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AHW/90/016/EDS

---VIA FEDERAL EXPRESS---

Mr. Charles E. MacDonald, Chief
Transportation Branch
NMSS:SGTB, Mail Stop WF4E4
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Dear Mr. MacDonald:

Nuclear Assurance Corporation (NAC) hereby requests an amendment to the NLI-1/2 cask Certificate of Compliance 9010, Revision 27, which currently permits shipment of up to 24 PWR fuel rods in the cask. The current license allows a burnup of up to 55,000 MWD/MTU with a maximum enrichment of 3.70 weight percent uranium-235. NAC has repeatedly received requests for shipments of rods with greater enrichment or higher burnup for the U.S. utilities; therefore, NAC has reviewed the capability of the cask to carry higher burnup fuel. The attached SAR change pages show the analyses necessary to justify shipment of up to 25 PWR rods with a maximum enrichment of 4.9 weight percent and a maximum burnup of 60,000 MWD/MTU. The higher burnup is permitted by using the borated neutron shield fluid configuration specified in the Certificate, paragraph 5.(b)(1)(i) on page 5, "**PWR fuel assembly may have a maximum average burnup of 56,000 MWD/MTU provided the minimum cooling time prior to shipment is 450 days and <u>the neutron shield fluid contains 1.0 weight percent boron</u>. (The borated fluid may be left in the shielding tanks during the shipment of other contents.)" The shipment of a high burnup assembly required the boron to suppress the secondary gammas caused when the higher neutron flux is stopped by the neutron shield. Thus, all future shipments of PWR rods under the amended PWR rod shipment provision will use the borated shield tank. A shielding calculation is provided in the enclosed change pages to the NLI-1/2 SAR.

The original design enrichment limit for the NLI-1/2 cask for a PWR assembly is 3.7 weight percent. This allows a conservative margin of criticality safety with a full assembly. NAC evaluated the most reactive pitch achievable by rods with 4.9 w/o uranium-235, and calculated the reactivity of square (5 by 5) and circular (homogenized) arrangements of the 25 rods. The attached change pages to the SAR show that the maximum reactivity of 25 rods in any geometry is less than 0.55, with all corrections for bias and uncertainties.

The currently approved analysis for up to 24 PWR rods used a conservative heat load of 1.65 kilowatts. NAC's calculation of the heat load for 25 rods with 60,000 MWD/MTU resulted in a heat load of 1.35 kilowatts. This lower heat source

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is caused by the irradiation cycle used in the source calculations, which for the new analysis is based on an actual operating PWR reactor instead of an idealized calculation. However, the higher heat source of 1.65 kilowatts is used in the revision for conservatism.

The final change requested is to permit the shipment of fuel rods with an active fuel length of 150 inches instead of the 144 inches currently permitted. NAC has shipped assemblies with 150-inch active lengths in the past under letter amendments granted for one time shipments, but we believe that a continuing need for the longer length exists. A planned shipment from Calvert Cliffs has one rod with an enrichment greater than 3.7 weight percent and all rods have an active fuel length greater than 144 inches, which caused us to prepare this amendment application. NAC has reviewed the shielding of the NLI-1/2 cask and has verified that the length of the lead and uranium gamma shield annuli are 160.44 and 167.9 inches respectively, and the length of the neutron shield fluid region is 163.75 inches. These shielding lengths are adequate to cover the 150-inch active fuel length requested, as demonstrated in the shipments made in the past.

A check for $150.00 is enclosed for this amendment in accordance with 10 CFR 170.31. Please contact me if you have any questions or require additional information.

Sincerely,

NUCLEAR ASSURANCE CORPORATION

Alan H Well

Alan H. Wells, PhD
Chief Engineer
Engineering Design Services

AHW/kkg

enclosures (2)

NLI-1/2 SPENT FUEL SHIPPING CASK DATA

Fuel Data	1-PWR Type Fuel Assembly	2-BWR Type Fuel Assemblies*	Consolidated PWR Fuel Rods	Metallic Fuel (Max. 21 Rods)	PWR Rods***	BWR Rods****
Envelopes, inches	8.60 sq x 171.5	5.44 sq x 176.25	8.75 sq x 171.5	1.36" diameter	25 rods	24 rods
Enrichment w/o U-235	3.7	2.65	3.7	Natural	4.9	2.65
Weight of Uranium	475 kg	197 kg	950 kg	1,145.5 kg 54.5 kg per rod	58.2 kg	40 kg
Max. Avg. Burnup (MWD/MTU)**	40,000	34,000	40,000	1,600	60,000	50,000
Avg. Specific Power	40 kW/kg U	27 kW/kg U	40 kW/kg U	-----	44 kW/kg U	27 kW/kg U
Cask weight, loaded Calculated	47,350	47,077 lbs.	49,250 lbs.	47,480 lbs	46,455 lbs.	-----

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Cask Data and Dimensions

Cask Design Weight	48,000 lbs	
Gross Vehicle Weight	73,280 lbs.	
Cask Assembly Envelope	72.25" in diameter 238.31" length	Normal Cavity Operating Pressure - 26 psig Maximum Cavity Operating Pressure - 117 psig (accident conditions)
Cask Body Envelope	40" in diameter 193" long	Neutron Shield Water Jacket - ethylene glycol, 52% volume, -42 degree F freezing point
Internal Cavity	13.375" in diameter 178" long	
Inner Container	12,625" in diameter 178" long	

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*With or without control rods or burnable poison rods or with additional irradiated fuel rods inserted and secured in the guide thimbles. Maximum initial uranium content shall be 495 kg and the maximum average initial U-235 enrichment shall be 3.35 w/o.

** PWR fuel assembly may have a maximum average burnup of 56,000 MWD/MTU, provided that the assembly meets the criteria established in Part 6 of Section III and the neutron shield fluid contains 1.0 w/o boron. (The boron fluid may be left in the shielding tanks during the shipment of other contents.)

*** Up to 25 PWR rods may be shipped provided that the maximum average burnup does not exceed 60000 MWD/MTU, the enrichment does not exceed 4.9 w/o U-235 and that the neutron shield fluid contains 1.0 w/o boron.

**** Up to 24 BWR rods may be shipped, provided that the parameters of the rod shipment are within the bounds of the parameters shown above for BWR rods.

Table III-I

PARAMETERS FOR DESIGN BASIS FUEL

Type	Maximum Average Burnup MWD/MTU	Average Specific Power kW/kg U	Initial Enrichment w/o U-235	kgU Per Assembly
PWR	40,000	40	3.70	475
BWR	34,000	27	2.65	197
Consolidated PWR Fuel	40,000	40	3.70	950
Metallic Fuel	1,600	-------	Natural	54.5
PWR Rods	60,000	44	4.9	58 for 25 rods
BWR Rods	50,000	27	2.65	40 for 24 rods

Notes:

A PWR fuel assembly having maximum burnup up to 56,000 MWD/MTU may be transported, provided that the assembly meets the criteria given in Section III-6.0, and that the neutron shield water is boronated to 1 w/o boron.

A PWR fuel assembly configuration containing additional irradiated fuel rods inserted and secured in the guide thimbles is permissible provided the initial uranium content of the assembly does not exceed 495 kg and the maximum average initial U-235 enrichment does not exceed 3.35 w/o. Such an assembly may have no more than four fuel rods having a cooling time of 120 days.

Consolidated PWR fuel consists of the fuel rods from up to two (2) PWR fuel assemblies packed in a stainless steel canister in a triangular array. The loaded canister must be transported in a Configuration A.

Up to 25 PWR or 24 BWR rods may be shipped, provided that the parameters of the rod shipment are within the bounds of the parameters shown above for PWR and BWR rods.

TABLE III-3

REFERENCE DESIGN SUMMARY

Conditions	One PWR Fuel Assembly	Two BWR Fuel Assemblies*	Consolidated PWR Fuel Rods	Metallic Fuel	25 PWR Rods	24 BWR Rods
Loading	475 kgU	197 x 2 kgU	950 kgU	1,145.5 kgU	58.2 kgU	40 kgU
Initial Enrichment	3.7 w/o	2.65 w/o	3.7 w/o	Natural	4.9 w/o	2.65 w/o
Avg. Specific Power	40 kW/kg	27 kW/kg	40 kW/kg	-----	44 kW/kg	27 kW/kg
Max. Avg. Burnup (MWD/MTU)	40,000	34,000	40,000	1,600	60,000	50,000
Cooling Time (days)	150	120	4,380	365	150	150
Sources						
Total Gamma Energy (MeV/sec)	3.074×10^{16}	2.257×10^{16}	2.05×10^{16}	1.253×10^{15}	4.01×10^{15}	2.66×10^{15}
Total Neutron Source (n/sec)	7.55×10^{8}	6.43×10^{8}	8.74×10^{8}	2.289×10^{5}	1.08×10^{9}	1.17×10^{8}
Total Decay Heat (kW)	10.63	7.93	0.6	0.75	1.65	1.18

NOTES:

A PWR fuel assembly having maximum burnup up to 56,000 MWD/MTU may be transported, provided that the assembly meets the criteria given in Section III-6.0, and that the neutron shield water is borated to 1 w/o boron.

A PWR fuel assembly configuration containing additional irradiated fuel rods inserted and secured in the guide thimbles is permissible provided the initial uranium content of the assembly does not exceed 495 kg and the maximum average initial U-235 enrichment does not exceed 3.35 w/o. Such an assembly may have no more than four fuel rods having a cooling time of 120 days.

Consolidated PWR fuel consists of the fuel rods from up to two (2) PWR fuel assemblies packed in a stainless steel canister in a triangular array. The loaded canister must be transported in a Configuration A.

Up to 25 PWR or 24 BWR rods may be shipped, provided that the parameters of the rod shipment are within the bounds of the parameters shown above for PWR and BWR rods. The neutron shield water must be borated to 1 w/o boron when shipping PWR rods.

7.0 METALLIC FUEL SOURCES

Additional analyses have been performed relative to the transport of up to 21 rods of metallic fuel. These rods are 53.75 kgU per rod nominally, using natural uranium metal fuel. The burnups achieved by these rods are low compared to PWR fuel, as shown in Tables III-1 and III-3.

The ORIGEN computer code was used to calculate the source terms given below. The analyses show that up to 21 metallic fuel rods that meet the following conditions are acceptable for transport.

Maximum Average Initial Enrichment	Natural, 0.711 w/o U-235
Maximum Initial Uranium Content	54.5 kgU
Gamma Source Strength	5.97×10^{13} MeV/sec.
Neutron Source Strength	1.07×10^{4} n/sec.
Thermal Output	35.7 watts
Minimum Cool Time	365 days

8.0 PWR AND BWR ROD SOURCES

Additional analyses have been performed relative to the transport of up to 25 rods of PWR or 24 rods of BWR fuel with burnups of 60,000 MWD/MTU and 50,000 MWD/MTU respectively, and cool times of 150 days minimum in both cases. The total sources for rods of either fuel type are lower than the high burnup PWR and the design basis BWR (2 BWR assemblies) fuel as shown below. The analyses show that up to 25 PWR and 24 BWR rods, with the sources given, are acceptable for transport.

PWR

Source Type	High Burnup PWR Assembly	PWR Rods (25 Total)	Percent Of High Burnup PWR
gamma (MeV/sec)	1.0×10^{16}	4.01×10^{15}	40.1%
neutron (n/sec)	1.86×10^{9}	1.08×10^{9}	58.1%
Heat (kW)	10.63	1.65	16%

BWR

Source Type	Design Basis BWR Assemblies	BWR Rods (24 Total)	Percent of Design Basis BWR
gamma (MeV/sec)	2.257×10^{16}	2.66×10^{15}	12%
neutron (n/sec)	6.43×10^{8}	1.17×10^{8}	18%
Heat (kW)	7.93	1.18	15%

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4.13 Effect of PWR or BWR Rods

The maximum heat load in the cask with up to 25 rods is 1.65 kW. The temperature of the hottest rod in normal operation and hypothetical fire accident conditions were calculated using the SCOPE program. The fuel rods are placed in a rod holder that is inserted into the cask to support the fuel. No credit for heat conduction was taken for this holder; the fuel rods were modeled free in helium. The parameters used in this analysis are compared to the design basis PWR assembly in Table VIII-12.

TABLE VIII-12

PWR ROD ANALYSIS PARAMETERS

	Intact PWR	PWR Rods	BWR Rods
Number of Rods	204	25	24
Burnup (MWD/MTU)	40,000	60,000	50,000
Cool Time (days)	150	150	150
Heat Rate (kW)	10.6	1.65	1.18
Ambient Temperature	130°F	130°F	130°F
Cask Cavity Gas	Helium	Helium	Helium
Rod Array	Square	Square	Square

The thermal analysis results are summarized in Table VIII-13 and are compared to the design basis PWR assembly, demonstrating that 25 PWR or 24 BWR rods developed significantly lower temperatures than the design basis PWR assembly.

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TABLE VIII-13

PWR AND BWR ROD MAXIMUM TEMPERATURE

	Heat (kW)	Normal Operation Temperature (°F)	Hypothetical Accident Temperature (°F)
Intact PWR	10.6	1013	1102
PWR Rods (25)	1.65	393	556
BWR Rods (24)	1.18	350	503

The comparisons of maximum rod temperatures for up to 25 PWR or 24 BWR rods show that temperatures developed in normal operation and hypothetical fire accident conditions are much less than the maximum rod temperatures for the design basis PWR fuel. The actual heat source from 25 PWR rods is less than 1.65 kW, but 1.65 kW is used as a bounding case.

The cask surface temperature during normal operation with PWR rods is 229°F and 223°F with BWR rods. These are much lower than the design basis PWR fuel cask surface temperature of 340°F. Thus, shipment of up to 25 PWR rods or 24 BWR rods is safe from a thermal standpoint.

4.5 Shielding Analysis for PWR or BWR Rods

The gamma and neutron sources generated by a PWR assembly and by 25 PWR rods or 24 BWR rods are given in Table IX-21. The gamma source for PWR rods is 40 percent of the high burnup PWR assembly gamma source. The neutron source is 58 percent of the high burnup PWR assembly neutron source. The dose rates for the rod shipments may be obtained by multiplying the high burnup assembly dose rates by the appropriate percentages. The results of these calculations are shown in Table IX-22. Similar calculations comparing the BWR rods to the design basis BWR assembly are shown in Table IX-23.

The results given in Table IX-22 show that the dose rates from 25 PWR rods are much less than the dose rates from the high burnup PWR assembly. Similarly, the dose rates given in Table IX-23 for 24 BWR rods are much less than the design basis assembly. The shipment of up to 25 PWR or 24 BWR rods at 150 days cool time is, therefore, safe even though the burnups are greater than the design basis PWR and BWR assembly burnups.

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TABLE IX-21

PWR ASSEMBLY AND PWR OR BWR ROD SOURCE STRENGTHS

	SAR High Burnup PWR Assembly	25 PWR Rods[1]	SAR Design Basis PWR Assembly	24 BWR Rods[2]
Decay Time, days	150	150	150	150
Thermal Output, kW	10.63	1.65 (16%)	10.63	1.18 (11%)
Gamma, MeV/sec	1.00x 10^{16}	4.01 x 10^{15} (40.1%)	3.074 x 10^{16}	2.66 x 10^{15} (9%)
Neutrons, n/sec	1.86 x 10^{9}	1.08 x 10^{9} (58.1%)	7.55 x 10^{8}	1.17 x 10^{8} (16%)
Fission Products, Ci Total	2.31 x 10^{6}*	2.83 x 10^{5} (12.3%)**	2.17 x 10^{6}***	2.3 x 10^{5} (10%)**

$$\% = \frac{\text{Source of Rods at 150 days}}{\text{Source of Assembly at 150 days}}$$

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[1] Calculated with the LOR2 version of ORIGEN2 which yields conservative results. Values in parentheses represent percentage as compared to SAR High Burnup PWR Assembly.

[2] From DOE/ET/34014-10, "Extended Fuel Burnup Demonstration Program." Final Report, Sept. 1983. Values in parentheses represent percentage as compared to SAR Design Basis PWR Assembly.

* Calculated with the LOR2 version of ORIGEN2.

** Total Fission Product Curies for rods were not listed in the Final Report data tables, but were obtained directly from the computer results.

*** From Table IX-15

TABLE IX-22

25 PWR ROD DOSE RATES

Normal Operation: (6 feet from Personnel Shield)*
(High Burnup PWR Assembly dose rates in parentheses)

Source	Fuel Midplane	Top	Bottom
Primary Gamma	0.36 (0.91)	0.23 (0.58)	0.17 (0.42)
Neutron	2.02 (3.47)	3.24 (5.57)	2.95 (5.07)
Secondary Gamma	0.12 (0.20)	0.01 (0.01)	0.01 (0.01)
Ground Scatter Gamma	0.02 (0.06)	0.02 (0.04)	0.02 (0.04)
Ground Scatter Neutron	1.01 (1.73)	0.95 (1.63)	0.95 (1.63)
Total Gamma	0.50 (1.17)	0.26 (0.63)	0.20 (0.47)
Total Neutron	3.03 (5.20)	4.19 (7.20)	3.90 (6.70)
TOTAL	3.53 (6.37)	4.45 (7.83)	4.10 (7.17)

Hypothetical Accident: (3 feet from cask surface)*

Source	Fuel Midplane	Top	Bottom
Primary Gamma	49.3 (123.)	1.0 (2.5)	0.92 (2.3)
Neutron	124. (213.)	25.8 (44.4)	29.3 (50.5)
Secondary Gamma	0.8 (1.3)	1.2 (2.1)	1.0 (1.8)
Ground Scatter Gamma	2.5 (6.2)	0.04 (0.1)	0.08 (0.2)
Ground Scatter Neutron	62.2 (107.)	12.1 (20.9)	15.0 (25.9)
Total Gamma	52.6 (131.)	2.24 (4.7)	2.0 (4.3)
Total Neutron	186. (320.)	37.9 (65.3)	44.3 (76.4)
TOTAL	239. (451.)	40.1 (70.0)	46.3 (80.7)

* Based on Table IX-10, Page IX-26

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10.3 Computer Codes

The calculations for k-infinity were performed using the XSDRNPM module of SCALE-2. Calculations for k-effective were performed using NITAWL, XSDRNPM, and KENO-IV modules of SCALE-2. Dancoff correction factors and effective moderator cross-sections for NITAWL were calculated by the NULIF code provided by Babcock and Wilcox.

10.4 Criticality Evaluation for Metallic Fuel

The metallic fuel has only natural enrichment, 0.711 w/o uranium-235. Metallic natural uranium fuel cannot achieve criticality in any geometric configuration with (light) water as a moderator. Neither is an array of packages containing natural uranium fuel critical, with or without light water moderation. Table X-7 demonstrates that the loaded cask meets the criteria established for Fissile Class I packages, as defined by 10 CFR 71.38. A description of the fuel and its configuration in the cask are provided in the following section.

10.5 Criticality Evaluation for PWR or BWR Rods

The enrichment limits for BWR (2.65 w/o) fuel assemblies are maintained for the BWR rod shipments, as shown on page II-0, NLI-1/2 Spent Fuel Shipping Cask Data. Since the enrichment of the rods has not been increased beyond the design basis, the criticality analyses for the BWR assemblies bound the reactivity of the BWR rod shipments, and the rod shipments are critically save.

The enrichment limit for a PWR rod shipment is 4.9 w/o uranium-235. This enrichment is higher than the design basis enrichment limit. During the shipment of PWR rods, it is hypothetically possible for the rods to attain their optimum or most reactive pitch. Therefore, it is necessary to calculate the optimum pitch for a PWR rod and determine the reactivity of an array of 25 rods.

The XSDRNPM discrete ordinates code was used to determine k_∞ values for various rod pitches. A pitch of 1.53 centimeters was used as a starting point. The pitch was increased by a small distance and k_∞ was calculated for that case. The pitch was steadily increased and k_∞ calculated until a maximum value of k_∞ was determined. The values for each pitch analyzed are listed below:

Pitch	k_∞
1.53	1.4983526
1.56	1.5044017
1.58	1.5076288
1.60	1.5103494
1.62	1.5125901
1.64	1.5143920
1.66	1.5156379
1.68	1.5165032
1.70	1.5169899
1.72	1.5170627
1.74	1.5168190
1.76	1.5162339
1.78	1.5153357
1.80	1.5141438
1.82	1.5126569
1.84	1.5109039

A peak in k_∞ was seen at a pitch of 1.72 centimeters. This is the optimum pitch for the PWR rods. KENO-IV was used to model a square 5 x 5 array containing 25 rods at optimum pitch inside the NLI-1/2 cask. This case gave a k_{eff} of 0.52478 ± 0.00254, which corresponds to a k_s of 0.545. A homogenized, cylindrical array of 25 rods yielded a k_s of 0.540, indicating that the array geometry does not have a strong effect on reactivity. Therefore, the NLI-1/2 cask can safely transport 25 PWR rods with an enrichment of 4.9 w/o uranium-235.

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Table X-7
SUMMARY OF CRITICALITY EVALUATION FOR METALLIC FUELS
FISSILE CLASS I

NORMAL CONDITIONS	
Number of undamaged packages calculated to be subcritical (Fissile Class I must be infinite; Fissile Class II must be at least 25; and Fissile Class III must be at least identical shipment.)	Infinite*
Optimum interspersed hydrogenous moderation (required for Fissile Class I)	yes
Closely reflected by water (required for Fissile Class II and III)	yes
Package size, cm^3	60,240
ACCIDENT CONDITIONS	
Number of damaged packages calculated to be subcritical (Fissile Class I must be at least 250; Fissile Class II must be at least 10; and Fissile Class III must be at least 1.	250*
Optimum interspersed hydrogenous moderation, full water reflection	yes
Package size, cm^3	60,240
Other Transport Index (must not exceed 10 for Fissile Class II)	Not Applicable

*Natural Enrichment Uranium Fuel cannot go critical in any configuration, with or without (light) water moderation. No combination of damaged or undamaged packages can result in criticality.

SECTION XI - APPENDIX D
SUPPLEMENTAL ANALYSIS FOR FISSION GAS RELEASE

1.0 Summary

The NLI-1/2 cask is designed to safely contain irradiated fuel under a variety of normal and accident conditions. To verify the design for shipment of a high burn-up fuel assembly (having a burnup of 58,600 MWD/MTU), analyses of leak rates and total release were performed in accordance with ANSI - 14.5-1977 and 10 CFR 71.36 (a) (2).

The permitted leak rate is found to be 1.24 x 10^{-4} cm^3/sec. and the post accident condition leak rate is found to be 1.79 x 10^{-5} cm^3/sec. The quantity of material released is much less than the 1000-curie limit imposed by IAEA Safety Series 6. This analysis shows that the transport of high burn-up fuel with four extra rods is not limited by fission gas release.

The results of this analysis are a bounding condition. PWR fuel assemblies having a burnup of 40,000 MWD/MTU without extra rods will develop less internal pressure and have lower leak rates. The fission product inventory of 25 PWR rods with a burnup of 60,000 MWD/MTU will be lower than a high burn-up fuel assembly with 208 rods. Metallic fuel does not develop internal pressure as oxide fuel does, and fission product inventories are much lower because of the lower burnup and long cool time. The total fission gas inventory of 21 rods of metallic fuel cooled 1 year is 609 curies, which is much less than the 4950 curies present in the intact PWR fuel.

The fission gas activity of the Mark 42 fuel assembly is much lower than that of the design basis PWR fuel assembly as shown in Table IX-24. The percentage of fission gas that is released from the fuel assembly is also much lower for the Mark 42 fuel because it has a metal form and is not an oxide. Therefore, the activity released during normal operations and during an accident will be bounded by the design PWR fuel assembly analysis.

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