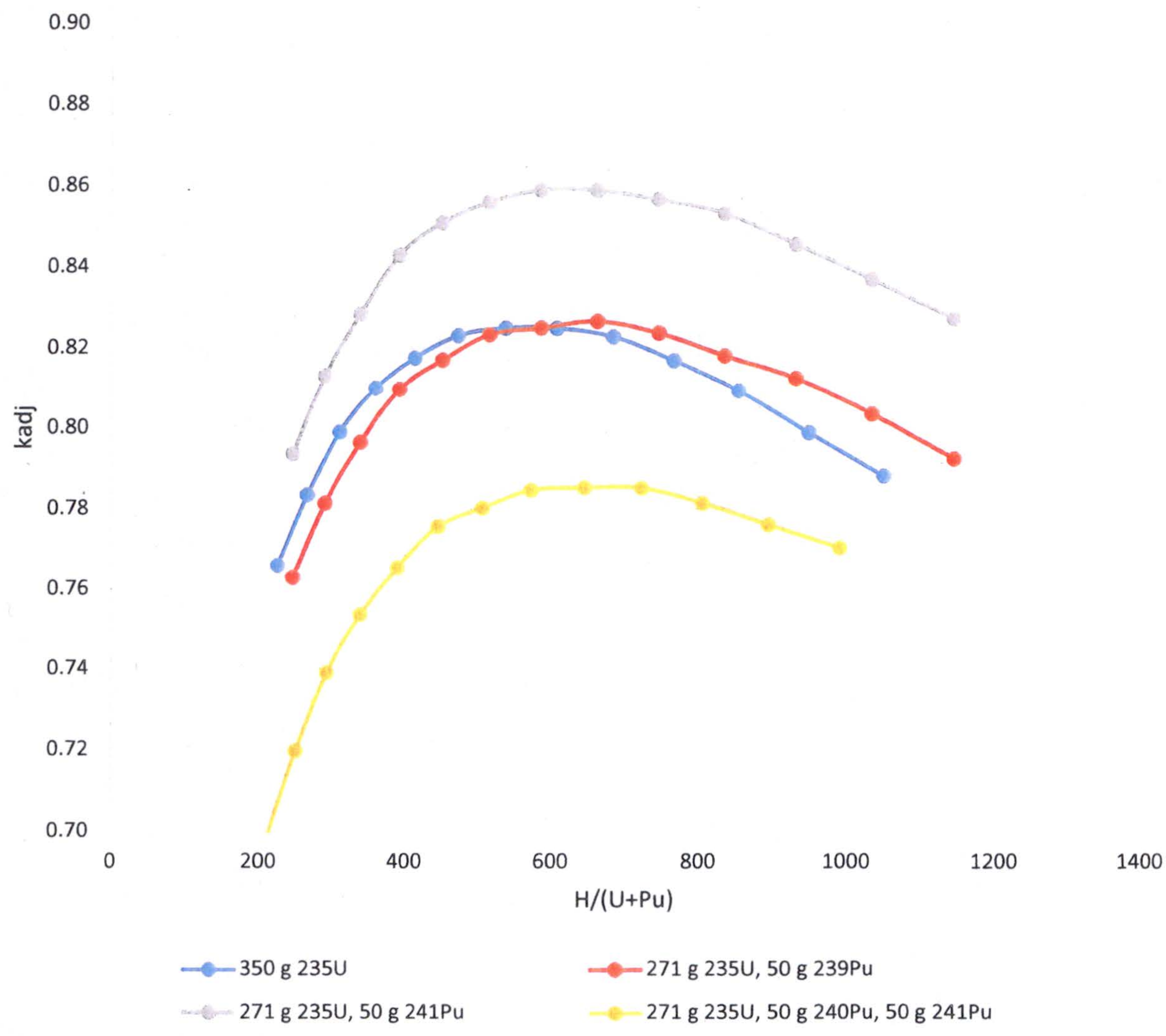


Figure 1: Mixture ^{235}U, ^{239}Pu and ^{241}Pu with Water, Water Reflected

^{241}Pu is more reactive than ^{239}Pu. The unrealistic aspect of this is if ^{241}Pu is present, there will be ^{240}Pu which is essentially a thermal absorber. Since ^{241}Pu is produced from neutron capture in ^{240}Pu and since ^{241}Pu is fissile and has a shorter half-life than ^{240}Pu, there will be more ^{240}Pu than ^{241}Pu. The last curve in the figure included 50 gram of ^{240}Pu in addition to the 50 grams ^{241}Pu. With ^{240}Pu present, the system is less reactive than if just ^{235}U or ^{235}U and ^{239}Pu are present.

With the limits on the amount of unencapsulated plutonium and ^{233}U, the fraction critical equation provides an adequate method of handling mixed species.

Table 1: 350 g ^{235}U, 0 g ^{239}Pu, 0 g ^{241}Pu as Metal Mixed with Water in a Water Reflected Sphere

Radius (cm)	Water Volume (cm^3)	H/(U+Pu)	k_{eff}	Sigma	k_{adj}	Case Name
9	3035.02	225.83	0.75464	0.00066	0.76596	lic_350U_0Pu_r090
9.5	3572.76	265.84	0.77214	0.00068	0.78350	lic_350U_0Pu_r095
10	4170.18	310.30	0.78762	0.00071	0.79904	lic_350U_0Pu_r100
10.5	4830.44	359.43	0.79859	0.00073	0.81005	lic_350U_0Pu_r105
11	5556.67	413.46	0.80625	0.00065	0.81755	lic_350U_0Pu_r110
11.5	6352.02	472.65	0.81172	0.00072	0.82316	lic_350U_0Pu_r115
12	7219.62	537.20	0.81366	0.00068	0.82502	lic_350U_0Pu_r120
12.5	8162.62	607.37	0.81359	0.00067	0.82493	lic_350U_0Pu_r125
13	9184.16	683.38	0.81137	0.00071	0.82279	lic_350U_0Pu_r130
13.5	10287.39	765.47	0.80576	0.00056	0.81688	lic_350U_0Pu_r135
14	11475.43	853.87	0.79821	0.00054	0.80929	lic_350U_0Pu_r140
14.5	12751.44	948.82	0.78766	0.00058	0.79882	lic_350U_0Pu_r145
15	14118.56	1050.54	0.77698	0.00056	0.78810	lic_350U_0Pu_r150

Table 2: 271 g ^{235}U, 50 g ^{239}Pu, 0 g ^{241}Pu as Metal Mixed with Water in a Water Reflected Sphere

Radius (cm)	Water Volume (cm³)	H/(U+Pu)	k_{eff}	Sigma	k_{adj}	Case Name
9	3036.70	246.37	0.75147	0.00073	0.76293	lic_271U_50Pu239_r090
9.5	3574.44	290.00	0.77006	0.00066	0.78138	lic_271U_50Pu239_r095
10	4171.86	338.47	0.78501	0.00074	0.79649	lic_271U_50Pu239_r100
10.5	4832.12	392.03	0.79838	0.00067	0.80972	lic_271U_50Pu239_r105
11	5558.35	450.95	0.80570	0.00065	0.81700	lic_271U_50Pu239_r110
11.5	6353.70	515.48	0.81210	0.00064	0.82338	lic_271U_50Pu239_r115
12	7221.30	585.87	0.81362	0.00069	0.82500	lic_271U_50Pu239_r120
12.5	8164.30	662.38	0.81537	0.00063	0.82663	lic_271U_50Pu239_r125
13	9185.85	745.26	0.81242	0.00065	0.82372	lic_271U_50Pu239_r130
13.5	10289.07	834.76	0.80663	0.00070	0.81803	lic_271U_50Pu239_r135
14	11477.11	931.15	0.80102	0.00068	0.81238	lic_271U_50Pu239_r140
14.5	12753.12	1034.67	0.79216	0.00062	0.80340	lic_271U_50Pu239_r145
15	14120.24	1145.59	0.78121	0.00058	0.79237	lic_271U_50Pu239_r150

Table 3: 271 g ^{235}U, 0 g ^{239}Pu, 50 g ^{241}Pu as Metal Mixed with Water in a Water Reflected Sphere

Radius (cm)	Water Volume (cm³)	H/(U+Pu)	k_{eff}	Sigma	k_{adj}	Case Name
9	3039.22	246.57	0.78225	0.00068	0.79361	lic_271U_50Pu241_r090
9.5	3576.96	290.20	0.80147	0.00071	0.81289	lic_271U_50Pu241_r095
10	4174.38	338.67	0.81696	0.00067	0.82830	lic_271U_50Pu241_r100
10.5	4834.64	392.24	0.83141	0.00071	0.84283	lic_271U_50Pu241_r105
11	5560.87	451.16	0.83945	0.00067	0.85079	lic_271U_50Pu241_r110
11.5	6356.22	515.69	0.84456	0.00069	0.85594	lic_271U_50Pu241_r115
12	7223.82	586.08	0.84757	0.00065	0.85887	lic_271U_50Pu241_r120
12.5	8166.82	662.58	0.84749	0.00065	0.85879	lic_271U_50Pu241_r125
13	9188.36	745.46	0.84535	0.00060	0.85655	lic_271U_50Pu241_r130
13.5	10291.59	834.97	0.84180	0.00062	0.85304	lic_271U_50Pu241_r135
14	11479.63	931.35	0.83424	0.00061	0.84546	lic_271U_50Pu241_r140
14.5	12755.64	1034.88	0.82565	0.00054	0.83673	lic_271U_50Pu241_r145
15	14122.76	1145.79	0.81594	0.00059	0.82712	lic_271U_50Pu241_r150

Table 4: 271 g ^{235}U, 0 g ^{239}Pu, 50 g ^{240}Pu, 50 g ^{241}Pu as Metal Mixed with Water in a Water Reflected Sphere

Radius (cm)	Water Volume (cm^3)	H/(U+Pu)	k_{eff}	Sigma	k_{adj}	Case Name
9	3034.18	212.99	0.68824	0.00065	0.69954	lic_271U_50Pu241_50pu240_r090
9.5	3571.92	250.74	0.70851	0.00064	0.71979	lic_271U_50Pu241_50pu240_r095
10	4169.35	292.67	0.72789	0.00062	0.73913	lic_271U_50Pu241_50pu240_r100
10.5	4829.60	339.02	0.74216	0.00072	0.75360	lic_271U_50Pu241_50pu240_r105
11	5555.83	390.00	0.75386	0.00072	0.76530	lic_271U_50Pu241_50pu240_r110
11.5	6351.18	445.83	0.76425	0.00067	0.77559	lic_271U_50Pu241_50pu240_r115
12	7218.78	506.74	0.76900	0.00061	0.78022	lic_271U_50Pu241_50pu240_r120
12.5	8161.79	572.93	0.77336	0.00063	0.78462	lic_271U_50Pu241_50pu240_r125
13	9183.33	644.64	0.77399	0.00062	0.78523	lic_271U_50Pu241_50pu240_r130
13.5	10286.55	722.08	0.77399	0.00059	0.78517	lic_271U_50Pu241_50pu240_r135
14	11474.60	805.48	0.77030	0.00054	0.78138	lic_271U_50Pu241_50pu240_r140
14.5	12750.61	895.05	0.76491	0.00056	0.77603	lic_271U_50Pu241_50pu240_r145
15	14117.72	991.02	0.75905	0.00061	0.77027	lic_271U_50Pu241_50pu240_r150

Peer Review

I reviewed the calculations using procedure NCSE-02, Rev. 45 as guidance. I verified that:

Methodology and Validation

- The analysis uses a methodology permitted by procedure and the license.
- The applicability of referenced documents has been demonstrated.
- The methodology has been described in the analysis and is acceptable.
- Calculations of k_{eff} performed in the analysis have been performed on a validated and verified computer system.
  (**Note**: Pu is not validated and these calculations are for comparison only.)
- For calculations performed in the analysis, application of the appropriate margin of subcriticality has been demonstrated.
  (**Note:** The bias for HEU was applied to the Pu for consistency only.)

Assumptions, Calculations and Modeling

- The assumptions have been clearly described and demonstrated to be conservative.
- Parameters that are not controlled have been demonstrated to be at their most reactive condition for the system.
- The base model is described in sufficient detail to allow independent verification and demonstrates that the system is conservatively modeled.
- Computer models have been reviewed to ensure:
  - the optimum conditions have been included.

- correct materials, geometry, boundary conditions have been modeled.
- The models adequately converge.
- The following cases were reviewed: lic_350U_0Pu_r125, lic_271U_50Pu241_r120, lic_271U_50Pu239_r120, lic_271U_50Pu241_50pu240_r135

Prepared by: Larry L. Wetzel

Peer review by: Todd Stinson

Sample Input Cases

lic_350U_0Pu_r110.inp

```
=csas5
0 g Pu ' pu-239 0 Pu-239, H/X=413.46 rad=11.00
v7-238
read comp
uranium 1 den=6.2777E-02 1.0 300 92235 100 end
' pu-239 1 den=0.0000E+00 1.0 300 end
h2o 1 den=9.9487E-01 1.0 300 end
h2o 2 1.00 300 end
end comp
read para htm=no npg=2000 gen=1000 nsk=100 end para
read geometry
global unit 1
sphere 1 1 11.0000
sphere 2 1 41.4800
end geometry
end data
end
```

lic_271U_50Pu239_r100.inp

```
=csas5
50 g Pu pu-239 100 Pu-239, H/X=338.47 rad=10.00
v7-238
read comp
uranium 1 den=6.4696E-02 1.0 300 92235 100 end
pu-239 1 den=1.1937E-02 1.0 300 end
h2o 1 den=9.9417E-01 1.0 300 end
h2o 2 1.00 300 end
end comp
read para htm=no npg=2000 gen=1000 nsk=100 end para
read geometry
global unit 1
sphere 1 1 10.0000
sphere 2 1 40.4800
end geometry
end data
end
```

lic_271U_50Pu241_r100

```
=csas5
50 g Pu pu-241 0 Pu-239, H/X=338.47 rad=10.00
v7-238
read comp
```

```
uranium 1 den=6.4696E-02 1.0 300 92235 100 end
pu-241 1 den=1.1937E-02 1.0 300 end
pu-240 1 den=0.0000E+00 1.0 300 end
h2o 1 den=9.9417E-01 1.0 300 end
h2o 2 1.00 300 end
end comp
read para htm=no npg=2000 gen=1000 nsk=100 end para
read geometry
global unit 1
sphere 1 1 10.0000
sphere 2 1 40.4800
end geometry
end data
end
```

lic_271U_50Pu241_50pu240_r130

```
=csas5
50 g Pu pu-241 0 Pu-239, H/X=745.05 rad=13.00
v7-238
read comp
uranium 1 den=2.9448E-02 1.0 300 92235 100 end
pu-241 1 den=5.4331E-03 1.0 300 end
pu-240 1 den=5.4331E-03 1.0 300 end
h2o 1 den=9.9609E-01 1.0 300 end
h2o 2 1.00 300 end
end comp
read para htm=no npg=2000 gen=1000 nsk=100 end para
read geometry
global unit 1
sphere 1 1 13.0000
sphere 2 1 43.4800
end geometry
end data
end
```

BWX Technologies, Inc. Babcock & Wilcox, a McDermott company	**Naval Nuclear** **Fuel Division**	
To	M. P. Akers, Licensing Administrator, X6687	
From	M. V. Mitchell, Engineer, Nuclear Criticality Safety, X5195	File No. Or Ref. NCS-1998-039
Subj.	Nuclear Criticality Safety Evaluation Supporting SER98-007, "Packaging of (NMC) Drums," Phase 4	Date February 18, 1998

1.0 Summary:

SER98-007, "Packaging of (NMC) Drums," Phase 4, requests approval to change how 55-gallon waste drums are handled in the Mixed Waste Building. Currently, 55-gallon drums are allowed to be loaded up to 350 grams of U-235 ("corrected") and stacked two high. As a result of this evaluation, the 55-gallon drums will be limited to only 100 grams of U-235 based on the raw drum counter results and the drums can continue to be stacked two high.

2.0 System Description:

The Mixed Waste Building is used to store mixed waste contained in 55-gallon drums until it can be shipped offsite for disposal. The 55-gallon drums are limited to 100 grams U-235 and can be stacked 2-high in order to maximize use of floor space.

3.0 Methodology:

This Nuclear Criticality Safety Analysis was performed according to NCSE-02 [Ref. 1].

This evaluation is based on approved references and computer calculations. When computer calculations are performed, the keff limit for the worst case normal condition is < 0.92 (keff + σ + bias) and the keff limit for all single credible upset conditions is < 0.95 (keff + 2σ + bias). This system was modeled using the SCALE 4.2 package (CSAS25 module) with the 27-group cross section library on the H/P workstation (NCS1). The bias used for the output associated with these models are 0.016 [Ref. 2 and 3].

4.0 System Analysis:

The parameters that affect reactivity are:

1. Chemical form.
2. Enrichment.
3. Density.
4. Moderation (Interspersed and Interstitial).

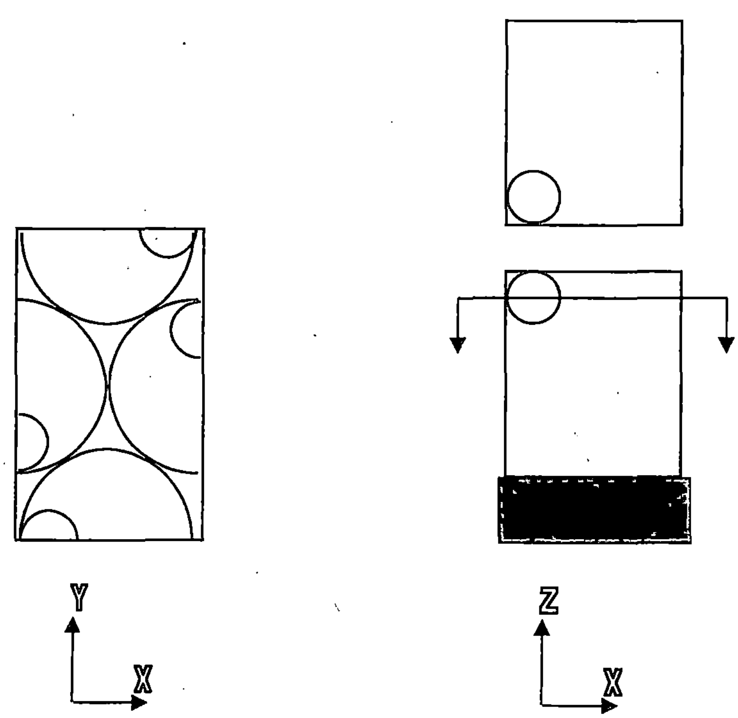
5. Reflection.
6. Geometry.
7. Mass.
8. Spacing.

The assumptions used while performing this evaluation are:

1. The chemical form was assumed to be uranium metal (ρ = 18.81 g/cc).
2. The enrichment was assumed to be 100 wt% U-235.
3. The drums on the bottom layer are resting directly on 12 inches of nominal density Oak Ridge concrete.
4. Moderating material within the drums containing beryllium was modeled as BeO (ρ = 3.011 g/cc).
5. Reflecting/moderating material within the drums not containing beryllium was modeled as having all degrees of nominal density water (ρ ≤ 0.9982 g/cc).

In order to analyze this system, an infinite, 2-high, triangular pitched; array of 55-gallon drums was modeled. Each drum consisted of a cylinder that had a nominal inside diameter (I.D.) of 22 ½ inches and an inside height (I.H.) of 33 ½ inches [Ref. 4]. The lower layer of 55-gallon drums was modeled sitting on 12 inches of Oak Ridge concrete. The upper layer of 55-gallon drums was modeled 5 inches above the top of the lower layer taking into account a pallet that would be necessary to stack these drums.

The fuel material within the drums was modeled as having a spherical shape, offset within the drum, for optimal interaction. Mirror boundary conditions were used on the x and y faces. See figure below.

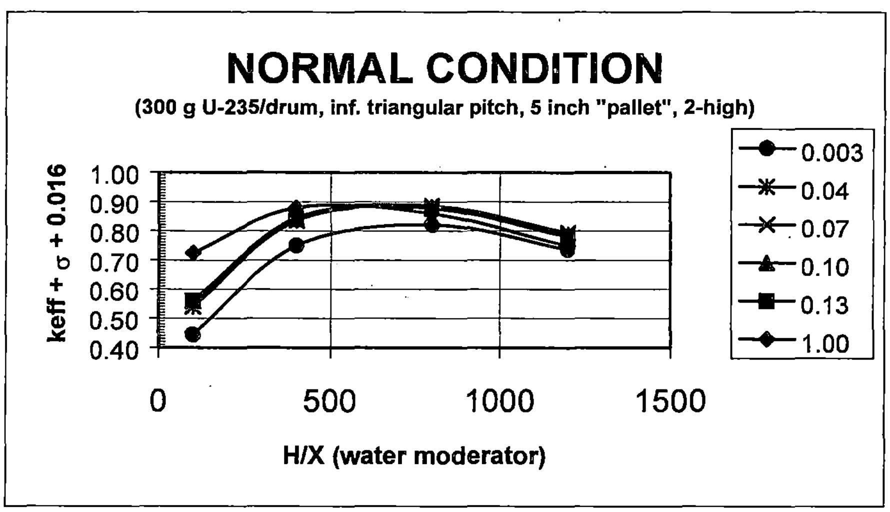


In order to determine if the worst case normal condition meets the license criteria (keff + σ + 0.016), a parameter study was performed. This study involved the above model with each drum containing 300 grams of U-235 at varying degrees of moderation (H/X). The uranium metal water mixtures were modeled on the floor of the drums in the top layer and up against the top on the bottom layer. The balance of material in the drums was modeled as having a varied volume fraction of water less than or equal to one. The room (that volume outside of the drums) was modeled as having a water volume fraction of 3.4E-5. The results follow:

	0.003 volume fraction water			0.04 volume fraction water			0.07 volume fraction water		
H/X	Case	Keff	σ	Case	Keff	σ	Case	Keff	σ
100	021	0.4256	0.0016	017	0.5218	0.0017	013	0.5393	0.0017
400	022	0.7309	0.0018	018	0.8172	0.0017	014	0.8257	0.0018
800	023	0.8023	0.0016	019	0.8642	0.0015	015	0.8685	0.0015
1200	024	0.7182	0.0014	020	0.7705	0.0012	016	0.7752	0.0014

	0.10 volume fraction water			0.13 volume fraction water			1.00 volume fraction water		
H/X	Case	Keff	σ	Case	Keff	σ	Case	Keff	σ
100	009	0.5428	0.0016	005	0.5435	0.0018	001*	0.7058	0.0018
400	010	0.8226	0.0017	006	0.8236	0.0017	002	0.8622	0.0012
800	011	0.8616	0.0015	007	0.8593	0.0016	003	0.8842	0.0014
1200	012	0.7675	0.0012	008	0.7627	0.0013	004	0.7285	0.0013

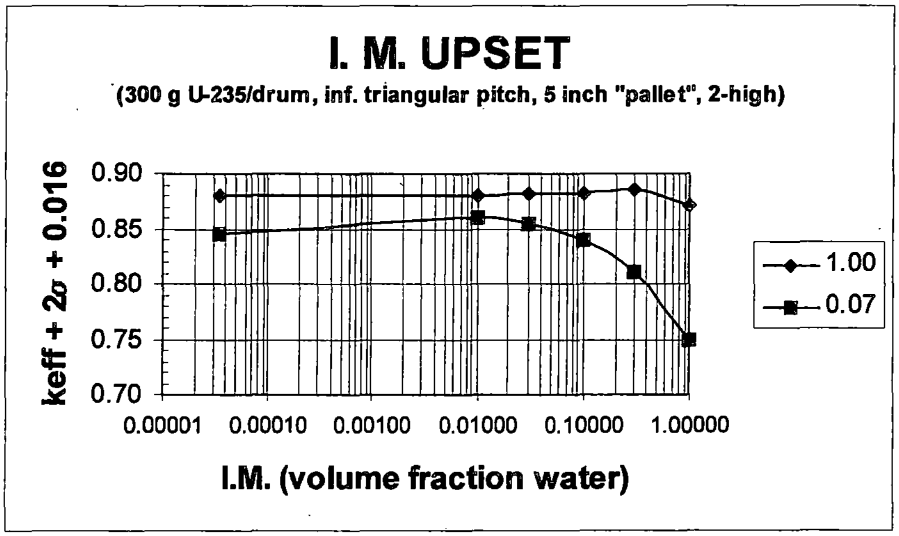
* Copy in Appendix C.



The keff + σ + 0.016 remains below 0.92 for all reflector/moderator combinations.

Next, an Interspersed Moderator upset condition was investigated. This was accomplished by taking cases 002 and 014 above and rerunning them with varying degrees of Interspersed Moderator. The results follow:

	0.07 volume fraction water in drums			1.00 volume fraction water in drums		
I.M. (volume fraction water)	Case	Keff	2σ	Case	Keff	2σ
3.4E-5	014	0.8257	0.0035	002	0.8622	0.0024
0.01	059	0.8399	0.0035	054	0.8611	0.0023
0.03	060	0.8344	0.0034	055	0.8630	0.0023
0.10	061	0.8214	0.0035	056	0.8627	0.0025
0.30	062	0.7919	0.0035	057	0.8664	0.0026
1.00	063	0.7298	0.0036	058	0.8527	0.0024



The system keff + 2σ + 0.016 for an Interspersed Moderator upset condition remains below 0.95.

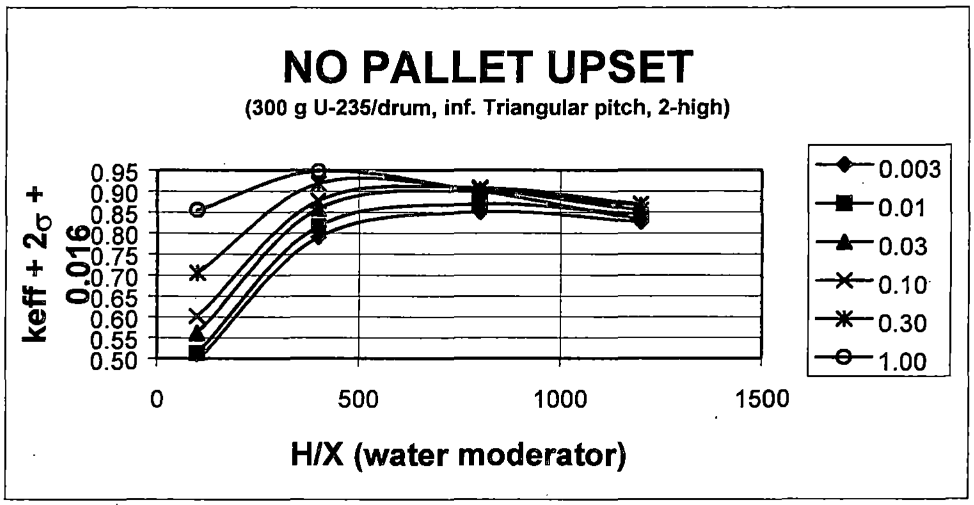
Next, the effect of stacking these drums 2-high without spacing between the layers (no pallets) was investigated. This was accomplished by simply referencing a parameter study performed in Reference 5 which addressed stacking as an upset condition. This study modeled an array of 55-gallon drums stacked two high with the second layer resting directly on the bottom layer. The fuel mixtures were modeled on the floor of the drum in the second layer and just under the lid of the drum on the lower layer. This results in eight fuel bearing units in close proximity.

The reflecting/moderating material, which occupies the balance of the drums, was modeled as having varied volume fraction of water less than or equal to one. The results are reiterated below:

	0.003 volume fraction water			0.01 volume fraction water			0.03 volume fraction water		
H/X	Case	Keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	010*	0.4751	0.0034	014*	0.4935	0.0034	018*	0.5414	0.0034
400	011*	0.7709	0.0036	015*	0.7970	0.0037	019*	0.8376	0.0039
800	012*	0.8308	0.0030	016*	0.8500	0.0032	020*	0.8811	0.0030
1200	013*	0.8085	0.0027	017*	0.8256	0.0026	021*	0.8468	0.0025

	0.10 volume fraction water			0.30 volume fraction water			1.00 volume fraction water		
H/X	Case	Keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	022*	0.5815	0.0035	026*	0.6856	0.0037	030*	0.8349	0.0038
400	023*	0.8578	0.0034	027*	0.8981	0.0038	031*	0.9293	0.0022
800	024*	0.8889	0.0030	028*	0.8850	0.0030	032*	0.8810	0.0031
1200	025*	0.8505	0.0024	029*	0.8364	0.0026	033*	0.8133	0.0027

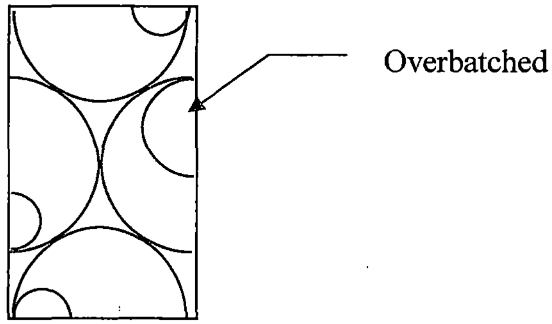
* From Reference 5.



The system keff + 2σ + 0.016 which results from not using a pallet remains below 0.95.

Next, the upset condition involving the stacking of these drums more than 2-high will be addressed. Presently, the Mixed Waste Building is the only location in which the stacking of 55-gallon waste drums 2-high is allowed. All other locations require a single layer. Historically, the prevention of stacking more than 2-high in the Mixed Waste Building has been controlled administratively, by disallowing it on the NCS posting. Since there has been no indication that this is no longer effective, coupled with the instability of an array stacked more than 2-high, stacking 55-gallon drums more than 2-high in the Mixed Waste Building is not considered to be credible.

Next, the effect on system keff was investigated as a function of U-235 overbatching. This was accomplished by taking the normal case model above and varying the U-235 mass in 1 out of every 4 drums. Both, the drum on the top layer and bottom layer were overbatched. See figure below:



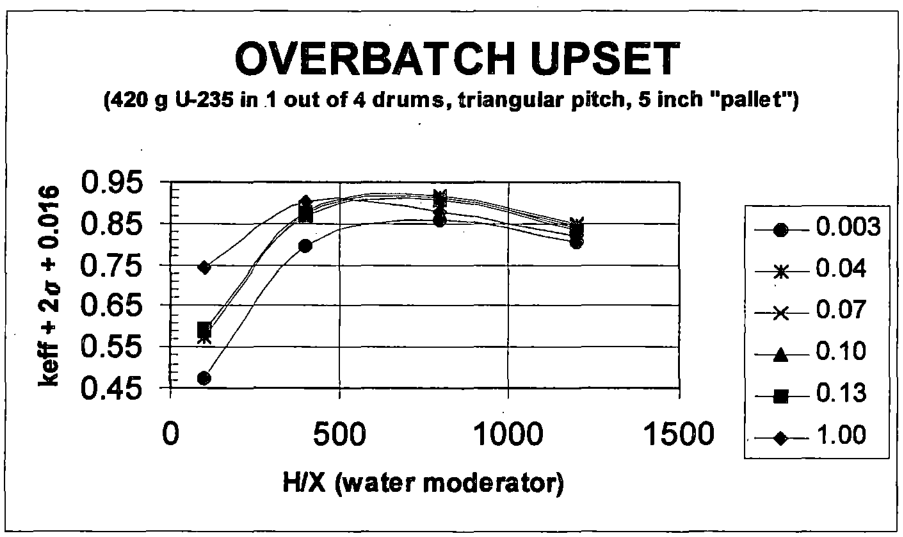
The overbatched drums were modeled with the same H/X as the others and the balance of the drums were modeled as having a varied volume fraction of water less than or equal to one. The room (that volume outside of the drums) was modeled as having a water volume fraction of 3.4E-5. The results follow:

Overbatch of 420 grams U-235:

	0.003 volume fraction water			**0.04 volume fraction water**			**0.07 volume fraction water**		
H/X	**Case**	**Keff**	2σ	**Case**	**Keff**	2σ	**Case**	**Keff**	2σ
100	050	0.4560	0.0034	046	0.5552	0.0033	042	0.5691	0.0036
400	051	0.7762	0.0033	047	0.8523	0.0035	043	0.8602	0.0034
800	052	0.8376	0.0033	048	0.8939	0.0031	044	0.8965	0.0030
1200	053	0.7865	0.0026	049	0.8274	0.0025	045	0.8291	0.0026

	0.10 volume fraction water			**0.13 volume fraction water**			**1.00 volume fraction water**		
H/X	**Case**	**Keff**	2σ	**Case**	**Keff**	2σ	**Case**	**Keff**	2σ
100	038	0.5691	0.0035	034	0.5747	0.0036	030	0.7222	0.0040
400	039	0.8582	0.0035	035	0.8501	0.0034	031*	0.8815	0.0036
800	040	0.8938	0.0030	036	0.8886	0.0029	032	0.8603	0.0030
1200	041	0.8225	0.0027	037	0.8163	0.0026	033	0.7998	0.0027

* Copy in Appendix C.

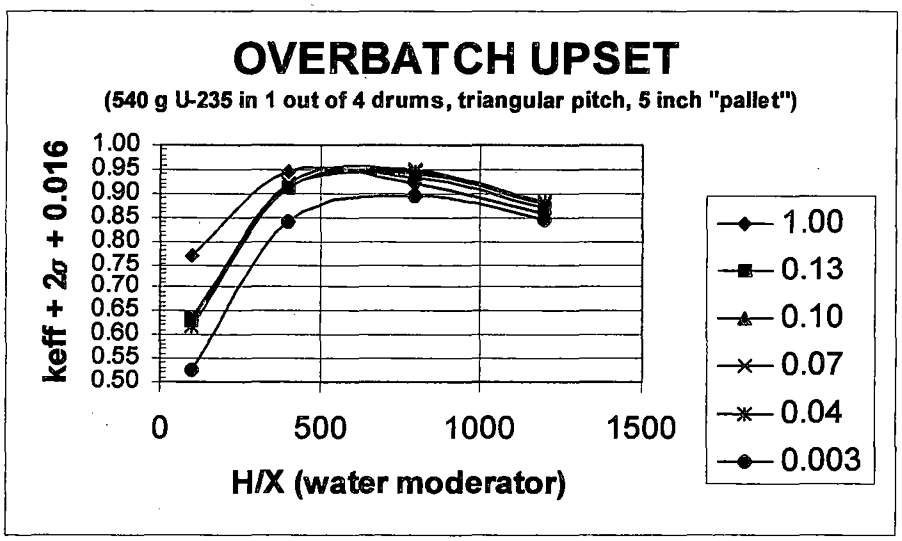


Overbatch of 540 grams U-235:

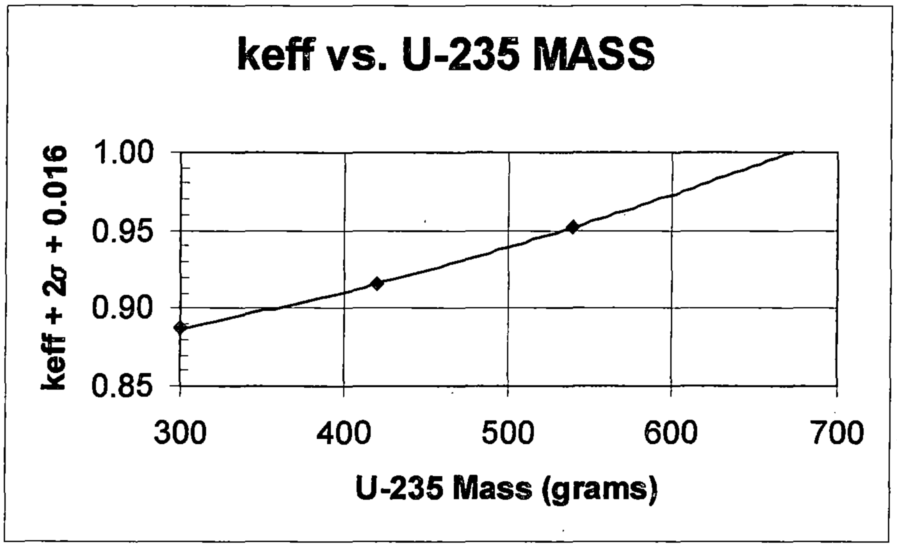
	0.003 volume fraction water			0.04 volume fraction water			0.07 volume fraction water		
H/X	Case	Keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	084	0.5062	0.004	080	0.5975	0.004	076	0.6086	0.004
400	085	0.8217	0.004	081	0.8902	0.004	077	0.0113	0.004
800	086	0.8771	0.003	082	0.9261	0.003	078	0.9295	0.003
1200	087	0.8251	0.003	083	0.8658	0.003	079	0.8607	0.003

	0.10 volume fraction water			0.13 volume fraction water			1.00 volume fraction water		
H/X	Case	Keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	072	0.6106	0.0036	068	0.6135	0.0039	064	0.7500	0.0040
400	073	0.8935	0.0036	069	0.8930	0.0035	065	0.9245	0.0036
800	074	0.9240	0.0030	070	0.9154	0.0030	066*	0.9009	0.0031
1200	075	0.8599	0.0026	071	0.8527	0.0026	067	0.8392	0.0026

* Copy in Appendix C.



Next, the peak keff + 2σ + 0.016 was plotted against U-235 mass in order to determine the Failure and Safety Limits. This plot follows.



This systems keff + 2σ + 0.016 remains below 0.95 as long as the U-235 mass remains below 530 grams (in 1 out of 4 drums). This systems keff + 2σ + 0.016 remains below 1.00 as long as the U-235 mass remains below 670 grams (in 1 out of 4 drums).

The ROL and LCO for 55-gallon waste drums was set at 100 grams of U-235 and 300 grams of U-235 respectively [Ref. 5]. These same values will be relied upon in the Mixed Waste Building. Because the LCO is set at three times that of the ROL, 55-gallon drums can be triple-batched without even violating an LCO. This will cover all but one of the credible overbatch scenarios. The scenario that is not covered involves the presence of lumped fuel in a waste drum.

The presence of lumped fuel could lead to a gross under estimation of the U-235 mass in a 55-gallon drum as determined by the drum counter. Reference 5 institutes a two-tiered approach to loading ≤ 2.5-liter containers into 55-gallon drums. Loading ≤ 2.5-liter containers into 55-gallon drums presents the most probable pathway of introducing lumped fuel into a 55-gallon drum (material in ≤ 2.5-liter container can not be readily inspected, etc.). According to Reference 5, even if every container of material that is typically scrap contained perfectly lumped fuel, the drum would contain only 419 grams of U-235. Reference 5 also shows that more than 30% of a 55-gallon drum's inner containers containing material that is typically waste would have to be lumped before 420 grams would be contained. This quantity would represent a violation of the LCO but it would not exceed the SL.

Next, even though no spacing has been taken credit for when modeling these containers, Law of Substitution requires a minimum spacing of 12 inches edge-to-edge. But because there is a 15-inch spacing requirement in the drum count area, and drums flow from this area to the areas of concern to this evaluation, this spacing requirement will be adopted globally for these containers.

Next, operations would like to be able to place these drums into overpack containers. These containers act as secondary containment and typically have an I.D. of 25 ¼ inches [Ref. 6]. As long as the overpack container has an I.D. that is at least that of the modeled 55-gallon drum, 22 ½ inches, based on aerial density this is as acceptable as the 55-gallon drums.

Finally, beryllium in 55-gallon drums located within the Mixed Waste Building will be addressed. Operations has stated that they do not need to store beryllium-bearing wastes within the Mixed Waste Building. Therefore, beryllium-bearing waste will not be allowed in this building as a normal condition. The NCS posting will reflect this restriction.

According to Reference 7, as a part of project Sapphire, NNFD only received enough beryllium to fill eleven 55-gallon drums with beryllium (BeO, $\rho = 3.011$ g/cc). A parameter study was performed in Reference 7 which shows that even if eleven 55-gallon drums, each containing 300 grams U-235, with the balance of the drum filled with BeO, are stacked 2-high (no pallet) in a square pitched array, the system's keff + σ + 0.016 remains below 0.95.

The limits on the controlled parameters are as follows:

Controlled Parameter	ROL	LCO	SL	FL
U-235 mass overbatch (grams) [1 out of 4 drums]	100	300	530	670
Interspersed Moderation (volume fraction water)	≤ 3.4E-5	3.4E-5	None	None
Vertical edge-to-edge separation between layers (inches)	≥ 5	5	None	None
Horizontal edge-to-edge separation (inches) [between fuel in MWB and all other fuel accumulations]	≥ 15	12	None	None

≥ 55-gallon waste drums, with the above controls in place, meets the double contingency principle in that no single credible upset can lead to a criticality accident.

5.0 Equipment Important to Safety and Maintenance Schedules:

None.

6.0 Inspections, Tests, and Surveillance Requirements:

None, in addition to weekly engineering inspections and NCS quarterly audits.

7.0 Criticality Detector Coverage:

This analysis adds no additional scope to the existing criticality detection system. Therefore no change to the present detection system/configuration is warranted.

8.0 Operations Review:

An operations review was conducted on February 24, 1998, in which the requirements of this SER were discussed. The following people were in attendance: J. G. Ware (SER Requester) and M. V. Mitchell (NCS Analyst). No comments resulted.

9.0 Post Change Inspection Tracking Plan (PCITP) and Bias Selection:

Because this evaluation represents no additional NCS scope than presently exists, no Post Change Inspection Tracking Plan is required. Also, the selection of 0.016 as a bias for these calculations is considered to be acceptable.

NCS Manager Concurrence: FM Alcorn Date: 3/27/98
F. M. Alcorn

10.0 References:

Reference 1: Nuclear Criticality Safety Engineering Work Instructions, "Nuclear Criticality Safety Analyses & Quality Assurance Reviews," NCSE-02, Revision 18, Effective December 5, 1997.

Reference 2: Nuclear Criticality Safety Benchmark Notebook, CEB95-02, August 29, 1995.

Reference 3: M. V. Mitchell, "Validation of the CSAS25 module of SCALE4.2 with 27 Group Cross Section Set, on the HP (NCS1), for materials Containing Beryllium," NCS-1998-031, February 11, 1998.

Reference 4: NNFD Drawing, "UBE-1 Container (55-Gallon Capacity)," LP3023C, Revision 1, September 24, 1997.

Reference 5: M. V. Mitchell, "NCS Evaluation for SER98-007, 'Packaging of (NMC) Drums,' Phase 1," NCS-1998-011, January 29, 1998.

Reference 6: NNFD Drawing, "UBE-2 Container (70-Gallon Capacity)," LP3024C, Revision 0, September 24, 1997.

Reference 7: M. V. Mitchell, "NCS Evaluation for SER98-007, 'Packaging of (NMC) Drums,' Phase 3," NCS-1998-030, February 11, 1998.

Evaluated by: M. V. Mitchell 3/27/98
M. V. Mitchell

Quality Assurance Statement:

I have reviewed this evaluation in accordance with procedure NCSE-02. I have verified that:

a. The analysis report meets the requirements NCSE-02.
b. The method used to perform the analysis is permitted by SNM-42.
c. The double contingency principle is satisfied and adequately documented.

The QA'er checked _8_ of the computer calculations included in the analysis.

d. The model geometry accurately or conservatively represents the actual situation and is consistent with what is stated in the analysis.
e. The number densities are correct.
f. The boundary conditions are correct.
g. Approved cross sections and code options are used.
h. The convergence of k-effective is adequate.
i. The choice of the bias (0.016) is considered to be acceptable.

QA'ed by: J. W. Harwell

J. W. Harwell

APPENDIX A

NUCLEAR CRITICALITY SAFETY POSTING

SER98-007(Phase 4)/NCS-1998-039

MIXED WASTE BUILDING
≥ 55-Gallon Drums

TYPE:	Uranium.
FORM:	Waste, any form. No beryllium.
QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum.
SPACING:	MIN. 15 inches horizontal edge-to-edge spacing between fuel in the Mixed Waste Building and all other fuel accumulations.
	2-High stacking is allowed provided the top layer of drums is at least 5 inches above the bottom layer of drums.
MODERATION:	Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

PLANT-46, Rev. 0
3/25/98
SER98-007

Was:
M-54, Rev. 2
2/27/92

APPENDIX B

NUCLEAR CRITICALITY SAFETY REQUIREMENTS

SER98-007 (Phase 4)/NCS-1998-039

Nuclear Criticality Safety Requirements: SER98-007 (Phase 4)

Design/Installation/Construction Requirements:

None.

Pre-Operational Testing Instructions:

A. Administrative Controls (operator controlled parameters):

1.	TYPE:	Uranium.
2.	FORM:	Waste, any form. No beryllium.
3.	QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum.
4.	SPACING:	MIN. 15 inches horizontal edge-to-edge spacing between fuel in the Mixed Waste Building and all other fuel accumulations. 2-High stacking is allowed provided the top layer of drums is at least 5 inches above the bottom layer of drums.
5.	MODERATION:	Moderating materials are permitted only as necessary for normal operations.

B. Procedural Requirements:

1. Waste Operations shall review all area procedures affected by these changes and make appropriate changes. All changes shall be reviewed and approved by NCS.

2. All personnel who work with the new NCS posting shall be trained to it.

3. The NCS posting shall be appropriately posted.

D. Nuclear Safety Release:

1. An implementation review and pre-operational inspection are required. Completion of the requirements will be documented in a nuclear safety release.

During Operation Requirements:

None.

APPENDIX C

TYPICAL INPUT DECKS

SER98-007 (Phase 4)/NCS-1998-039

RUN 001: 300 g U-235/drum, 2-High Array, 5″ Pallet, Normal Condition, Material H/X = 100, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4      infhommed
u-235          1 0.0 6.5847-4   end
o              1 0.0 3.2912-2   end
h              1 0.0 6.5824-2   end
h2o            2                end
orconcrete     3                end
h2o            4 3.4-5          end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y   1 1 6.5318 orig 22.0432 0.0000 78.5582
    zhemicyl-y   2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x   1 1 6.5318 orig 0.0000 22.0432 78.5582
    zhemicyl-x   2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y   1 1 6.5318 orig -22.0432 0.0000 78.5582
    zhemicyl+y   2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x   1 1 6.5318 orig 0.0000 -22.0432 78.5582
    zhemicyl+x   2 1 28.5750 85.0900 0.0000
  unit 5
    hemisphe-y   1 1 6.5318 orig 22.0432 0.0000 6.5318
    zhemicyl-y   2 1 28.5750 85.0900 0.0000
  unit 6
    hemisphe-x   1 1 6.5318 orig 0.0000 22.0432 6.5318
    zhemicyl-x   2 1 28.5750 85.0900 0.0000
  unit 7
    hemisphe+y   1 1 6.5318 orig -22.0432 0.0000 6.5318
    zhemicyl+y   2 1 28.5750 85.0900 0.0000
  unit 8
    hemisphe+x   1 1 6.5318 orig 0.0000 -22.0432 6.5318
    zhemicyl+x   2 1 28.5750 85.0900 0.0000
  global
  unit 9
   cuboid        4 1 2p28.5750 2p49.4934 182.8800 0.0000
    hole 1            0.0000  49.4934    0.0000
    hole 2           28.5750   0.0000    0.0000
    hole 3            0.0000 -49.4934    0.0000
    hole 4          -28.5750   0.0000    0.0000
    hole 5            0.0000  49.4934   97.7900
    hole 6           28.5750   0.0000   97.7900
    hole 7            0.0000 -49.4934   97.7900
    hole 8          -28.5750   0.0000   97.7900
    replicate    4 1 4*0.0000 1200.0000 0.0000 1
    replicate    3 1 5*0.0000 30.4800 1
end geom
read bounds
  xyf=mirror
end bounds
```

```
end data
end
```

RUN 031: 300 g U-235 in 3 out of 4 drums, 420 g U-235 in 1 out of 4 drums, 2-High Array, 5" Pallet, Overbatch Condition, Material H/X = 400, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4      infhommed
u-235          1 0.0 1.6628-4   end
o              1 0.0 3.3253-2   end
h              1 0.0 6.6505-2   end
h2o            2                end
orconcrete     3                end
h2o            4 3.4-5          end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y   1 1 10.3339 orig 18.2411 0.0000 74.7560
    zhemicyl-y   2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x   1 1 11.5604 orig 0.0000 17.0146 73.5295
    zhemicyl-x   2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y   1 1 10.3339 orig -18.2411 0.0000 74.7560
    zhemicyl+y   2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x   1 1 10.3339 orig 0.0000 -18.2411 74.7560
    zhemicyl+x   2 1 28.5750 85.0900 0.0000
  unit 5
    hemisphe-y   1 1 10.3339 orig 18.2411 0.0000 10.3339
    zhemicyl-y   2 1 28.5750 85.0900 0.0000
  unit 6
    hemisphe-x   1 1 11.5604 orig 0.0000 17.0146 11.5604
    zhemicyl-x   2 1 28.5750 85.0900 0.0000
  unit 7
    hemisphe+y   1 1 10.3339 orig -18.2411 0.0000 10.3339
    zhemicyl+y   2 1 28.5750 85.0900 0.0000
  unit 8
    hemisphe+x   1 1 10.3339 orig 0.0000 -18.2411 10.3339
    zhemicyl+x   2 1 28.5750 85.0900 0.0000
  global
  unit 9
    cuboid       4 1 2p28.5750 2p49.4934 182.8800 0.0000
    hole 1            0.0000  49.4934    0.0000
    hole 2           28.5750   0.0000    0.0000
    hole 3            0.0000 -49.4934    0.0000
    hole 4          -28.5750   0.0000    0.0000
    hole 5            0.0000  49.4934   97.7900
    hole 6           28.5750   0.0000   97.7900
    hole 7            0.0000 -49.4934   97.7900
    hole 8          -28.5750   0.0000   97.7900
```

```
    replicate    4 1 4*0.0000 1200.0000 0.0000 1
    replicate    3 1 5*0.0000 30.4800 1
end geom
read bounds
  xyf=mirror
end bounds
end data
end
```

RUN 066: 300 g U-235 in 3 out of 4 drums, 540 g U-235 in 1 out of 4 drums, 2-High Array, 5″ Pallet, Overbatch Condition, Material H/X = 800, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4     infhommed
u-235           1 0.0 8.3272-5  end
o               1 0.0 3.3310-2  end
h               1 0.0 6.6620-2  end
h2o             2               end
orconcrete      3               end
h2o             4 3.4-5         end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y  1 1 13.0130 orig 15.5620 0.0000 72.0769
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 15.8296 orig 0.0000 12.7454 69.2604
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 13.0130 orig -15.5620 0.0000 72.0769
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 13.0130 orig 0.0000 -15.5620 72.0769
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  unit 5
    hemisphe-y  1 1 13.0130 orig 15.5620 0.0000 13.0130
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 6
    hemisphe-x  1 1 15.8296 orig 0.0000 12.7454 15.8296
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 7
    hemisphe+y  1 1 13.0130 orig -15.5620 0.0000 13.0130
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 8
    hemisphe+x  1 1 13.0130 orig 0.0000 -15.5620 13.0130
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  global
  unit 9
    cuboid      4 1 2p28.5750 2p49.4934 182.8800 0.0000
    hole 1          0.0000   49.4934    0.0000
    hole 2          28.5750   0.0000    0.0000
```

```
    hole 3          0.0000 -49.4934   0.0000
    hole 4        -28.5750   0.0000   0.0000
    hole 5          0.0000  49.4934  97.7900
    hole 6         28.5750   0.0000  97.7900
    hole 7          0.0000 -49.4934  97.7900
    hole 8        -28.5750   0.0000  97.7900
    replicate   4 1 4*0.0000 1200.0000 0.0000 1
    replicate   3 1 5*0.0000 30.4800 1
end geom
read bounds
  xyf=mirror
end bounds
end data
end
```

BWX Technologies, Inc. | **Naval Nuclear Fuel Division**
Babcock & Wilcox, a McDermott company

To	M. P. Akers, Licensing Administrator, X6687	
From	M. V. Mitchell, Engineer, Nuclear Criticality Safety, X5195	File No. Or Ref. NCS-1998-011
Subj.	Nuclear Criticality Safety Evaluation Supporting SER98-007, "Packaging of (NMC) Drums," Phase 1	Date January 30, 1998

1.0 Summary:

SER98-007, "Packaging of (NMC) Drums," Phase 1, requests approval to change how 55-gallon waste drums are handled at the point of generation (Drum Count Area), Super Compactor and the Outside Storage Area. Currently, 55-gallon drums are allowed to be loaded up to 350 grams of U-235 ("corrected"). As a result of this evaluation, 55-gallon drums will be limited to only 100 grams of U-235 based on the raw drum counter results. This evaluation does not cover those drums that will contain a significant volume of beryllium.

2.0 System Description:

There are currently several waste and scrap streams generated at NNFD. These materials result from a myriad of uranium based production activities. For the purposes of this evaluation, all streams will be treated as belonging to one of the following groups:

1. Dry Low Level Waste (shows up at the drum count area in a sealed 55-gallon drum with sufficient ESP-II results, loaded in accordance with NCS posting PLANT-05 [Ref. 1]).
2. Streams that are typically waste that show up in the Drum Count Area in ≤ 2.5-liter containers (can be classified as scrap at the drum counter based on U-235 mass).
3. Streams that are typically scrap that show up in the Drum Count Area in ≤ 2.5-liter containers (can be classified as waste counter based on U-235 mass).
4. Waste streams that show up in the Drum Count Area in either a 5-gallon bucket or a one-gallon can.
5. T. P. Solids (loaded per LER95-25 [Ref. 2]).
6. Be Filter Press Solids (Loaded per SER95-61 [Ref. 3]).

These materials are loaded, processed (supercompactor, etc.), temporarily stored, and then shipped off-site to an appropriate disposal sight. This evaluation will concentrate on the waste material, which comes from streams 2, 3, and 4 above. Streams 1 and 5 above will be covered by this evaluation after drum count indicates that these drums contain less than 100 grams U-235 as determined by the drum counter.

For the purposes of this evaluation, the term drum counter will encompass the Segmented Gamma Scanner (SGS) as well.

3.0 Methodology:

This Nuclear Criticality Safety Analysis was performed according to NCSE-02 [Ref. 4].

This evaluation was based on computer calculations. The keff limit for the worst case normal condition is < 0.92 (keff + σ + bias) and the keff limit for all single credible upset conditions is < 0.95 (keff + 2σ + bias). This system was modeled using the SCALE 4.2 package (CSAS25 module) with the 27-group cross section library on the H/P workstation (NCS1). The bias used for the output associated with this model is 0.016 [Ref. 5].

4.0 System Analysis:

The parameters that affect reactivity are:

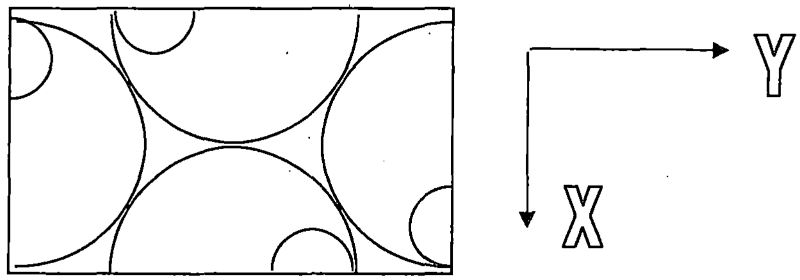
1. Chemical form.
2. Enrichment.
3. Density.
4. Moderation (Interspersed and Interstitial).
5. Reflection.
6. Geometry.
7. Mass.
8. Spacing.

The assumptions used while performing this evaluation are:

1. The chemical form was assumed to be uranium metal (ρ = 18.81 g/cc).
2. The enrichment was assumed to be 100 wt% U-235.
3. The drums are sitting directly on 12 inches of nominal density Oak Ridge concrete.
4. Reflecting/moderating material within the drum was modeled as full density water (ρ=0.9982 g/cc) when in a single layer.
5. Reflecting/moderating material within the drum was modeled as having all degrees of nominal density water ($\rho \leq$ 0.9982 g/cc) when drums are stacked.

To analyze this system an infinite, triangular pitched; array of 55-gallon drums was modeled. Each drum consisted of a cylinder that had a nominal inside diameter (I.D.) of 22 ½ " and an inside height (I.H.) of 33 ½" [Ref. 6]. The array was modeled sitting on 12 inches of Oak Ridge concrete.

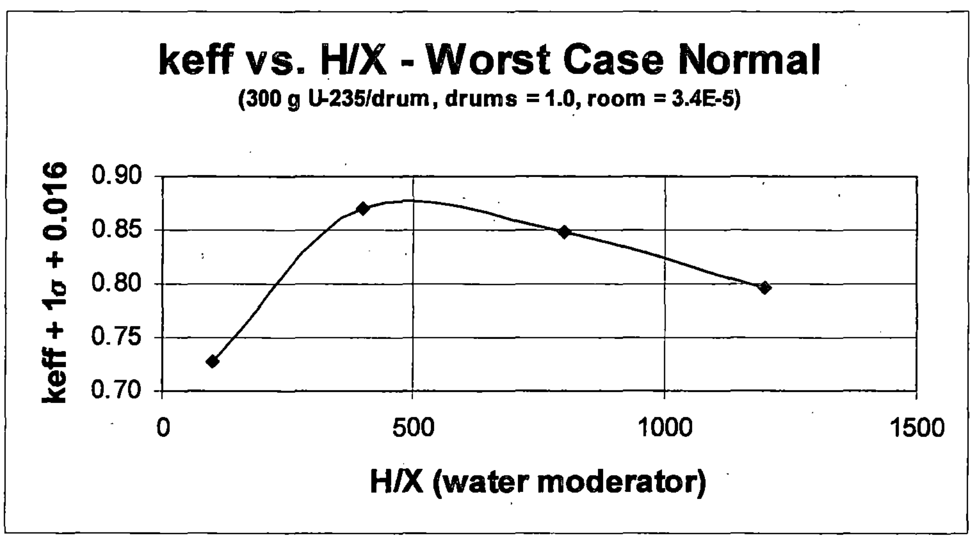
The material within the drums was modeled as having a spherical shape, offset within the drum, for optimal interaction. Mirror boundary conditions were used on the x and y faces. See figure below.



In order to determine if the worst case normal condition meets the license criteria (keff + σ + 0.016), a parameter study was performed. This study involved the above model with each drum containing 300 grams of U-235 at varying degrees of moderation (H/X). The uranium metal water mixtures were modeled on the floor of the drum with the balance of the drum filled with nominal density water (drums = 1.0). The room (that volume outside of the drums) was modeled as having a water volume fraction of 3.4E-5 (room = 3.4E-5). The results follow:

H/X	Case	Keff	σ
100	001*	0.7095	0.0019
400	002	0.8524	0.0019
800	003	0.8307	0.0016
1200	004	0.7797	0.0013

* Copy in Appendix A.

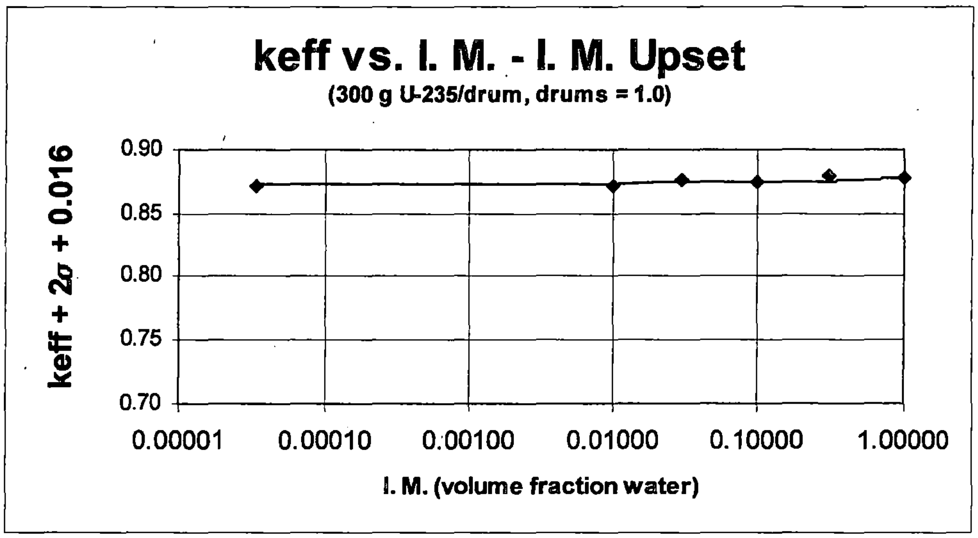


The worst case normal condition, H/X ≈ 500, is less than 0.92.

Next, an Interspersed Moderator upset condition was investigated. This was accomplished by taking case 002 above (just below optimal moderation) and rerunning it with varying degrees of Interspersed Moderator. The results follow:

I.M. (volume fraction water)	Case	Keff	2σ
3.4E-5	002	0.8524	0.0037
0.01	005	0.8514	0.0039
0.03	006	0.8561	0.0038
0.10	007	0.8546	0.0035
0.30	008	0.8602	0.0037
1.00	009*	0.8576	0.0037

* Copy in Appendix A.



The system keff + 2σ + 0.016 for an Interspersed Moderator upset condition remains below 0.95.

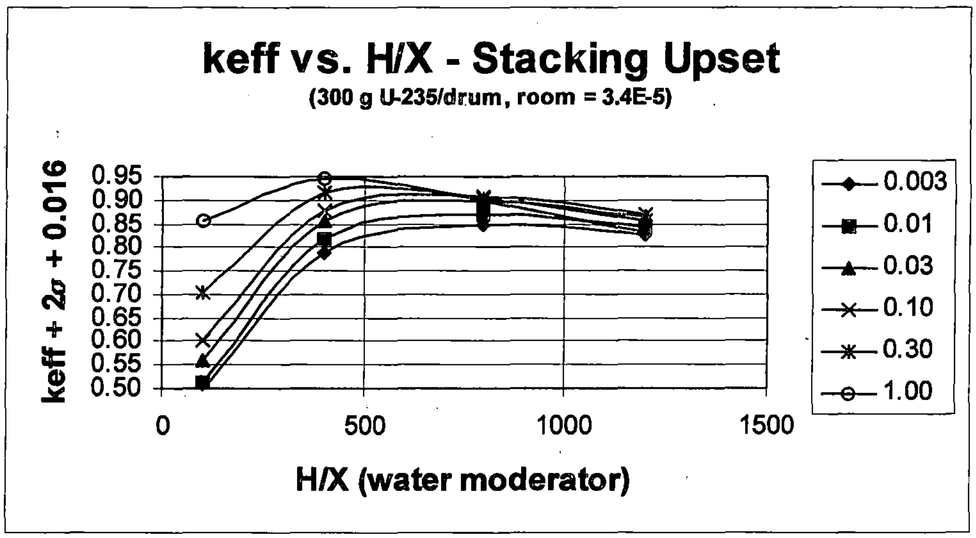
Next, a stacking upset condition was investigated. This was accomplished by taking normal case model and adding a second layer to it. The fuel mixtures were modeled on the floor of the drum in the second layer and just under the lid of the drum on the lower layer. This results in eight fuel bearing units in close proximity.

The reflecting/moderating material, which occupies the balance of the drums, was modeled as having varied volume fraction of water less than or equal to one. The results follow:

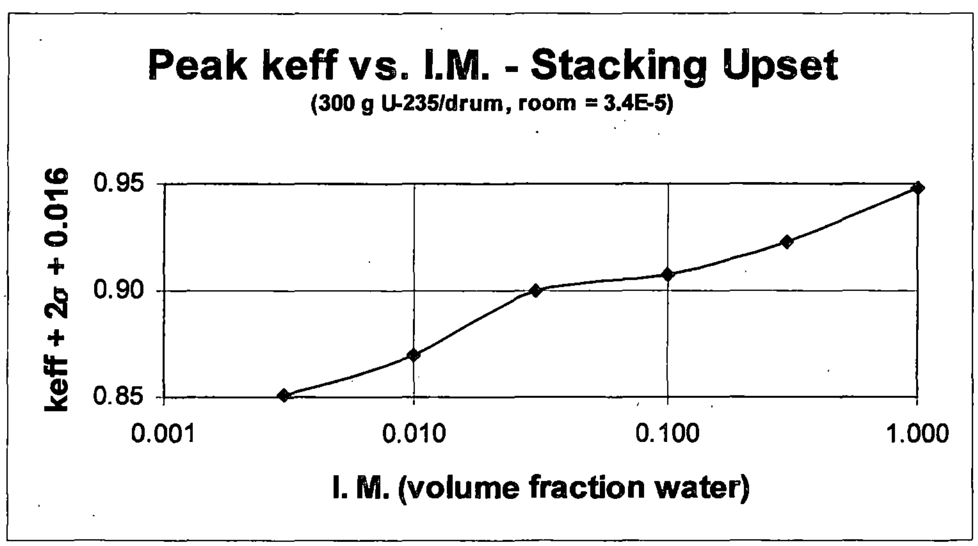
	0.003 vol. frac. Water			0.01 vol. frac. water			0.03 vol. frac. Water		
H/X	Case	keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	010	0.4751	0.0034	014	0.4935	0.0034	018	0.5414	0.0034
400	011	0.7709	0.0036	015	0.7970	0.0037	019	0.8376	0.0039
800	012	0.8308	0.0030	016	0.8500	0.0032	020	0.8811	0.0030
1200	013	0.8085	0.0027	017	0.8256	0.0026	021	0.8468	0.0025

	0.10 vol. frac. Water			0.30 vol. frac. water			1.00 vol. frac. Water		
H/X	Case	keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	022	0.5815	0.0035	026	0.6856	0.0037	030	0.8349	0.0038
400	023	0.8578	0.0034	027	0.8981	0.0038	031	0.9293	0.0022
800	024*	0.8889	0.0030	028	0.8850	0.0030	032	0.8810	0.0031
1200	025	0.8505	0.0024	029	0.8364	0.0026	033	0.8133	0.0027

* Copy in Appendix A.



The peak keff + 2σ + 0.016 for each line was then plotted against the degree of I.M. This allows us to plot this information in a form that is more familiar.

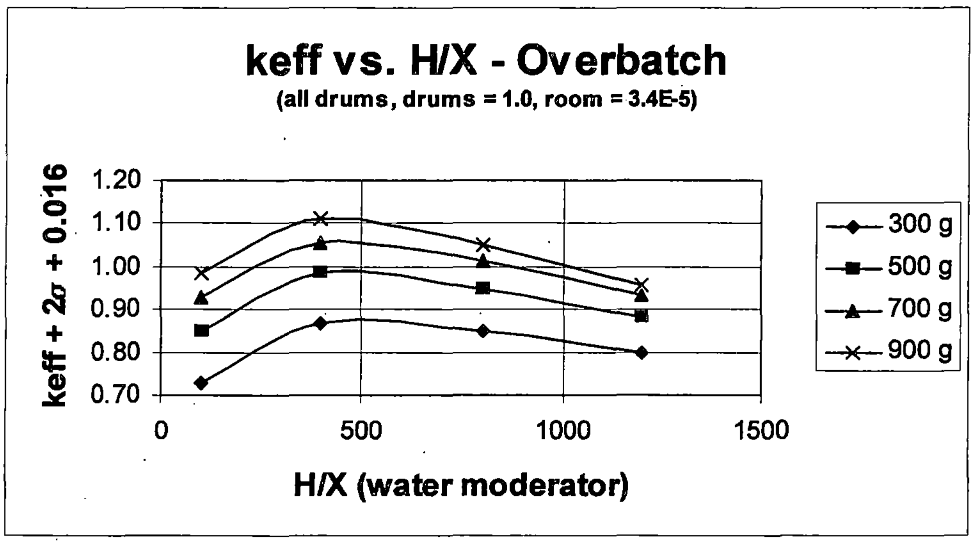


The system keff + 2σ + 0.016 for a stacking upset condition remains below 0.95.

Next, an overbatch upset condition was investigated. This was accomplished by taking the normal case model and varying the U-235 mass per drum (every drum is overbatched). The results follow:

	Every Drum Overbatched								
	500 g U-235/drum			700 g U-235/drum			900 g U-235/drum		
H/X	Case	keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	034	0.8284	0.0040	038	0.9104	0.0041	042	0.9653	0.0038
400	035	0.9657	0.0037	039	1.0338	0.0037	043	1.0900	0.0038
800	036	0.9272	0.0030	040	0.9929	0.0031	044	1.0314	0.0030
1200	036	0.8635	0.0027	041*	0.9145	0.0027	045	0.9378	0.0026

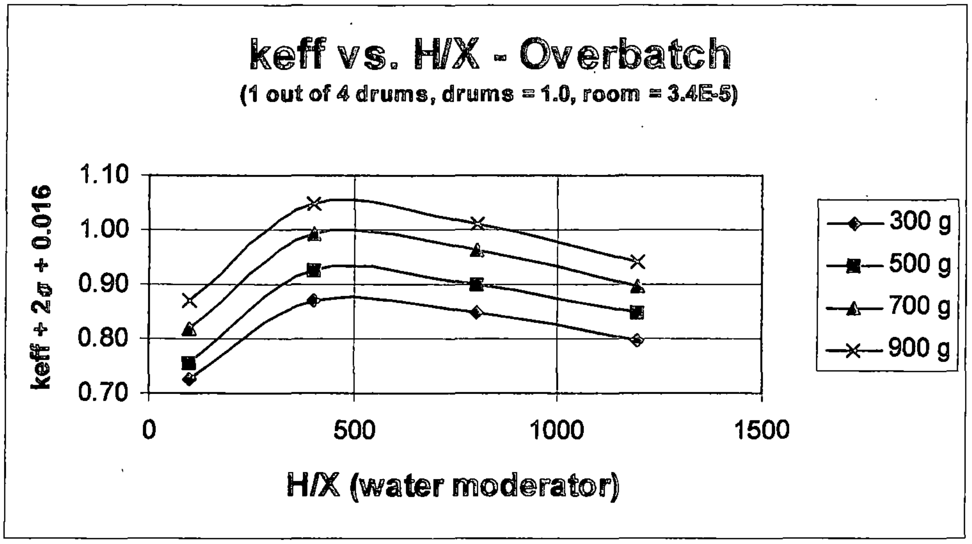
* Copy in Appendix A.



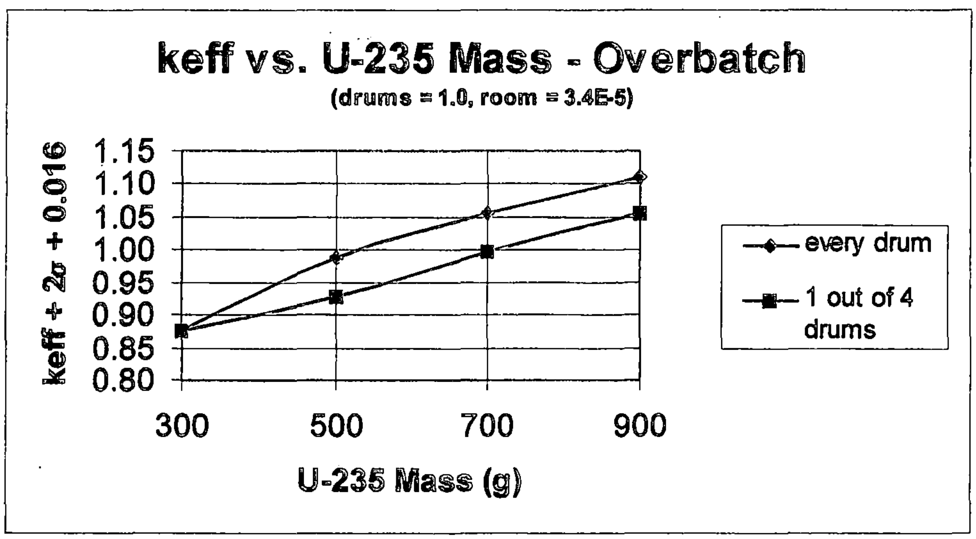
Next, only 1 out of every 4 drums was overbatched. This was accomplished by taking the normal model and overbatching only one of the drums. The results follow:

	1 Out of 4 Drums Overbatched								
	500 g U-235/drum			700 g U-235/drum			900 g U-235/drum		
H/X	Case	keff	2σ	Case	Keff	2σ	Case	Keff	2σ
100	046	0.7361	0.0038	050	0.7991	0.0040	054	0.8507	0.0042
400	047	0.9044	0.0037	051	0.9746	0.0038	055	1.0302	0.0038
800	048	0.8825	0.0030	052*	0.9448	0.0031	056	0.9919	0.0030
1200	049	0.8300	0.0026	053	0.8786	0.0026	057	0.	0.00

* Copy in Appendix A.



Next, the peak keff + 2σ + 0.016 for each line was taken and plotted against the U-235 mass for both of the above cases.



This systems keff + 2σ + 0.016 remains below 0.95 as long as the U-235 mass remains below 420 grams in every drum or below 560 grams in 1 out of 4 drums. This systems keff + 2σ + 0.016 remains below 1.00 as long as the U-235 mass remains below 520 grams in every drum or below 690 grams in 1 out of 4 drums.

Presently, when 55-gallon drums are loaded based on drum count results, operations is required to "correct" the U-235 values [Ref. 7]. They are at present, required to remain below 350 grams of U-235 per drum. This correction factor, actually a multiplication factor, is used to account for lumped fuel in our waste which would cause the drum counter to underestimate the U-235 mass due to the self-attenuation of the material. By requiring operations to apply this correction factor on every container, we are in a sense saying that we believe that it is normal to have fuel that is lumped in

our waste material. It is the contention of this evaluation that the presence of lumped fuel in our waste material is an upset condition and not a normal condition.

In the past, NNFD loaded 55-gallon drums using drum count results in order to comply with NCS U-235 mass limits. This was done regardless of the magnitude of the drum count results (i.e. used for both waste and scrap material). This practice was shown to be less than adequate [Ref. 8]. Subsequently, NNFD has developed a two-tier approach to loading waste into 55-gallon drums and has suspended the loading of scrap material into anything other than a ≤ 2.5-liter container based on drum count results.

The two-tier approach involved the placement of all waste/scrap streams into one of two bins. One bin includes all those streams that are typically waste material (but could be considered to be scrap based on drum count) that have a low probability of containing lumped fuel material. The other bin includes all those streams that are typically scrap material (but could be considered to be waste based on drum count) that have a higher probability of containing lumped fuel material.

Both bins have a unique waste/scrap threshold criteria based on the qualitative probability of lumped fuel being present. Containers with less than 8 grams of U-235 from the (typically) waste bin are considered to be waste material. Containers with less than 1.32 grams of U-235 from the (typically) scrap bin are considered to also be waste material.

If one assumes that a container from the (typically) scrap stream contained fuel that was lumped, and the drum count results were less than 1.32 grams of U-235, the container could contain up to 6.1 x 1.32 = 7.92 grams of U-235 [Ref. 7]. If an operator loading 55-gallon drums places 52 ≤ 2.5-liter containers into a drum (this is all that will practically fit in a 55-gallon drum) there could be as much as 419 grams of U-235. This is below the safety limit on an infinite array of like overbatched drums as well as a single drum.

Next, if a 55-gallon drum has been loaded with containers containing material from the (typically) waste bin, each containing 8 grams of U-235, the drum counter would have to be off by a factor of 4.2 on every container before the safety limit could be exceeded. Another way of stating this is that more than approximately 30% of the containers would have to contain lumped fuel. This is not considered to be credible.

Finally, one-gallon cans and 5-gallon buckets must have an independent U-235 mass estimate (i.e. net weight gain, etc.) prior to even sending them to the drum counter [Ref. 7]. Therefore, these containers will not be addressed specifically in this evaluation.

Using these above criteria, 55-gallon drums can be loaded with these materials up to 100 grams of U-235 based on drum count results.

A listing of the currently approved waste/scrap bins follows. This will be maintained in NMC's procedure E46-80 [Ref. 9], or subsequent procedure, and may not be changed without approval from NCS.

Streams That Are Typically Waste [Ref. 9] (≤ 8 grams U-235/2.5-liter container)	**Streams That Are Typically Scrap [Ref. 9] (≤ 1.32 grams U-235/2.5-liter container)**
Combustibles (SC)	Glasswash Solids
Duct Cleanout	Grinding Wheel Solids (S4/S1)
Feed Column Solids	Machine Chips
Filtered Solids	Saw Solids
Filters	Vacuum Bags
G1 Material	Vacuum Solids
Glasswash Solids (S3/S7)	Waste Column Scrap
Graphite Tubes	
Grinder Solids (S2)	
Leach Solids	
LL Diss. Hood Clean Out	
Non-Combustibles (SC)	
Scrubber Solids	
Soda Ash	
Sponges	
Still Bottoms	
T. P. Solids	
Vacuum Solids (S3/S7)	
Vaseline	

Even though no spacing has been taken credit for when modeling these containers, Law of Substitution requires a minimum spacing of 12 inches edge-to-edge. But because there is a 15-inch spacing requirement in the drum count area, and drums flow from this area to the areas of concern to this evaluation, this spacing requirement will be adopted globally for these containers.

The NCS postings in the drum counter area will be changed for consistency with these new limits (Appendix A). The NCS posting on the trailer storage at waste treatment will be changed for consistency also (Appendix A).

Next, operations would like to be able to place these drums or compacted pucks into overpack containers. These containers act as secondary containment and typically have an I.D. of 25 ¼ inches [Ref. 10]. As long as the overpack container has an I.D. that is at least that of the modeled 55-gallon drum, 22 ½ inches, based on aerial density this is as acceptable as the 55-gallon drums.

The limits on the controlled parameters are as follows:

Controlled Parameter	ROL	LCO	SL	FL
U-235 mass per drum (grams) [every drum]	100	300	420	520
U-235 mass per drum (grams) [1 out of 4 drums]	100	300	560	690
Interspersed Moderation (volume fraction water)	≤ 3.4E-5	3.4E-5	None	None
Horizontal edge-to-edge separation (inches)	≥ 15	12	None	None

≥ 55-gallon waste drums, with the above controls in place, meets the double contingency principle in that no single credible upset can lead to a criticality accident.

Finally, because we are changing 55-gallon drum requirements, coupled with the fact that there are probably drums currently in existence that do not meet the new requirements, operations must identify all 55-gallon drums currently in existence that do not meet the requirements of this evaluation. Operations must submit a plan as to how these drums will be handled in the future (this plan must include a labeling program to facilitate easy identification).

5.0 Equipment Important to Safety and Maintenance Schedules:

None.

6.0 Inspections, Tests, and Surveillance Requirements:

None.

7.0 Criticality Detector Coverage:

This analysis adds no additional scope to the existing criticality detection system. Therefore no change to the present detection system/configuration is warranted.

8.0 Operations Review:

An operations review was conducted on February 10, 1998, in which the requirements of this SER were discussed. The following people were in attendance: J. G. Ware (SER Requester) and M. V. Mitchell (NCS Analyst). No comments resulted.

9.0 Post Change Inspection Tracking Plan (PCITP) and Bias Selection:

Because this evaluation represents no additional NCS scope than presently exists, no Post Change Inspection Tracking Plan is required. Also, the selection of 0.016 as a bias for these calculations is considered to be acceptable.

NCS Manager Concurrence: FM Alcorn Date: 2/11/98
F. M. Alcorn

10.0 References:

Reference 1: NCS Posting, "55-Gallon Waste Storage Drums," PLANT-05, Revision 0, June 20, 1994.

Reference 2: M. V. Mitchell, "NCS Analysis Re-evaluating the U-235 Dynamic Inventory Mass Limit at Waste Treatment: LER95-25 Phase I and Phase II," MVM96-14, NCS-1996-103, May 13, 1996.

Reference 3: C. E. Boman, "NCS Analysis of Beryllium Waste Stream Pretreatment System: SER95-61," CEB95-09, NCS-1995-086, December 20, 1995.

Reference 4: Nuclear Criticality Safety Engineering Work Instructions, "Nuclear Criticality Safety Analyses & Quality Assurance Reviews," Revision 18, Effective December 5, 1997.

Reference 5: Nuclear Criticality Safety Benchmark Notebook, CEB95-02, August 29, 1995.

Reference 6: NNFD Drawing, "UBE-1 Container (55-Gallon Capacity)," LP3023C, Revision 1, September 24, 1997.

Reference 7: NNFD Procedure, SS-07-05, "Packaging and Measurement of Scrap and Waste," Revision 2, Dated July 16, 1997.

Reference 8: F. M. Alcorn, "Criticality Safety Analysis Team Report for June 29, 1994 Incident," DRUMCSA.REP, NCS-1994-134, August 22, 1994.

Reference 9: NNFD Procedure, E46-80, "Processing Containers in the Drum Count/SGS Area," Revision 17.

Reference 10: NNFD Drawing, "UBE-2 Container (70-Gallon Capacity)," LP3024C, Revision 0, September 24, 1997.

Evaluated by: M. V. Mitchell 2/11/98
M. V. Mitchell

Quality Assurance Statement:

I have reviewed this evaluation in accordance with procedure NCSE-02. I have verified that:

a. The analysis report meets the requirements NCSE-02.
b. The method used to perform the analysis is permitted by SNM-42.
c. The double contingency principle is satisfied and adequately documented.

The QA'er checked 8 of the computer calculations included in the analysis.

d. The model geometry accurately or conservatively represents the actual situation and is consistent with what is stated in the analysis.
e. The number densities are correct.
f. The boundary conditions are correct.
g. Approved cross sections and code options are used.
h. The convergence of k-effective is adequate.
i. The choice of the bias (0.016) is considered to be acceptable.

QA'ed by: JW Harwell 2/11/98
J. W. Harwell

APPENDIX A

NUCLEAR CRITICALITY SAFETY POSTINGS

SER98-007(Phase 1)/NCS-1998-011

TRAILER STORAGE
≥ 55-Gallon Drums

TYPE:	Uranium.
FORM:	Waste, any form.
QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum.
SPACING:	MIN. 15 inches horizontal edge-to-edge spacing between this trailer and all other fuel accumulations.
	NO spacing requirement between these like drums on trailer. NO stacking allowed.
MODERATION:	Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

PLANT-11, Rev. 1
2/2/98
SER98-007

Was:
PLANT-11, Rev. 0
6/1/95
LER95-23

OUTSIDE STORAGE AREA

≥ 55-Gallon Drums

TYPE: Uranium.

FORM:	QUANTITY:		SPACING:
Any form, no beryllium	MAX. 100 grams U-235	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
Be Filter Press Solids	Unknown	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
T. P. Solids	Unknown	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.

MODERATION: Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

PLANT-35, Rev. 1
2/2/98
SER98-007

Was:
PLANT-35, Rev. 0
6/30/97
SER97-59

SUPERCOMPACTOR ROOM
≥ 55-Gallon Drums

TYPE:	Uranium.
FORM:	Packaged low level solid waste.
QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum. Operator shall identify each incoming drum and verify that the contents of the drum (as labeled) are within limits.
SPACING:	MIN. 15 inches horizontal edge-to-edge spacing between fuel in the Supercompactor Room and all other fuel accumulations. NO spacing requirement between drums. NO stacking allowed.
MODERATION:	Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

PLANT-26, Rev. 1
2/2/98
SER98-007, LER89-140d

Was:
PLANT-26, Rev. 0
10/4/96
LER89-140d

SUPERCOMPACTOR IN-FEED
≥ 55-Gallon Drums

TYPE:	Uranium.
FORM:	Packaged low level solid waste.
QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum. Operator shall identify each incoming drum and verify that the contents of the drum (as labeled) are within limits. The U-235 mass in each drum must be based on drum count. The assigned U-235 mass shall be compared to the original drum count output prior to compaction.
SPACING:	NO spacing requirement between drums. NO stacking allowed.
MODERATION:	Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

PLANT-43, Rev. 0
2/2/98
SER98-007, LER89-140d

Was:
SC-2, Rev. 3
4/11/94
LER89-140d

DRUM COUNT AREA
FLOOR STORAGE

TYPE: Uranium.

FORM:	QUANTITY		SPACING:
Any Form	MAX. 100 grams U-235	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
Be Filter Press Solids	Unknown	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
T.P. Solids	Unknown	≥ 55-gallon drums	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
Contaminated Raschig rings	Unknown	5-gallon buckets	NO spacing requirement between these containers. NO stacking. MIN. 15 inches horizontal edge-to-edge spacing required between these containers and all other fuel accumulations.
Any Form	Unknown	One HEPA filter	MIN. 36 inches horizontal edge-to-edge spacing required between this filter and all other fuel accumulations.

MODERATION: Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

BAY12A-01, Rev. 5
2/2/98
SER98-007

Was:
BAY12A-01, Rev. 4
6/30/97
SER97-059

DRUM COUNTER

TYPE: Uranium.

FORM:	QUANTITY:		SPACING:
Any form	MAX. 7.0 kg (15.43 lb.) Net weight	MAX. One ≤ 2.5-liter container	MIN. 15 inches horizontal edge-to-edge spacing required between this container and all other fuel accumulations **except:** • MAX. 3 transmission plates, MAX. 25 grams each.
Any form	MAX. 350 grams U-235	MAX. One 1-gallon can	
Any form	MAX. 350 grams U-235	MAX. One 5-gallon bucket	
Contaminated Raschig rings	Unknown	MAX. One 5-gallon bucket	
Any form	MAX. 100 grams U-235	MAX. One ≥ 55-gallon drum	
Be Filter Press Solids, T. P. Solids	Unknown	MAX. One ≥ 55-gallon drum	
Any form	Unknown	MAX. One HEPA filter	MIN. 36 inches horizontal edge-to-edge spacing required between this item and all other fuel accumulations **except:** • MAX. 3 transmission plates, MAX. 25 grams each.

MODERATION: Moderating materials are permitted only as necessary for normal operations.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

BAY 12A-02, Rev. 5
2/2/98
SER98-007

Was:
BAY 12A-02, Rev. 4
11/21/97
SER97-059

SEGMENTED GAMMA SCANNER

TYPE: Uranium.

FORM:	QUANTITY:		SPACING:
Any form	MAX. 100 grams U-235	MAX. One ≥ 55-gallon Drum	MIN. 15 inches horizontal edge-to-edge spacing required Between this container and all other fuel accumulations.
Be Filter Press Solids, T. P. Solids	Unknown		

MODERATION: Moderating materials are permitted only as necessary for normal operation.

DO NOT REMOVE THIS SIGN WITHOUT APPROVAL FROM NUCLEAR CRITICALITY SAFETY

BAY 12A-05, Rev. 2
2/2/98
SER98-007

Was:
BAY 12A-05, Rev. 1
6/30/97
SER97-059

APPENDIX B

NUCLEAR CRITICALITY SAFETY REQUIREMENTS

SER98-007 (Phase 1)/NCS-1998-011

Nuclear Criticality Safety Requirements: SER98-007 (Phase 1)

Design/Installation/Construction Requirements:

None.

Pre-Operational Testing Instructions:

A. Administrative Controls (operator controlled parameters):

1.	TYPE:	Uranium.
2.	FORM:	Waste, any form.
3.	QUANTITY:	MAX. 100 grams U-235 per ≥ 55-gallon drum.
4.	SPACING:	MIN. 15 inches horizontal edge-to-edge spacing between a group of these drums and all other fuel accumulations. NO spacing requirement between these like drums. NO stacking allowed.
5.	MODERATION:	Moderating materials are permitted only as necessary for normal operations.

6. ≤ 2.5-liter containers containing material that has the potential of containing lumped fuel material [Section 6.3.4 of E46-80], shall contain less than or equal to 1.32 grams of U-235 based on drum counter results.

7. ≤ 2.5-liter containers containing material that has little potential of containing lumped fuel material [Section 6.3.6 of E46-80], shall contain less than or equal to 8.00 grams of U-235 based on drum counter results.

B. Procedural Requirements:

1. Operations shall identify each 55-gallon drum currently in existence that does not meet the requirements of this evaluation. A copy of this list shall be provided to NCS.

2. Operations shall generate a plan that describes how the above non-compliant 55-gallon drums will be managed in the future. This plan shall include a labeling scheme to facilitate easy identification. NCS shall concur with this plan.

3. Procedure SS-07-05 shall be revised for consistency with the requirements in this evaluation.

4. Waste Operations shall review all area procedures affected by these changes and make appropriate changes. All changes shall be reviewed and approved by NCS.

5. NMC Operations shall review all area procedures affected by these changes and make appropriate changes. All changes shall be reviewed and approved by NCS.

6. All personnel affected by the changes/new NCS postings contained in Appendix A shall be trained to them.

7. All NCS postings in Appendix A shall be appropriately posted.

D. Nuclear Safety Release:

1. An implementation review and pre-operational inspection are required. Completion of the requirements will be documented in a nuclear safety release.

During Operation Requirements:

None.

APPENDIX C

TYPICAL INPUT DECKS

SER98-007 (Phase 1)/NCS-1998-011

RUN 001: 300 g U-235/drum, Single Layer Array, Normal Condition, Material H/X = 100, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4     infhommed
u-235           1 0.0 6.5847-4  end
o               1 0.0 3.2912-2  end
h               1 0.0 6.5824-2  end
h2o             2               end
orconcrete      3               end
h2o             4 3.4-5         end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y  1 1 6.5318 orig 22.0432 0.0000 6.5318
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 6.5318 orig 0.0000 22.0432 6.5318
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 6.5318 orig -22.0432 0.0000 6.5318
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 6.5318 orig 0.0000 -22.0432 6.5318
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  global
  unit 5
    cuboid      4 1 2p28.5750 2p49.4934 1285.0000 0.0000
    hole 1        0.0000  49.4934 0.0000
    hole 2       28.5750   0.0000 0.0000
    hole 3        0.0000 -49.4934 0.0000
    hole 4      -28.5750   0.0000 0.0000
    cuboid      3 1 2p28.5750 2p49.4934 1285.0000 -30.4800
end geom
read start
  nst=0
  xsm=-28.5750 xsp=28.5750
  ysm=-49.4934 ysp=49.4934
  zsm=0.0000 zsp=85.0900
end start
read bounds
  xyf=mirror
end bounds
end data
```

```
end
```

RUN 009: 300 g U-235/drum, Single Layer Array, Interspersed Moderator Upset Condition, Material H/X = 400, Drum = 1.00 volume fraction water, Room = 1.00 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4      infhommed
u-235           1 0.0 1.6628-4  end
o               1 0.0 3.3253-2  end
h               1 0.0 6.6505-2  end
h2o             2               end
orconcrete      3               end
h2o             4 1.00          end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y  1 1 10.3339 orig 18.2411 0.0000 10.3339
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 10.3339 orig 0.0000 18.2411 10.3339
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 10.3339 orig -18.2411 0.0000 10.3339
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 10.3339 orig 0.0000 -18.2411 10.3339
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  global
  unit 5
    cuboid      4 1 2p28.5750 2p49.4934 1285.0000 0.0000
    hole 1        0.0000  49.4934 0.0000
    hole 2       28.5750   0.0000 0.0000
    hole 3        0.0000 -49.4934 0.0000
    hole 4      -28.5750   0.0000 0.0000
    cuboid      3 1 2p28.5750 2p49.4934 1285.0000 -30.4800
end geom
read start
  nst=0
  xsm=-28.5750 xsp=28.5750
  ysm=-49.4934 ysp=49.4934
  zsm=0.0000 zsp=85.0900
end start
```

```
read bounds
  xyf=mirror
end bounds
end data
end
```

RUN 024: 300 g U-235/drum, Stacking Upset Condition, Material H/X = 800, Drum = 0.10 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4       infhommed
u-235           1 0.0 8.3272-5  end
o               1 0.0 3.3310-2  end
h               1 0.0 6.6620-2  end
h2o             2 0.10          end
orconcrete      3               end
h2o             4 3.4-5         end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y  1 1 13.0130 orig 15.5620 0.0000 72.0769
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 13.0130 orig 0.0000 15.5620 72.0769
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 13.0130 orig -15.5620 0.0000 72.0769
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 13.0130 orig 0.0000 -15.5620 72.0769
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  unit 5
    cuboid      4 1 2p28.5750 2p49.4934 85.0900 0.0000
    hole 1        0.0000  49.4934 0.0000
    hole 2       28.5750   0.0000 0.0000
    hole 3        0.0000 -49.4934 0.0000
    hole 4      -28.5750   0.0000 0.0000
  unit 6
    hemisphe-y  1 1 13.0130 orig 15.5620 0.0000 13.0130
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 7
    hemisphe-x  1 1 13.0130 orig 0.0000 15.5620 13.0130
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
```

```
  unit 8
    hemisphe+y  1 1 13.0130 orig -15.5620 0.0000 13.0130
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 9
    hemisphe+x  1 1 13.0130 orig 0.0000 -15.5620 13.0130
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  unit 10
    cuboid      4 1 2p28.5750 2p49.4934 85.0900 0.0000
    hole 6        0.0000  49.4934 0.0000
    hole 7       28.5750   0.0000 0.0000
    hole 8        0.0000 -49.4934 0.0000
    hole 9      -28.5750   0.0000 0.0000
  global
  unit 11
    array 1  0.0000 0.0000 0.0000
    replicate   4 1 4*0.0000 1200.0000 0.0000 1
    replicate   3 1 5*0.0000 30.48 1
end geom
read array
  ara=1
  nux=1 nuy=1 nuz=2
  fill 5 10 end fill
end array
read bounds
  xyf=mirror
end bounds
end data
end
```

RUN 041: 700 g U-235/drum, Overbatch Upset Condition, Material H/X = 1200, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4      infhommed
u-235          1 0.0 5.5547-5  end
o              1 0.0 3.3329-2  end
h              1 0.0 6.6659-2  end
h2o            2               end
orconcrete     3               end
h2o            4 3.4-5         end
end comp
55-gallon drums
read parm
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
```

```
    hemisphe-y  1 1 19.7538 orig 8.8212 0.0000 19.7538
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 19.7538 orig 0.0000 8.8212 19.7538
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 19.7538 orig -8.8212 0.0000 19.7538
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 19.7538 orig 0.0000 -8.8212 19.7538
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  global
  unit 5
    cuboid      4 1 2p28.5750 2p49.4934 1285.0000 0.0000
    hole 1        0.0000  49.4934 0.0000
    hole 2       28.5750   0.0000 0.0000
    hole 3        0.0000 -49.4934 0.0000
    hole 4      -28.5750   0.0000 0.0000
    cuboid      3 1 2p28.5750 2p49.4934 1285.0000 -30.4800
end geom
read start
  nst=0
  xsm=-28.5750 xsp=28.5750
  ysm=-49.4934 ysp=49.4934
  zsm=0.0000 zsp=85.0900
end start
read bounds
  xyf=mirror
end bounds
end data
end
```

RUN 052: 700 g U-235 in one out of every four drums, 300 grams in the remaining drums, Overbatch Upset Condition, Material H/X = 800, Drum = 1.00 volume fraction water, Room = 3.4E-5 volume fraction water.

```
=csas25
55-gallon drums
27groupndf4       infhommed
u-235            1 0.0 8.3272-5  end
o                1 0.0 3.3310-2  end
h                1 0.0 6.6620-2  end
h2o              2               end
orconcrete       3               end
h2o              4 3.4-5         end
end comp
55-gallon drums
read parm
```

```
  npg=500 gen=465 nsk=15 tme=600 tba=60
end parm
read geom
  unit 1
    hemisphe-y  1 1 13.0130 orig 15.5620 0.0000 13.0130
    zhemicyl-y  2 1 28.5750 85.0900 0.0000
  unit 2
    hemisphe-x  1 1 17.2599 orig 0.0000 11.3151 17.2599
    zhemicyl-x  2 1 28.5750 85.0900 0.0000
  unit 3
    hemisphe+y  1 1 13.0130 orig -15.5620 0.0000 13.0130
    zhemicyl+y  2 1 28.5750 85.0900 0.0000
  unit 4
    hemisphe+x  1 1 13.0130 orig 0.0000 -15.5620 13.0130
    zhemicyl+x  2 1 28.5750 85.0900 0.0000
  global
  unit 5
    cuboid      4 1 2p28.5750 2p49.4934 1285.0000 0.0000
    hole 1        0.0000  49.4934 0.0000
    hole 2       28.5750   0.0000 0.0000
    hole 3        0.0000 -49.4934 0.0000
    hole 4      -28.5750   0.0000 0.0000
    cuboid      3 1 2p28.5750 2p49.4934 1285.0000 -30.4800
end geom
read start
  nst=0
  xsm=-28.5750 xsp=28.5750
  ysm=-49.4934 ysp=49.4934
  zsm=0.0000 zsp=85.0900
end start
read bounds
  xyf=mirror
end bounds
end data
end
```