FRAMATOME ANP
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FRAMATOME ANP, Inc.

May 13, 2005
RDM:05:006

Division of Fuel Cycle Safety and Safeguards
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
Attn: William C. Gleaves
11555 Rockville Pike
Rockville MD 20852-2739

Reference: SNM License 1168, Docket No. 70-1201
FANP Letter dated April 11, 2005 (CFH:05:011)
NRC Letter dated May 5, 2005 (TAC No. L31886)

Subject: Response to RAI Questions: Application for License Amendment to Change the Applied Administrative Margin for Finished Fuel Assemblies at Two Workstations

Dear Mr. Gleaves:

Framatome ANP (FANP) is hereby providing the response to subject NRC Request for Additional Information (RAI) to support the referenced licensing action for the applications at two workstations, the fuel assembly air cleaning station and control rod assembly drag gauge station, involving a single finished fuel assembly at each station to use an administrative margin of 0.02 for off-normal conditions.

Attachment I to this letter contains the RAI response From FANP

If you or your staff have any questions, require additional information, or wish to discuss this, please contact Mr. Charlie Holman at (434) 832-5276, or me at (423) 735-4018.

Sincerely,

Richard D. Montgomery

Richard D. Montgomery, Advisory Engineer
Nuclear Criticality Safety & Shipping Containers
Framatome ANP, Inc.

ATTACHMENT I

Response to NRC RAI Questions

TAC No L31886

Framatome ANP Responses to RAI dated May 5, 2005

1. The k_{eff} calculations for the referenced benchmarks (output values taken from Table 23 of Ref. [2] for the Validation Report, dated 3/10/2004 – this was the set of data used for trending and computing bias) were rerun on the computer system that criticality safety calculations are currently performed on for the Mount Athos Road (MAR) facility. The verification of PC-SCALE 4.4a on this system is documented in Ref. [5], dated 10/28/2004. Note that this verification report simply documents that the installation of SCALE 4.4a is functioning properly by comparing calculated output of sample input decks (provided by ORNL) to the provided output to these input decks computed that was computed and verified on an ORNL platform. Applicable sample input cases, e.g. for CSAS and KENO V.a modules, are always re-executed near the time new calculations are performed to provide assurance that no change has occurred in the PC operating system and the code executables since the time of installation.

   In Table 1, the k_{eff} value, its standard deviation, and the EALF (three parameters calculated by SCALE) obtained by rerunning the benchmark cases on the MAR PC platform are compared to those listed in Ref [2]. The results were found to be identical to those listed in Ref. [2].

Table 1 Results for the 83 benchmark cases calculated on the Mount Athos Road PC used for criticality safety calculations compared to the results listed in Ref. [2] (values used for trending and computing bias).

Case	*Calculated on MAR Computer 1/28/2005 (Ref. [5])*			*Listed in Ref. [2] From Validation Report*			*Differences*		
	$k_{calc,ref5}$	$\sigma_{calc,ref5}$	$EALF_{ref5}$ (eV)	$k_{calc,ref2}$	$\sigma_{calc,ref2}$	$EALF_{ref2}$ (eV)	$k_{calc,ref5} - k_{calc,ref2}$	$\sigma_{calc,ref5} - \sigma_{calc,ref2}$	$EALF_{ref5} - EALF_{ref2}$
c004	0.9971	0.0008	0.1127	0.9971	0.0008	0.1127	0	0	0
c005b	0.9960	0.0008	0.1129	0.9960	0.0008	0.1129	0	0	0
c006b	0.9960	0.0008	0.1128	0.9960	0.0008	0.1128	0	0	0
c007a	0.9966	0.0008	0.1127	0.9966	0.0008	0.1127	0	0	0
c008b	0.9948	0.0008	0.1135	0.9948	0.0008	0.1135	0	0	0
c009b	0.9963	0.0008	0.1137	0.9963	0.0008	0.1137	0	0	0
c010b	0.9980	0.0008	0.1145	0.9980	0.0008	0.1145	0	0	0
c011b	0.9983	0.0009	0.1135	0.9983	0.0009	0.1135	0	0	0
c012b	0.9975	0.0007	0.1145	0.9975	0.0007	0.1145	0	0	0
c013b	0.9956	0.0010	0.1128	0.9956	0.0010	0.1128	0	0	0
c014b	0.9970	0.0009	0.1138	0.9970	0.0009	0.1138	0	0	0
c029b	0.9967	0.0008	0.1129	0.9967	0.0008	0.1129	0	0	0
c030b	0.9977	0.0009	0.1129	0.9977	0.0009	0.1129	0	0	0
c031b	0.9975	0.0008	0.1145	0.9975	0.0008	0.1145	0	0	0
aclp1	0.9911	0.0008	0.1724	0.9911	0.0008	0.1724	0	0	0
aclp2	0.9937	0.0006	0.2517	0.9937	0.0006	0.2517	0	0	0
aclp3	0.9954	0.0006	0.1960	0.9954	0.0006	0.1960	0	0	0
aclp4	0.9897	0.0007	0.1905	0.9897	0.0007	0.1905	0	0	0
aclp5	0.9881	0.0008	0.1660	0.9881	0.0008	0.1660	0	0	0
aclp6	0.9905	0.0008	0.1712	0.9905	0.0008	0.1712	0	0	0

Case	*Calculated on MAR Computer 1/28/2005 (Ref. [5])*			*Listed in Ref. [2] From Validation Report*			*Differences*		
	$k_{calc,ref5}$	$\sigma_{calc,ref5}$	$EALF_{ref5}$ (eV)	$k_{calc,ref2}$	$\sigma_{calc,ref2}$	$EALF_{ref2}$ (eV)	$k_{calc,ref5} - k_{calc,ref2}$	$\sigma_{calc,ref5} - \sigma_{calc,ref2}$	$EALF_{ref5} - EALF_{ref2}$
aclp7	0.9899	0.0007	0.1497	0.9899	0.0007	0.1497	0	0	0
aclp8	0.9900	0.0006	0.1536	0.9900	0.0006	0.1536	0	0	0
aclp9	0.9918	0.0007	0.1408	0.9918	0.0007	0.1408	0	0	0
aclp10	0.9907	0.0007	0.1489	0.9907	0.0007	0.1489	0	0	0
acp11a	0.9950	0.0007	0.2002	0.9950	0.0007	0.2002	0	0	0
acp11b	0.9954	0.0006	0.1996	0.9954	0.0006	0.1996	0	0	0
acp11c	0.9950	0.0006	0.2017	0.9950	0.0006	0.2017	0	0	0
acp11d	0.9931	0.0006	0.2029	0.9931	0.0006	0.2029	0	0	0
acp11e	0.9958	0.0006	0.2030	0.9958	0.0006	0.2030	0	0	0
acp11f	0.9937	0.0008	0.2044	0.9937	0.0008	0.2044	0	0	0
acp11g	0.9952	0.0007	0.2047	0.9952	0.0007	0.2047	0	0	0
aclp12	0.9913	0.0006	0.1696	0.9913	0.0006	0.1696	0	0	0
aclp13	0.9922	0.0009	0.1975	0.9922	0.0009	0.1975	0	0	0
acp13a	0.9904	0.0008	0.1976	0.9904	0.0008	0.1976	0	0	0
aclp14	0.9889	0.0007	0.2003	0.9889	0.0007	0.2003	0	0	0
aclp15	0.9847	0.0007	0.2065	0.9847	0.0007	0.2065	0	0	0
aclp16	0.9842	0.0007	0.1734	0.9842	0.0007	0.1734	0	0	0
aclp17	0.9881	0.0006	0.2054	0.9881	0.0006	0.2054	0	0	0
aclp18	0.9887	0.0007	0.1721	0.9887	0.0007	0.1721	0	0	0
aclp19	0.9912	0.0007	0.2056	0.9912	0.0007	0.2056	0	0	0
aclp20	0.9891	0.0007	0.1731	0.9891	0.0007	0.1731	0	0	0
aclp21	0.9859	0.0008	0.1535	0.9859	0.0008	0.1535	0	0	0
rcon01	1.0000	0.0007	2.4196	1.0000	0.0007	2.4196	0	0	0
rcon02	1.0004	0.0006	2.4260	1.0004	0.0006	2.4260	0	0	0
rcon03	0.9967	0.0008	2.5128	0.9967	0.0008	2.5128	0	0	0
rcon04	0.9995	0.0007	2.5002	0.9995	0.0007	2.5002	0	0	0
rcon05	1.0010	0.0008	2.4541	1.0010	0.0008	2.4541	0	0	0
rcon06	1.0002	0.0008	2.4924	1.0002	0.0008	2.4924	0	0	0
rcon07	0.9974	0.0008	1.6242	0.9974	0.0008	1.6242	0	0	0
rcon08	1.0159	0.0007	1.1080	1.0159	0.0007	1.1080	0	0	0
rcon09	0.9972	0.0006	1.4533	0.9972	0.0006	1.4533	0	0	0
rcon10	0.9974	0.0007	1.4738	0.9974	0.0007	1.4738	0	0	0
rcon11	0.9953	0.0008	1.4963	0.9953	0.0008	1.4963	0	0	0
rcon12	0.9979	0.0008	1.4999	0.9979	0.0008	1.4999	0	0	0
rcon13	0.9981	0.0008	1.5132	0.9981	0.0008	1.5132	0	0	0
rcon14	0.9964	0.0007	1.5193	0.9964	0.0007	1.5193	0	0	0
rcon15	0.9991	0.0007	1.5206	0.9991	0.0007	1.5206	0	0	0
rcon16	0.9960	0.0006	0.4216	0.9960	0.0006	0.4216	0	0	0
rcon17	0.9951	0.0006	0.4275	0.9951	0.0006	0.4275	0	0	0
rcon18	0.9933	0.0006	0.4377	0.9933	0.0006	0.4377	0	0	0
rcon19	0.9951	0.0006	0.4382	0.9951	0.0006	0.4382	0	0	0
rcon20	0.9948	0.0007	0.4407	0.9948	0.0007	0.4407	0	0	0
rcon21	0.9947	0.0006	0.4457	0.9947	0.0006	0.4457	0	0	0
rcon28	0.9965	0.0007	1.0039	0.9965	0.0007	1.0039	0	0	0
mdis01	0.9912	0.0009	0.2828	0.9912	0.0009	0.2828	0	0	0

Case	*Calculated on MAR Computer 1/28/2005 (Ref. [5])*			*Listed in Ref. [2] From Validation Report*			*Differences*		
	$k_{calc,ref5}$	$\sigma_{calc,ref5}$	$EALF_{ref5}$ (eV)	$k_{calc,ref2}$	$\sigma_{calc,ref2}$	$EALF_{ref2}$ (eV)	$k_{calc,ref5} - k_{calc,ref2}$	$\sigma_{calc,ref5} - \sigma_{calc,ref2}$	$EALF_{ref5} - EALF_{ref2}$
mdis02	0.9892	0.0009	0.2621	0.9892	0.0009	0.2621	0	0	0
mdis03	0.9835	0.0009	0.2648	0.9835	0.0009	0.2648	0	0	0
mdis04	0.9894	0.0010	0.2512	0.9894	0.0010	0.2512	0	0	0
mdis05	0.9918	0.0009	0.2408	0.9918	0.0009	0.2408	0	0	0
mdis06	1.0007	0.0008	0.2293	1.0007	0.0008	0.2293	0	0	0
mdis07	0.9920	0.0008	0.2254	0.9920	0.0008	0.2254	0	0	0
mdis08	0.9861	0.0010	0.2504	0.9861	0.0010	0.2504	0	0	0
mdis09	0.9878	0.0009	0.2479	0.9878	0.0009	0.2479	0	0	0
mdis10	0.9915	0.0009	0.2226	0.9915	0.0009	0.2226	0	0	0
mdis11	1.0028	0.0008	0.2053	1.0028	0.0008	0.2053	0	0	0
mdis12	1.0072	0.0008	0.1940	1.0072	0.0008	0.1940	0	0	0
mdis13	0.9921	0.0009	0.1946	0.9921	0.0009	0.1946	0	0	0
mdis14	0.9894	0.0008	0.2304	0.9894	0.0008	0.2304	0	0	0
mdis15	0.9881	0.0009	0.2271	0.9881	0.0009	0.2271	0	0	0
mdis16	1.0004	0.0009	0.1906	1.0004	0.0009	0.1906	0	0	0
mdis17	0.9990	0.0008	0.1791	0.9990	0.0008	0.1791	0	0	0
mdis18	0.9962	0.0009	0.1749	0.9962	0.0009	0.1749	0	0	0
mdis19	0.9938	0.0008	0.1739	0.9938	0.0008	0.1739	0	0	0

2. The computer operating system used in Mount Athos Road criticality safety calculations is Microsoft Windows XP Professional, and the hardware platform is a Dell Optiplex GX270 (PC-SCALE 4.4a software verification report for this computer system is documented in Ref. [5] of the validation report).

   For calculations associated with single assemblies, the CSAS25 sequence with the LATTICECELL option and the SQUAREPITCH card is used for processing the ENDF/B-V 44 group cross section library. Materials defined for single assembly calculations can be UO_2, stainless steel, zirconium alloys or pure zirconium, water, and/or void. Generally, compounds/alloys available in the standard composition library will be employed to define these materials. The UO_2 compound ("UO2") requires the definition of weight percents for the uranium isotopes present. For the other available compounds/alloys used, this is not required. The only cases where compounds/alloys available in the standard composition library may not be used are for zirconium or steel alloys that are not available in the library. In these cases, they may be defined as arbitrary materials ("ARBM" prefix), where the theoretical density and weight percents for each natural element or isotope are required data, along with the normal requirements for a pre-defined compound, or as a basic mixture of natural elements, isotopes, compounds, or alloys in which the density multiplier is set to zero, and the required data is number density in atoms/b-cm.

   The Monte Carlo calculation is performed using KENO V.a. The k_{eff} value chosen to be the result of an individual case is reported in the KENO output as the average k_{eff} that provided the best convergence, along with the number of generations skipped in computing that average k_{eff}. The analyst will review the plots of average k_{eff} by generations run and average k_{eff} by generations skipped to visually verify that source convergence has been achieved. In addition, the analyst will review the results reported in the output giving the result of the chi-squared test for normality (reports whether or not the chi-squared test was passed at the 95% confidence level), and will observe frequency (histogram) plots of individual generation k_{eff} values to visually verify that the generation k_{eff} values are normally distributed. Note that these checks are not explicitly documented in the criticality safety analyses.

Typically, 1000 histories per neutron generation ("NPG") are run, and the analyst will define the total number of neutron generations to allow for a standard deviation less than or equal to 0.0010 (0.1%), which can be on the order of 1000 generations ("GEN"). Also, the number of generations skipped ("NSK") would normally defined as 100 or less. For single assembly modeling, CUBOIDS, CYLINDERS, and/or ARRAYS can be used in the KENO V.a geometry specification. No biasing data or albedo boundary conditions are employed for single flooded assembly models. The only boundary condition specified for a single flooded assembly would be a vacuum boundary condition, which would be specified on the external surface of a 12 inch water reflector on all sides of the assembly (bounding condition for the design application discussed in the validation report). Because 12 inches of water isolates the assembly, using a vacuum boundary condition is appropriate.

3. In criticality safety analyses for finished fuel assemblies, the assemblies are not modeled with any nominal parameters. Specifically, they are modeled with the maximum pellet outer diameter, the maximum clad inner diameter, and the minimum clad outer diameter. This maximizes the amount of water in an assembly lattice, while also maximizing the amount of fuel. The pellet density is modeled as 97.5% of the theoretical density, and the U-235 enrichment is modeled as 5.1 wt%. The latter adds the largest amount of conservatism to the calculated k_{eff}, as actual enrichment values for specific contracts (assembly designs for power plants) are generally much less than 5.1 wt% (~ 4.5 wt%). Actual enrichment values would not exceed 5.0 wt%.

   Table 2 shows worst-case nominal dimensional values (over the existing contracts), manufacturing tolerances, bounding values, and the values that would actually be used in the model (far right column) for the most reactive assembly type produced at Mount Athos Road (MAR). In addition, the pin layout for this assembly type is shown in Figure 1. Note that for this particular assembly type, the enrichment does not currently exceed 4.30 wt%.

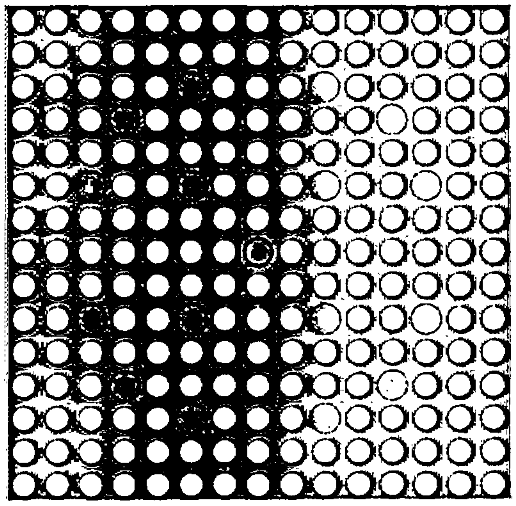
   The worst case nominal parameters for any given assembly design type produced at MAR were determined by comparing the nominal values for all existing or anticipated fuel contracts that use that given design type, and maximizing the pellet diameter while minimizing the clad thickness and guide tube/instrument tube thickness, and maximizing the amount of water in the assembly lattice. In general, this corresponds to assuming the maximum nominal pellet outer diameter (OD), maximum nominal clad inner diameter (ID), minimum nominal clad OD, maximum nominal guide tube/instrument tube ID, and minimum nominal guide tube/instrument tube OD. The worst case manufacturing tolerances for a given parameter are standard for a given assembly design type. This study to determine bounding assembly dimensions was performed by a senior criticality safety analyst, and is documented in the "MAR Pit Criticality Safety Analysis", FANP document number 32-5052962-01 (rev. 1 *archived internally* 3/29/05).

Although the sensitivity of the calculated k_{eff} has not been examined for each of the manufacturing tolerances, the cumulative effect of using conservative modeling parameters has been found to be ~3-4 %Δk for the most reactive assembly type. This reactivity margin is primarily due to the conservative modeling of U-235 enrichment. Changes to other parameters alone, such as the pellet OD, produce statistically insignificant changes in system reactivity.

Table 2 Design parameters for the most reactive assembly type.

Dimension/ Quantity	Nominal (lengths in inches)	Tolerance (lengths in inches)	Bounding (lengths in inches)	Modeled Values (lengths are bounding values converted to cm)
Pellet OD	0.3615	0.0007	0.3622	**0.91999**
Clad ID	0.368	0.002	0.37	**0.93980**
Clad OD	0.416	0.002	0.414	**1.05156**
Guide Tube OD	0.53	0.002	0.528	**1.34112**
Guide Tube ID	0.498	0.002	0.5	**1.27000**
Instrument Tube OD	0.493	0.002	0.491	**1.24714**
Instrument Tube ID	0.441	0.002	0.443	**1.12522**
Pitch	0.568	-	0.568	**1.44272**
Active Length	144	-	150	**381**
Max %TD	96	1.5	97.5	**97.5**
Enrichment (wt%)	4.25 (typical)	0.05	4.30 (typical)	**5.1**

Figure 1 Pin layout for the most reactive assembly type – 16 guide tube (GT) and 1 instrument tube (IT) locations.



4. The derivation for the conversion from V^m/V^f to $H/^{235}U$ is shown below.

$$H/^{235}U=\frac{Atoms\ H}{Atoms\ U-235}\approx\left(\frac{Mass\ H}{Mass\ U-235}\right)\left(\frac{6.02x10^{23}\ Atoms\ H}{1\ g\ H}\right)\left(\frac{235\ g\ U-235}{6.02x10^{23}\ Atoms\ U-235}\right)$$

$$=235\left(\frac{Mass\ H}{Mass\ U-235}\right)\approx 235\left(\frac{Mass\ H_2O}{Mass\ UO_2}\right)\left(\frac{2\ g\ H}{(2+16)\ g\ H_2O}\right)\left(\frac{(235+2*16)\ g\ UO_2}{\left(\left(\frac{wt\%\ U-235}{100}\right)*235\right)g\ U-235}\right)$$

$$=\left(\frac{2960}{wt\%\ U-235}\right)\left(\frac{Mass\ H_2O}{Mass\ UO_2}\right)\approx\left(\frac{2960}{wt\%\ U-235}\right)\underbrace{\left(\frac{Volume\ H_2O}{Volume\ UO_2}\right)}_{V^m/V^f}\left(\frac{1\ g\ H_2O}{1\ cm^3\ H_2O}\right)\left(\frac{1\ cm^3\ UO_2}{\left(\frac{\%TD}{100}\right)*10.96\ g\ UO_2}\right)$$

$$=\left(\frac{27010}{(wt\%\ U-235)*(\%TD)}\right)\left(V^m/V^f\right)$$

$-$ *For* 5.0*wt*% *and* 100%*TD*, *this reduces to*:

$$H/^{235}U=\left(\frac{27010}{5.0*100}\right)\left(V^m/V^f\right)=54.02\left(V^m/V^f\right)$$

In the validation report, the conversion factor is defined to be 27.01, which is a factor of two less than the factor derived above. Looking back at the previous derivation done, it was found that this factor of two difference arose from the ratio of the mass of hydrogen to the mass of water (2/18).

The areas of the validation report that will be changed by this correction are Table 3-2, Table 4-1, and Table 5-2 (tables used to define the design application for MAR for single flooded fuel assemblies). Corrections to these tables are shown below.

Note that this mistake had no effect on the $H/^{235}U$ ratios calculated for the benchmark experiments. The values listed for the benchmarks in Appendix A were calculated separately from those in Tables 3-2, 4-1, and 5-2, and have been confirmed to be correct. The ratios for the benchmarks were verified to be correct. Also note that, in Table 5-2 below, the corrected design application for $H/^{235}U$ for single assemblies falls well within the AOA for the benchmark experiments.

Table 3-2 Characteristics of the MAR Application Areas involving Heterogeneous UO_2 Single flooded fuel Assemblies

Parameter	Single flooded fuel Assemblies
Fissile Material Physical/Chemical Form	UO_2 Rods Structured in a Passive Lattice
Maximum Isotopic Composition of Fissile Material[1]	5.0 wt% ^{235}U
Maximum Oxide Density [g/cm^3]	10.686[2]
Type of Moderation	Heterogeneous
Optimum Moderation[3]	$H/^{235}U = 160 - 270$ $v^m/v^f = 3 - 5$
Anticipated Absorber/Reflector Materials	➢ Water ➢ Concrete ➢ Zirc (Cladding, grids, flow mixers, instrument and guide tubes) ➢ Stainless Steel (Top and Bottom Nozzles)
Typical Geometry	Cylinders Cuboids Arrays

[1] Based on 30B UF6 Cylinder limiting enrichment and physical measurements from both suppler and FANP.

[2] 97.5% TD corresponds to a nominal 96% TD with 1.5% TD contract tolerance. The pellet density is confirmed on a lot basis prior to shipment from HRR to MAR.

[3] A factor of 54.02 is used to convert volume ratios to atomic ratios assuming 5.0 wt% ^{235} U for application cases.

Table 4-1 Anticipated Characteristics for the Design Application Involving Single Flooded Fuel Assemblies

Fuel Configuration	Reflector Condition	Chemical Form	^{235}U wt%	$H/^{235}U$	v^m/v^f	EALF [eV]	k_{eff} Range
Fuel Assembly Area[1]							
Isolated Assembly (Full Interstitial Moderation)	Water and concrete	UO_2	5.1%	156 – 178	2.9 – 3.3	0.19 – 0.25	0.94 – 0.97
Expected Range of Design Applications for Fuel Assemblies	**Water and concrete**	**UO_2**	**5.1%**	**156 – 178**	**2.9 – 3.3**	**0.19 – 0.25**	**0.94 – 0.97**

[1] Fuel Assemblies are undermoderated and designed to be individually subcritical

Table 5-2 AOA – Comparison of Key Parameters and Definition of Validated AOA for Single Flooded Fuel Assemblies

Parameter	Design application (cf. Table 4-1)	Benchmark (cf. Table 5-1)	Validated AOA
Geometrical shape	Heterogeneous lattices; Rectangular	Heterogeneous lattices; Rectangular	Heterogeneous lattices; Rectangular
Absorber / Reflector	Water Concrete Zirc Metals Stainless Steel	Water Concrete Zirc Metals Aluminum Stainless Steel Polyethylene	Water Concrete Zirc Metals Stainless Steel Polyethylene
Chemical form	UO_2	UO_2	UO_2
Enrichment [wt%]	5.1	2.45 – 4.74	5.1
$H/^{235}U$	156 – 178	17.4 – 255.9	17.4 – 255.9
EALF [eV]	0.19 – 0.25	0.11 – 2.48	0.11 – 2.48

5. This amendment request involves applications at two workstations.

The first is a cleaning station where finished fuel assemblies are cleaned through a process where the assembly is lowered past a series of air nozzles. The process takes place in a shroud such that the air is drawn away from the assembly to a scrubber that collects the metal fines generated during the assembly fabrication process. The shroud is located in a pit below grade with respect to the plant floor. The physical dimensions and handling mechanism of the cleaning station allow only one assembly to be present at a time.

The second workstation is a drag gauge station where control rod assemblies are inserted into finished assemblies and the drag or force required to pull the control rod assembly out of the fuel assembly is measured. Fuel assemblies for the drag gauge test are lowered in the pit through an opening in the steel grating. The opening is only large enough for one assembly at a time, and the drag gauge station is located approximately seven feet from the air cleaning station.

Since these workstations are the final quality related steps prior to packaging assemblies for shipment, only finished undamaged assemblies are placed at these locations.

The normal condition at these workstations is a finished fuel assembly in air. The calculated k_{eff} for assemblies under normal condition is low (~0.5).

These workstations were evaluated with the implementation of the Integrated Safety Analysis (ISA). The bounding credible abnormal condition for each location is a flooded assembly. This was found to be the bounding credible abnormal case through the MAR ISA what-if process (ref. Mount Athos Road ISA Summary, rev. 1 submitted January, 2005), and the case is evaluated in the MAR Pit Criticality Safety Analysis (FANP document # 32-5052962-01, rev. 1 archived internally 3/29/05). In a flooded condition, the assemblies are isolated with respect to interaction. Assemblies in these workstations are also located a minimum of nine inches from the concrete wall and floor of the pit. Based on application modeling, the concrete reflection does not increase the reactivity of the system and 12 inches of water reflection provides the bounding case. In a flooded condition the assemblies would not become buoyant and be displaced. No accident sequence was identified in the ISA process that resulted in damage to assemblies at these workstations. Without interaction or concrete reflection, modeling of these workstations would involve a single fuel assembly fully immersed in water at 12 inches on all sides.

These workstations are controlled to prevent criticality using the double contingency principle. Double contingency is applied such that each control is independent and unlikely to fail. Criticality accidents are limited by assuring that under normal and abnormal conditions, the workstations are subcritical, including use of an approved margin of subcriticality. The current double contingency analysis has been reviewed by the ISA review team.

Should the amendment request be accepted, the double contingency controls for the workstations will be spacing and moderation. Spacing is controlled such that assembly locations are limited for interactive effects under credible and abnormal conditions to maintain subcriticality for the system with an approved margin of safety given the loss of the other leg of double contingency. Moderation is controlled such that the workstations under credible and abnormal conditions remain subcritical with an approved margin of safety given the loss of the other leg of double contingency.

6. As stated in Section 5.1 of the validation report, four benchmark experiments were selected from published data. These benchmark experiments were previously published in pier reviewed journals and also used in NUREG/CR-6361. The studies in NUREG/CR-6361 were specific to validation applications involving fuel assemblies. Two of the four benchmarks have been reviewed and incorporated into the ICSBEP-Handbook. Additional details of the experiments were provided with incorporation into the Handbook. However, these have had a negligible effect of the results of the validation. For instance, chemical analysis of fuel rods had provided a more exacting enrichment. However, this enrichment difference has a negligible effect on the system k_{eff}. The remaining two benchmark experiments are scheduled to be incorporated into the Handbook.

   The pier reviewed journals were used to construct models of the benchmark experiments. The results of these studies were incorporated into documented FANP "Validation Reports" as noted in the submitted validation report for single fuel assemblies. Each report was independently reviewed. The original journal author's were consulted for cases where discrepancies were noted or additional information was needed (experimental uncertainties).

17 of the benchmark experiments described in Table A-2 have been incorporated into the Handbook as LEU-COMP-THERM-002 and 009. Footnote b) merely states that the source of the experimental uncertainties is not listed in the referenced Handbook experiment. Footnote c) states that the experimental uncertainties were based on the calculation uncertainties in parameters and assumptions in the benchmark models of the original reference and not the handbook.

The benchmark experiments described in Table A-6 have not been incorporated into the Handbook. These experiments contain Gadolinia and were not included in the bias and uncertainty determination as stated in the validation report. These experiments have been identified for incorporation into the Handbook.

28 of the benchmark experiments described in Table A-8 have been incorporated into the Handbook as LEU-COMP-THERM-011 and 051. The experimental uncertainties originally listed in Table A-8 are consistent with the uncertainties reported in above Handbook experiments.

The benchmark experiments described in Table A-12 have not been incorporated into the Handbook, but 8 appear in NUREG/CR-6361. However, the rods used in the experiments are the same rods as used in experiment listed in Table A-8. These experiments have been identified for incorporation into the Handbook. The experimental uncertainties listed in Table A-12 are consistent with the uncertainties reported in Table A-8, from which the majority of experiments have been incorporated into the Handbook.

The benchmark experiments described in Table A-14 have not been incorporated into the Handbook, but 8 appear in NUREG/CR-6361. However, the rods used in these experiments are the same rods as used in LEU-COMP-THERM-007, 034, 037, 038, 039, 040, and 050. The experiments listed in Table A-14 have been identified for incorporation into the Handbook. The experimental uncertainties listed in Table A-14 are consistent with the uncertainties reported in the above identified experiments that have been incorporated into the Handbook.

The collection of experiments used (45 from the ICSBEP Handbook, and 16 from NUREG/CR-6361) in the validation report for single fuel assemblies were originally modeled based on pier reviewed journals. Written reports of the results of these validation studies were issued as internal FANP documents. Each of the internal FANP validation documents was independently reviewed. In addition, a majority of the selected experiments were incorporated into NUREG/CR-6361. The experiments used in NUREG/CR-6361 were determined to be sufficiently pier reviewed and determined to be acceptable for use as benchmarks. Two of the pier reviewed journals used in this validation have been subsequently incorporated into the Handbook as four different benchmarks. The remaining two pier reviewed journals used in this validation have been identified for incorporation into the Handbook. These benchmarks are similar to other benchmarks, performed by the same author's, that are currently published in the

Handbook. Therefore, the experiments used in this validation have an established history of selection as benchmark experiments.

Additional information is provided in the response to Questions 9 and 10.

Tables 3 and 4 provide listings of benchmark cases used in bias and trending calculations in the submitted validation report, that are documented in either the current revision to the ICSBEP Handbook (45 total) or NUREG/CR-6361 (16 total), respectively. Note that some benchmark cases listed may appear in both references.

Table 3 Listing of MAR validation report benchmark cases that are also listed in the ICSBEP Handbook.

MAR Validation Report Case ID	ICSBEP Handook Case ID
c001x	LEU-COMP-THERM-002 case 1
c002x	LEU-COMP-THERM-002 case 3
c003x	LEU-COMP-THERM-002 case 2
c004	LEU-COMP-THERM-002 case 4
c007a	LEU-COMP-THERM-009 case 4
c008b	LEU-COMP-THERM-009 case 3
c009b	LEU-COMP-THERM-009 case 6
c010b	LEU-COMP-THERM-009 case 5
c011b	LEU-COMP-THERM-009 case 8
c012b	LEU-COMP-THERM-009 case 7
c014b	LEU-COMP-THERM-009 case 1
c013b	LEU-COMP-THERM-009 case 2
c031b	LEU-COMP-THERM-009 case 9
c005b	LEU-COMP-THERM-009 case 24
c006b	LEU-COMP-THERM-009 case 25
c029b	LEU-COMP-THERM-002 case 26
c030b	LEU-COMP-THERM-002 case 27

aclp1	LEU-COMP-THERM-011 case 1
aclp2	LEU-COMP-THERM-011 case 2
aclp3	LEU-COMP-THERM-011 case 4
aclp4	LEU-COMP-THERM-011 case 10
aclp5	LEU-COMP-THERM-011 case 11
aclp6	LEU-COMP-THERM-011 case 12
aclp7	LEU-COMP-THERM-011 case 13
aclp8	LEU-COMP-THERM-011 case 14
aclp9	LEU-COMP-THERM-011 case 15
aclp10	LEU-COMP-THERM-051 case 1
aclp11a	LEU-COMP-THERM-051 case 2
aclp11b	LEU-COMP-THERM-051 case 3
aclp11c	LEU-COMP-THERM-051 case 4
aclp11d	LEU-COMP-THERM-051 case 5
aclp11e	LEU-COMP-THERM-051 case 6
aclp11f	LEU-COMP-THERM-051 case 7
aclp11g	LEU-COMP-THERM-051 case 8
aclp12	LEU-COMP-THERM-051 case 9
aclp13	LEU-COMP-THERM-051 case 10
aclp13a	LEU-COMP-THERM-051 case 11
aclp14	LEU-COMP-THERM-051 case 12
aclp15	LEU-COMP-THERM-051 case 13
aclp16	LEU-COMP-THERM-051 case 14
aclp17	LEU-COMP-THERM-051 case 15
aclp18	LEU-COMP-THERM-051 case 16

aclp19	LEU-COMP-THERM-051 case 17
aclp20	LEU-COMP-THERM-051 case 18
aclp21	LEU-COMP-THERM-051 case 19

Table 4 Listing of MAR validation report benchmark cases that are also listed in NUREG/CR-6361.

MAR Validation Report Case ID	NUREG/CR-6361 Case ID
mdis02	ANS33-AL1
mdis04	ANS33-STG
mdis05	ANS33-EP1
mdis06	ANS33-EB1
mdis08	ANS33-AL2
mdis11	ANS33-EP2
mdis12	ANS33-EB2
mdis14	ANS33-AL3
rcon01	BW1645T2
rcon06	BW1645T1
rcon07	BW1645T3
rcon09	BW1645S2
rcon15	BW1645S1
rcon16	BW1645O2
rcon21	BW1645O1
rcon28	BW1645T4

7. The discrete enrichments were specifically identified in revised Figures 6-3 and 6-4. In the revised Figure 6-3, considering only the 4.75 and 4.31 wt% enrichment benchmark experiments still provides adequate coverage for the parameter EALF [eV] for the design application involving a single fuel assembly which ranges from 0.19 to 0.25 eV. The validated AOA for EALF [eV] considering only the higher enrichment data ranges from 0.11 to 0.28 which provide sufficient coverage for the application. Excluding the lower enrichment data also reduces the bias from 0.0055 to 0.0052. Including the lower enrichment data leads to conservative results. Therefore, the proposed USL-1 curve for the AOA for EALF [eV] as indicated in Figure 6-3 is appropriate and conservative. Also, using USLSTATS to trend only the higher enrichment data produces a USL-1 result that is consistent with the result using all data. A minimum USL-1 value of 0.965 is indicated in Figure 6-3 of the validation report while the revised calculation (attached below) indicates a USL-1 value of 0.9648 for an EALF value of 0.21 eV.

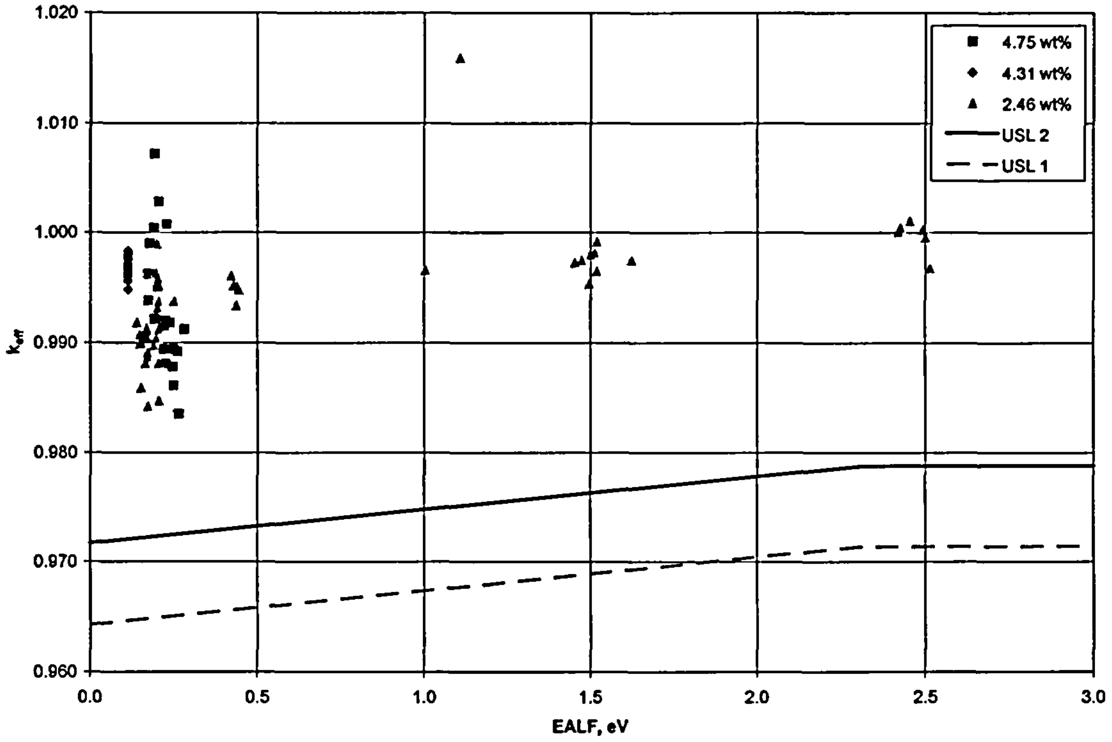
   In the revised Figure 6-4, considering only the 4.75 and 4.31 wt% enrichment benchmark experiments still provides adequate coverage for the parameter H/^{235}U atomic ratio for the design application involving a single fuel assembly which ranges from 156 to 178. The validated AOA for the $\mathrm{H}/^{235}\mathrm{U}$ atomic ratio considering only the higher enrichment data ranges from 137 to 255 which provide sufficient coverage for the application. Excluding the lower enrichment data also reduces the bias from 0.0055 to 0.0052. Therefore, including the lower enrichment data leads to conservative results. Therefore, the proposed USL-1 curve for the $\mathrm{H}/^{235}\mathrm{U}$ atomic ratio as indicated in Figure 6-4 is appropriate and conservative. Also, using USLSTATS to trend only the data bounding the single assembly application (156 – 178) produces a USL-1 result that is consistent with the result using all data. A minimum USL-1 value of 0.967 is indicated in Figure 6-4 of the validation report while the revised calculation (attached below) indicates a USL-1 value of 0.9643 for an $\mathrm{H}/^{235}\mathrm{U}$ ratio of 171.

Table 5 summarizes the comparison between calculated USL-1 values for when all data is used and when a reduced data set is used.

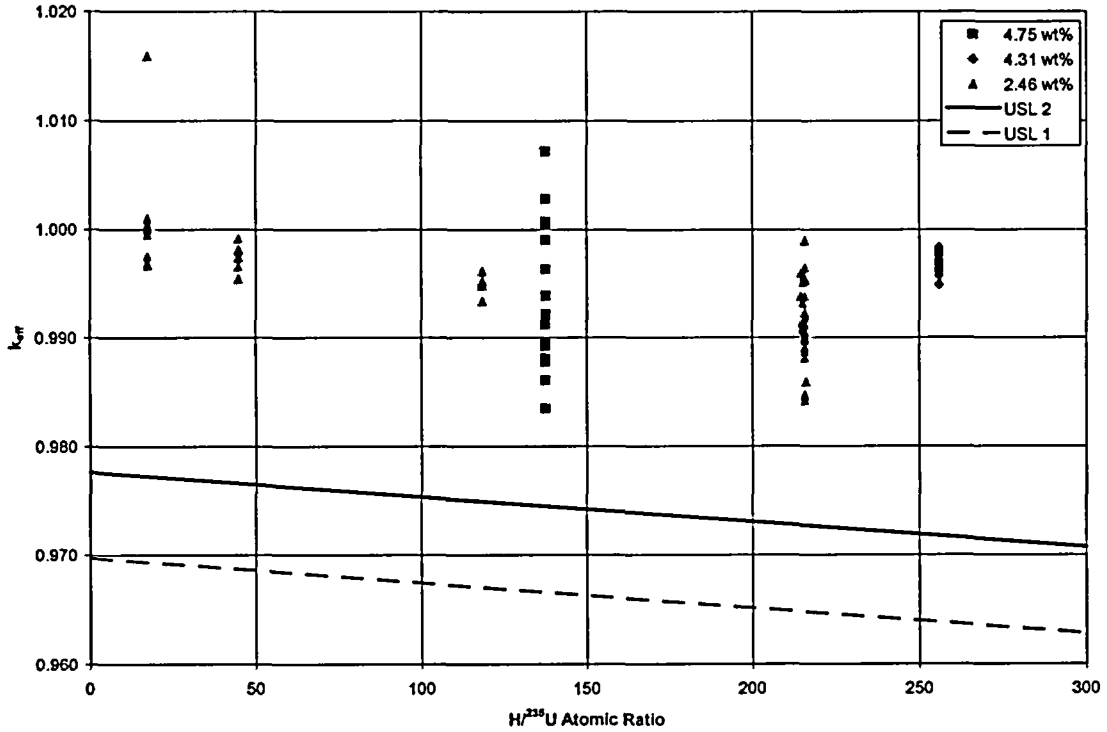
Table 5 Comparison of USL-1 values for all data used and for reduced data sets.

Trending parameter	USL-1 for All Data Used	USL-1 for Reduced Data Set	*Note that reduced data set corresponds to:* *1) For the EALF trending parameter, removing low-enriched (2.46wt%)* *2) For the $\mathrm{H}/^{235}\mathrm{U}$ trending parameter, retaining low enriched (2.46wt%) only for the higher $\mathrm{H}/^{235}\mathrm{U}$ value (~ 215)*
EALF (eV) (see Revised Figure 6-3)	0.965	0.9648	
$\mathrm{H}/^{235}\mathrm{U}$ (see Revised Figure 6-4)	0.967	0.9643	

Therefore, trends in the bias have been adequately evaluated for all discrete subsets of benchmark experiments analyzed in the validation report and the results do not invalidated the USL-1 value proposed for the single fuel assembly application.



Revised Figure 6-3



Revised Figure 6-4

Revised EALF with k_{eff} – Higher Enrichment Data

```
               uslstats: a utility to calculate upper subcritical
                     limits for criticality safety applications

 ********************************************************************************
                     Version 1.3.7, May 18, 1999
                      Oak Ridge National Laboratory
 ********************************************************************************


   Input to statistical treatment from file:ealf2.in

 Title: EALF with keff for heterogeneous benchmarks

   Proportion of the population = .999
   Confidence of fit           = .950
   Confidence on proportion    = .950
   Number of observations      =  33
   Minimum value of closed band =   0.00
   Maximum value of closed band =   0.00
   Administrative margin       =   0.02


   independent    dependent     deviation           independent    dependent
 deviation
   variable - x   variable - y    in y           variable - x   variable - y    in y

    1.12700E-01    9.97100E-01    2.20000E-03         1.90600E-01    1.00040E+00
 1.70000E-03
    1.12700E-01    9.96600E-01    2.20000E-03         1.94000E-01    1.00720E+00
 1.60000E-03
    1.12800E-01    9.95600E-01    2.30000E-03         1.94600E-01    9.92100E-01
 1.70000E-03
    1.12800E-01    9.96000E-01    2.10000E-03         2.05300E-01    1.00280E+00
 1.60000E-03
    1.12900E-01    9.97700E-01    2.30000E-03         2.20400E-01    9.89400E-01
 1.60000E-03
    1.12900E-01    9.96700E-01    2.20000E-03         2.22600E-01    9.91500E-01
 1.70000E-03
    1.12900E-01    9.96000E-01    2.00000E-03         2.25400E-01    9.92000E-01
 1.60000E-03
    1.13500E-01    9.98300E-01    2.30000E-03         2.27100E-01    9.88100E-01
 1.70000E-03
    1.13500E-01    9.94800E-01    2.30000E-03         2.29300E-01    1.00070E+00
 1.60000E-03
    1.13700E-01    9.96300E-01    2.20000E-03         2.40800E-01    9.91800E-01
 1.70000E-03
    1.13800E-01    9.97000E-01    2.30000E-03         2.47900E-01    9.87800E-01
 1.70000E-03
```

```
   1.14500E-01   9.97500E-01   2.20000E-03          2.50400E-01   9.86100E-01
1.70000E-03
   1.14500E-01   9.98000E-01   2.20000E-03          2.51200E-01   9.89400E-01
1.70000E-03
   1.14500E-01   9.97500E-01   2.20000E-03          2.62100E-01   9.89200E-01
1.70000E-03
   1.73900E-01   9.93800E-01   1.60000E-03          2.64800E-01   9.83500E-01
1.70000E-03
   1.74900E-01   9.96200E-01   1.70000E-03          2.82800E-01   9.91200E-01
1.70000E-03
   1.79100E-01   9.99000E-01   1.60000E-03

  chi =  4.1212 (upper bound = 9.49). The data tests normal.


     Output from statistical treatment

  EALF with keff for heterogeneous benchmarks

   Number of data points (n)                  33
   Linear regression, k(X)                 1.0030 + (-4.6764E-02)*X
   Confidence on fit (1-gamma) [input]         95.0%
   Confidence on proportion (alpha) [input]     95.0%
   Proportion of population falling above
   lower tolerance interval (rho) [input]     99.9%
   Minimum value of X                        0.1127
   Maximum value of X                         0.2828
   Average value of X                        0.17651
   Average value of k                       0.99477
   Minimum value of k                        0.98350
   Variance of fit, s(k,X)^2                1.7877E-05
   Within variance, s(w)^2                   3.6770E-06
   Pooled variance, s(p)^2                   2.1554E-05
   Pooled std. deviation, s(p)               4.6426E-03
   C(alpha,rho)*s(p)                       2.2534E-02
   student-t @ (n-2,1-gamma)                  1.69570E+00
   Confidence band width, W                  8.3604E-03
   Minimum margin of subcriticality, C*s(p)-W       1.4174E-02

   Upper subcritical limits: ( 0.11270    <= X <=  0.28280    )
   ***** *********** *******

   USL Method 1 (Confidence Band with
   Administrative Margin)          USL1 = 0.9747 + (-4.6764E-02)*X

   USL Method 2 (Single-Sided Uniform
   Width Closed Interval Approach)   USL2 = 0.9805 + (-4.6764E-02)*X
```

```
  USLs Evaluated Over Range of Parameter X:
  **** ********* **** ***** ** ********* **

  X: 1.13E-1  1.37E-1  1.61E-1  1.86E-1  2.10E-1  2.34E-1  2.59E-1  2.83E-1
     ------------------------------------------------------------------
USL-1:  0.9694  0.9683  0.9671  0.9660  0.9648  0.9637  0.9625  0.9614
USL-2:  0.9752  0.9741  0.9730  0.9718  0.9707  0.9695  0.9684  0.9673
     ------------------------------------------------------------------

 ***************************************************************************
                    Thus spake USLSTATS
                         Finis.
```

Revised H/^{235}U with k_{eff} - Data Bounding the Assembly Application Area

```
          uslstats: a utility to calculate upper subcritical
                 limits for criticality safety applications

 ***************************************************************************
                  Version 1.3.7, May 18, 1999
                   Oak Ridge National Laboratory
 ***************************************************************************


  Input to statistical treatment from file:h235u.in

Title: HTO235U with keff for heterogeneous benchmarks

  Proportion of the population = .999
  Confidence of fit           = .950
  Confidence on proportion     = .950
  Number of observations       =  61
  Minimum value of closed band =   0.00
  Maximum value of closed band =   0.00
  Administrative margin        =   0.02


  independent    dependent     deviation           independent    dependent
deviation
  variable - x   variable - y     in y            variable - x   variable - y      in y

   1.37600E+02    9.91200E-01    1.70000E-03         2.15830E+02    9.98900E-01
1.20000E-03
   1.37600E+02    9.89200E-01    1.70000E-03         2.15830E+02    9.84700E-01
1.70000E-03
   1.37600E+02    9.83500E-01    1.70000E-03         2.15830E+02    9.88700E-01
1.30000E-03
   1.37600E+02    9.89400E-01    1.70000E-03         2.15870E+02    9.88100E-01
1.10000E-03
```

```
   1.37600E+02   9.91800E-01   1.70000E-03       2.15870E+02   9.90500E-01
1.40000E-03
   1.37600E+02   1.00070E+00   1.60000E-03       2.15870E+02   9.89900E-01
1.10000E-03
   1.37600E+02   9.92000E-01   1.60000E-03       2.15870E+02   9.90000E-01
1.30000E-03
   1.37600E+02   9.86100E-01   1.70000E-03       2.15870E+02   9.91800E-01
1.10000E-03
   1.37600E+02   9.87800E-01   1.70000E-03       2.15890E+02   9.84200E-01
2.00000E-03
   1.37600E+02   9.91500E-01   1.70000E-03       2.15890E+02   9.88100E-01
1.20000E-03
   1.37600E+02   1.00280E+00   1.60000E-03       2.15890E+02   9.91200E-01
1.20000E-03
   1.37600E+02   1.00720E+00   1.60000E-03       2.15890E+02   9.89100E-01
1.30000E-03
   1.37600E+02   9.92100E-01   1.70000E-03       2.15910E+02   9.89700E-01
9.00000E-04
   1.37600E+02   9.89400E-01   1.60000E-03       2.15910E+02   9.90400E-01
1.30000E-03
   1.37600E+02   9.88100E-01   1.70000E-03       2.15970E+02   9.95200E-01
9.00000E-04
   1.37600E+02   1.00040E+00   1.70000E-03       2.16190E+02   9.85900E-01
1.70000E-03
   1.37600E+02   9.99000E-01   1.60000E-03       2.55920E+02   9.97100E-01
2.20000E-03
   1.37600E+02   9.96200E-01   1.70000E-03       2.55920E+02   9.96000E-01
2.00000E-03
   1.37600E+02   9.93800E-01   1.60000E-03       2.55920E+02   9.96000E-01
2.10000E-03
   2.14520E+02   9.93700E-01   1.00000E-03       2.55920E+02   9.96600E-01
2.20000E-03
   2.14700E+02   9.95800E-01   8.00000E-04       2.55920E+02   9.94800E-01
2.30000E-03
   2.15050E+02   9.91300E-01   9.00000E-04       2.55920E+02   9.96300E-01
2.20000E-03
   2.15140E+02   9.93100E-01   8.00000E-04       2.55920E+02   9.98000E-01
2.20000E-03
   2.15220E+02   9.90700E-01   1.10000E-03       2.55920E+02   9.98300E-01
2.30000E-03
   2.15320E+02   9.95000E-01   9.00000E-04       2.55920E+02   9.97500E-01
2.20000E-03
   2.15320E+02   9.95000E-01   8.00000E-04       2.55920E+02   9.95600E-01
2.30000E-03
   2.15570E+02   9.91100E-01   9.00000E-04       2.55920E+02   9.97000E-01
2.30000E-03
   2.15670E+02   9.92200E-01   1.30000E-03       2.55920E+02   9.96700E-01
2.20000E-03
   2.15730E+02   9.95400E-01   9.00000E-04       2.55920E+02   9.97700E-01
2.30000E-03
```

```
  2.15790E+02   9.93700E-01   8.00000E-04          2.55920E+02   9.97500E-01
2.20000E-03
  2.15830E+02   9.96300E-01   8.00000E-04

 chi =  5.6393 (upper bound = 9.49). The data tests normal.


    Output from statistical treatment

 HTO235U with keff for heterogeneous benchmarks

  Number of data points (n)                 61
  Linear regression, k(X)                 0.9901 + ( 1.5472E-05)*X
  Confidence on fit (1-gamma) [input]           95.0%
  Confidence on proportion (alpha) [input]        95.0%
  Proportion of population falling above
  lower tolerance interval (rho) [input]       99.9%
  Minimum value of X                       137.6000
  Maximum value of X                        255.9200
  Average value of X                      200.58230
  Average value of k                      0.99323
  Minimum value of k                       0.98350
  Variance of fit, s(k,X)^2               2.1844E-05
  Within variance, s(w)^2                  2.6189E-06
  Pooled variance, s(p)^2                  2.4463E-05
  Pooled std. deviation, s(p)              4.9460E-03
  C(alpha,rho)*s(p)                     2.1007E-02
  student-t @ (n-2,1-gamma)                    1.67165E+00
  Confidence band width, W                     8.4651E-03
  Minimum margin of subcriticality, C*s(p)-W       1.2542E-02

  Upper subcritical limits: (  137.60      <= X <=    255.92    )
  ***** *********** *******

  USL Method 1 (Confidence Band with
  Administrative Margin)           USL1 = 0.9617 + ( 1.5472E-05)*X

  USL Method 2 (Single-Sided Uniform
  Width Closed Interval Approach)   USL2 = 0.9691 + ( 1.5472E-05)*X


  USLs Evaluated Over Range of Parameter X:
  **** ********* **** ***** ** ********* **

  X:  1.38E+2  1.55E+2  1.71E+2  1.88E+2  2.05E+2  2.22E+2  2.39E+2  2.56E+2
     ---------------------------------------------------------------
USL-1:   0.9638   0.9641   0.9643   0.9646   0.9648   0.9651   0.9654   0.9656
USL-2:   0.9713   0.9715   0.9718   0.9720   0.9723   0.9726   0.9728   0.9731
     ---------------------------------------------------------------
```

```
******************************************************************************
            Thus spake USLSTATS
                Finis.
```

8. Five benchmark experiments containing poison plates in Table A-2 are applicable to models of undamaged fuel assemblies without poison materials. These five experiments consist of assemblies with external absorber plates containing boron positioned between assemblies. These experiments are highly thermalized as indicated by EALF values at the lower end of the validated AOA of 0.11 eV. The H/^{235}U ratios for these experiments are at the upper end of the validated AOA of 255.9. LEU-COMP-THERM-009 indicates that for the non-boron/non-cadmium plates, the sensitivity in k_{eff} is less than 0.85%Δk. For the boron and cadmium bearing plates, the sensitivity is less than 2.5% Δk, indicating that the absorption present in these cases is not strong, which means that they are suitable for single assemblies without neutron absorbing materials.

   Removing these experiments from Table A-2 decreases the bias in this experimental data from 0.0017 to 0.0014. Including the poison plate data in the bias determination is conservative; however, the Δk_{eff} difference of 0.0003 is negligible.

9. A review of the ICSBEP data, refer to attached table after Question 10, suggests that at most 18 additional experiments are directly applicable to single fuel assemblies, denoted with the ** symbol. Four additional experiments in LEU-COMP-THERM-002 could be added however based on the published results these values will cluster near the existing modeled experiments of 4.31 wt%. Three additional experiments in LEU-COMP-THERM-007 could be added however based on the published results these values will cluster near the existing modeled experiments of 4.738 wt%. Approximately eleven additional experiments in LEU-COMP-THERM-037 could be added. The results closely match cases already modeled at enrichments of 4.738 wt% however these cases will fill in data between the already modeled 4.31 and 4.738 wt% cases. These newer cases do not appear to affect the distribution since they calculate close to unity. Therefore, a total of 18 experiments could be added that are directly applicable to single fuel assemblies, however, based on the reported results the cases do not appear to affect the bias or uncertainty in a non-conservative fashion.

   Several other experiments are considered to be applicable, denoted with the ‡‡ symbol, but their enrichments are lower than needed and/or the lattice geometry (hexagonal) is different from that used in MAR. Therefore, while these cases are similar they are not directly applicable to the single fuel assembly configurations used at MAR.

   Several other experiments are not applicable, denoted with the ▲ symbol, since their enrichments out of the desired range or not close to 5.0 wt% to warrant use and/or the experiments use various strong neutron absorbers.

The chosen experiments used in the MAR validation for a single fuel assembly application were considered to be acceptable and that additional data, as indicated in a review of the ICSBEP, would not change the bias or uncertainty in a non-conservative fashion to warrant incorporation. The difference between the highest benchmark enrichment modeled (4.74 wt%) and the bounding enrichment for the application (5.1 wt%) of 0.36 wt% is well within the allowed extrapolation value for enrichment in NUREG/CR-6698 (1.5 wt%). Also, based on experiments near 7.5 and 10.0 wt%, previously QA'd by FANP, the bias with enrichment does not appear to be significant. Therefore, FANP believed that the cases used in the validation report for a single fuel assembly application were adequate and that the additional data as noted would not alter the results leading to a higher negative bias for the trended parameters including enrichment, EALF and $H/^{235}U$ atomic ratio.

10. The MAR validation covers the application of a single fuel assembly. Other licensees and DOE validations reviewed by FANP cover entire processes and/or homogeneous and heterogeneous systems separately. Therefore, FANP believes that the noted differences are due to the limited scope of the MAR validation. Additional information is provided in the response to Question 9.

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
‡‡ LEU-COMP-THERM-001	Water-Moderated U(2.35)O2 Fuel Rods in 2.032-cm Square-Pitched Arrays		Applicable – But enrichment is outside of desired near 5.0 wt%
** LEU-COMP-THERM-002	Water-Moderated U(4.31)O2 Fuel Rods in 2.54-cm Square-Pitched Arrays	5	Applicable – One experiment used in this benchmark appears in Table A-2 of the MAR validation. Four experiments can be added but the distribution will be similar to the 14 cases in Table A-2
▲ LEU-COMP-THERM-003	Water-Moderated U(2.35)O2 Fuel Rods in 1.684-cm Square-Pitched Arrays (Gadolinium Water Impurity)		Not Applicable – enrichment is outside of desired near 5.0 wt% and experiments further contain Gd
▲ LEU-COMP-THERM-004	Water-Moderated U(4.31)O2 Fuel Rods in 1.892-cm Square-Pitched Arrays (Gadolinium Water Impurity)		Not Applicable – experiments contain Gd
▲ LEU-COMP-THERM-005	Critical Experiments with Low-Enriched Uranium Dioxide Fuel Rods in Water Containing Dissolved Gadolinium		Not Applicable – experiments contain Gd
‡‡ LEU-COMP-THERM-006	Critical Arrays of Low Enriched UO2 Fuel Rods with Water-to-Fuel Volume Ratios Ranging from 1.5 to 3.0	18	Applicable – But enrichment is outside of desired near 5.0 wt%

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
**, ‡‡ LEU-COMP-THERM-007	Water Reflected 4.738 Wt.% Enriched Uranium Dioxide Fuel Rod Arrays	10	Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Six experiments consist of hexagonal lattices. Three experiments can be added but the distribution will be similar to the cases in Table A-12
▲ LEU-COMP-THERM-008	Critical Lattice of UO2 Fuel Rods and Perturbing Rods in Borated Water	17	Not Applicable – enrichment is outside of desired near 5.0 wt% and experiments further contain Gd
‡‡ LEU-COMP-THERM-009	Water-Moderated Rectangular Clusters of U(4.31)O2 Fuel Rods (2.54-cm Pitch) Separated by Steel, Boral, Copper, Cadmium, Aluminum, or Zircalloy-4 Plates	27	Applicable – But more representative of an array of slightly interacting assemblies. Experiments used in this benchmark appear in Table A-2 of the MAR validation
‡‡ LEU-COMP-THERM-010	Critical Arrays of Water-Moderated U(4.31)O2 Fuel Rods Reflected by Two Lead, Uranium, or Steel Walls	30	Applicable – But more representative of an array of slightly interacting assemblies
‡‡ LEU-COMP-THERM-011	Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel, Part I - Absorber Rods	15	Applicable – But enrichment is outside of desired near 5.0 wt%
‡‡ LEU-COMP-THERM-012	Water-Moderated Rectangular Clusters of U(2.35)O2 Fuel Rods (1.684-cm Pitch) Separated by Steel, Boral, Boroflex, Cadmium, or Copper Plates (Gadolinium Water Impurity)		Applicable – But more representative of an array of slightly interacting assemblies. Enrichment is outside of desired near 5.0 wt%

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
‡‡ LEU-COMP-THERM-013	Water-moderated Rectangular Clusters of U(4.31)O2 Fuel Rods (1.892-cm pitch) Separated by Steel, Boral, Boroflex, Cadmium, or Copper Plates, with Steel Reflecting Walls		Applicable – But more representative of an array of slightly interacting assemblies
▲ LEU-COMP-THERM-014	Water-Reflected Arrays of U(4.31)O2 Fuel Rods (1.890-cm and 1.715-cm Square Pitch) in Borated Water		Not Applicable – experiments contain Boron
‡‡ LEU-COMP-THERM-015	The VVER Experiments: Regular and Perturbed Hexagonal Lattices of Low- Enriched UO2 Fuel Rods in Light Water	165	Applicable – Only 11 of the 4.4wt% experiments are desirable but lattices are hexagonal
▲ LEU-COMP-THERM-016	Water-Moderated Rectangular Clusters of U(2.35) O2 Fuel Rods (2.032-cm Pitch) Separated by Steel, Boral, Copper, Cadmium, Aluminum, or Zircaloy-4 Plates		Not Applicable –more representative of an array of slightly interacting assemblies. Enrichment is outside of desired near 5.0 wt%
▲ LEU-COMP-THERM-017	Critical Arrays of Water-Moderated U(2.35)O2 Fuel Rods Reflected by Two Lead, Uranium, or Steel Walls		Not Applicable –more representative of an array of slightly interacting assemblies. Enrichment is outside of desired near 5.0 wt%
▲ LEU-COMP-THERM-018	Light Water Moderated and Reflected Low Enriched Uranium Dioxide (7 wt.%) Rod Lattice		Not Applicable – enrichment is above desired near 5.0 wt%
‡‡ LEU-COMP-THERM-019	Water-Moderated Hexagonally Pitched Lattices of U(5%)O2 Stainless Steel Clad Fuel Rods	3	Applicable – But lattices are hexagonal

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
‡‡ LEU-COMP-THERM-020	Water-Moderated Hexagonally Pitched Partially Flooded Lattices of U(5%)O2 Zirconium Clad Fuel Rods	7	Applicable – But lattices are hexagonal
▲ LEU-COMP-THERM-021	Hexagonally Pitched Partially Flooded Lattices of U(5%)O2 Zirconium Clad Fuel Rods Moderated by Water with Boric Acid	6	Not Applicable –lattices are hexagonal and contain Boron
▲ LEU-COMP-THERM-022	Uniform Water-Moderated Hexagonally Pitched Lattices of Rods with U(10%)O2 Fuel		Not Applicable – enrichment is above desired near 5.0 wt%. Values for these experiment appear in Appendix B of the MAR validation report
▲ LEU-COMP-THERM-023	Partially Flooded Uniform Lattices of Rods with U(10%)O2 Fuel		Not Applicable – enrichment is above desired near 5.0 wt%. Values for these experiment appear in Appendix B of the MAR validation report
▲ LEU-COMP-THERM-024	Water-Moderated Square-Pitched Uniform Lattices of Rods with U(10%)O2 Fuel		Not Applicable – enrichment is above desired near 5.0 wt%. Values for these experiment appear in Appendix B of the MAR validation report
▲ LEU-COMP-THERM-025	Water-Moderated Hexagonally Pitched Lattices of U(7.5%)O2 Stainless-Steel- Clad Fuel Rods		Not Applicable – enrichment is above desired near 5.0 wt%. Values for these experiment appear in Appendix B of the MAR validation report
‡‡ LEU-COMP-THERM-026	Water-Moderated U(4.92)O2 Fuel Rods in 1.29, 1.09, and 1.01 cm Pitch Hexagonal Lattices at Different Temperatures	6	Applicable – But lattices are hexagonal

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
▲ LEU-COMP-THERM-027	Water Moderated and Lead Reflected 4.75% Enriched Uranium Dioxide Rod Arrays	4	Not Applicable –more representative of an array of slightly interacting assemblies separated with Pb
LEU-COMP-THERM-028	In progress		
▲ LEU-COMP-THERM-029	Water Moderated and Reflected 4.75% Enriched Uranium Dioxide Rod Arrays Surrounded by Hafnium Plates		Not Applicable –lattices contain Hafnium
LEU-COMP-THERM-030	In progress		
‡‡ LEU-COMP-THERM-031	Water-Moderated Hexagonally Pitched Partially Flooded Lattices of U(5%)O2 Zirconium-Clad Fuel Rods	6	Applicable – But lattices are hexagonal
▲ LEU-COMP-THERM-032	Uniform Water-Moderated Lattices of Rods With U(10%)O2 Fuel in Range from 20 Degrees to 274 Degrees C		Not Applicable – enrichment is above desired near 5.0 wt%
▲ LEU-COMP-THERM-033	Reflected and Unreflected Assemblies of 2 and 3%-Enriched Uranium Fluoride in Paraffin		Not applicable – Experiment is a homogeneous configuration
▲ LEU-COMP-THERM-034	Four 4.738% Enriched Uranium Dioxide Rod Assemblies Contained in Cadmium, Borated Stainless Steel or Boral Square Canisters, Water Moderated and Reflected		Not Applicable –more representative of an array of slightly interacting assemblies separated by absorbers
▲ LEU-COMP-THERM-035	Critical Arrays of Low-Enriched UO2 Fuel Rods in Water with Soluble Poison of Gadolinium or Boron Poison		Not Applicable – experiments contain Gd and Boron. Enrichment is outside of desired near 5.0 wt%

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
▲ LEU-COMP-THERM-036	The VVER Experiments: Regular and Perturbed Hexagonal Lattices of Low- Enriched UO2 Fuel Rods in Light Water - Part 2	69	Not Applicable –lattices are hexagonal. Enrichment is outside of desired near 5.0 wt%
** LEU-COMP-THERM-037	Water-Moderated and Partially Concrete-Reflected 4.738-wt.%-Enriched Uranium Dioxide Rod Arrays	11	Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments are noted as rerun experiments in the Handbook report. The non-duplicated data can be added. Cases are similar to LEU-COMP-THERM-039
▲ LEU-COMP-THERM-038	Water-Moderated 4.738-wt.%-Enriched Uranium Dioxide Rod Arrays Next to a Borated Concrete Screen		Not Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments contain Boron
** LEU-COMP-THERM-039	Incomplete Arrays of Water Reflected 4.738 Wt.% Enriched Uranium Dioxide Fuel Rods	17	Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments involve missing rod lattices. Cases are similar to LEU-COMP-THERM-037
▲ LEU-COMP-THERM-040	Four 4.738% Enriched Uranium Dioxide Rod Assemblies Contained in Borated Stainless Steel or Boral Square Canisters, Water Moderated and Reflected by Lead or Steel		Not Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments contain various absorbers

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
‡‡ LEU-COMP-THERM-041	Storage Arrays of 3%-Enriched LWR Assemblies: The CRISTO II Experments in the EOLE Reactor		Applicable – But enrichment is outside of desired near 5.0 wt%
‡‡ LEU-COMP-THERM-042	Water-Moderated Rectangular Clusters Of U(2.35)O2 Fuel Rods (1.684-Cm Pitch) Separated By Steel, Boral, Boroflex, Cadmium, Or Copper Plates With Steel Reflecting Walls		Applicable – But enrichment is outside of desired near 5.0 wt%
LEU-COMP-THERM-043	In progress		
LEU-COMP-THERM-044	In progress		
LEU-COMP-THERM-045	In progress		
LEU-COMP-THERM-046	In progress		
▲ LEU-COMP-THERM-047	Fuel Transport Flask Critical Benchmark Experiments with Low-Enriched Uranium Dioxide Fuel		Not Applicable – enrichment is outside of desired near 5.0 wt% and in some cases above 5.0 wt%
‡‡ LEU-COMP-THERM-048	Light Water Moderated and Reflected Low Enriched Uranium (3 wt.% 235U) Dioxide Rod Lattices		Applicable – But enrichment is outside of desired near 5.0 wt%
▲ LEU-COMP-THERM-049	Maracas Program: Polythene Reflected Critical Configurations with Low Enriched and Low Moderated Uranium Dioxide Powder U(5)O2		Not applicable – Experiment is a homogeneous configuration
▲ LEU-COMP-THERM-050	^{149}Sm Solution Tank in the Middle of Water-Moderated 4.738-Wt.%-Enriched Uranium Dioxide Rod Arrays		Not Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments contain Samarium

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
▲ LEU-COMP-THERM-051	Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel, Part II - Isolating Plates	15	Not Applicable – enrichment is outside of desired near 5.0 wt%. Experiments contain B_4C rods
▲ LEU-COMP-THERM-052	Uranium Dioxide (4.738-Wt.%-Enriched) Fuel Rod Arrays Moderated and Reflected by Gadolinium Nitrate Solution		Not Applicable – Experiments used in this benchmark are similar to those listed in Table A-13 in the MAR validation. Experiments contain Gd
LEU-COMP-THERM-053	In progress		
LEU-COMP-THERM-054	In progress		
‡‡ LEU-COMP-THERM-055	Light-Water Moderated and Reflected Low-Enriched Uranium (3 wt.% ^{235}U) Dioxide Rod Lattices	2	Applicable – But enrichment is outside of desired near 5.0 wt%
LEU-COMP-THERM-056	In progress		
LEU-COMP-THERM-057	In progress		
LEU-COMP-THERM-058	In progress		
LEU-COMP-THERM-059	In progress		
LEU-COMP-THERM-060	In progress		
▲ LEU-COMP-THERM-061	VVER Physics Experiments: Hexagonal (1.27-cm Pitch) Lattices of U(4.4 wt.% ^{235}U)O2 Fuel Rods in Light Water, Perturbed by Boron, Hafnium, or Dysprosium Absorber Rods, or by Water Gap with/without Empty Aluminum Tubes	10	Not Applicable – experiments contain absorbers

Benchmark Document	Experiment Descriptions	Total Number of Experiments	Applicability to Single Fuel Assemblies
‡‡ LEU-COMP-THERM-062	2.6%-Enriched UO2 Rods in Light-Water Moderator with Borated Stainless Steel Plate: Single Arrays		Applicable – But enrichment is outside of desired near 5.0 wt%
▲ SUB-LEU-COMP-THERM-001	Fuel Transport Flask Subcritical Benchmark Experiments with Low Enriched Uranium (3wt.% ^{235}U) Dioxide Fuel		Not Applicable –more representative of an array of slightly interacting assemblies. Enrichment is outside of desired near 5.0 wt%