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U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

Report No.:	99900003/96-01
Organization:	General Electric Company (GE) General Electric Nuclear Energy (GE-NE) Nuclear Energy Production (NEP) Wilmington, North Carolina
Contact:	Ralph J. Reda, Manager Fuels and Facility Licensing
Nuclear Industry Activity:	GE provides boiling-water reactor (BWR) reload core designs, safety analysis, and licensing, fuel assemblies, fuel-related core components, and fuel-related inspection services to the U.S. nuclear industry.
Dates:	May 6 - 10, 1996
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Enclosure 2

1 INSPECTION SUMMARY:

From May 6 through 10, 1996, the U.S. Nuclear Regulatory Commission (NRC) conducted a performance-based inspection of the General Electric (GE) Nuclear Energy (GE-NE), activities at the Nuclear Energy Production (NEP) facilities in Wilmington, North Carolina. This inspection focused on technically directed observations and evaluations of GE activities related to (1) under prediction of the safety limit minimum critical power ratio (SLMCPR) for several licensee plants and (2) out-of-specification low density fuel pellets (LDPs) that were loaded into fuel rods and shipped to licensees in fuel assemblies.

The inspection bases were:

- General Design Criterion (GDC) 10, "Reactor Design," and GDC 12, "Suppression of Reactor Power Oscillations," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Part 50, "Licensing of Production and Utilization Facilities," of Title 10 of the Code of Federal Regulations (10 CFR).

- Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50.

- 10 CFR Part 21, "Notification of Failure to Comply or Existence of a Defect."

- Section 4.2, "Fuel System Design," of NRC NUREG-0800, "Standard Review Plan" (SRP), Revision 2, dated July 1981, and its Appendix A, "Evaluation of Fuel Assembly Structural Response to Externally Applied Forces," Revision 0.

- "GE Nuclear Energy, Quality Assurance Program Description," NEDO-11209-04A, Revision 8, Class 1 (approved by the NRC on March 31, 1989, as meeting the requirements of Appendix B to 10 CFR Part 50), hereafter referred to as the "QA topical report."

- Amendment 22 of the "General Electric Standard Application for Reload (GESTAR) II," topical report documented in NEDE-24011-P-A, "General Electric Standard Application For Reactor Fuel," (approved by the NRC on July 23, 1990).

- "General Electric BWR Thermal Analysis Basis (GETAB): Data, Correlation and Design Application," NEDE-10958-PA, January 1977 (approved by the NRC and referenced in GESTAR).

During this inspection, three instances were identified where GE failed to conform to NRC requirements and approved methodology. These nonconformances are discussed in Section 3.1 of this report.

During this inspection, the team noted weaknesses and observations concerning GE activities that affect quality. Neither the weaknesses nor the observations described in this report require any specific action or written response.

2 STATUS OF PREVIOUS INSPECTION FINDINGS

The open findings from the previous NRC inspection of GE (conducted from August 14 through September 1, 1995, and documented in Inspection Report 99900003/95-01, March 5, 1996) were not reviewed during this inspection. However, concerns associated with the determination of the SLMCPR that were identified during the previous inspection were reviewed during this inspection.

3 INSPECTION FINDINGS AND OTHER COMMENTS

This inspection included an evaluation of the adequacy of GE processes and activities for determining the safety limit minimum critical power ratio (SLMCPR) which ensures that 99.9% of the fuel rods avoid boiling transition and out-of-specification low density fuel pellets (LDPs). The emphasis of the team's evaluation was on the fuel development and engineering, corrective actions, the requirements of 10 CFR Part 21, and GE licensee notifications related to the SLMCPR and LDP issues.

3.1 Safety Limit Minimum Critical Power Ratio (SLMCPR)

a. Inspection Scope

On March 16, 1995, GE met with NRC staff and stated that they would submit a request to replace the current generic SLMCPR analysis with a cycle-specific analysis. During the presentation GE stated that (1) conservative generic analysis restricts benefits of more efficient designs, (2) actual designs show higher bundle peaking factors permitted by increased thermal margin, (3) cycle-specific evaluations can reflect more realistic radial power assumptions, and (4) its cycle-specific SLMCPR methodology would be submitted to NRC in 1995.

During the NRC inspection of NEP activities conducted from August 14 through September 1, 1995 (NRC Inspection Report 99900003/95-01, March 5, 1996) the team followed up on GE's March 16, 1995, presentation to the NRC staff by evaluating GE's methodology for determining the SLMCPR. That inspection identified several concerns associated with the determination of SLMCPR. Those concerns related to areas where significant changes had been made to the methodology used to determine the SLMCPR, which were considered to be outside the NRC approved generic method described in GESTAR. For instance, the revision to the R-factor methodology used in determining the SLMCPR for the GE11, GE12, and GE13 fuel designs was of special concern since (1) the SLMCPR calculated with this new methodology increased from 1.07 for GE11 fuel to 1.09 for GE13 fuel even though an additional spacer had been added in the GE13 design for critical power ration (CPR) improvement and (2) the revised methodology had not been submitted for NRC review.

During this inspection, the team questioned GE staff regarding its response to the concerns raised by the previous NRC inspection team. The team learned through interviews and discussions with GE staff that, aside from submitting the revised fuel rod R-factor model, NEDC-32505-P, "R-Factor Calculation Method for GE11, GE12, and GE13 Fuel," GE had taken no action with regard to the concerns raised by the previous NRC team.

On March 27, 1996, GE advised NRC by telephone that its SLMCPR error issue was under review as a potential reportable concern (PRC). GE stated that the generic GE11 SLMCPR of 1.07 was not "bounding" for a licensee operating in a 2-year cycle with a large batch fraction (37%) of fresh GE11 fuel. GE attributed the SLMCPR error to an analytical procedure deficiency and claimed to be evaluating all plants as rapidly as possible to assure that the plant/cycle-specific SLMCPR value was bounded by the generic SLMCPR used as the licensing basis.

However, during its April 17, 1996, meeting with the NRC staff (several licensees were also present at the meeting), GE stated that the erroneous safety limit MCPR values were due to nonconservatism in the generic analysis methods and may not be restricted to GE11 fuel and large batch fractions.

The generic analysis for each fuel type (e.g., GE11, GE12, or GE13) is based on the analysis of a reference equilibrium core of the fuel type at the cycle exposure corresponding to the most limiting exposure state point. The reference core is designed with flat fuel rod bundle power distribution and core radial power distribution such that the generic SLMCPR value determined for the reference core was expected to bound all reload core applications. GE discovered that this was not valid and concluded that cycle-specific analyses of each reload core was necessary to confirm that the generic SLMCPR value remained bounding for each GE fueled BWR licensee. GE indicated that they had performed preliminary cycle-specific analyses and based on the results, had informed licensees and recommended corrective actions for 13 plants most likely to be impacted by the cycle-specific analyses.

Therefore, the primary focus of this inspection was the nonconservative under prediction of the GE11 SLMCPR. In Section 3.1.b.4 of this report the team traced the under prediction of SLMCPR to the miscalculation of the R-factors used in the engineering computer program GESAM for SLMCPR analysis.

b. <u>Observations and Findings</u>

b.1 Cycle-Specific Safety Limit MCPR Methodology

As part of the evaluation of the cycle-specific SLMCPR methodology, the team reviewed the recent application of this method to the Edwin I. Hatch unit 1 Cycle 17 SLMCPR reevaluation. The Hatch unit 1 Cycle 17 licensed safety limit MCPR is 1.07 and the initial GE screening evaluation based on the GESAM DIST analytical method also indicated a

value of 1.07, at the limiting peak-hot-excess (PHE) reactivity statepoint. The detailed cycle-specific GESAM Monte Carlo calculation, which was completed and verified on May 3, 1996, resulted in a SLMCPR of 1.06. The Hatch unit 1 Cycle 17 calculation, together with all the SLMCPR reevaluations, was documented in DRF J11-0286. The new cycle-specific methodology included an extensive design verification checklist for both the PANACEA design basis statepoint evaluation and the GESAM-OLCPOW, Monte Carlo analysis. The Hatch unit 1 Cycle 17 SLMCPR analysis was performed for the beginning-of-cycle (BOC), PHE reactivity, and end-of-cycle (EOC) statepoints. The analysis used the approved set of plant instrumentation and monitoring uncertainties.

The principal differences between GE's implementation of the NRC approved generic SLMCPR method (described in Amendment 22 of GESTAR) and the cycle-specific method, as described in the design record files (DRFs) are the determination of the core loading and the design basis reactor statepoint. In the generic methodology, a conservative bounding core is established by selecting a large, high power density, equilibrium core with a large fuel batch fraction. In the cycle-specific approach the actual core loading (e.g., Hatch unit 1 Cycle 17) is assumed, including the cycle-specific local fuel bundle exposures and fuel rod R-factors. In the generic method, the fuel bundle design (enrichments, spacers, etc.) and bundle exposures are selected to give the flattest (most conservative) R-factor distribution.

The SLMCPR is very sensitive to the number of fuel bundles close (to within ~0.10 ΔMCPR) to the MCPR limiting bundle, and the determination of the core design basis CPR distribution is a critical step in the SLMCPR analysis. The GE procedure (Y1003C04, "GETAB Safety Limit," Revision 2) used to implement the generic method recommends (but does not require) that the search for the design basis statepoint be performed by adjusting the rod pattern to maximize the power in an annular zone, under xenon-free conditions in order to maximize the control rod inventory and, consequently, the radius of the high powered annular zone. The team concluded that, by only recommending the method to search for the design basis statepoint instead of requiring the method to be used, GE's search method may not in all instances conform the NRC approved methods described in GETAB. For instance, through discussions with the GE staff, the team learned that the GE12 design basis power distribution included a centrally located cylindrical peak power region rather than an annular peak power zone.

The NRC approved methodology described in GETAB requires that the search for the design basis statepoint be performed by adjusting the rod pattern to maximize the power in an annular zone. Therefore, the team concluded that the input assumptions used in recent generic SLMCPR analysis of GE12 (and possibly other fuel designs) did not provide for a large annular peak power region placing a large fraction of fuel bundles near the limit.

The cycle-specific method makes no recommendation concerning the radial shape of the high powered region, however, all calculations-to-date (including Hatch unit 1 Cycle 17) have used a centrally located cylindrical region. In addition, the cycle-specific calculations have used equilibrium xenon conditions rather than the xenon-free conditions recommended in the generic method.

In both methods, the design basis statepoint is determined by performing a series of PANACEA (core analysis) calculations to obtain a bounding CPR distribution. In the cycle-specific method, the search is continued until the limiting bundle is at the operating limit MCPR and 10% of the fuel bundles are within 0.20 ΔCPR of the limiting bundle. If this is not possible, after an unspecified number of trials, the MCPR distribution is renormalized so that the peak bundle is at the operating limit (if necessary) and the current CPR distribution is taken to be bounding. In the case of Hatch unit 1 Cycle 17, the 10% search criteria was satisfied for the BOC and EOC statepoints, however, for the PHE reactivity statepoint only 6.4% of the fuel bundles were brought to within 0.20 ΔCPR of the limiting bundle and, therefore, the search criteria was not satisfied. The team concluded that this less conservative PHE statepoint was responsible, in part, for the reduced PHE SLMCPR of 1.03, relative to the 1.06 SLMCPR obtained for the BOC and EOC statepoints.

In recent applications of the generic method, bundle CPR distributions which are more conservative than the distributions resulting from the cycle-specific 10% search criteria have been used. For example, the GE9 D-lattice and C-lattice bounding CPR distributions included ~20% and ~15% respectively, of the fuel bundles within 0.20 ΔCPR of the limiting bundle. The GE11 SLMCPR analysis included ~20% of the fuel bundles within 0.20 ΔCPR of the limiting bundle.

It is important to compare these recent SLMCPR statepoint distributions with the design basis bundle power distribution provided in GETAB. Bundle power distributions are compared since bundle CPR distributions were not provided in GETAB. The GETAB statepoint was conservatively flat and included ~28% of the fuel bundles within 10% of the peak powered bundle. The GE9 design basis statepoint included ~8% of the fuel bundles within 10% of the limiting bundle and the GE11 statepoint included ~4% of the bundles within 10% of the limiting bundle. The team concluded that these comparisons show that the core statepoints used by GE in the recent SLMCPR calculations are not as conservative as that shown in the NRC approved GETAB statepoint methodology. Therefore, GE's failure to search for the design basis statepoint by maximizing the power in an annular zone constitutes Nonconformance 99900003/96-01-02.

In both the cycle-specific and generic methods, the search for the bounding CPR distribution is performed by varying the control rod pattern. In the cycle-specific method only the positions of the inserted rod sequence group (e.g., A2) are varied. However, in the generic method the search is not restricted to a specific rod group and results in a more conservative SLMCPR value.

Based on discussions with the GE staff and the review of the DRFs, the team found that there were certain features of the generic analysis selection of the bounding plant, core conditions, fuel bundles and control rod pattern that, when taken together, provide a high level of confidence that the SLMCPR is bounding when applied to a specific plant.

Additionally, the team identified concerns with several aspects of the cycle-specific method that may result in a non-conservative value for the SLMCPR and are, therefore, considered by the team to be weaknesses in the cycle-specific method. These weaknesses are summarized in the following:

(1) **Design Basis CPR Distribution**

The cycle-specific SLMCPR calculations only require 10% of the fuel bundles to be within 0.20 ΔCPR of the limiting bundle. The generic method, characterized by an annular region of limiting bundles, maintains ~20% of the fuel bundles within 0.20 ΔCPR of the limiting bundle. In addition, the recent design basis statepoints appear to be less conservative than the GETAB statepoint. Since the SLMCPR is very sensitive to the number of fuel bundles close to the limiting bundle, these differences are expected to have a significant effect on the SLMCPR.

(2) **Determination of the Limiting Control Rod Pattern**

The cycle-specific method determines the limiting control rod pattern by varying only the inserted control rod sequence. In the generic method, no constraint is placed on the selection of the control rods and a more conservative SLMCPR results.

(3) **Termination of the Search for Maximum Safety Limit MCPR**

The procedure for terminating the search for the maximum SLMCPR in the cycle-specific method allows the search to be terminated without satisfying the intended search criteria. Consequently, this procedure does not ensure that a bounding SLMCPR is determined. The team noted that in the case the search procedure does not ensure a bounding SLMCPR, a conservative addition to the SLMCPR may be required.

(4) **Xenon-Free Design Basis CPR Distribution**

In order to maximize the control rod inventory and expand the search for the maximum SLMCPR, the generic method assumes the design basis statepoint is xenon-free. The cycle-specific search for the bounding SLMCPR is more limited in that equilibrium xenon conditions are assumed.

The team considered these issues to be a weakness in the GE's cycle-specific SLMCPR procedures to ensure that a bounding SLMCPR is determined, as required by the NRC approved methodology described in GESTAR.

b.2 Underestimate of GE11 Safety Limit MCPR

The SLMCPR is determined by (1) the GEXL, plant instrumentation and core monitoring uncertainties, (2) the design basis bundle-wise CPR distribution, and (3) the local bundle R-factor distribution. The DRFs for the generic GE9 and GE11 SLMCPR analyses, and the more recent cycle-specific SLMCPR evaluation for Hatch unit 1 Cycle 17 were reviewed to determine the cause of the underestimate of the GE11 SLMCPR. The DRF documentation indicated that the instrumentation and monitoring uncertainties used in both the GE11 and GE9 SLMCPR analyses were identical, and that the GEXL uncertainty was slightly higher for GE11 (3.1 vs. 3.0%). The uncertainties used were consistent with NRC approved values.

The design basis bundle-wise CPR distributions for the GE9, GE11 and Hatch unit 1 Cycle 17 SLMCPR analyses were also compared. The GE11 CPR distribution was comparable or flatter (more conservative) than the GE9 and Hatch unit 1 Cycle 17 distributions, with more than 20% of the fuel bundles within 0.20 ΔCPR of the limiting bundle.

Both the GE11 and Hatch unit 1 Cycle 17, GE12 fuel designs include part length rods and the R-factors are calculated with the new R-factor model described in NEDC-32505-P **[procedure no. corrected by staff]**, described in Section 3.1.b.3 of this report. A comparison of the GE11 and Hatch unit 1 Cycle 17 GE12 pin-wise R-factor distributions indicated that the GE11 R-factor distribution was highly peaked and nonconservative compared to the relatively flat Hatch unit 1 Cycle 17 R-factor distributions. The pin-wise GE11 D-lattice R-factors ranged from 0.62 to 1.01, while the range of the typical Hatch unit 1 Cycle 17 GE12 D-lattice R-factors only varied from 1.025 to 0.89.

In view of the agreement and/or conservatism of the uncertainties and the CPR distribution, the team concluded that the use of the nonconservatively peaked R-factors was responsible for the under prediction of the GE11 SLMCPR. In addition, the team noted that the large variation observed in the GE11 R-factor distribution (0.62 to 1.01) typically only occurs at BOC and that BOC fuel bundles may have been used in the GE11 SLMCPR analysis. In order to understand the source of the incorrect R-factors (e.g., use of BOC fuel bundles, changes in the definition/application of the R-factor model) and completely define the impact, a detailed description of the determination of the GE11 R-factors is required. The team considered the lack of a detailed description of the source of the incorrect R-factors and GE's failure to perform a root-cause analysis to be a weakness in GE's response to this issue; as raised by the previous NRC inspection team and documented in Inspection Report 99900003/95-01.

The bundle R-factors for the GE11 fuel design were calculated by NEP's Nuclear Fuel Design Group and transmitted by letter to the group performing the SLMCPR analysis. While the transmittal stated that the fuel bundles were especially designed to provide the flattest R-factor distributions, no verification of the R-factor data was indicated. The GE11 DRF included a design verification checklist which confirmed that bounding R-factors were used in the SLMCPR determination.

Since the R-factors were actually not bounding, the team concluded that the design verification of the R-factor data used in the GE11 SLMCPR analysis was not adequate and the design verification of the R-factor data used in the GE11 SLMCPR analysis failed to identify this deficiency. Therefore, GE's failure to adequately verify the R-factor data constitutes Nonconformance 99900003/96-01-03.

b.3 Revised R-Factor Model

The GE11 fuel design included part length rods and required the development of the new calculational model and procedure for determining the bundle R-factors. As noted in Section 3.1.a of this report, this new R-factor definition and application were of concern to the previous NRC inspection team and resulted in a request for a detailed description of the new R-factor methodology. In response to the previous NRC inspection (Inspection Report 99900003/95-01, March 5, 1996) GE provided NRC a description of the revised fuel rod R-factor model (NEDC-32505-P, "R-Factor Calculation Method for GE11, GE12, and GE13 Fuel"). This model includes several new features including (1) a change in the definition of the R-factor model in which the effects of adjacent rods are based on the axially integrated rod power, rather than the local axially-dependent rod power, (2) the introduction of "correction factors" in the definition of the R-factor for the GE11 and GE13 fuel designs, and (3) a change in the weighting factors for adjacent fuel rods.

On the basis of its review of NEDC-32505-P and discussions which the GE staff, the team concluded that these changes are not simply changes in GEXL input but rather constitute basic changes in the GEXL/SLMCPR methodology that require NRC review. Also on the basis of its review of this method and the GE11 R-factors, it appeared to the team that the new R-factor methodology was either not applied or applied incorrectly in the determination of the GE11 SLMCPR.

b.4 Nonconservative Safety Limit MCPR

Because of the complex and sensitive dependence of the SLMCPR on the bundle-wise CPR and the rod-wise R-factor distributions, a definitive observation of a nonconservative SLMCPR generally requires a complete engineering computer program GESAM/OLCPOW Monte Carlo reevaluation. GESTAR requires that the SLMCPR be reevaluated for new fuel bundle designs which involve changes to the enrichment or spacer designs.

However, the calculations involved are extremely long-running and GE typically determines the SLMCPR for each fuel type (e.g., GE11) but does not reevaluate the SLMCPR for subsequent cycle-specific core/bundle designs. Consequently, the nonconservative SLMCPR was not identified until a complete SLMCPR reevaluation was performed during the application of the cycle-specific methodology to a mixed-core reload.

During the initial GE application of the cycle-specific methodology to Grand Gulf Cycle 9, the cycle-specific SLMCPR was calculated to be greater than the generic maximum SLMCPR. Since the Grand Gulf **[plant reference corrected by staff]** core included both GE and Siemens Power Corporation fuel bundles, the cycle-specific/generic SLMCPR comparisons were inconclusive. In order to completely understand this difference, GE immediately performed a cycle-specific analysis for River Bend Cycle 7. This analysis also resulted in cycle-specific values that exceed the generic GE11 SLMCPR, and show that the generic analysis was not bounding as assumed.

The GE staff stated that this analysis was completed at the end of February 1996, and that this was GE's first indication that the GE11 SLMCPR analysis was not bounding. However, GE's preliminary safety concern (PSC) 9608, to review the potential nonconservatism in the SLMCPR to determine if a potential reportable concern (PRC) evaluation should be initiated was not started until March 14, 1996. (This issue is discussed further in Section 3.3 of this report.)

The team concluded that in addition to the fuel design SLMCPR reevaluation, another opportunity existed for GE to identify the nonconservative SLMCPR. In certain cases, the relative magnitudes of the SLMCPR may be determined by comparing the input distributions. For example, if the R-factor distribution for a given bundle is always larger (i.e., the R-factor for each rod is higher), then the SLMCPR for this bundle design will be larger. Recognizing that the R-factors used in the GE11 SLMCPR analysis were not bounding when compared to many other fuel bundles, a comparison of available R-factor distributions would have indicated that the GE11 SLMCPR was nonconservative. The team concluded that this comparison was apparently not made by GE because the GE11 R-factors were assumed to be bounding.

The SLMCPR/GESAM program for the cycle-specific SLMCPR analyses is a recently developed program based on the OLCPOW program referenced in GESTAR. In response to the team's request, during this inspection, to produce benchmark results showing the validation of GESAM versus OLCPOW, GE submitted a letter to NRC staff after the inspection, RJR-96-065, June 12, 1996, attesting that the two codes are equivalent. During the PRC (10 CFR Part 21) evaluations, GE relied on procedure restrictions (a check list) and independent design verification for quality assurance of the new methods. The letter indicates that the restrictions and design verification requirements will be reduced after the ongoing qualification of GESAM in accordance with the QA program.

The procedure restrictions and design verification requirements alluded to by GE were reviewed during this inspection and appeared to be reasonable for the interim. However, the team identified some calculation procedure weaknesses that are of concern. In addition, QA of the SLMCPR methods for GESAM calculations had not been performed in accordance with the NRC approved QA topical and the team did not find any evidence that the GESAM calculation results had been validated.

b.5 Quality Assurance

As a result of its review of the generic and cycle-specific determinations of the SLMCPR, as documented in the DRFs and supporting procedures, the team identified several concerns associated with the implementation of the GE QA topical. These concerns are (1) the calculation/data verification performed for the GE11 SLMCPR analysis (2) the GE11 and subsequent reload design reviews, and (3) the generic method used to perform the SLMCPR analysis.

In addition, the team concluded that both the GE11 SLMCPR design review and the subsequent cycle-specific reload core design reviews failed to recognize the need to reconfirm that the GE11 SLMCPR R-factors remain bounding. Also, recognizing that the GE11 and GE13 design basis core power shapes are similar, the increase of the SLMCPR from 1.07 for GE11 to 1.09 for GE13 should have shown GE the need to review both the GE11 and GE13 R-factors.

The generic method used to determine the SLMCPR is described in the GE procedure Y1003C04, "GETAB Safety Limit," Revision 2. This procedure was written in 1977 and does not correspond to present GE practice. For example, the generic procedure recommends that the design basis statepoint should include an annular region of CPR limiting bundles under no-xenon conditions, while the current practice is to calculate the design basis statepoint for a centrally located cylindrical region of CPR limiting bundles under equilibrium xenon conditions. While this procedure was identified for review and updating on March 19, 1996, the team concluded that the adequacy of the periodic review and updating of these SLMCPR procedures was a weakness.

According to GE QA staff interviewed by the team, no deviation from a procedure involving safety related analysis was permitted except to implement a deviation by means of a design review. This step was followed by GE and was documented in an April 15, 1996, memo, DRF-J11-02861, "SLMCPR Calculation Process Design Review Report." The memo documents the approach that will be used for performing cycle-specific analyses to determine the SLMCPR. It identifies those areas in the current procedure Y1003C04 from which a deviation will be made. The team concluded that GE conformed to their QA procedures with respect to initiating a deviation from an existing safety related procedure.

The team reviewed the method of verifying the cycle-specific analyses contained in DRF-J11-02861. This reviewed showeu that the verifier limited the verification to a check of the checklist prepared by the Responsible Engineer for the analyses. Although no restrictions are placed on the verifiers activities, the team's review of the calculational files showed that the independent verifier did not deviate from the scope of the verification or the method of verification specified by the Responsible Engineer. The team concluded that this lack of independent activity by the verifier was a weakness in GE's verification process.

In the generic method, the SLMCPR is determined by a Monte Carlo calculation performed using the OLCPOW option of the GESAM program. The GESAM/OLCPOW code is not a Level-2 program and, therefore, requires independent verification when applied in the SLMCPR analysis. This verification is performed using the DIST analytical method.

Based on a review of the GESAM/OLCPOW and DIST calculations and discussions with the GE staff, the team concluded that the DIST method is not sufficiently accurate to provide the required independent verification of the SLMCPR calculation. The team, therefore, concluded that the verification of the GESAM/OLCPOW program was not adequate.

b.6 **Mixed Core Analyses**

In the case of a mixed core including both GE and Siemens fuel bundles, a new GEXL correlation is determined for the Siemens fuel. The new correlation is based on CPR data calculated (by the licensee) using the Siemens CPR correlation rather than actual measured data. The calculated data is fit by using the GEXL correlation and adjusting the definition of the R-factor to obtain optimum agreement. The uncertainty in the new GEXL correlation, for application to Siemens fuel, is determined by a statistical (sum-of-squares) combination of (1) a conservative estimate of the Siemens CPR correlation uncertainty and (2) the uncertainty in the fit of the new GEXL correlation to the calculated data. This statistical combination of the uncertainties assumes that the fitting error of the Siemens correlation to the experimental data and the fitting error of the new GEXL correlation to the Siemens correlation are independent. However, the team found that GE had not documented a justification for this assumption nor was one provided to the team.

The team concluded that mixed cores had no direct impact on the input nonconservatisms previously discussed or on the failure to reconfirm the acceptability of fuel type design changes. However, the team did note that GE identified an additional error involving a failure to properly count the number of fuel pins that represent 0.1% of the core when mixed fuel bundles with different fuel rod arrays coexist.

b.7 3-D MONICORE System

The SLMCPR provides the critical power margin required to account for the uncertainty in the on-site core surveillance predictions and the uncertainty in the GEXL correlation. The SLMCPR is determined by a Monte Carlo uncertainty-propagation simulation in which the core surveillance instrumentation and input data are varied randomly, based on their expected uncertainties. The core surveillance at BWR plants is generally performed with the advanced 3-D MONICORE system, although one plant is still using the older P-1 core performance algorithm. While there are substantial differences between these two core surveillance methods, the SLMCPR calculation is currently performed using the older P-1 method.

In response to the inspection team's concerns raised during the previous August 1995 inspection, GE stated that the determination of the SLMCPR is not affected by these 3-D MONICORE/P-1 differences, and the current SLMCPR calculation is applicable to both plants using the 3-D MONICORE or the P-1 core surveillance method. However, in view of the several recent concerns associated with the SLMCPR, the team concluded that the inconsistency between the actual 3-D MONICORE plant monitoring and the assumed P-1 monitoring may result in a nonconservative determination of the SLMCPR. The team, therefore, considered this to be a weakness in the GE method for determining the safety limit MCPR.

b.8 Safety Limit MCPR Error

Prior to this inspection of GE, GE attributed the erroneous safety limits MCPR for several plants to large batch fractions of GE11 fuel in core reloads designed for 24 month operating cycles. The generic analyses for each fuel type is based on the analysis of a reference equilibrium core comprised only of the fuel type being evaluated. GESTAR approved SLMCPR methods require that the reference core be designed with flat core radial power distribution and flat rod bundle power distribution so that a maximum number of fuel bundles/rods can be placed on limits with a selected control blade pattern. However the team could not confirm that this procedure was followed by GE.

GE expected that the SLMCPR determined for the reference core by analyses at the most limiting exposure state point would be conservative with respect to any actual application. However, GE continued to change the rod powers and enrichment and R-factor distributions of the approved fuel type without further analyses and without confirming that the generic value of SLMCPR remained bounding. Cores consisting of mixed 8x8 and 9x9 fuel bundles (fewer rods in the core) and designed for flatter power distributions also contributed to cycle-specific non-conservative changes in the SLMCPR (i.e., lower number of failed rods needed to reach the 0.1% allowable limit).

GESTAR and similar Amendment 22 compliance evaluation reports for other GE fuel types clearly identify SLMCPR sensitivity to fuel bundle design parameters affecting the bundle R-factor distribution and the core radial power distribution. The team's evaluation of the GE11 reference design used for SLMCPR determinations showed that the bundle R-factor distributions were much more peaked than typical reference designs and resulted in a non-conservative generic SLMCPR determination. Subsequent design changes to fuel enrichment level and distribution produced flatter bundle R-factor distributions to degrade the SLMCPR in subsequent cycle-specific designs.

Section 1.1.5.A of Amendment 22 of GESTAR (NEDE-24011-P-A), states that the safety limit MCPR shall be recalculated following the steps in 1.1.5.B or reconfirmed when a new fuel design or new critical power correlation is introduced. Section 1.1.5.B describes the reference core conditions and input assumptions to be used when performing the safety limit MCPR calculations. Section 1.1.7.C describes the criteria for establishing new critical power correlation and refers to GETAB to determine coefficients in the correlation.

However, GE failed to recalculate or reconfirm the applicability of the generically determined SLMCPR to these new fuel bundle designs as required by NRC approved methodology in GESTAR. For instance, GE9 fueled cores were designed with core radial power distributions flatter than that of the reference core without confirming the applicability of the generic SLMCPR. Therefore, GE's failure to recalculate or reconfirm the applicability of the generically determined SLMCPR to these new fuel bundle designs as required by NRC approved methods in GESTAR constitutes Nonconformance 99900003/96-01-01.

c. <u>Conclusions</u>

The team found that the defect in GE's generic SLMCPR determination related to the selection of a reference fuel/core design with input condition power distribution that did not satisfy the objective of placing the maximum number of fuel pins near peak power as required by the NRC approved GETAB statistical analysis procedure. Specifically, the team concluded that the input assumptions used in recent generic SLMCPR analysis did not provide for a large annular peak power region placing a large fraction of fuel bundles near the limit as required by the NRC approved methods in GETAB. (See Nonconformance 99900003/96-01-02 described in Section 3.1.b.1 of this report.)

It appears that the cycle-specific methodology envisioned by GE is a means of eliminating or reducing conservatism employed in the generic analyses in order to compensate for the more limiting SLMCPR values in recent fuel designs. It turns out that GE current methods did not preclude cycle-specific analyses, and in fact, the methods actually required that the core and fuel designs be checked prior to the start of the cycle to be sure that previous generic fuel type SLMCPR analyses

were bounding from the standpoint of core power distribution of fuel bundle design R-factors. In addition, GE's failure to comply with analysis procedures referenced in plant technical specifications appears to place these licensees in nonconformance with their technical specifications.

The team identified the following concerns with GE's cycle-specific SLMCPR method that may result in a nonconservative SLMCPR value: (1) the cycle-specific SLMCPR calculations only require 10% of the fuel bundles to be within 0.20 ΔCPR of the limiting bundle versus the generic method, characterized by an annular region of limiting bundles, that maintains ~20% of the fuel bundles within 0.20 ΔCPR of the limiting bundle; (2) the cycle-specific method determines the limiting control rod pattern by varying only the inserted control rod sequence versus the generic method where no constraint is placed on the selection of the control rods, therefore, a more conservative SLMCPR results; (3) the procedure for terminating the search for the maximum SLMCPR in the cycle-specific method allows the search to be terminated without satisfying the intended search criteria; and (4) in order to maximize the control rod inventory and expand the search for the maximum SLMCPR, the generic method assumes the design basis statepoint is xenon-free where as the cycle-specific search for the bounding SLMCPR is more limited in that equilibrium xenon conditions are assumed.

The team concluded that GE's changes in the R-factor calculation method are not simply changes in GEXL input but rather constitute basic changes in the GEXL/SLMCPR methodology that require NRC review. The team also concluded that the new R-factor methodology was either not applied or applied incorrectly in the determination of the GE11 SLMCPR. The team concluded that the R-factor data used in the GE11 SLMCPR analysis was not adequately verified since the R-factors were actually not bounding and the design verification of the R-factor data used in the GE11 SLMCPR analysis failed to identify this deficiency. (See Nonconformance 99900003/96-01-03 described in Section 3.1.b.2 of this report.)

GE assumed the generic methodology applied to new core designs without checking the applicability of the present methodology to the new core designs. At the time the supplemental reload licensing report is prepared for a particular plant and cycle, GE failed to confirm that the generic bounding SLMCPR analysis did indeed bound the current loading pattern and the current bundle designs. Instead, GE assumed that the bounding analysis was valid. Specifically, GE's failure to recalculate or reconfirm the applicability of the generically determined SLMCPR to new fuel bundle designs was evident in the DRF for the supplemental reload design report. For instance, in the DRF for River Bend Cycle 7 the SLMCPR limits were listed by fuel assembly type but the DRF did not contain a statement that the bundle specific designs had been checked to confirm that the product line bounding analysis was valid. Nor was any comment made as to whether the bounding analysis was valid for the planned core loading pattern.

GE's failure to recalculate or reconfirm the applicability of the generically determined SLMCPR to these new fuel bundle designs as required by the NRC approved methods in GESTAR resulted in eight licensee reactor cores loaded with GE11 fuel and three reactor cores loaded with GE9 fuel having SLMCPR limits higher than the licensed values. (See Nonconformance 99900003/96-01-01 described in Section 3.1.b.8 of this report.)

3.2 Low Density Pellets (LDPs)

a. Inspection Scope

In February 1996, GE employees found that the as-fabricated fuel pellet density of certain pellets was out-of-specification. These out-of-specification fuel pellets were LDPs and some had been loaded into fuel rods and shipped to various reactor sites. GE's initial assessment determined that the LDP problem was due to incomplete blending of a lubricant called "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** with UO_2 powder. "Mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** is a powder used as a lubricant during the pellet pressing operation.

Since the "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** process was first introduced in late 1993, GE traced the production history and determined that the LDP problem could cover the period of late 1993 to February 1996. Several NRC licensees plants including some foreign reactors were involved. Some of the involved fuel was either recalled or corrected on site. However, some involved fuel had been loaded into reactors for irradiation. In addition, GE indicated that several fuel designs were also involved, however, no gadolinia pellets were involved in this LDP problem because gadolinia pellets do not use the "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** process.

Since the LDPs could affect the fuel performance and overall analyses, the team evaluated GE's safety assessment of LDP problem and the production of uranium fuel pellets from powder formation to pellet control and distribution for fuel rod loading.

b. Observations and Findings

b.1 Characterization

GE's initial characterization of the low density pellet (LDP) problem was summarized a letter to NRC, "GE Fuel Pellet Density Report," April 15, 1996. As a result of the team's assessment of the initial characterization, GE performed an additional characterization that was provided in a letter to NRC, "Low Density Fuel Pellets," June 25, 1996. The purpose of GE's characterization of the LDP problem were two fold:

- to define the physical characteristics of the LDPs such that these characteristics can be included in conservative bounding analyses that demonstrate that the thermal-mechanical specified acceptable fuel design limits (SAFDLs) are not exceeded with the introduction of the LDPs in operating reactors, and
- to identify the root cause of the problem.

The former will be discussed in this section while the root cause analysis will be discussed later in this report. The major purpose of this effort was to identify those characteristics of the LDPs that are different from the standard fabricated pellet population and that may impact the thermal-mechanical analyses. The major characteristics that can impact the thermal-mechanical analyses are pellet density and densification. This section will be subdivided into GE's characterization of the pellet density and densification behavior of the LDPs. The first part of both subsections will discuss GE's initial characterization effort and the background for the team's conclusion that additional characterization was necessary. The second part of both subsections will discuss the additional characterization performed by GE and the team's evaluation of this additional characterization.

b.1.1 Pellet Density

One of the problems in characterizing the pellet density of the LDPs is that the low density pellets showed up only sporadically in the fabrication campaigns since the introduction of a new lubricant in late 1993 for pressing the powder into pellets. GE's preliminary estimate is that less than 0.3% of the ~400,000 rods produced between late 1993 and January of 1996 are affected (out of 179,376 scanning traces of individual rods examined, 515 rod scanning traces showed the signature of LDPs) and that less than 15% of the pellets within an affected rod are actually below the specification for pellet density and, therefore, are characterized as LDPs.

GE attempted to reproduce the LDP problem by taking a can of UO_2 powder with the new lubricant and pressing and sintering the powder into pellets without mixing the powder. The pellets from this fabrication effort were a little low in density from the nominal density but were within GE specifications. GE had to add a significantly larger amount of lubricant than normally used before they could reproduce the LDPs. The team reviewed this effort and concluded that another parameter must be influencing the occurrence of the LDPs in addition to insufficient powder mixing. This additional parameter may be powder activity which is a measure of how easily the powder can be sintered. For example, a high activity powder sinters very quickly while a low activity powder sinters more slowly. In the case of LDPs, a high activity

powder will sinter before the lubricant can escape as a gas and the gas is trapped in the pellet creating the LDPs. With this scenario two factors must be present to create the LDPs: (1) insufficient powder mixing and (2) high activity powder.

In order to characterize the pellet density of LDPs, GE initially used only one tray of recently fabricated fuel pellets that exhibited pellets with low density characteristics (some pellets in the tray showed slight bulging at the ends). It should be noted that there are approximately 2000 pellets in a tray and a tray makes 5 to 6 fuel rods. GE measured the pellet density distribution of this tray of suspect pellets using a gamma densitometer to obtain a distribution of pellet densities in this tray. GE also used the gamma densitometer to measure the density distribution of one recently fabricated tray without low density pellets. The tray with low density pellets had approximately 13% of the pellet population below the GE specification for pellet density.

There is a problem with the gamma densitometer measurement of pellet density in that the method has a significant bias in measured density (measured density is biased low) at low pellet densities and also the accuracy of the measurement is unknown at the low densities. Because of the suspected bias in the gamma densitometer measurement at low densities, GE has taken three low density pellets (less than 90% theoretical density (TD) based on the gamma densitometer measurements) at different densities and performed a more accurate measurement of pellet density using the vacuum impregnation/water immersion measurement technique (this technique will be referred to as the vacuum impregnation measurement). The vacuum impregnation measurement technique is considered to be one of the more accurate techniques for measuring fuel densities to within typically 0.2% TD. These three vacuum impregnation measurements were then plotted against the gamma densitometer measurements for these same pellets and GE used this plot to estimate the true densities of all the gamma densitometer measurements made on the LDPs from the one tray. Based on these measurements GE initially determined that the lowest gamma densitometer measurement of density from the tray examined was approximately 87% TD and the true density to be approximately 91% TD based on the calibration to the three vacuum impregnation measurements. Based on these initial measurements GE has estimated the effect of the local pellet density on SAFDLs using a density of 91% TD as noted below in Section 3.2.b.2 of this report.

The team questioned GE on whether pellet density measurements using the gamma densitometer and/or the more accurate vacuum impregnation technique were performed on pellets from other trays or fuel rods with suspected low density pellets. GE stated that there were a few LDPs from other sources but the large majority of the LDPs examined to date were from the one tray. The team noted

that the low density pellet distribution is based on the examination of only one tray out of over 30,000 to 40,000 trays fabricated during the time of the suspected LDP problem and several hundred of these trays may have LDPs. Therefore, it is very difficult to determine if the one tray examined to date and its associated density distribution is representative of the trays with LDPs fabricated since late 1993.

Also, the team's examination of the three LDPs that were measured using the more accurate vacuum impregnation measurement of density indicates that the gamma densitometer measurement may have an uncertainty of 1% TD or greater but the accuracy of this method could not be determined for LDPs based on only the three GE measurements.

The team concluded that GE did not have an adequate estimate of the low density pellet distribution to be able to bound the lowest individual pellet densities fabricated since late 1993. Therefore, the team requested that GE examine other LDPs from other fuel rod/trays fabricated during the time period since late 1993 and measure the densities using both the gamma densitometer and the vacuum impregnation techniques on at least 6 additional LDPs (the required number of vacuum impregnation measurements is much lower because they are only used to estimate the accuracy of the gamma densitometer measurement).

As a result of the team's request, GE examined the densities of additional LDPs from five other trays to (1) determine the accuracy of the gamma densitometer measurements by performing additional vacuum impregnation tests on the LDPs, and (2) verify that a density of 91% TD is a reasonable lower bound on the LDPs. GE's further characterization of the LDPs is summarized in a letter to the NRC, "Low Density Fuel Pellets," June 25, 1996. The results of this further characterization demonstrates that the 2 sigma uncertainty in the gamma densitometer measurement at a density of 87 to 88% TD is approximately 1.3% TD. GE's further characterization consisted of selecting 8 LDPs from 5 different trays. The purpose of GE selecting the LDPs was to find those pellets in the trays with the lowest densities and all selected pellets had to have actual densities below 94% TD. From the 40 LDPs selected, only one pellet had a density as low as the lowest density found in their initial examination of all the pellets from one tray.

The team concluded that GE's further characterization of the LDP problem was adequate and demonstrated that GE's assumption of 91% TD provides a reasonable lower bound of density for the LDPs for use in thermal-mechanical analyses.

b.1.2 Pellet Densification

The team questioned GE on whether the pellet densification characteristics of the low density pellets had been examined in the initial GE characterization because, in general, lower density pellets have larger pellet densification than higher density pellets. In addition, larger pellet densification can adversely affect the fuel melting and LOCA analyses. The team also questioned GE on what values of densification were used as input to the GE LDP analyses of the SAFDLs. GE stated that they had performed pellet densification tests on the LDPs and the measured densification values for these pellets were within GE specifications for pellet densification. GE also stated that the densification values for standard pellets were used for the thermal-mechanical analyses of the LDP problem.

The team examined the initial densification data and found that only 8 measurements were made on the LDPs. The mean densification for these 8 LDPs was twice the amount of the mean densification of the GE standard density pellets.

The team also examined the GE specifications on pellet densification which states, "Mean Pellet Densification - The upper 95% confidence limit on the mean density increase for any pellet type in a project shall not exceed (GE densification limit is proprietary)" and for "Individual Pellet Densification - The upper 95/95 tolerance limit on the individual density increase in a project shall not exceed (GE densification limit is proprietary)."

The team was concerned that the upper 95% confidence limit on the mean density increase had been exceeded by the low density pellets contrary to the GE conclusions. Therefore, the team examined the GE definition of "pellet type" which is stated as "a population of pellets obtained from a single UO_2 powder source that has been processed under the same range of operational conditions and which exhibits a consistent and predictable densification behavior." The team concluded that the LDPs were of a different pellet type than the standard density GE pellets because the LDPs were processed under different or non-standard conditions (i.e., insufficient mixing of the powder) and their densification behavior was inconsistent with the standard density pellets (i.e., twice the densification of the standard pellets) which is a statistically significant variation of the mean compared to the standard density pellets of this project. If the LDPs are considered to be of a different pellet type then the mean densification of the LDP type exceeds the upper 95% confidence limit specified by GE on mean density increase for a pellet type within a project. GE disagreed with the teams interpretation of the LDPs being a different pellet type because both the LDPs and standard density pellets were made during the same fabrication campaign for a given project.

The team was less concerned with whether the densification of the LDPs exceeded the GE specifications because the LDPs already exceed GE specifications on density. The team was more concerned about whether the LDPs have been sufficiently characterized and the assumptions used in the LDP analyses sufficiently bound the LDP characteristics to provide assurance that the LDPs do not exceed thermal-mechanical SAFDLs.

The team concluded that there is most likely a significant difference between the densification characteristics of the LDP's and the standard density GE pellet but that there has not been adequate characterization of the LDPs population by GE to determine the densification characteristics of the LDPs.

The team requested that further densification tests were needed for the LDPs in order to determine appropriately bounding values for input to the thermal-mechanical analyses. GE agreed to obtain further densification data on the LDPs by taking additional density and densification data on LDPs from several fuel rods or trays with LDPs.

As noted above, GE has selected 8 LDPs each from 5 different trays for a total of 40 additional LDPs. GE performed densification tests on each of these 40 LDPs and found the mean densification to be approximately 2.5 times the densification of the standard GE pellets and the upper 95 percentile densification was also greater than observed for standard GE pellets.

The team concluded that GE's further characterization of the densification properties of LDPs was adequate for use in evaluating the impact of LDPs on thermal-mechanical performance.

b.2 Thermal-Mechanical Analyses

GE's initial thermal-mechanical analyses presented in a letter to NRC, "GE Fuel Pellet Density Report," April 15, 1996, made some assumptions about the pellet density and densification properties of the LDPs based on their characterization of the LDP problem. These assumptions were used by GE to perform thermal-mechanical analyses to demonstrate that the LDP problem does not exceed their SAFDLs for normal operation, anticipated operational occurrences (AOOs), and accidents.

GE identified six analyses and SAFDLs that may be influenced by changes in the fuel pellet density and these are: (1) fuel melting, (2) fuel rod internal pressure, (3) cladding strain, (4) thermal-hydraulic performance, (5) rod drop accident, and (6) loss of coolant accidents (LOCAs). These analyses are either dependent on local fuel properties (local axial location in the rod) or rod-average fuel properties. This was important for modeling the GE LDP problem because it is a localized problem in a fuel rod where less than 15% of the pellets in an affected rod are LDPs. Those analyses that are dependent on local fuel properties are fuel melting, cladding strain, and LOCA. Those analyses

that are dependent on average fuel properties are fuel rod internal pressures, thermal-hydraulic performance, and rod drop accident. As a result of the team's evaluation of the analyses in GE's April 15, 1996, letter to NRC, GE has revised the three analyses that are dependent on local LDP properties based on further GE characterization of the densification properties of the LDPs and these revised analyses were summarized in GE's June 25, 1996, letter to NRC.

For those analyses that are dependent on local fuel properties GE assumed that the minimum pellet density observed in their initial characterization of the LDP was the density of the peak power pellet, and the average pellet density of the rod is assumed to be the lowest permitted by GE fuel weight tolerances. For those analyses that are dependent on rod average fuel properties the average pellet density is assumed to be the lowest permitted by GE fuel weight tolerances. GE correspondingly assumed a lower local linear heat generation rate (LHGR) and rod-average LHGR due to the lower fissile content resulting from the lower local and average fuel densities. The remaining input, other than local and rod-average pellet density and local LHGR, for these analyses remained the same as those previously approved in GESTR-Mechanical (NEDE-24011-P) and GESTR-LOCA (NEDE-23785-1-P-A).

The team concluded that the GE assumption of average fuel rod density being the lowest permitted by the fuel weight specifications is conservative. However, as noted above in the Section 3.2.b.1 of this report, the team concluded that GE did not initially characterize the LDPs adequately to conclude that the lowest density observed and assumed in the local fuel analyses of the peak power pellet bounded the population of LDPs fabricated by GE. The characterization was inadequate because GE only selected one small population of LDPs to characterize the problem rather than sampling from the broader population of LDPs fabricated. As a result, GE performed additional characterization of the LDPs that demonstrated that the 91% TD assumed by GE is a reasonable estimate of the lower bound density of the LDPs.

The team also questioned GE on the assumptions used for pellet densification of the LDPs at the peak power pellet location because, in general, lower fuel densities result in higher pellet densification. GE stated that for the initial analysis of the LDP problem GE used the same densification as for their standard fuel pellets. As noted in the Section 3.2.b.1 of this report, the team examined the small amount of GE densification data on the LDPs and found the nominal densification to be twice that of GE standard pellets. The increased pellet densification of the LDPs is of concern because this can increase local fuel temperatures. The team concluded that GE initial characterization efforts had not adequately characterized the pellet densification of the LDPs. The team requested further characterization of the densification properties of the LDPs and that these properties be included in those thermal-mechanical analyses that are dependent on local fuel properties, such as fuel melting, cladding strain and LOCA analyses, in order to demonstrate that the respective SAFDLs are not exceeded.

As previously stated, GE performed the additional characterization of the LDPs including the densification properties of the LDPs. These properties were used by GE in their revised analyses of fuel melting, cladding strain, and LOCA, as presented in GE's letter to NRC dated June 25, 1996.

b.3 GE Analyses

GE issued an initial report in its letter to NRC dated April 15, 1996, that summarized analyses that assessed the impact of the LDP problem on the following six fuel performance SAFDLs: (1) fuel melting, (2) fuel rod internal pressure, (3) cladding strain, (4) thermal-hydraulic performance, (5) rod drop accident, and (6) LOCA identified in Section 4.2 of the NRC SRP (NUREG-0800). GE performed revised analyses of fuel melting, cladding strain, and LOCA as summarized in its June 25, 1996, letter to the NRC. GE concluded that the other SAFDLs identified in Section 4.2 of the NRC SRP such as cladding collapse, cladding fretting, axial growth, corrosion/hydriding, rod bowing, and seismic loadings are not affected by the LDP problem. The team concurs that only the identified six SAFDLs are affected by the LDP problem.

It should be noted that cladding collapse might be expected to be impacted by the presence of LDPs because pellet densification was one of the contributing factors for the observed cladding collapse in PWR rods in the early 1970s. However, the GE cladding collapse analysis is not dependent on pellet densification because GE conservatively assumes the axial gap in the fuel column is of sufficient size to allow the cladding to collapse into the gap, i.e., the fuel pellet column offers no support to the cladding to prevent collapse. Therefore, an increase in pellet densification and subsequent axial fuel column gap size does not affect the cladding collapse calculation.

A summary of the initial GE analyses of the identified six SAFDLs from its April 15, and June 25, 1996 letters to NRC plus the team's evaluation of both analyses is provided in the following.

(1) Fuel Melting

GE presented a summary of the initial results in its April 15, 1996, letter to NRC of their GESTR-Mechanical analyses for the GE8B/GE9B/GE10/GE11/GE13 fuel rod designs to evaluate the potential for fuel centerline melting during an AOO event. The GE analyses used standard design and conservative licensing assumptions with the exceptions that (1) the fuel average density was assumed to be the lowest possible permitted by fuel weight tolerances on the rod, and (2) the peak power pellet was assumed to have the minimum pellet density found by GE in the characterization of the LDP problem. The lower fuel densities assumed in this analysis result in lower fuel thermal conductivity and higher fuel temperatures and fission gas release (FGR) in the

fuel rod on average and also higher temperatures in the peak power pellet and greater chance for fuel melting. The GE analyses concluded that fuel melting will not occur during the bounding AOO at the worst time in the fuel lifetime.

The team reviewed the analyses presented in GE's April 15, 1996, letter to NRC and concluded that the input of pellet density and densification on the local high power pellet may not bound the LDPs because the LDPs had not been adequately characterized to assure that the input was bounding. For example, the GE input for pellet densification of the high power pellet was assumed to be equal to a standard pellet. The few available GE densification data on the LDPs demonstrated that they had twice the densification on average as the GE standard pellet. An increase in densification of the peak pellet will increase the fuel temperatures of this peak pellet. Therefore, the team could not conclude that the GE fuel melting analyses demonstrated that fuel melting would not occur for fuel rods with the LDP problem.

As a result GE has performed revised analyses (GE's June 25, 1996, letter to NRC) using actual measured densification properties of the LDPs and verified that the LDP density input of 91% TD is indeed bounding based on further characterization. These revised analyses demonstrate that fuel melting will not occur for LDPs for the bounding AOO at the worst time in the fuel lifetime. The team concluded that GE's revised analyses was acceptable.

(2) Fuel Rod Internal Pressure

GE has performed GESTR-Mechanical analyses for the GE8B/GE9B/GE10/GE11/GE13 fuel rod designs to evaluate the potential for fuel rod pressure to exceed the rod internal pressure SAFDL. The GE analyses assume standard design and conservative licensing assumptions with the exception that the fuel rod average density was assumed to be the lowest permitted by fuel rod weight tolerances. Fuel rod FGR is an integrated effect that takes place over the whole fuel length and, therefore, the GE assumption of lowest average pellet density based on the lowest fuel weight tolerance is conservative. GE also looked at the sensitivity of having lower density and standard density zones at different locations within the fuel rod and obtained nearly identical results as those with the assumption of the same average smeared density over the whole fuel length. The GE analyses demonstrated that fuel rods with LDPs will not exceed the rod internal pressure design ratio of 1.0 with at least 95% confidence for a rod operating at the bounding envelope of power versus exposure.

The team reviewed these analyses and concluded that even though the GE analysis results are approaching the rod pressure limit, there is adequate conservatism in the rod internal pressure analyses. Therefore, the GE LDPs meet the SAFDL for rod internal pressures.

(3) **Cladding Strain**

GE presented the initial results in its April 15, 1996, letter to NRC of the GESTR-Mechanical analyses for the GE8B/GE9B/GE10/GE11/GE13 fuel designs that evaluate the effect of LDPs on pellet/cladding interaction (PCI) and resulting cladding strain during an AOO event. This GE analysis used standard design and conservative licensing assumptions with the exceptions that, as with the fuel melting analyses, (1) the fuel average density is assumed to be the lowest possible permitted by fuel weight tolerances on the rod, and (2) the peak power pellet is assumed to have the minimum pellet density found by GE in the characterization of the LDP problem. The lower fuel densities assumed in this analysis results in lower fuel thermal conductivity and higher FGR, that results in higher cladding strains.

GE also examined the possibility of the LDPs having different fuel relocation than the standard pellets. If the LDPs experienced more cracking than the standard pellets it could be hypothesized that the LDPs could possibly result in more PCI than resulting from the standard pellets. As a result GE tried to induce thermal cracking in the LDPs by heating the LDPs and rapidly cooling them. At fuel pellet temperatures typical of normal operation GE experienced difficulty in cracking the LDPs, however, pellet fracturing was observed when the temperatures were increased. GE also performed similar thermal cracking tests on GE standard density pellets and compared the cracking results of the standard and low density pellets. The results showed no difference in the cracking behavior between the standard and low density pellets. From this GE concluded that pellet cracking behavior of the LDPs was similar to the standard pellets and relocation should be similar for these two pellet types. Therefore, the GE analyses assumed that the LDP fuel relocation was the same as the GE standard pellets.

The initial GE analyses demonstrated that cladding strain in fuel rods with LDPs remained below the 1.0% strain limit as required by Section 4.2 of the SRP for the bounding AOOs at the worst time in the fuel lifetime.

The NRC team reviewed the initial GE cladding strain analyses and concluded that the input of pellet density and densification on the local high power pellet may not bound the LDPs because the LDPs had not been adequately characterized to assure that the input was bounding. In addition, the GE analyses showed that they

were very close to the 1.0% strain limit and changes to either pellet density or densification could change the results of the analysis. Therefore, the team concluded that the GE fuel melting analyses did not demonstrate that cladding strain would not exceed the 1.0% strain SAFDL for fuel rods with the LDP problem.

As a result, GE performed revised analyses of cladding strain (June 25, 1996, letter to NRC) using actual measured densification properties of the LDPs and verified that the LDP density input of 91% TD is indeed bounding based on further characterization. These revised analyses demonstrate that cladding strain will not exceed the 1.0% strain SAFDL for fuel rods with LDPs for the bounding AOO at the worst time in the fuel lifetime. The team concluded that GE's revised analyses was acceptable.

(4) Thermal-Hydraulic Performance

GE did not perform specific analyses of the impact of the LDPs on thermal-hydraulic performance but offered an argument in its April 15, 1996, letter to NRC as to why the LDPs will not adversely affect this SAFDL, that argument is summarized below. Thermal-hydraulic performance is a function of the thermal time constant of the fuel rod and can be divided into two types of analyses (1) a core wide analysis, and (2) a hot channel analysis. A decrease in pellet density and an increase in pellet densification compared to GE standard density pellets will increase the thermal time constant of the fuel rod.

For the core wide thermal hydraulic response, an increase in the thermal time constant decreases the thermal performance margin because it increases the magnitude of a rapid depressurization-type AOO. However, because of the small number of fuel pellets and even smaller number of fuel rods affected by the LDP problem in a core, the decrease in core wide transient performance will most likely be imperceptible.

For the hot channel analysis, the increased thermal time constant delays the heat transfer to the coolant during an AOO and, therefore, increases the hot channel thermal performance margin. However, the actual magnitude of this increased margin is also probably small (although the effect will be larger than for the core) due to the small number of fuel pellets and rods with the LDP problem that would exist within an individual assembly.

The team found GE's arguments acceptable for why the LDP problem has little impact on thermal performance.

(5) Control Rod Drop Accident

GE did not perform specific analyses of the impact of the LDPs on the control rod drop accident but has offered an argument in its April 15, 1996, letter to NRC as to why the LDPs will not adversely affect this accident. The control rod drop accident is initiated from reduced power conditions (either cold or hot standby conditions) due, in part, to significantly higher control blade reactivity worth at these conditions. The reactivity insertion in the surrounding fuel assemblies is then determined assuming adiabatic heat transfer conditions. The resultant fuel enthalpy values are then compared to a SAFDL of 280 cal/gm that assures core coolability. The margin of acceptability for this SAFDL is very large and independent of the thermal time constant because adiabatic conditions are assumed.

For the radiological consequences of this accident, the failure threshold of the fuel rods is a function of two limits (1) a reactivity limit of 170 cal/gm and (2) a thermal performance limit of boiling transition. These two limits are used to determine the number of failed fuel rods. The reactivity of the fuel rod is calculated assuming adiabatic conditions and is not impacted by the thermal time constant. Therefore, the 170 cal/gm limit is not effected by the LDP problem. As discussed in thermal hydraulic performance above, the thermal performance margin to boiling transition increases with an increase in the thermal time constant for the LDPs. Therefore, the radiological consequences of the control rod drop accident will most likely result in a small improvement with the presence of LDPs.

The team found GE's arguments acceptable for why the LDP problem has either no, or improved performance, with respect to the control rod drop accident.

(6) Loss-of-Coolant Accident

GE performed specific analyses of the impact of the LDPs on fuel stored energy for their different fuel designs and argued that the results of LOCA sensitivity analyses to fuel stored energy (NEDE-30996P-A) demonstrate that the increased stored energy due to the LDPs will not adversely affect LOCA peak cladding temperatures (PCTs). A decrease in pellet density and increase in pellet densification due to local LDPs increase local fuel temperatures and, therefore, fuel stored energy at the onset of the LOCA. However, for all GE BWRs (with exception of BWR/2s), the maximum PCTs occur during blowdown rather than at the initial loss of primary coolant stage of the accident. As a result, GE sensitivity analyses have demonstrated that the increase in stored energy of the peak power pellet due to the minimum observed local

density of the LDPs is more than offset by the decrease in decay heat caused by the lower fissile content of the LDPs. Therefore, GE states that no increase in PCTs is expected for LOCA in GE plants due to the LDP problem.

For BWR/2s, the LOCA performance is more sensitive to the number and timing of fuel rod failures due to fuel rod internal pressures and initial PCTs, e.g., a reduction in the allowable maximum average planar linear heat generation rate (MAPLHGR) would be necessary if additional fuel rod failures resulted due to increased rod pressures and higher PCTs during the initial heatup stage of the LOCA. GE assumed for the BWR/2 analysis that the fuel rod average density was equal to the lowest density allowed by the GE fuel rod tolerance on fuel rod weight. This assumption maximizes fuel rod internal pressures but did not maximize the initial PCTs during heatup which is dependent on local pellet density and densification. The GE result of the BWR/2 LOCA analysis for the LDP problem is that the increase in fuel rod pressure is not sufficient to significantly alter the onset of fuel rod perforations and, therefore, does not alter the results of the LOCA.

The team reviewed the GE analyses of stored energy in its April 15, 1996, letter to NRC for all GE plants and fuel designs with respect to LOCA and concluded that the input of pellet density and densification on the local high power pellet may not bound the LDPs because the LDPs have not been adequately characterized to assure that the input was bounding and, therefore, the calculated stored energy may not be bounding.

As a result, GE performed revised stored energy analyses using actual measured densification properties of the LDPs as input, and summarized the results in its June 25, 1996 letter to NRC. These revised results show that stored energy increases for LDPs but the increase for all GE plants is still not sufficient to significantly increase LOCA PCTs based on the sensitivity analyses in NEDE-30996P-A. For all plants except BWR/2s the stored energy increase from the revised analyses is still offset by the reduced decay heat. For BWR/2s, the increase in rod pressures from the revised analyses still does not significantly alter the onset of fuel rod perforations. GE was questioned if the increased stored energy from the LDPs in BWR/2s would increase PCTs and, therefore, alter the onset of fuel rod perforations. GE responded that the sensitivity analyses in NEDE-30996P-A demonstrate that the increased stored energy from LDPs has little impact on initial PCTs and, therefore, will not alter the onset of perforations. The team found GE's revised stored energy analyses in the June 25, 1996, letter to NRC acceptable.

b.4 Powder Blending

The team observed GE's uranium powder process through and including the blending of uranium powder. Blending is the key to forming a uniform mixture of the powder. The team examined the process qualification record when "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** was first added to the process. Properly blended and mixed with the uranium oxide powder, the "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** enhanced lubrication of the pellet press machine resulting in fuel pellets with a more uniform density. One of the acceptance criteria for the qualification batch was a specified time (minutes) for the blending operation (mixture of "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** and uranium powder). The team concluded that the "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** blending process had been adequately qualified.

The team observed "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** being weighed on a scale and determined that during the weighing process, the scale's pointer fluctuated to the extent that it was difficult to read the actual weight. GE informed the team that because the problem was verbally identified, rather than in a written format, it did not take corrective actions. The team concluded that for this instance, GE's actions lacked the proper attention to adequately perform problem identification and resolution for a parameter that directly related to the quality of pellets. The team considered this a weakness in the pellet process.

The team found that the procedures for powder production did not specify the tumbling time to meet the qualification batch value. Further, there were no checklists or quality hold points to verify blending. The team considered this a procedural weakness. However, the team noted that the procedures and checklists were being revised. In addition, GE was adding computer controls to the blending process.

b.5 Pelleting

The team, during discussions with plant personnel, determined that operators of the pellet presses document their comments on a press production log which includes the following information: the date of operation, the shift, identification of the operator, the boat (pan used to hold pellets during the sintering process) card number, the identification of the can with fuel powder, the tare and gross weights of the boat, the net weight, the green density, the number of pellets pressed per minute, the press number, and the enrichment (in percent). The team reviewed the press production logs generated during the November 1995 to February 1996 period and found the following comments repeated:

- nine instances of fluffy powder
- seven instances of pellet density out of range
- six instances of lumpy powder
- five instances of bad powder
- four instances of weak powder
- three instances of not tumbling the cans to blend the acrawax with uranium oxide powder
- two instances of pellets not holding together
- one instance of the powder being like wet flour.

Additionally, on December 22, 1995, an operator recorded that powder can AUG 2106 had not been tumbled. On January 9, 1996, the press operator logged that cans AUG 2183 and 2184 were not tumbled resulting in chipped pellets. On January 13, 1996, a fuel pellet loader observed that the pellets did not hold together because their ends were bloated (convex).

On the basis of its review of the press operators log, the team noted several precursors that may have resulted in LDPs.

b.6 Sampling and Testing

The team reviewed the adequacy of the methodology to verify pellet integrity on the basis of testing pellet samples for specific characteristics during the manufacturing process. In F-S-179, "Quality Notice," Revision 4, October 16, 1995, GE established a rationale for powder/pellet sampling. The quality notice prescribed the various characteristics that are to be verified, the frequency at which they are to be verified, and the rationale for sampling. The team found that powder and pellets are sampled at the following stages of production.

(1) Preblended Powder

The enrichment of Ammonia Diuranate (ADU) in the preblended powder is monitored by taking a sample from **[deleted pursuant to 10 CFR 2.790 - document described a specific value]** cans of powder to calculate the accountability factors and to obtain the data for blend feed.

(2) Blended Powder

The estimation of impurities in the blend is monitored by taking a sample **[deleted pursuant to 10 CFR 2.790 - document described a specific value]** blend and determining the acceptability of the population and assurance of moderation control.

(3) UO_2 Pellets

Pellet density in UO_2 pellets is monitored by testing **[deleted pursuant to 10 CFR 2.790 - document described a specific value]** to determine if the product/process is performing to the applicable specification.

[deleted pursuant to 10 CFR 2.790 - document described a specific value] pellets were selected from each pellet boat after it completed the sintering stage, for initial density testing. Before the LDP problem, [deleted pursuant to 10 CFR 2.790 - document described a specific value] pellets were selected from the bottom of the boat and [deleted pursuant to 10 CFR 2.790 - document described a specific value] pellets from the top of the boat.

As part of its corrective actions to address the LDP problem, GE now selects [deleted pursuant to 10 CFR 2.790 - document described a specific value] pellets from the bottom of the boat, and one pellet from the top of the boat.

GE was not able to provide the inspection team with a statistical bases for the adequacy of test sample selection. The lack of a statistical basis of the pellet sampling plan was considered by the team to be a weakness in GE's pellet processing.

b.7 Pellet Integrity

The team reviewed the various tests used by GE to determine the following characteristics of pellets which are measured during the manufacturing process: surface roughness, green density, sintered density, dimensions, thermal stability. The team identified no adverse findings in this area.

b.8 Quality Control

The team reviewed the following documents used by QC inspectors to verify the integrity of the manufacturing process at various stages of production.

- Quality Control Inspector Instructions (QCII) 2.2.1.1, "Acceptance and Release of Line Material In-House & Ship Powder Blends," Revision 9, dated February 14, 1996
- QCII 3.2.2, "Pellet Sampling and Release," Revision 32, dated November 6, 1995
- QCII 6.2.5.1, "(Gd, U)O_2 Pellet Sampling and Release," Revision 23, dated November 6, 1995
- Quality Control Operator Requirements, 2.1.1.46, "Sampling requirements on Blends," Revision 3, dated January 30, 1986

The team observed that QC implemented the above QCIIs and maintained statistics of the results to demonstrate to that there were no adverse trends. However, the team observed that there were no requirements for QC to independently examine work areas where problems are likely to occur and document the findings.

For instance, QC did not attempt to evaluate the problems experienced by the fuel pellet pressers and the fuel pellet loaders which were documented in the operator logs. The team concluded that if QC had brought the problems documented in the operator logs to the attention of the appropriate production engineers, they may have evaluated them to determine whether they were contributors to the LDP problem; if so, they may have been identified before LDPs were shipped to licensees. The team also observed that in some instances where problems were identified, QC relied on statistical sampling to characterize or bound the problem without documenting an adequate basis to ensure the problem was bounded. The team considered these observations as weaknesses in GE's pelleting process.

The team observed a single pellet from another fuel tray mixed with natural uranium pellet on a pellet tray prepared for rod loading. The pellet dimensions were different from the remaining pellets on the tray. When the team disclosed this observation during the inspection, GE investigated this discrepancy and determined that this pellet was from a tray that was used to manufacture fuel over six months before. GE hypothesized that this pellet was dislodged and got mixed with the pellets of the other tray.

The pellet had not been loaded into a fuel rod. GE stated that even though the operator had missed detecting the oversized pellet during the visual check, the scanning device, which monitored the dimensions of the pellets, would have rejected the pellet because it was oversized, and thus prevented its entry into a fuel rod. However, the team was concerned about the inadequate controls at the pellet and tray activities, which made such pellet mixup possible, and GE's belated detection of the incorrect size pellet.

b.9 Corrective Actions Taken

The team reviewed actions taken to correct the problem identified in Corrective Action Request (CAR) 0039. The CAR was issued on March 19, 1996, to identify that a specific tray contained pellets that exceeded the specification requirements relative to density and voids. According to GE the largest contributor to the LDP problem was the possibility that the containers were not tumbled. The corrective action recommended in CAR 0039 was to sensitize the operators involved in the importance of the process of tumbling the fuel powder and "mixing lubricant" **[revised pursuant to 10 CFR 2.790 - document described a specific trade name]** mix. The team reviewed training documents which listed the Temporary Operating Instruction (TOI) and the signatures of persons trained. The review indicated that individuals were trained on TOI B-3483 issued on March 1, 1996, "Gathering Information Related to Bloated Pellets," as acknowledged by the signatures of the trainees. The team identified no adverse findings in this area.

b.10 Root Cause Analysis

The team evaluated GE's root cause analysis. It showed that on February 22, 1996, GE first discovered the LDPs when an operator noticed two adjacent fuel pellets with slightly convex end faces. The team concluded that the analysis failed to consider the press operators previous comments on the quality of the blend, and investigate their affect on the problem.

On January 9, 1996, for instance, the press operator on shift Z documented that cans identified as AUG 2183 and 2184 had not been tumbled. Four days later on January 13, 1996, a fuel rod loading station operator attempted to pick up a group of pellets by squeezing its ends. The group of pellets did not hold together and fell apart. The operator observed that the pellets did not hold together because their ends were convex (same indication was observed later on February 22, 1996, and determined by GE to be characteristic of LDPs). A "Q Hold" tag was issued for the tray because it contained pellets with raised end surfaces. A nonconformance was written to identify that the end surfaces of the pellets were raised and not concave. The pellet dimensions were verified to be acceptable, and the nonconformance was closed without examining the densities of the pellets. The nonconformance dispositioned the pellets as "use as-is."

In another instance, on December 22, 1995, a pellet press operator documented that a can identified as AUG 2106 had not been tumbled. The team concluded that if GE had investigated these comments it may have determined whether they were precursors that contributed to the LDPs. GE's root cause team did not evaluate the pellet press operator's complaints to determine if the pellets produced from those mixtures had low densities. Therefore, the team concluded that the GE's root cause analysis was not adequate in identifying when the LDPs first occurred or evaluating all contributing factors.

c. Conclusions

The team evaluated the GE's safety analyses and corrective action for LDPs. Based on the team's evaluation and the additional characterization information, the team concluded that (1) there were no additional significant safety concerns, (2) the consequences of postulated accidents were not underestimated, (3) the control rod insertability was not affected, and, therefore (4) the LDPs problem was satisfactorily resolved.

The team's evaluation showed certain weaknesses in the GE's pelleting process. Principal contributing factors to these weaknesses included apparent deficiencies in development of procedures, managing problem identification and corrective actions, and QA involvement. Specifically, the team found weaknesses in (1) determining the weight of the mixture because the pointer on the blending mix weighing machine fluctuates, (2) the lack of a statistical bases for selecting the quantity of samples, (3) the adequacy of corrective action taken when

cans of powder had not been tumbled and GE did not examine the density of the pellets manufactured from those cans, (4) the instructions to QA/QC to resolve verbal complaints, and (5) the root cause analysis did not identifying when the first LDPs occurred or evaluate all contributing factors.

3.3 10 CFR Part 21 Program

a. Inspection Scope

In an August 1995 document titled "Discussion of Deviation from Design Procedure" (observations made during the SLMCPR analysis for the Kernkraftwerk Krümmel plant) GE determined that within a fuel type for a particular fuel design it was possible to have an R-factor distribution that would yield a higher number of fuel rods that would approach boiling transition than the bounding values used in its generic SLMCPR analyses.

However, as described in Section 3.1.b.4 of this report, GE claimed that its first indication that the GE11 SLMCPR analysis was not bounding occurred at the end of February 1996 as the result of completing a cycle-specific analyses for River Bend Cycle 7. The River Bend Cycle 7 analysis also resulted in cycle-specific SLMCPR values that exceed the generic GE11 SLMCPR and show that GE's generic analysis was not bounding as assumed by GE.

Also in August 1995, an NRC inspection team raised several concerns related to areas where GE had made significant changes to the methodology used to determine the SLMCPR. With regard to the previous team's concerns, during this inspection the team was told by GE staff that no action had been taken to address those concerns.

Therefore, the team reviewed the chronology of GE's SLMCPR, as well the LDP issue, to evaluate GE's responsiveness to these issues and evaluated GE's notices sent to GE fueled BWR licensees to evaluate the accuracy and effectiveness of the notices.

b. Observations and Findings

b.1 Safety Limit MCPR

A GE internal letter dated March 15, 1996, initiated potential safety concern (PSC) 9608 to review the safety limit MCPR issue. A follow-up GE internal letter requested that the PSC be evaluated to determine if it represents a potentially reportable condition (PRC) and that results be documented in a design record file (DRF). Corrective actions were to be identified and justification for PSC closure was to be provided within 10 working days or it would automatically become a PRC (i.e., an evaluation under 10 CFR Part 21 requirements would be necessary).

On March 27, 1996, the NRC was advised, by a telephone call from GE, that the SLMCPR concern was under internal review as a PRC. The NRC was told that the generic GE11 SLMCPR of 1.07 was not bounding for a plant (River Bend) operating in a 2-year cycle with a large batch fraction (37%) of the fresh GE11 fuel. GE claimed that the error was attributed to an analytical procedure deficiency and stated that it was in the process of evaluating all plants as rapidly as possible to assure that the plant-specific SLMCPR was bounded by the generic SLMCPR used as the licensing basis. (The telephone call is documented in a March 29, 1996, letter from GE Fuel and Facility Licensing Manager to NRC.)

On March 28, 1996, GE issued PRC 9604 to perform the 10 CFR Part 21 reportability evaluation of the SLMCPR issue.

On April 17, 1996, GE met with the NRC staff (several licensees were also represented at the meeting) for an update on the status of its SLMCPR review. At this meeting, the NRC staff was informed that the erroneous safety limits were due to non-conservatism in the generic analysis methods and may not be restricted to GE11 fuel and large batch fractions. GE concluded that cycle-specific analyses of each reload core was required to confirm that the generic SLMCPR value remained bounding. GE indicated that they had performed preliminary cycle-specific analyses and based on the results, had recommended corrective actions to 13 GE fueled BWR plants most likely to be affected by the cycle-specific analyses.

During this meeting, the NRC staff agreed that administrative control of the operating limit MCPR, as recommended by GE, was an appropriate response to the safety issue until correct safety limits could be verified and technical specifications and core operating limits reports (COLRs) could be revised to reflect the correct SLMCPR values. GE also proposed long term actions to recover the lost thermal margin, but the NRC staff indicated these actions were relatively low priority.

In its April 22, 1996, letter, RJR-96-044, to NRC, GE documented its perspective of the April 17, 1996, meeting and transmitted the proprietary version of material presented at the meeting. Also included was a list of the 13 plants that had been identified, based on preliminary analyses of 22 plants, for priority attention in the reevaluation of the SLMCPR for current operating cycles. The letter listed GE's short-term action items as follow:

- perform SLMCPR evaluation of all plants with GE fuel as soon as possible
- inform affected plants immediately of higher SLMCPR analysis results even if the value is preliminary
- licensees to immediately establish administrative controls to conform to a higher value of SLMCPR (even when unverified) and to implement changes in the process computer data upon receipt of a verified higher SLMCPR value

- licensees to inform the NRC when administrative controls are implemented

During this inspection, the team reviewed GE's customer correspondence on the SLMCPR issue. GE sent its customers a white paper entitled, "Safety Limit MCPR Calculation," informing them of the SLMCPR error and of the April 17, 1996, meeting with NRC staff. These notifications, dated April 2, 3, and 4, 1996, differed only slightly, and no plant specific recommendations for action were provided. The customers were advised that no specific actions were believed to be necessary until plant specific evaluations are completed. At that time, GE believed the problem was limited to plants having large reload batch fractions of GE11 fuel to support longer operating cycles.

The team concluded that these notifications did not address the recommended corrective actions that GE had claimed to have sent to 13 plants during the April 17, 1996, meeting with NRC staff.

On April 18, 1996, GE letters to 29 domestic plants transmitted the plant specific calculation results and recommendations for administrative actions that GE had claimed to have sent during the April 17, 1996, meeting with NRC staff. Of the 29 plants notified, 16 plants were told that they were at low risk for a non-conservative erroneous SLMCPR value. A summary of the team's findings from its review of GE's April 18, 1996, letter to selected plants follows:

- Clinton, classified as low risk, even though the EOC preliminary evaluation resulted in 1.082 value versus an existing SLMCPR value of 1.07. However, it was later determined that a verified calculation of 1.07 at EOC had been completed prior to the April 18, 1996, notification.

  The status of the Clinton plant was further confused by the information provided in GE's May 24, 1996, letter to NRC, "10 CFR Part 21, Reportable Condition, Safety Limit MCPR Evaluations," which indicated that Clinton had an unverified SLMCPR value of 1.08 versus a technical specification value of 1.07. The NRC staff learned later during a telephone conversation with GE that verification of the Clinton MCPR was completed on May 29, 1996, and the existing technical specification value of 1.07 is correct. However, the Clinton licensee did not provide 10 CFR 50.72(b) notification of any administrative control action while the unverified evaluation indicated that the technical specification was in error.

- Hatch unit 2, classified as low risk, was later informed (May 2, 1996, letter) that the calculated SLMCPR value was 1.08 versus a licensed value of 1.06 for its GE9 fuel and that administrative controls to protect the revised safety limit should be imposed. On May 3, 1996, the 1.08 value was verified and the Hatch unit 2 project manager was verbally notified. A May 8, 1996, letter from GE confirmed the verbal notification.

- Monticello, classified as low risk, was later informed (May 8, 1996, letter) that the verified SLMCPR value is 1.08 versus a licensed value of 1.07 for its GE11 fuel and that administrative controls should be imposed to protect the revised safety limit.

- Nine Mile Point unit 1, classified as low risk, was later determined to have a verified SLMCPR value of 1.10 for the GE11 fuel in this BWR2 reactor.

- Hope Creek was notified that the preliminary unverified value of SLMCPR was 1.09 (based on EOC calculations) versus a licensed value of 1.07 for its GE9 fuel. The licensee had already provided NRC with an April 16, 1996, event report of action to impose administrative controls for a 1.10 SLMCPR based on GE notification (believed to be verbal) on that date. Verified calculations for BOC and PHE were completed on May 7, 1996, and the maximum SLMCPR verified value was 1.08 at BOC. A May 8, 1996, letter to Hope Creek indicated that the final verified value was 1.08, even though a final calculation for the EOC had not been completed.

  The team questioned the omission of the EOC calculation (which had been limiting in the preliminary assessment); GE personnel agreed that EOC should be evaluated but explained a logic which could support its omission. Further review of the Hope Creek DRF by the team showed that the EOC results could not be achieved because the limiting bundle could not be placed on the operating limit. At that time, additional calculations were planned at an exposure life between PHE and EOC with sufficient rod worth remaining to challenge the BOC maximum safety limit result.

- Cooper, classified as low risk, was later notified (April 25, 1996, letter) of an unverified SLMCPR value of 1.07 (the licensed value was 1.06), and then was reported to have a verified value of 1.05 (no impact) in GE's May 24, 1996, 10 CFR Part 21 notification letter to NRC.

In its May 24, 1996, letter "10 CFR Part 21, Reportable Condition, Safety Limit MCPR Evaluations," GE informed NRC of the reportable condition of its SLMCPR evaluations. The 10 CFR Part 21 notification identified 12 plants with new SLMCPR limits above the currently licensed values. In addition to Hatch 2, Monticello, and Nine Mile Point 1 (original low risk plants), 9 of the 13 plants identified as high risk in the initial evaluation were found to have inadequate SLMCPR limits and license changes are needed. High risk plants that were found to have acceptable SLMCPR limits were Peach Bottom 2, Brunswick 1, Fermi 2, and Duane Arnold.

However, verified analyses had not been completed for 6 plants reported in GE's May 24, 1996, letter, and as previously discussed, the existing SLMCPR was later (May 29, 1996) verified for 1 of these plants (Cooper) that was affected by GE's preliminary analyses.

Thus, from the time the potential design defect was identified (March 15, 1996), approximately one month elapsed until notifications of needed interim corrective actions were issued by GE. The validated analyses were not completed until near the end of May, over two months after the PSC evaluation began. In the interim, one plant (Nine Mile Point 1) was not notified to take corrective action until May 21, 1996, even though the SLMCPR was 1.10 compared to a technical specification value of 1.07.

The final results of the GE's 10 CFR Part 21 evaluation showed nonconservative values of SLMCPR for 11 operating cores, 3 with GE9 fuel and 8 with GE11 fuel. As described in Section 3.1.b.8 of this report, the team concluded that design defects resulting in nonconservative values of SLMCPR in 11 currently operating cores was due to GE's failure to recalculate or reconfirm the applicability of the generic SLMCPR as required by the NRC approved methods in GESTAR. In addition, GE's failure to comply with analysis procedures referenced in plant technical specifications appears to place these licensees in nonconformance with their technical specifications.

b.2 Low Density Pellets

During its review of PSC 9606, "Low Density Fuel Pellets," April 4, 1996, and GE letter RJR 96-041 to NRC, "GE Fuel Pellet Density Report," April 15, 1996, the team raised questions concerning the adequacy of GE's characterization information used as an input to the fuel performance evaluation. The team also identified certain other weaknesses with GE's root cause evaluation. (See Section 3.2.b.1 and 3.2.b.10 of this report.)

Pursuant to the issues raised by the team, GE agreed to reopen this issue as a PRC to address the team's questions. In its letter RJR 96-070 to NRC, "Low Density Fuel Pellets," June 25, 1996, GE responded to the characterization questions raised by the team and assessed the impact to the original fuel performance evaluation or conclusions.

GE concluded that the revised characterization information was consistent with its earlier information used as an input to the earlier fuel performance evaluation.

c. <u>Conclusions</u>

c.1 Safety Limit MCPR

According to GE, the SLMCPR problem was discovered about March 15, 1996, even though in August 1995, GE realized that it was possible to have an R-factor distribution that would yield a higher number of fuel rods that would approach boiling transition than the bounding values used in the generic analyses. Again in August 1995 **[year corrected by staff]**, an NRC inspection team raised several concerns related to changes to the methodology used to determine the SLMCPR, however, GE staff told the team that no action had been taken to address those concerns.

On the basis of its evaluation of the information that GE had in August 1995, the team concluded that GE could have taken actions to evaluate the SLMCPR problem earlier than its "discovery date" of March 28, 1996, when GE initiated its PRC evaluation.

The team found that from the time the potential design defect was identified (March 28, 1996), approximately one month elapsed before GE notified licensees of needed interim corrective actions. GE's failure to evaluate its potential SLMCPR problem when indications of the problem first appeared in August 1995 and to timely notify licensees of the need to take interim corrective actions is considered a weakness in GE's responsiveness to the SLMCPR issue.

The team concluded that the results of detailed final analyses were sometimes inconsistent with results of the preliminary scoping analyses and that GE's understanding of the issue changed during the licensee notification process. Generally, only one sentence of a two page letter provided information on the cycle-specific core analyses, and for some plants, the status changed significantly with little explanation. Consequently, sequential correspondence was sometimes conflicting and potentially confusing to licensee.

With regard to the GE assessment of the impact of the design error on affected plants, the team concluded that the notification correspondence was, in some instances, inaccurate and misleading in the characterization of NRC positions. For example, it was asserted that NRC had somehow relieved licensees of the need to evaluate impact of the SLMCPR error on previous operating cycles. Clearly, GE can not attribute an interpretation of the regulations to NRC without supporting NRC documentation. In another example, the notification correspondence from GE strongly implied that NRC is receptive to near term recovery of lost thermal margin by review and credit for claimed conservatism associated with power distribution, instrumentation, and direct gamma heating. In fact, the NRC indicated that submittals of this nature would receive low priority attention and was non-committal on the likelihood for approval.

The team concluded that the GE staffing level applied to the SLMCPR plant specific evaluations was inadequate to provide clear and accurate corrective information to its customers on a schedule appropriate for the safety issues involved. The team also concluded that the clarity and effectiveness of GE's notifications could have been enhanced if GE had placed less attention to deemphasizing the impact of the error on affected plants and more attention to timely completion of the plant evaluations and to reporting and explaining the plant specific results.

c.2 Low Density Pellets

Based on its evaluation of GE's additional characterization information for the low density pellet event, the team concluded that (1) there were no additional significant safety concerns, (2) the consequences of postulated accidents were not underestimated, (3) the control rod insertability was not affected, and, therefore (4) the LDPs problem was satisfactorily resolved.

3.4 Entrance and Exit Meetings

In the entrance meeting on May 6, 1996, the NRC team met with members of GE management and staff, and discussed the scope of the inspection. The team also reviewed its responsibilities for handling proprietary information as well as those of GE. In addition the team established contact persons within the management and staff of the applicable GE organizations.

During its exit meeting with GE management and staff, on May 10, 1996, the team discussed its findings and concerns, as well as GE's weaknesses.

PARTIAL LIST OF PERSONS CONTACTED

Armijo, J.S.	General Manager, Nuclear Fuel
Congdon, S.P.	Manager, Design Process Improvement
Currier, J.W.	Manager, Customer Service
Embley, J.L.	Licensing Program Manager, Fuels & Facility Licensing
Hauser, T.M.	Manager, GENE, Quality Assurance
Kipp, C.P.	General Manager, Production
Marlowe, M.O.	Manager, Fuel Materials Programs, Nuclear Fuel
McCaughey, D.A.	Manager, Fuel Quality
Potts, G.A.	Manager, Operating Fuel Performance/Support
Reda, R.T.	Manager, Information Management Systems
Sependa, W.J.	Manager, Chemical Product Line
Serell, D.C.	Technical Program Manager, Nuclear Fuel Americas
Sick, P.W.	Manager, Nuclear Quality Assurance
Smith, C.W.	Sr. Licensing Engineer, Fuels & Facility Licensing
Williams, R.D.	Fuel Project Manager, Nuclear Fuel Americas

ITEMS OPENED AND DISCUSSED

Opened

99900003/96-01-01 NON	Failure to recalculate or reconfirm generic SLMCPR
99900003/96-01-02 NON	Failure to use NRC approved methods in GETAB
99900003/96-01-03 NON	Failure to verify R-factors

Discussed

- GE letter MFN 074-96 to NRC, "10 CFR Part 21, Reportable Condition, Safety Limit MCPR Evaluation," May 24, 1996