SOUTHERN CALIFORNIA
EDISON®
An EDISON INTERNATIONAL® Company

A. Edward Scherer
Manager of
Nuclear Regulatory Affairs

July 27, 2007

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Subject: **Docket Nos. 50-361 and 50-362**
Response to Request for Additional Information in Support of Amendment Application Numbers 243 and 227
Proposed Change Number (PCN) 556, Revision 1
Request to Revise Fuel Storage Pool Boron Concentration
San Onofre Nuclear Generating Station Units 2 and 3

Reference: 1) Letter from N. Kalyanam (NRC) to Richard M. Rosenblum (SCE) dated May 7, 2007; Subject: San Onofre Nuclear Generating Station, Units 2 and 3 – Request for Additional Information on the Proposed Amendment to Revise Fuel Storage Pool Boron Concentration (TAC Nos. MD1405 and MD 1406)

2) Letter from J. T. Reilly (SCE) to the U. S. Nuclear Regulatory Commission (Document Control Desk) dated June 15, 2007; Subject: Docket Nos. 50-361 and 50-362, Amendment Application Numbers 243 and 227, Proposed Change Number (PCN) 556, Revision 1, Request to Revise Fuel Storage Pool Boron Concentration San Onofre Nuclear Generating Station Units 2 and 3

Dear Sir or Madam:

By letter dated May 7, 2007 (Reference 1), and through subsequent teleconferences, the U.S. Nuclear Regulatory Commission issued a request for additional information regarding Proposed Change Number (PCN) 556.

P.O. Box 128
San Clemente, CA 92672
949-368-7501
Fax 949-368-7575

A001

NRR

By letter dated June 15, 2007 (Reference 2) Southern California Edison (SCE) submitted the responses to questions 1 through 27, with the exception of questions 25 and 26. This letter provides the SCE responses to questions 25 and 26 from the NRC Staff (Enclosure). Response to question 26 contains the following commitment:

> SCE will apply a 6.6% reduction to the CECOR computer code determination of fuel assembly burnup for all fuel assemblies prior to determination of the allowable storage location per the proposed Technical Specification 4.3.1 and Licensee Controlled Specification 4.0.100.

SCE has evaluated the supplemental information under the standards set forth in 10CFR50.92(c) and determined that SCE's original finding of "No significant hazards consideration" is not changed.

If you have any questions or require additional information, please contact Ms. Linda T. Conklin at (949) 368-9443.

Sincerely,

Enclosure: As stated

cc: B. S. Mallett, Regional Administrator, NRC Region IV
N. Kalyanam, NRC Project Manager, San Onofre Units 2 and 3
C. C. Osterholz, NRC Senior Resident Inspector, San Onofre Units 2 and 3

Southern California Edison (SCE)

San Onofre Nuclear Generating Station (SONGS), Units 2 and 3

Docket Nos. 50-361 and 50-362

Enclosure

Responses to NRC Staff Questions 25 and 26 Regarding
Proposed Change Notice (PCN) 556

NRC Question 25: Bounding Conditions for Storage Patterns

The licensee considered in its criticality analyses the following storage patterns and GT-Inserts: (1) unrestricted storage; (2) SFP peripheral storage; (3) 2x2 storage patterns; (4) 3x3 storage patterns; (5) credit for inserted CEAs; (6) credit for Erbium rods; (7) credit for Pu241 decay; (8) credit for GT-Inserts; and (9) credit of burnup effects to compensate for no Boraflex poison credit. Based on its results of the criticality analyses, the licensee proposed the allowable storage patterns and the associated enrichment-burnup limits at discrete numbers of cooling years in Tables 4-3 through 4-34, and Figures 4-1 through 4-32 of the criticality analysis report (CAR) for the NRC staff to review. The Tables and Figures include 23 individual storage patterns and various combined patterns with associated enrichment ranging from 0.94 to 5.0 w/o, the burnup of up to 55.68 GWD/MTU, and the cooling times of up to 20 years).

Discuss the conditions in terms of the storage pattern, enrichment, burnup, cooling time, and boron concentration used to determine the values of each (underlined for emphasis) of the following parameters, and demonstrate that these values are the bounding values and applicable to the proposed allowable storage patterns for the assemblies in the SFP.

(a) the parameters included in Appendix D to the CAR. These parameters include: KENO-V.a method bias, KENO-V.a method bias 95/95 uncertainty, k-nominal and its associated sigma, normal pool temperature bias, CEA insertion bias, eccentric loadings, and manufacturing tolerances including tolerances of rack storage cell wall thickness, rack storage cell ID, rack storage cell pitch and U235 enrichment.

(b) the axial burnup bias discussed in the draft RAI 11 response.

(c) the reactivity equivalencing uncertainty and discharge burnup uncertainties discussed in the draft RAI 14, and RAI 15 response, respectively.

(d) the boron concentration of 370 ppm to maintain k-eff less than 0.95 discussed in Section 5.1 of the CAR.

SCE Response:

Part (a)

The conditions under which the parameters in Appendix D of Attachment L of the submittal were determined are discussed below.

Appendix D is a two page summary of Appendix B (Region I) and Appendix C (Region II) analyses. Every number in Appendix D (except ranges of expected values) can be

found in Appendices B and C. Appendices B and C are key elements of this criticality analysis report. In Appendix B (or C), the fresh fuel enrichment for all cell storage in Region I (or II) is determined. The fresh fuel enrichment for Region I (or II) is 2.47 weight percent (w/o) (or 1.23 w/o) and the resulting 0 ppm 95/95 k-inf, which includes all applicable biases and uncertainties, is 0.99687 (or 0.99803).

These 95/95 k-inf values were determined with infinite 3-D KENO-Va models. KENO-Va has been benchmarked and validated against industry standard B&W critical experiments. The tolerances and pool temperature bias in Appendices B and C are from Table 4-1 on page 34 of Attachment L of the submittal. The tolerances have been evaluated for the full range of enrichments and expected soluble boron concentrations. The most adverse tolerances for the whole enrichment range and from 0 ppm to 1000 ppm for each spent fuel pool (SFP) region is used. One-thousand ppm bounds the total soluble boron requirement of 970 ppm to maintain k-eff less than or equal to 0.95. Including the effect of soluble boron on the tolerances is an additional conservatism for the no soluble boron k < 1.0 cases.

The storage of burned fuel is handled with reactivity equivalencing. The CASMO-3 computer program is used for reactivity equivalencing. Tables 4-3 through 4-25 and Figures 4-1 through 4-21 of Attachment L of the submittal resulted from reactivity equivalencing.

First the assembly is depleted in 2-D in CASMO-3 at conservative reactor conditions to maximize plutonium and eliminate any axial burnup bias.

Next, in the following 2-D CASMO-3 restart cases at selected burnups (5, 10, 20, 30, 40, 50 GWD/T) and cooling times, the depleted assembly is placed in Region I (or II) fuel rack geometry under the conservative conditions of 0 ppm, 68 F, and no Xenon.

The CASMO-3 results produce a table of k-inf of the depleted fuel assembly in the fuel storage rack versus burnup at different cooling times for Region I (or Region II).

As discussed earlier, the fresh fuel enrichment 95/95 k-inf for Region I (0.99687) and Region II (0.99803) are the target k-inf for interpolation in the fuel rack k-inf vs burnup table. For example, for a 4.5 w/o fuel assembly, the resulting interpolated burnup values are 18.61 GWD/T (Region I, 0 years cooling) and 48.43 GWD/T (Region II, 0 years cooling). That is, for Region I, a 4.50 w/o assembly burned to 18.61 GWD/T and zero cooling time is equivalent to a fresh assembly at 2.47 w/o in fuel rack geometry. For Region II, a 4.50 w/o assembly burned to 48.43 GWD/T and zero cooling time is equivalent to a fresh assembly at 1.23 w/o in fuel rack geometry. Since the fresh fuel target k-inf is a 95/95 value with all applicable biases and uncertainties, the resulting Tables 4-3 through 4-25 and Figures 4-1 through 4-21 are also 95/95 including all biases and uncertainties.

In a similar manner the remaining values in Tables 4-3 through 4-25 and Figures 4-1 through 4-21 of Attachment L of the submittal are calculated at various cooling times.

(i) The KENO-V.a method bias and 95/95 uncertainty were determined by analysis of B&W critical experiments (storage patterns). See Table 3-1 of Attachment L of the submittal. The bias and uncertainty have been determined at a 95/95 probability/confidence level.

The $k_{95/95}$ for 16 cases is 2.524.

KENO-Va is a multigroup Monte Carlo transport computer program to calculate the k-eff of a three-dimensional system. KENO-Va accurately models geometrically complex systems.

The B&W criticality experiments have similar nuclear characteristics to spent fuel storage and are applicable to conditions encountered during the handling of light water reactor (LWR) fuel outside reactors. This B&W critical experiment set has been previously used by SCE for spent fuel pool criticality analyses reviewed and approved by the NRC (Reference 6). The boron concentration in the experiments ranges from 0 ppm to 1037 ppm which bounds the total soluble boron requirement of 970 ppm to maintain k-eff less than or equal to 0.95.

The 16 fuel patterns analyzed by SCE include the following:

Fuel rods arranged in 25x25 approximate cylindrical array
Nine square arrays of fuel rods with zero pin pitch separation
Nine square arrays of fuel rods separated by one pin pitch separation
Nine square arrays of fuel rods separated by 4 pin pitches
Nine unit assemblies separated by 1 pin pitch and metal isolation sheets
Nine unit assemblies separated by 3 pin pitches and metal isolation sheets

These combinations of soluble boron and fuel rod arrays/assemblies separated by water and by metal isolation sheets (simulated rack cells) – fuel patterns – demonstrate the ability of KENO-Va to accurately model a wide range of LWR spent fuel pool conditions.

KENO-Va is a multi-group transport theory computer code with detailed modeling of the geometries including individual fuel pins, guidetubes, water gaps, and metal sheets. Storage patterns are modeled consistently. KENO-Va is used to calculate the poolwise k-eff which is driven by the assembly with the highest reactivity. Variations in storage patterns (enrichment, control rod) do not affect its ability in predicting the k-eff.

(ii) K-nominal and its associated sigma uncertainty is case dependent. A representative range of values is shown in Appendix D. Actual KENO results for Region I (0.96400 $\pm$ 0.00063) and Region II (0.97086 $\pm$ 0.00048) are shown in Appendices B and C. The Region I storage pattern is an infinite array of 2.47 w/o U235 fresh assemblies, 68 degrees F, and 0 ppm.

The Region II storage pattern is an infinite array of 1.23 w/o U235 fresh assemblies, 68 degrees F, and 0 ppm. KENO is run with 503 neutron generations, and at least 2000 neutrons per generation. Since the first 3 generations of KENO results are skipped, the $k_{95/95}$ for 500 cases is 1.763.

(iii) The pool temperature bias has been evaluated for both Region I and Region II storage patterns. An infinite 2-D CASMO-3 model is used for both Region I and Region II. For both storage regions, the temperature range is from 68F to 160F, and the soluble boron range is from 0 ppm to 1000 ppm. One-thousand ppm bounds the total soluble boron requirement of 970 ppm to maintain k-eff less than or equal to 0.95. The Region I enrichment range is from 1.85 w/o to 5.1 w/o. (The final Region I fresh enrichment is 2.47 w/o). The Region II enrichment range is from 1.20 w/o to 1.85 w/o. (The final Region II fresh enrichment is 1.23 w/o.) See Table 4-1 of Attachment L of the submittal. The most adverse value for the whole enrichment range and from 0 ppm to 1000 ppm for each SFP region is used. This is an additional conservatism for the no soluble boron $k < 1.0$ cases.

As shown in Table 4-1, a conservative bias is used. Sixty-eight degrees F is the lowest expected temperature. The upper temperature limit of 160 F is the maximum expected non-accident spent fuel pool temperature from UFSAR Section 9.1.3.1.

K-eff of a system is driven by the assembly with highest reactivity. For storage patterns, it is the highest reactivity assembly that dominates the reactivity response to the temperature. For Region I, the fuel temperature bias is determined for up to 5.1 w/o, which exceeds the enrichment limit of 4.8 w/o. As shown in Table 4-1 of Attachment L to the submittal, the highest temperature bias which occurs at 5.1 w/o is selected. For Region II which doesn't have a water gap between storage cells, the temperature reactivity effect is significantly smaller than the Region I values and is negative (more conservative) at 0 ppm. A conservative temperature bias of 0.003 is used for both the 0 ppm case and the borated cases.

This value is more conservative than the temperature reactivity for the highest enrichment allowed for unrestricted storage in Region II.

(iv) The manufacturing tolerances have been evaluated for both Region I and Region II storage patterns. The methodology is consistent with SCE's NRC approved methodology in Reference 6. An infinite 2-D CASMO-3 model is used for both Region I and Region II. For both storage regions, the temperature range is from 68F to 160F, and the soluble boron range is from 0 ppm to 1000 ppm. The Region I enrichment range is from 1.85 w/o to 5.1 w/o. (The final Region I fresh enrichment is 2.47 w/o). The Region II enrichment range is from 1.20 w/o to 1.85 w/o. (The final Region II fresh enrichment is 1.23 w/o). See Table 4-1 of Attachment L of the submittal. The manufacturing dimensional tolerances have been obtained from the manufacturer of the racks, Westinghouse. The enrichment tolerance limit of 0.05 w/o is consistent with our fuel

manufacturing/enrichment specifications. The most adverse value for the whole enrichment range and from 0 ppm to 1000 ppm for each SFP region is used. This is an additional conservatism for the no soluble boron k < 1.0 cases.

The manufacturing tolerances were evaluated for the unrestricted fuel patterns (Tables 4-3 and 4-11) described in Appendices B and C of Attachment Variations due to storage patterns are expected to be small because k-eff of the system is a flux and volume weighted quantity and is not affected by small local variations. For example, as shown in the Beaver Valley Unit 2 Spent Fuel Rack Criticality Analysis With Credit For Soluble Boron (CAA-98-158-Rev 1, November 1998):

Tolerance	All Cell Storage	3-out-of-4 Storage	Difference
	Δk	Δk	Δk
Cell Inner Dimension	0.00010	0.00005	0.00005
Cell Pitch	0.00306	0.00215	0.00091
Cell Wall Thickness	0.00532	0.00453	0.00079
Wrapper Thickness	0.00273	0.00232	0.00041

These small Δk's are easily compensated for by the large, conservative power (2%), reactivity equivalencing (3.98%), and discharge burnup uncertainty (4.76%) which will be applied. (See response to RAI #26.)

In addition, the SCE criticality analysis conservatively ignored the fuel assembly grids. The negative reactivity provided by the grids (0.11% ρ) would also compensate for the small variations due to the pattern effect.

(v) The CEA insertion bias was evaluated at 68 degrees F and 0 ppm. These conditions maximize CEA worth and thus the bias. An infinite array of fuel assemblies was modeled in both CASMO-3 and KENO.

This is a comparison between two computer programs. KENO was found to be conservative compared to CASMO-3 (i.e., KENO under-predicts CEA worth thus requiring a higher discharge burnup for storage). Nevertheless, a CEA insertion bias (CASMO3 – KENO CEA worth difference) is included in the calculations of k-eff when CEAs are present.

The true CEA insertion bias is a credit of -0.007 Δk. However, a bias of +0.007 is included in any case when CEAs are present. As a result, a conservative bias of 0.014 (0.007+0.007) is present.

As described in response to RAI # 25(i), the ability of KENO-Va to predict reactivity is not significantly affected by the variations in storage patterns. This conservative bias (0.014) is much larger than the KENO-Va bias of 0.00814 from the benchmarking (Table 3-1 of Attachment L to the submittal).

(vi) The eccentric loading tolerance was evaluated for both Region I and Region II racks at 68 degrees F and 0 ppm because this tolerance is insensitive to soluble boron. Infinite KENO models were set up for both Region I and Region II. In these infinite models, groups of 4 assemblies are moved as close together as possible in the corner where four storage locations meet. This tolerance was found to be only applicable to Region I as discussed in Section 4.2 of Attachment L of the submittal.

The variation in enrichment and loading pattern is expected to be small because the k-eff of a system is flux and volume weighted integral quantity and is not affected by small local variations. As shown in the Beaver Valley Unit 2 Spent Fuel Rack Criticality Analysis With Credit For Soluble Boron (CAA-98-158-Rev 1, November 1998), the eccentric loading tolerance Δk decreases as fewer than 4 assemblies are moved together. Thus SCE has analyzed the worst fuel pattern of 4 assemblies moved together.

Also the fuel assembly grids are not modeled. The negative reactivity provided by the grids (0.11% ρ) would also compensate for enrichment and fuel pattern effects.

Thus the final 0 ppm soluble boron k < 1.0 results for Region I and Region II shown in Appendices B and C, Tables 4-3 through 4-25, and Figures 4-1 through 4-21 are 95/95 results including all applicable biases and uncertainties.

The discussion of two uncertainties applicable to the 0 ppm case and how they will incorporated is fully discussed in Question 26:

(1) CASMO-3 burnup uncertainty (0.01 Δk at 30 GWD/T, linear with burnup, and,

(2) Discharge burnup uncertainty.

To summarize here, these uncertainties are both applied to the assembly discharge burnup and then this decreased assembly burnup is used in Tables 4-3 through 4-25 and Figures 4-1 through 4-21 to find an acceptable storage pattern.

Part (b)

As discussed in the responses to RAIs #10 and #11, an axial burnup bias for San Onofre Units 2 and 3 fuel assemblies is not required due to the conservative assumptions used in the assembly depletion calculation. This conservatism does not depend on any fuel storage rack properties or conditions (pattern, temperature, ppm). The axial burnup bias depends on actual reactor core conditions vs conservative modeling assumptions in CASMO reactivity equivalencing cases.

The axial burnup distribution in a discharged fuel assembly depends on the temperatures, boron concentration, and power distribution in the reactor when the fuel assembly was irradiated. When the fuel assembly is discharged, the axial burnup distribution is now fixed. Placement of this discharged fuel assembly in the fuel storage racks does not change this fixed axial burnup distribution.

In Table 4-2 of Attachment L of the submittal and in the response to RAI #11, it is shown that the axial burnup bias is 0.0 Δk for a San Onofre Units 2 and 3 16x16 fuel assembly with large water holes (the CEA guide tubes displace 4 fuel rods instead of 1 fuel rod).

In the submittal approved in Reference 6, an independent method was used to show that the San Onofre fuel assembly axial bias is 0.0 Δk. The burnup distribution from a discharged San Onofre assembly was converted to equivalent fresh enrichments. The equivalent fresh enrichments were input to a 3-D KENO model. A second 3-D KENO model with uniform enrichment corresponding to the assembly average burnup was also set up. This comparison also showed that the axial bias was 0.0 Δk.

Part (c)

The reactivity equivalencing uncertainty (0.01 Δk at 30 GWD/T, linear with burnup) is conservative. As shown in the response to RAI #14, this value is consistent with a 5% uncertainty previously accepted by the NRC in Reference 6.

The discharge burnup uncertainty contains two components:

(1) the assembly power measurement uncertainty, and,

(2) the plant power measurement uncertainty.

As discussed in the response to RAI #15, SCE uses the CECOR computer program to determine the assembly power values. CECOR assembly power uncertainty is 4.76%. The plant power measurement uncertainty is conservatively assumed to be 2%. Although these two independent components can be statistically combined, in the determination of the boron requirement the two components are combined deterministically to result in an uncertainty of 7%.

Part (d)

Determination of 370 ppm for k-eff less than or equal to 0.95 is discussed in the response to RAI #13. All manufacturing tolerance uncertainties have been evaluated over a soluble boron range from 0 to 1000 ppm and 68 deg F to 160 deg F, with the most adverse values over the entire temperature and soluble boron range being used in the determination of k-eff less than 1.0 at 0 ppm. Since the effect of temperature and soluble boron have been included in the k-eff less than 1.0 analysis, they are automatically included in the determination of 370 ppm for k-eff less than or equal to 0.95.

As discussed in the response to RAI #13, an entire storage pool 3-D KENO model is used which models every Region I and Region II storage cell with fresh assembly enrichments adjusted for the amount of soluble boron present.

NRC Question 26: Available Margins in the Results of the Criticality Analyses

As indicated in the CAR, the licensee determined the allowable storage patterns and the associated enrichment limits based on calculations of following sets of conditions:

I. For cases with unborated water in the SFP, the k-eff is maintained to be less than 1.0 at a 95/95 level, and

II. For Cases with borated water in the SFP, the k-eff is maintained to be less than or equal to 0.95 at a 95/95 level.

Provide information to demonstrate that the available margins in the results of the criticality analyses for all the allowable storage patterns are sufficient to bound the uncertainties for the following parameters that are not included in the criticality analyses. If the available margins are not sufficient, the licensee should perform the criticality analyses including all uncertainties, and present the results of analyses and the allowable storage patterns and the associated enrichment-burnup limits for the NRC staff to review.

(a) the reactivity equivalencing uncertainty and discharge burnup uncertainty (discussed in RAI 1(c)) that are not included in the criticality analyses for cases with unborated water (discussed in RAI 2.I), and

(b) the biases and uncertainties for the parameters included in Appendix D to the CAR (discussed in RAI 1(a)), and the axial burnup bias discussed in RAI 1(b) that are not included in the criticality analyses for cases with borated water (discussed in RAI 2.II).

SCE Response:

Part (a)

SCE will conservatively account for the reactivity equivalencing and discharge burnup uncertainties by reducing the discharge burnup of the fuel assemblies to be placed in the spent fuel storage racks. After the discharge burnup has been decreased by these uncertainties, then the Region I and Region II Tables and Figures of proposed TS 4.3.1 and LCS 4.0.100 will be used to determine the storage patterns. This is in addition to the reactivity equivalencing and discharge burnup uncertainties already included in the boron requirements (Sections 5.2 and 5.3 of Attachment L of the SCE submittal.) Applying the combined uncertainties on the discharge burnup is conservative as opposed to including them in the statistical summation shown in Appendix D of Attachment L of the SCE submittal. The total uncertainty by which the discharge burnup will be decreased is 6.6 %.

The total uncertainty is derived as follows.

(1) Reactivity Equivalencing Uncertainty

The reactivity equivalencing uncertainty is 0.01 Δk at 30 GWD/T, linear with burnup. As shown in the response to RAI #14, this is equivalent to 5% of the decrease in reactivity with burnup for up to 60 GWD/T. The reactivity equivalencing uncertainty is converted to a burnup uncertainty.

Using the tabular data in the response to RAI #14, a reactivity uncertainty is related to a burnup uncertainty as follows:

$$\%\text{ Burnup Uncertainty} = (\Delta\text{Burnup} / \Delta k) * \text{Reactivity Uncertainty} * 100\%$$

$$\%\text{ Burnup Uncertainty} = \frac{(30 - 0)\ \text{GWD/T}}{(1.40058 - 1.14909)\ \Delta k} * \frac{(0.01\ \Delta k)}{(30\ \text{GWD/T})} * 100\% = 3.98\ \%$$

(2) Discharge Burnup Uncertainty

The discharge burnup is a time-integrated value. As shown in response to RAI #15, the discharge burnup uncertainty includes a 4.76% assembly power measurement uncertainty and a 2% plant power uncertainty. In the response to RAI #15, these two components were applied deterministically, which is overly conservative. For the determination of the total burnup uncertainty, these two components are combined with the reactivity equivalencing uncertainty using the statistical summation method employed in Appendix D of Attachment L of the submittal.

The combined, total uncertainty is calculated as follows.

Total Uncertainty (%) = SQRT $\{(3.98\%)^2 + (2.00\%)^2 + (4.76\%)^2\} = 6.52\ \%$

The result is rounded up to 6.6%. A 6.6% reduction will be applied to the CECOR computer code determination of fuel assembly burnup for all fuel assemblies prior to determination of the allowable storage per the proposed TS 4.3.1 and LCS 4.0.100.

Part (b)

As discussed in the response to RAI #25, the uncertainties for the parameters included in Appendix D and the axial burnup bias are applicable to both the unborated and borated conditions. No other uncertainties or allowances are required.