NCS Calculation Note Number:	Revision:	Page Number:	Total Pages:
CN-CRI-06-35	1	1	94

NCS Calculation Note Title:

PWR Fuel Assembly Parametric Calculations

Objective:

Model each Pressurized Water Reactor (PWR) fuel assembly type currently authorized to be fabricated, stored, or handled at the CFFF. For each fuel type, determine bounding credible model, accounting for dimensional tolerances. Determine bounding assembly type(s) for use in Nuclear Criticality Safety (NCS) analyses.

Results:

Based on analyses of each of the authorized fuel types, it is concluded that is the most reactive PWR fuel assembly authorized to be fabricated, stored, or handled at the CFFF, for all configurations investigated herein. Therefore, for NCS analyses performed for the CFFF, the may be assumed to be the bounding PWR fuel assembly type, as long as the modeled configuration is not greatly dissimilar to one of the configurations investigated herein.

In addition, for all Westinghouse PWR assembly types modeled herein ( ), it is concluded that the effects of tolerances on are insignificant and may be neglected.

Additional conclusions are summarized in Section 2.0.

Author (Print):	Author (Sign):	Date:
Sean T. Gough Robert P. Taylor, Jr.		
Technical Reviewer (Print):	Technical Reviewer (Sign):	Date:
Michael R. Corum		
NCS Engineering Manager (Print):	NCS Engineering Manager (Sign):	Date:
Ralph J. Winiarski, Jr.		

Revision Log

Rev	Date	Revision Description/Reason
0	01/07	Original Issue
1	N/A	Added analyses

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

1.1 Background/Purpose

This calculation note documents parametric analyses of all PWR fuel assembly types that are currently authorized to be fabricated, stored, or handled at the CFFF, with respect to approved Criticality Safety Evaluations (CSEs). Although fuel assemblies are constructed for many customers at the CFFF, these fuel assemblies actually fall into a limited number of general fuel designs . Within these general types, most customer-specific options are not important to the NCS calculations. For NCS calculations, only the following data are important:

The purpose of these calculations is to derive bounding analytical models for each of the approved fuel types, as well as to determine the bounding fuel type(s) to be used in subsequent CSEs and other NCS analyses.

Herein, the fuel assembly types are identified by the old historical designation (e.g.,), as well as a new three-part code:

1.2 Limits of Applicability

The assembly types modeled herein bound the various customer-specific variants currently fabricated at the CFFF, as well as fuel variants credibly expected to be fabricated at the CFFF in the near future, as listed in Reference 2. Fuel assembly types not listed herein are not necessarily bound by the CSEs issued and approved for CFFF operations, and may not be fabricated, stored, or handled at the CFFF.

Any introduction of a new fuel assembly design or revision to an existing design must be reviewed and approved by NCS Engineering, if the new or revised design results in a change to one of the parameters important to NCS, as listed in Section 1.0.

2.0 CONCLUSIONS

Based on Reference 2 and the analyses documented herein, the PWR fuel assembly types authorized to be fabricated, stored, or handled at the CFFF, with respect to NCS analyses, are:

No other PWR fuel assembly types may be fabricated, stored, or handled at the CFFF without demonstrating that they are bounded by one of the types above, in an approved NCS calculation note or Criticality Safety Evaluation (CSE).

Based on parametric analyses of these fuel types, the following conclusions are drawn:

Based on analyses of each of the authorized fuel types, it is concluded that the assembly is the most reactive PWR fuel assembly authorized to be fabricated, stored, or handled at the CFFF, for all configurations investigated herein. Therefore, for NCS analyses performed for the CFFF, the may be assumed to be the bounding PWR fuel assembly type, as long as the modeled configuration is not greatly dissimilar to one of the configurations investigated herein.

In addition, for all Westinghouse PWR assembly types modeled herein , it is concluded that the effects of tolerances on are insignificant and may be neglected.

3.0 ASSUMPTIONS & OPEN ITEMS

3.1 Assumptions

The analyses documented herein are based on the following assumptions:

5 wt% maximum ^{235}U enrichment modeled in all pellets: This is the maximum enrichment allowed by the CFFF license.

3.2 Open Items

There are no open items.

4.0 ACCEPTANCE CRITERIA

Per the CFFF license, calculated k_{EFF}s must be adjusted to account for statistical uncertainty and any applicable code bias and bias uncertainty. The final adjusted k_{EFF} is referred to as the 95/95 k_{EFF}:

The CFFF license further requires that the 95/95 k_{EFF} be demonstrated to be less than or equal to 0.95 for normal conditions and expected upsets, and that 95/95 k_{EFF} be demonstrated to be less than or equal to 0.98 for credible abnormal conditions.

5.0 COMPUTER CODES USED IN CALCULATION

The results documented herein are derived using the MCNP 5 code running on the WEC LINUX cluster [6] and using the default cross-section libraries [7]. For this combination of code and computational platform, Reference 1 provides a validation analysis for heterogeneous low-enriched UO_2 systems, which results in a . Table 1 lists the areas of applicability (AOAs) for the validation analysis and the calculations performed herein.

Table 1: Areas of Applicability

Parameter	Reference 1 Validation	Current Calculations
Fissile Material	UO_2	UO_2
Fissile Material Form	Solid	Solid

Based on the table above, the calculations documented herein are well within the validation AOA, with one minor exception.

Note that specific parameter control limits are not derived herein. Rather, parametric analyses of each authorized assembly type are performed, to gauge the effects of all associated dimensional tolerances. Therefore, no sensitivity calculations as described in Reference 3 are performed herein.

6.0 REFERENCES

1. Revolinski, S. M., *Determination of Bias for Heterogeneous Systems Modeled Using MCNP 5*, CN-CRI-06-39, Rev. 1, February 2007.

2.

3.

4. Petrie, L. M., Fox, P. B., and Lucius, K., *Standard Composition Library*, NUREG/CR-0200, Revision 6, Volume 3, Section M8, March 2000.

5. Walker, F. W., et al., *Chart of the Nuclides*, 14th Edition, General Electric Company, San Jose, CA, 1989.

6. Christian, W. R., *MCNP 5 Version 1.40 Installation Verification Report*, CE-06-452, December 7, 2006.

7. Revolinski, S. M., *MCNP 5 Benchmark Calculations for Low Enriched Heterogeneous Systems*, CN-CRI-06-38, January 2007.

8.

9.

7.0 CALCULATIONS

7.1 Method Discussion

The basic geometry of the fuel assembly models is described in Section 7.1.1, while material compositions employed in the analyses are described in Section 7.1.2.

7.1.1 Model Geometry

Figure 1 depicts an example model of a PWR fuel assembly.

Figure 1: Example PWR Fuel Assembly Model

7.1.2 Materials

UO_2 is modeled at theoretical mass density (10.96 g/cc [4]) using the weight fractions listed in Table 2.

H_2O is modeled with a mass density of 0.9982 g/cc [4]. Thermal scattering from hydrogen in water is modeled using the lwtr.60t light water $S(\alpha, \beta)$ table.

[a] The effect of modeling this density is investigated in Section 7.3.1.

Table 2: Material Compositions

Nuclide	Weight Fraction
UO_2	
^{235}U	0.044072
^{238}U	0.837369
^{16}O	0.118559

7.2 Input

The list of fuel assembly types currently authorized to be fabricated, stored, or handled at the CFFF, as well as associated nominal dimensions and tolerances, are documented in Reference 2. These data are reproduced below in Table 3, for PWR assemblies only.

Reference 2 also provides specific references for these data, as well as references for rod loading patterns and material specifications. These references are not reproduced herein.

Table 3: PWR Master Assembly List

*

Table 3: PWR Master Assembly List (continued)

**

Based on the nominal dimensions and tolerances listed in Table 3, Table 4 presents the for use in the parametric analyses documented herein.

Table 4: Min, Max, and Nominal Dimensions for Assembly Parameters (in cm)

Table 4: Min, Max, and Nominal Dimensions for Assembly Parameters (in cm) (continued)

Unless otherwise noted, all the calculations performed herein employ the nominal dimensions from Table 4.

7.3 Evaluations, Analysis, and Detailed Calculations

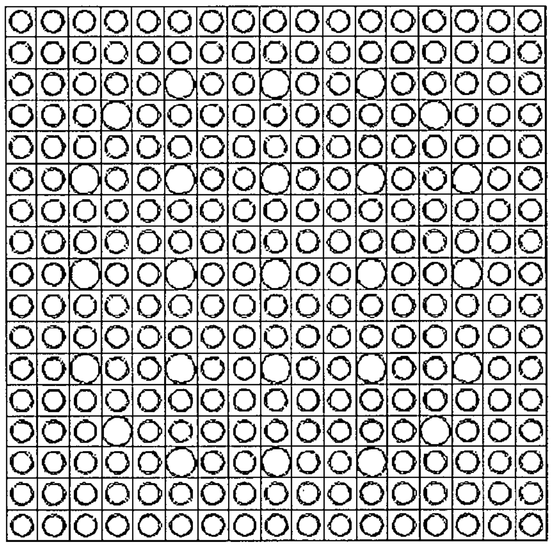
Section 7.3.1 presents initial parametric analyses used to define appropriate modeling conventions for the assembly types, as well as deriving general conclusions that apply to all of the assembly types. Section 7.3.2 presents the final analyses for each of the assembly types listed in Table 3. Section 7.3.3 presents a summary of the results.

7.3.1 Initial Parametric Analyses

In this section, initial parametric analyses are performed for a single assembly type,

,

From Table 3, there are



[b]

[b] Note that the configuration of thimbles and instrument tubes in a W17(3740) assembly is identical to the configuration for a W17(3600) assembly. Therefore, the configurations for modeling missing rods are also identical (see Figure 5).

[c] Note that the configuration of thimbles and instrument tubes in a W16(3600) assembly is identical to the configuration for a W16(3740) assembly. Therefore, the configurations for modeling missing rods are also identical (see Figure 10).

[d] Note that the configuration of thimbles and instrument tubes in a W14(4220) assembly is identical to the configuration for a W14(4000) assembly. Therefore, the configurations for modeling missing rods are also identical (see Figure 18).

[e] The source drawing cited in Reference 2 indicates that the overall grid tolerance is ~0.015" for CE14(4400) assemblies. Applying the pitch tolerance of 0.005" to every lattice cell results in increasing the assembly dimensions by 0.065", which far exceeds the assembly tolerance of 0.015".

[f] The source drawing cited in Reference 2 indicates that the overall grid tolerance is ~0.015" for CE16(3820) assemblies. Applying the pitch tolerance of 0.005" to every lattice cell results in increasing the assembly dimensions by 0.075", which far exceeds the assembly tolerance of 0.015".

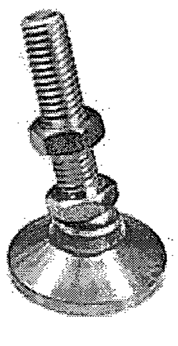
[g] The source drawing cited in Reference 2 indicates that the overall grid tolerance is ~0.015" for CE16(3740) assemblies. Applying the pitch tolerance of 0.005" to every lattice cell results in increasing the assembly dimensions by 0.075", which far exceeds the assembly tolerance of 0.015".

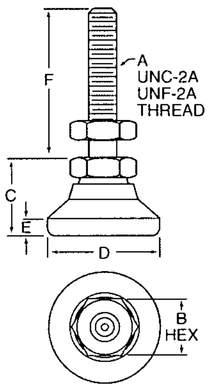
[h] Note that the configuration of thimbles and instrument tubes in a CE16(3740) assembly is identical to the configuration for a CE16(3820) assembly. Therefore, the configurations for modeling missing rods are also identical (see Figure 29).

VLIER IMPORT HIGH VALUE LEVELING PADS

These import leveling pads offer good quality product with value pricing. They have a hardened ball, except stainless, for high load ratings and wear. Large diameter base for added support. 15° off center swivel for quick leveling on sloped surfaces.

Stud Type

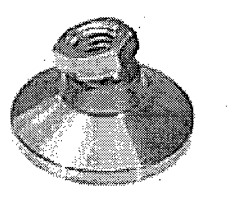


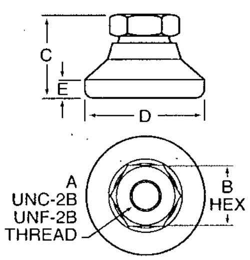


See table 4 below for additional discounts.

Cat. No.	A	B	C	D	E	F	Load Rate	Price Each 1-11
Steel - Gold Chromate								
HVTL-00	10-32	3/8	17/32	3/4	7/64	1	700	**4.18**
HVTL-10	10-32	3/8	17/32	3/4	7/64	2	700	**4.44**
HVTL-0	1/4-20	1/2	45/64	1	5/32	1 1/4	1,100	**4.04**
HVTL-15	1/4-20	1/2	45/64	1	5/32	2 1/2	1,100	**4.56**
HVTL-1	3/8-16	5/8	7/8	1 1/4	3/16	2	3,750	**5.20**
HVTL-20	3/8-16	5/8	7/8	1 1/4	3/16	4	3,750	**5.33**
HVTL-2	1/2-13	3/4	1 1/8	1 7/8	1/4	2	5,000	**5.47**
HVTL-25	1/2-13	3/4	1 1/8	1 7/8	1/4	4	5,000	**6.04**
HVTL-3	5/8-11	7/8	1 1/4	2 1/2	5/16	2	6,000	**8.25**
HVTL-30	5/8-11	7/8	1 1/4	2 1/2	5/16	4	6,000	**9.49**
HVTL-4	3/4-10	1 1/16	1 1/2	3	1/2	2	7,200	**12.23**
HVTL-35	3/4-10	1 1/16	1 1/2	3	1/2	4	7,200	**13.93**
HVTL-5	1-8	1 3/8	1 7/8	4	13/32	4 1/4	22,000	**20.62**
HVTL-40	1-8	1 3/8	1 7/8	4	13/32	8	22,000	**25.90**
Stainless Steel								
HVTL-00SS	10-32	3/8	17/32	3/4	7/64	1	700	**6.44**
HVTL-10SS	10-32	3/8	17/32	3/4	7/64	2	700	**7.20**
HVTL-0SS	1/4-20	1/2	45/64	1	5/32	1 1/4	1,100	**6.48**
HVTL-15SS	1/4-20	1/2	45/64	1	5/32	2 1/2	1,100	**8.55**
HVTL-1SS	3/8-16	5/8	7/8	1 1/4	3/16	2	3,750	**7.95**
HVTL-20SS	3/8-16	5/8	7/8	1 1/4	3/16	4	3,750	**13.17**
HVTL-2SS	1/2-13	3/4	1 1/8	1 7/8	1/4	2	5,000	**13.60**
HVTL-25SS	1/2-13	3/4	1 1/8	1 7/8	1/4	4	5,000	**16.57**
HVTL-3SS	5/8-11	7/8	1 1/4	2 1/2	5/16	2	6,000	**24.76**
HVTL-30SS	5/8-11	7/8	1 1/4	2 1/2	5/16	4	6,000	**29.97**
HVTL-4SS	3/4-10	1 1/16	1 1/2	3	1/2	2	7,200	**33.78**
HVTL-35SS	3/4-10	1 1/16	1 1/2	3	1/2	4	7,200	**39.67**
HVTL-5SS	1-8	1 3/8	1 7/8	4	13/32	4 1/4	22,000	**56.71**
HVTL-40SS	1-8	1 3/8	1 7/8	4	13/32	8	22,000	**61.38**

Socket Type





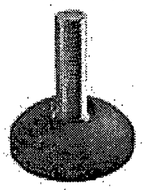
See table 4 below for additional discounts.

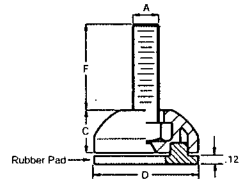
Cat. No.	A	Min. Thd. Depth	B	C	D	E	Load Rate	Price Each 1-11
Steel - Gold Chromate								
HVL-5	10-32	.17	3/8	17/32	3/4	7/64	700	**2.97**
HVL-6	1/4-20	.31	1/2	45/64	1	5/32	1,100	**3.34**
HVL-0	3/8-16	.38	5/8	7/8	1 1/4	3/16	3,750	**3.80**
HVL-1	1/2-13	.44	3/4	1 1/8	1 7/8	1/4	5,000	**4.38**
HVL-2	5/8-11	.44	7/8	1 1/4	2 1/2	5/16	6,000	**6.78**
HVL-3	3/4-10	.62	1 1/16	1 1/2	3	1/2	7,200	**9.69**
HVL-4	1-8	.81	1 3/8	1 7/8	4	13/32	22,000	**16.54**
Stainless Steel								
HVL-5SS	10-32	.17	3/8	17/32	3/4	7/64	700	**5.38**
HVL-6SS	1/4-20	.31	1/2	45/64	1	5/32	1,100	**5.05**
HVL-0SS	3/8-16	.38	5/8	7/8	1 1/4	3/16	3,750	**6.68**
HVL-1SS	1/2-13	.44	3/4	1 1/8	1 7/8	1/4	5,000	**13.10**
HVL-2SS	5/8-11	.44	7/8	1 1/4	2 1/2	5/16	6,000	**21.22**
HVL-3SS	3/4-10	.62	1 1/16	1 1/2	3	1/2	7,200	**29.71**
HVL-4SS	1-8	.81	1 3/8	1 7/8	4	13/32	22,000	**47.99**

Reid SELECT LEVELING PADS

Black Thermoplastic

These leveling pads are an economical choice for a wide range of applications. The base is made from reinforced thermoplastic. Threaded stem is made of treated steel. Optional non-skid rubber pads available separately. Metric dimensions are in millimeters.

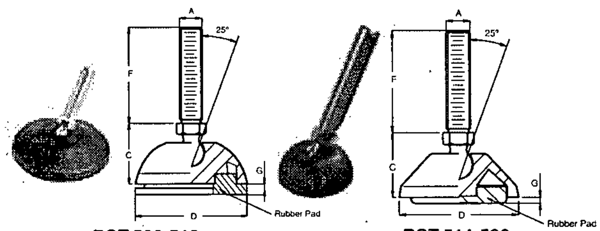




See table 4 below for additional discounts.

Cat. No.	A	C	D	F	Max. Static Load Lbs.	Price Each 1-11
RST-500	5/16-18	.51	1.26	1.50	1,763	**.63**
RST-501	3/8-16	.51	1.26	1.75	1,763	**.73**
RST-502	5/16-18	.51	1.57	1.50	1,763	**.66**
RST-503	3/8-16	.51	1.57	1.75	1,763	**.76**

Cat. No.	Description	Price Each 1-11
RST-504	Rubber Pad For 1.26" Base	**.41**
RST-505	Rubber Pad For 1.57" Base	**.49**

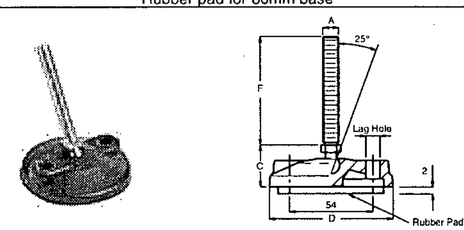


RST-506-513 **RST-514-530**

See table 4 below for additional discounts.

Cat. No.	A	C	D	F	G	Max. Static Load Newtons	Price Each 1-11
RST-506	M8	22	32	45	3	10,000	**1.97**
RST-507	M8	22	32	70	3	10,000	**2.26**
RST-508	M10	22	32	45	3	10,000	**2.03**
RST-509	M10	22	32	70	3	10,000	**2.53**
RST-510	M8	22	40	45	3	10,000	**2.07**
RST-511	M8	22	40	70	3	10,000	**2.37**
RST-512	M10	22	40	45	3	10,000	**2.13**
RST-513	M10	22	40	70	3	10,000	**2.63**
RST-514	M8	27	50	45	2	10,000	**2.09**
RST-515	M8	27	50	70	2	10,000	**2.38**
RST-516	M10	27	50	45	2	10,000	**2.14**
RST-517	M10	27	50	70	2	10,000	**2.71**
RST-518	M12	27	50	45	2	10,000	**2.42**
RST-520	M8	27	80	45	2	10,000	**2.70**
RST-521	M8	27	80	70	2	10,000	**3.01**
RST-522	M10	27	80	45	2	10,000	**2.76**
RST-523	M10	27	80	70	2	10,000	**3.37**
RST-524	M12	27	80	45	2	10,000	**3.06**
RST-525	M12	27	80	70	2	10,000	**3.78**
RST-526	M14	27	80	70	2	10,000	**4.25**
RST-527	M14	27	80	120	2	10,000	**6.23**
RST-528	M16	27	80	70	2	10,000	**5.73**
RST-529	M16	27	80	120	2	10,000	**6.58**
RST-530	M20	27	80	100	2	10,000	**7.91**

Cat. No.	Description	Price Each 1-11
RST-504	Rubber Pad For 1.26" Base	**.41**
RST-505	Rubber Pad For 1.57" Base	**.49**
RST-531	Rubber pad for 50mm base	**.86**
RST-532	Rubber pad for 80mm base	**1.57**



See table 4 below for additional discounts.

Cat. No.	A	C	D	F	Lag Hole	Max. Static Load Newtons	Price Each 1-11
RST-533	M8	27	80	45	9	10,000	**2.84**
RST-534	M8	27	80	70	9	10,000	**3.16**
RST-535	M10	27	80	45	9	10,000	**2.90**
RST-536	M10	27	80	70	9	10,000	**3.54**
RST-537	M12	27	80	45	9	10,000	**3.21**
RST-548	M12	27	80	70	9	10,000	**3.97**
RST-539	M14	27	80	70	9	10,000	**4.46**
RST-540	M14	27	80	120	9	10,000	**6.40**
RST-541	M16	27	80	70	9	10,000	**6.02**
RST-542	M16	27	80	120	9	10,000	**6.91**
RST-543	M20	27	80	100	9	10,000	**8.31**

Cat. No.	Description	Price Each 1-11
RST-544	Rubber pad for 80mm base with lagholes	**1.71**

4	Quantity	1-11	12-23	24-47	48-71	72-96	97-499	500+
	Discount	Net	7%	12%	20%	25%	30%	Call