INSPECTION REPORT

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OFFICE OF NUCLEAR REACTOR REGULATION
DIVISION OF REACTOR INSPECTION AND LICENSEE PERFORMANCE

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Licensee: Pacific Gas and Electric Company
77 Beale Street, Room 1451
San Francisco, California 94106

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Summary: The inspection resulted in identifying certain weaknesses that will be overcome by the licensee's successful completion of the post-modification tests.

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission's (NRC's) Vendor Inspection Branch (VIB), Division of Reactor Inspection and Licensee Performance (DRIL), Office of Nuclear Reactor Regulation (NRR), with participation by the Division of Reactor Safety and Projects, Region V, conducted inspections at the corporate offices of the licensee, Pacific Gas and Electric Company (PG&E) in San Francisco, California, April 29 through May 3, 1991, as documented in Inspection Report (IR) 50-323/91-202, dated November 15, 1991, and again on April 27 through June 5, 1992, documented herein. During these inspections, the team evaluated PG&E's procurement and commercial grade dedication activities for the emergency diesel generator (EDG) set for Diablo Canyon Nuclear Power Plant Unit 2 (DCNPP2). According to PG&E, the new sixth (No. 2-3) EDG set will be identical (i.e., like for like) to DCNPP's five existing EDGs.

During the inspection reported in IR 50-323/91-202, the team focused on the commercial grade dedication activities for the diesel engine component of the EDG set. PG&E procured the diesel engine for the 2-3 EDG set as a commercial grade component. For its original dedication approach (described in a letter (DCL-91-067) dated March 27, 1991, responding to NRC questions raised during a meeting in Rockville, Maryland, on January 20, 1991), PG&E based its commercial grade dedication on the performance history (Method 4*) of identical diesel engines. Because of its concerns with the adequacy of available documented industry-wide performance history data, PG&E supplemented the performance history bases with a commercial grade survey (Method 2) of the manufacturer of the diesel engine, GE Locomotive (GE-L) of Montreal, Canada.

PG&E examined selected mechanical components of the diesel engine during its commercial grade survey and identified additional concerns with GE-L's commercial quality program. Therefore, PG&E augmented the commercial grade survey by performing source

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*To dedicate and qualify the commercial grade 2-3 EDG set, PG&E used the four acceptance methods described in the Electric Power Research Institute's (EPRI's) Report NP-5652, "Guideline for the Utilization of Commercial Grade Items in Nuclear Safety-Related Applications (NCIG-07)," and the recommendations outlined in the Nuclear Management and Resources Council's Report 90-13, "Nuclear Procurement Program Improvements." EPRI NP-5652 described the four acceptance methods for commercial grade items as: (1) special tests and inspections, (2) commercial grade survey of supplier, (3) source verification, and (4) acceptable supplier/item performance record.

verification (Method 3) of certain of the manufacturer's activities and by performing certain special tests and inspections (Method 1) on the engine's power train parts.

In its earlier report (IR 50-323/91-202), the team identified several weaknesses with PG&E's procurement and commercial grade dedication activities that resulted in concerns with the quality and reliability of the 2-3 EDG set. For instance, PG&E, through its commercial grade dedication program, did not demonstrate reasonable assurance that all design, material, and performance characteristics specific to the 2-3 EDG's ability to perform its intended safety function had been verified and that the bases of the original seismic qualification of DCNPP's five existing EDGs had been maintained.

The team concluded that additional inspections were necessary because of the weaknesses identified during its inspection of PG&E's procurement and dedication of the diesel engine. Therefore, on August 5 through 9, 1991, the team conducted an inspection of the supplier for the power generator component for the 2-3 EDG set, NEI Peebles—Electric Products, Inc. (P-EP), of Cleveland, Ohio. PG&E procured the power generator from P-EP as a safety-related component and in its acceptance of the purchase order from PG&E, P-EP accepted the responsibility to ensure overall compliance with all the applicable provisions of Appendix B to 10 CFR Part 50 and the reporting requirements of 10 CFR Part 21.

As a result of the team's inspection of P-EP (IR 99900772/91-01 dated January 15, 1992), the most significant inspection finding identified was that P-EP failed to demonstrate: (1) reasonable assurance that the items specified as critical by PG&E met the quality and reliability requirements of Appendix B to 10 CFR Part 50; (2) that the critical characteristics of such items had been adequately verified; and (3) that the items are capable of performing their design and safety-related functions. Specifically, P-EP failed to demonstrate that the critical characteristics of the following had been verified: (1) the items specified as critical that the manufacturer of the power generator procured as commercial grade and (2) the stator coil's resistance temperature detectors, slip rings, adhesives, and the mounting sleeve insulator for the slip rings that P-EP procured as commercial grade.

The team also identified as nonconformances other elements of P-EP's quality program and its implementation that failed to meet NRC requirements. For example, P-EP did not establish adequate measures for, and to implement adequate control of, its external design interface with its sister organization and manufacturer of the power generator, NEI Peebles Ltd., Peebles Electrical Machines (PEM), of Edinburgh, Scotland, United Kingdom.

Therefore, based on the nonconformances identified during its inspection of P-EP, the team concluded that additional inspections were necessary and conducted an inspection of PEM, September 23 through 27, 1991.

As a result of the team's inspection of PEM (IR 99901065/91-01 dated February 13, 1992), the most significant inspection finding identified was that PEM failed to demonstrate reasonable assurance that certain critical items (1) met all of PEM's procurement specifications to its suppliers of commercial grade material, (2) met all of P-EP's procurement specifications to PEM, (3) met all PG&E's requirements imposed on P-EP, and (4) met all the applicable NRC quality and technical requirements. Specifically, there was inadequate documented evidence that all the critical characteristics of such items were identified and adequately verified to ensure the items are capable of performing their safety-related functions. Examples of the critical items that were not adequately dedicated include the rotor pole magnet wire wrapped with varnished insulation tape that was specified to be unvarnished, the Bakelite electrical separation ring that was used as a load-bearing component part of the rotor shaft support assembly without an engineering basis for the design, and certain other commercial grade materials, parts, and equipment described in the report that were accepted on the basis of unvalidated certificates of conformance from PEM's commercial suppliers.

The team also identified other elements of PEM's quality program and its implementation that did not meet NRC requirements. For example, PEM had not established adequate measures for, nor implemented adequate control of, its external design interface with P-EP.

In its letter (DCL-92-009) dated January 17, 1992, responding to IR 50-323/91-202, PG&E replied that the issues identified in the IR appeared to evaluate each of the four dedication methods as separate methods. PG&E added that the issues identified in the IR would not represent weaknesses in the dedication program if the results of all four methods were appropriately considered as a means for providing reasonable assurance of the quality of the product.

In its letter (DCL-92-034) dated February 12, 1992, responding to the deficiencies identified during the team's inspection of P-EP (IR 99900772/91-01), PG&E replied that its evaluations, conducted during audits of P-EP and PEM, identified the same nonconformance issues discussed in the IR. Enclosures to PG&E's letter provided an itemization of the team's issues and the compensatory actions taken by PG&E to resolve the findings.

PG&E added that it was formulating a plan, in conjunction with P-EP, to address the team's concerns about the adequacy of the documentation and the completeness of P-EP specification, procedure equivalency and design change reviews, which were performed to resolve the concerns about the lack of program requirements for the P-EP/PEM interface.

During its meeting in Rockville, Maryland, on February 20, 1992, with representatives of the NRC to discuss the open issues from the previous inspections of PG&E, P-EP, and PEM, PG&E presented a revised approach for its dedication of the diesel engine and its compensatory actions taken for the power generator. PG&E's new approach was developed to address the team's concerns about the performance history of the engine and the long-term degradation and cyclic fatigue of certain critical parts of the diesel engine. Additionally, in its revised dedication approach, PG&E stated that it was not appropriate for its original dedication approach to characterize its use of acceptance Methods 1 and 3 as compensatory actions for the weaknesses identified during its commercial grade survey of GE-L. Also, during this meeting, the NRC staff suggested that PG&E consider performing endurance testing in combination with a breakdown and inspection of specific parts of the engine and power generator to possibly resolve the issues raised during the inspections of PG&E, P-EP, and PEM and to establish the reliability of the 2-3 EDG set to perform its safety function. At the conclusion of the meeting, PG&E agreed to develop, in consultation with GE-L, a program for supplemental endurance testing (post-modification tests) of the 2-3 EDG.

During its inspection of P-EP (IR 99900772/91-01) and PEM (IR 99901065/91-01), the team also identified certain weaknesses in PG&E's safety-related procurement of the power generator. Therefore, on March 10 through 17, 1992, an NRC team, led by Region V's Division of Reactor Safety and Projects, with participation by the VIB of DRIL/NRR, conducted an inspection of PG&E's procurement of the power generator (IR 50-275/92-09 and 50-323/92-09). The results of the inspection determined that PG&E did not conduct certain activities in a manner to ensure that the procurement of the power generator met its quality requirements.

On March 26, 1992, PG&E met in Rockville, Maryland, with representatives of the NRC to discuss endurance tests to be conducted on the 2-3 EDG. The endurance test will be used to resolve the NRC staff concerns about the long-term degradation and cyclic fatigue of certain critical parts of the diesel engine and the power generator. At the meeting, PG&E agreed to conduct post-test inspections of certain critical components of the diesel engine and power generator. PG&E also agreed to document its test and inspection plan in a letter submittal to the NRC.

In its letter (DCL-92-092) dated April 17, 1992, PG&E transmitted to the NRC its plan for the preoperational endurance testing of the 2-3 EDG and stated that the purpose of the testing was to further augment the basis for the commercial grade dedication of the EDG. PG&E added that this additional testing will facilitate resolution of the open items identified during the NRC's earlier inspection of PG&E and the issues raised during the inspections of P-EP and PEM. In its plan, PG&E identified the specific testing to be conducted, the equipment monitoring to be performed during the testing, the criteria to be used for evaluating component malfunctions or failures, and the inspections to be performed following completion of testing.

PG&E's revised dedication approach, presented to the NRC staff during the meeting on February 20, 1992, changed the relationship of two acceptance methods (Methods 2 and 4) by supplementing both methods with its review of design changes, thereby attempting to establish the similarity of the diesel engine for the 2-3 EDG to the five existing diesel engines at DCNPP. Specifically, PG&E (1) applied acceptance Method 2 to the dedication of the power train parts (originally, Method 2 applied only to mechanical components), (2) redefined the material tests and verification activities performed (originally performed as acceptance Method 1 activities) as compensatory actions for the weaknesses identified during its commercial grade survey of GE-L, and (3) applied acceptance Method 1 to only certain types of special inspections and testing activities. The revised dedication methodology for the mechanical components limited the use of acceptance Method 1 for only the diesel engine break-in test at GE-L, the integrated functional-performance tests at GEC Alsthom, and the post-modification tests at DCNPP2.

During this inspection, documented herein, the team focused its assessment on the licensee's procurement and commercial grade dedication of the static exciter-voltage regulator (SE-VR) and related cabinet, and certain instrumentation and control (I&C) components, panels, piping, and valves. The team also reviewed and evaluated PG&E's compensatory actions taken as a result of the deficiencies and unresolved items identified during the previous inspection of PG&E and the unresolved item and nonconformances identified during the inspections of P-EP and PEM. During its exit meeting with PG&E's staff on June 5, 1992, the team noted that PG&E's procedures to specify the requirements of the post-modification test and inspections were not complete. Therefore, the team agreed to evaluate PG&E documents submitted after the meeting. For instance, the documentation of certain procedures for the post-modification tests and of PG&E's evaluations of certain issues were submitted in December 1992.

With its letter (DCL-92-218) dated October 9, 1992, PG&E transmitted documentation associated with the open items identified during this inspection, including documentation specifying the requirements for the 2-3 EDG post-modification tests. Specifically, Enclosure 1 to PG&E's letter contained the post-modification functional tests and the post-modification preoperational endurance test. PG&E pointed out that the additional onsite testing of the 2-3 EDG at DCNPP2 is preoperational testing as distinguished from post-installation testing. Although the testing will be conducted using a temporary load bank, not actual plant loads, PG&E stated that the temporary load bank will be capable of simulating the resistive and reactive loads and transients necessary to adequately test the EDG.

Therefore, this report documents the team's review in the following areas: (1) PG&E's commercial grade dedication of the SE—VR and related cabinets and control panels, certain I&C components, piping, and valves; (2) PG&E's compensatory actions taken to resolve the issues identified during the earlier inspection (IR 50-323/91-202); (3) PG&E's compensatory actions taken to resolve the nonconformances identified during the inspection of P-EP (IR 99900772/91-01); (4) PG&E's compensatory actions taken to resolve the nonconformances identified during the inspection of PEM (IR 99901065/91-01); (5) PG&E's revised dedication approach; and (6) PG&E's post-modification tests. Closure of the issues identified during the inspections of PG&E, P-EP, and PEM is pending PG&E's successful completion of its compensatory actions taken as a result of the inspection findings. Specifically, the post-modification tests and inspections that will determine the adequacy of 2-3 EDG's design, materials, and manufacturing processes. With the exception of certain evaluations identified in the summary section of this report as open items, these tests and inspections are expected to resolve the team's remaining concerns by evaluating the EDG during operating and transient conditions necessary to detect problems, and by subjecting certain components of the EDG to operating cycles which would likely result in premature cyclic fatigue failure if defects were present.

CONTENTS

Page

EXECUTIVE SUMMARY iii

1 INTRODUCTION 1

1.1 Background 1
1.2 Regulatory Basis 3
1.3 Assessment 5

2 PROCUREMENT REVIEW 7

2.1 Diesel Engine 7
2.2 Power Generator 9
2.3 Static Exciter-Voltage Regulator 12

3 COMMERCIAL GRADE DEDICATION REVIEW 13

3.1 Diesel Engine 14

3.1.1 Power Train Parts 14
3.1.2 Mechanical Components 16
3.1.3 Status of Previous Diesel Engine Dedication Inspection Findings 17
3.1.4 Revised Engine Dedication Methodology . . . 32
3.1.5 Compensatory Actions for Power Train Parts and Mechanical Components 55

3.2 Power Generator 86

3.2.1 Design Control 89
3.2.2 Selection and Review for Suitability 98
3.2.3 Special Processes 104
3.2.4 Critical Item Evaluations 106

3.3 Static Exciter-Voltage Regulator 133
3.4 PG&E Supplied Items 136

4 SEISMIC QUALIFICATION REVIEW 138
5 EXIT MEETING 141
6 SUMMARY 142

Page

TABLES:

1 PG&E's Selected Critical Characteristics for the Power Generator's Critical Items 145

2 Diesel Engine Power Train Parts Supplied by Auburn Technologies Incorporated 148

3 PG&E's Selected Critical Characteristics for the Representative Parts From the Diesel Engine's Mechanical Components; Verified as Method 2 Compensatory Actions 149

4 PG&E's Selected Critical Characteristics From the Diesel Engine's Power Train Parts; Verified as Method 2 Compensatory Actions 152

5 Critical Characteristics of the 2-3 EDG Assembly . 155

6 Inspections and Tests of the Power Generator Following the Post-Modification Tests 157

7 Summary of Critical Stresses for the Main Components of the 2-3 EDG Set 159

APPENDIX A PERSONS CONTACTED 161

1 INTRODUCTION

This inspection report (IR) describes the U.S. Nuclear Regulatory Commission's (NRC's) inspection of Pacific Gas and Electric Company (PG&E) to determine if the licensee's procurement and commercial grade dedication activities resulted in adequately ensuring the quality and reliability of the sixth (No. 2-3) emergency diesel generator (EDG) set for Diablo Canyon Nuclear Power Plant Unit 2 (DCNPP2). Included in this report are unresolved items (concerns) and nonconformances from the earlier inspections, the findings of this inspection, and the team's followup review. The background, regulatory basis, and NRC's assessment of PG&E's procurement and dedication of the 2-3 EDG follow.

1.1 Background

The NRC assessed PG&E's procurement and commercial grade dedication of the 2-3 EDG set through team inspections of the procurement and dedication of certain components, evaluations of the seismic qualification of certain components, and meetings with PG&E's staff to discuss the issues raised during the inspections. During the inspections of the procurement and dedication of the 2-3 EDG set, the following were evaluated:

- a Model 18-251-F commercial grade diesel engine, including power-train parts and mechanical components, manufactured by GE Locomotive (GE-L) of Montreal, Canada
- a safety-related synchronous power generator supplied by NEI Peebles-Electric Products, Inc. (P-EP), of Cleveland, Ohio, and manufactured by NEI Peebles Ltd., Peebles Electrical Machines (PEM), of Edinburgh, Scotland, United Kingdom
- a commercial grade static exciter-voltage regulator (SE-VR) system and cabinets manufactured by Basler Electric Company of Highland, Illinois
- control panels, instrumentation and control (I&C) components, piping, and valves supplied by PG&E
- the assembly and testing of the 2-3 EDG set by GEC Alsthom of Toronto, Canada

A summary of the more significant events of the NRC assessment is provided, as follows.

- March 27, 1991 — PG&E transmitted (DCL-91-067) to the NRC its overall summary of the dedication methodology for the diesel engine.

- April 29–May 3, 1991 — NRC staff inspected the procurement and commercial grade dedication of the diesel engine at PG&E's corporate offices in San Francisco, California (IR 50-323/91-202).

- July 15, 1991 — PG&E's staff met with the NRC staff in Rockville, Maryland, to present a response and supporting documentation for questions raised during the NRC inspection.

- August 5–9, 1991 — NRC staff inspected the supplier of the power generator, P-EP (IR 99900772/91-01).

- September 23–27, 1991 — NRC staff inspected the manufacturer of the power generator, PEM (IR 99901065/91-01).

- February 20, 1992 — PG&E's staff met with the NRC staff in Rockville, Maryland, to present a revised approach to its commercial grade dedication methodology. The NRC staff suggested that PG&E perform an endurance test and post-test disassembly inspection that may assist to (1) resolve the issues raised during the inspections of PG&E, P-EP, and PEM; and (2) establish the reliability of the 2-3 EDG set to perform its safety function.

- March 10–17, 1992 — NRC Region V staff evaluated PG&E's quality program and its implementation for the procurement of the power generator (IR 50-275/92-09 and 50-323/92-09).

- March 26, 1992 — PG&E's staff met with the NRC staff in Rockville, Maryland, to discuss the concerns of the NRC staff and present PG&E's plan for conducting an endurance test and post-test disassembly inspection, later known as the post-modification preoperational endurance tests.

- April 17, 1992 — PG&E transmitted (DCL-92-092) to the NRC its plan for the post-modification preoperational endurance tests of the 2-3 EDG.

- April 27–June 5, 1992 — NRC staff inspected the commercial grade dedication of certain components of the 2-3 EDG at PG&E's corporate offices. The inspectors also reviewed PG&E's compensatory actions taken as a result of the deficiencies, nonconformances, and unresolved items identified during the NRC's inspections of PG&E, P-EP, and PEM.

- October 9, 1992 — PG&E transmitted (DCL-92-218) to the NRC its documentation associated with the open items from the NRC's inspection conducted April 27–June 5, 1992. The results of the NRC staff's review of PG&E's documentation are contained herein.

- December 1992 — Even though the team conducted its exit meeting for this inspection on June 5, 1992, the team agreed to continue its inspection efforts through its evaluation of PG&E's documents that were submitted after the team's exit meeting. For instance, PG&E's documentation of certain procedures for the post-modification tests and documentation of its evaluations of certain issues were available for the team's review in December 1992.

1.2 Regulatory Basis

Without installation of the 2-3 EDG set, PG&E had determined that DCNPP2 met the minimum requirements for station blackout in accordance with Title 10 of the Code of Federal Regulations, Part 50, Section 50.63 (10 CFR 50.63). However, as an additional "alternate ac source," as defined in 10 CFR 50.2 and addressed in 10 CFR 50.63(c)(2), the 2-3 EDG set provides DCNPP2 with significantly enhanced operational flexibility to meet station blackout requirements and minimize limiting conditions for operation and their effect. Nevertheless, PG&E classified the 2-3 EDG set as a safety-related component or system and stated that it intended the 2-3 EDG set to comply with all aspects of

10 CFR 50.63 and Criteria 17 and 18 of Appendix A to 10 CFR Part 50. Applicable NRC requirements related to identified licensing and design-basis events (DBE), specifically seismic qualification, are contained in Criterion 4 of Appendix A to 10 CFR Part 50.

An NRC regulation of particular relevance to PG&E's procurement of the commercial grade 2-3 EDG set was 10 CFR Part 21, "Reporting of Defects and Noncompliance." The term "dedication" is defined in 10 CFR 21.3(c-1) as the point at which an item or service becomes a "basic component," meaning essentially an item or service with safety-related functions (i.e., maintaining the integrity of the reactor coolant pressure boundary, shutting down the reactor and maintaining it in a safe shutdown condition, and preventing or mitigating the effects of design-basis accidents and the offsite release of radioactivity in excess of 10 CFR Part 100 guidelines). The term "commercial grade items" (CGIs) is defined in 10 CFR 21.3(a)(4)(a-1), as distinguished from basic components, as those items that are not subject to design requirements or specifications unique to NRC-licensed facilities, are used in other facilities, and are procured on the basis of the manufacturer's published product description (e.g., a catalog). The regulation allows the procurement of items that meet the definition of CGIs, but which are to become basic components, without invoking the reporting requirements of 10 CFR Part 21 in the procurement documents.

In so far as PG&E procured CGIs (e.g., the diesel engine and SE-VR) for safety-related service, their procurement and dedication constitute activities affecting quality; therefore, these activities must be controlled in accordance with the requirements of Appendix B to 10 CFR Part 50. Criteria III and VII of Appendix B are particularly pertinent to the procurement of basic components as well as the procurement and dedication of CGIs. PG&E's procurement and commercial grade dedication activities were reviewed for compliance with these and other applicable criteria of Appendix B to 10 CFR Part 50 as well as the requirements of 10 CFR Part 21.

In its Generic Letter (GL) 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products," dated March 21, 1989, and GL 91-05, "Licensee Commercial-Grade Procurement and Dedication Programs," dated April 9, 1991, the NRC provided further guidance and interpretations that clarify the requirements of Appendix B to 10 CFR Part 50 as they pertain to the procurement and dedication of CGIs. Therefore, PG&E's procurement and dedication activities for the 2-3 EDG set were also evaluated for consistency with the guidance and NRC staff positions as promulgated in these GLs.

Finally, with respect to procurement in general, including PG&E's procurement and dedication of CGIs, PG&E has committed to various industry standards (e.g., the American National Standards Institute (ANSI) Standard N45.2, "Quality Assurance Program Requirements for Nuclear Facilities," (1971), and its applicable daughter standards, and other publications, as endorsed or conditionally endorsed by NRC regulatory guides (RGs), NUREGs, and GLs) as stated in PG&E's topical report containing the quality program description contained in or referenced in PG&E's Final/Updated Safety Analysis Report (FSAR/USAR) for DCNPP2. Of particular relevance to PG&E's procurement of the 2-3 EDG set was the commitment, as expressed for the industry by the Nuclear Management and Resources Council (NUMARC) in NUMARC 90-13, "Nuclear Procurement Program Improvements," dated October 1990. In particular, PG&E, like other nuclear utilities, was committed to establish a program on or before January 1, 1990, for the procurement and dedication of CGIs consistent with Electric Power Research Institute (EPRI) Report NP-5652, "Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07)." The acceptance methods described in NP-5652 were conditionally endorsed by the NRC in GL 89-02, and the NRC staff positions on several dedication issues were later clarified in GL 91-05. Accordingly, as a secondary consideration, the team assessed the degree to which PG&E's procurement and commercial grade dedication activities for the 2-3 EDG set were consistent with these commitments.

In accordance with the above guidance, PG&E was to procure the 2-3 EDG set in accordance with the applicable provisions of its quality assurance (QA) program required by Appendix B to 10 CFR Part 50. The team evaluated PG&E's associated activities to these criteria. Moreover, the team evaluated PG&E's additional verification activities for certain basic components and its dedication activities for certain CGIs to determine if the results of those activities adequately ensured the suitability of those items for their intended safety-related functions and reasonably ensured the quality and reliability of the 2-3 EDG set for its safety-related application at DCNPP2.

1.3 Assessment

During this inspection, conducted April 27 through June 5, 1992, the team focused its inspection on PG&E's commercial grade dedication of the SE-VR and cabinet and control panels, certain I&C components, piping, and valves. The team also reviewed and evaluated PG&E's compensatory actions taken as a result of the deficiencies and unresolved items identified during the previous inspection of PG&E and the unresolved item and nonconformances identified during the inspections of P-EP and PEM. The team evaluated activities, held discussions with PG&E personnel, and reviewed records and procedures associated with PG&E's commercial grade dedication activities, compensatory actions, and seismic qualifications. This report also incorporates the team's review of certain additional documentation submitted by PG&E.

For the inspection of the commercial grade dedication of the SE-VR and related cabinet and I&C components, panels, piping, and valves, the team has characterized its findings as deficiencies or unresolved items. Deficiencies are either (1) the apparent failure of PG&E to comply with a requirement or (2) the apparent failure of PG&E to satisfy a written commitment or to conform to the provisions of applicable codes, standards, guides, or accepted industry practices. Unresolved items involve a concern about which more information is required to ascertain whether it is acceptable or deficient. These items will be reviewed by the NRC regional office for any enforcement actions.

For the review and evaluation of PG&E's compensatory actions taken as a result of the deficiencies and unresolved items identified during the previous inspection of PG&E (IR 50-323/91-202) and the unresolved item and nonconformances identified during the inspections of P-EP (IR 99900772/91-01) and PEM (IR 99901065/91-01), the team has characterized its findings for each of the issues raised in the aforementioned inspection reports as either closed or not closed. Certain items are considered closed if PG&E provided new information that led to an understanding of the conditions or facts attending the issue and/or PG&E's compensatory actions taken to resolve the issue are satisfactory. Items are not closed if more information is required to ascertain whether resolution of the issue is acceptable and/or closure of the issue is pending PG&E's successful completion of the post-modification tests that consist of the post-modification functional tests and the post-modification preoperational endurance test.

Because NRC's assessment of PG&E's procurement and commercial grade dedication of the 2-3 EDG set considered the collective results of several related events, this report describes (1) the review of the deficiencies, unresolved items, and nonconformances that were identified during inspections at PG&E, P-EP, and PEM; (2) the evaluation of PG&E's compensatory actions taken, including the revised commercial grade dedication methodology for the EDG and the added post-modification tests; (3) the items that remain open and require further action by PG&E; and (4) the NRC's conclusions based on the results of the overall assessment.

The specific areas and documentation reviewed and the team's findings are described in Sections 2, 3, and 4 of this report. Section 5 addresses the exit meeting of June 5, 1992. The NRC's summary is given in Section 6. The persons who participated in and who were contacted during this inspection are listed in Appendix A.

2 PROCUREMENT REVIEW

PG&E procured each of the major components for the 2-3 EDG set as separate items. PG&E's procurement, including the specified quality and technical requirements, for the diesel engine, the power generator, and the SE-VR are described below.

2.1 Diesel Engine

By Purchase Order (PO) ZS-1539-AA-9, dated January 30, 1990, to GE-L, PG&E procured a 2600-kW EDG set. The PO also included a commercial grade Model 18-251-F, stationary, oil-fueled, water-cooled, four-cycle, 18-cylinder, "V" diesel engine with cylinder liners. Revision 1 of the PO, issued March 8, 1990, did not change the basic quality and technical requirements originally specified. It did, however, impose certain requirements on GE-L, including the provisions of PG&E's Design Specification 1539, "Design Specification for Furnishing and Delivering Diesel Engine Generator Unit at Diablo Canyon Power Plant, Unit 2," Revision 1, dated January 19, 1990.

The design specification stated that the diesel engine shall conform to GE-L's Specification GS5100F (ALCO), "Specification, Diesel Generating Sets," dated June 9, 1978, and PG&E's Specification CG-P-Diesel, "Specification for Supplier's Certification Program," (CG-P-Diesel), Revision 1, dated December 21, 1989. CG-P-Diesel required, in part, that unless otherwise noted in the specification, the supplier (GE-L) shall plan, establish, implement, and maintain a QA program in accordance with the requirements of CAN3-Z299.3-85 of the Canadian Standards Association's (CSA's), Quality Assurance Program Standards (CAN3-Z299).

Status of Previous Procurement Inspection Findings:

During the NRC inspection of PG&E in 1991 (IR 50-323/91-202), the inspection team identified two deficiencies with PG&E's procurement documents issued to GE-L for the diesel engine of the 2-3 EDG set. PG&E responded to the NRC addressing these deficiencies and provided additional information during subsequent inspections.

(1) Deficiency 50-323/91-202-01 (CLOSED)

This deficiency reflected PG&E's failure to include in its procurement documents to GE-L adequate technical and quality requirements for the power train parts to ensure that the parts and the diesel engine perform their safety-related function. PG&E's procurement documents imposed CSA's CAN3-Z299.3-85 quality program and the additional quality requirements specified in Design Specification 1539 and CG-P-Diesel. Specifically, the CAN3-Z299.3-85 program did not provide controls for design activities (i.e., planning, processes, verifications, or reviews).

In its letter (DCL-92-009) to the NRC, dated January 17, 1992, PG&E responded that

- Revision 3 to CG-P-Diesel was issued to GE-L (without revising the PO) to more clearly define those requirements that were imposed beyond the requirements of CAN3-Z299.3-85 (i.e., design control and audits of GE-L's subsuppliers).

- GE-L's engineering procedure for processing engineering change notices (ECNs) was subsequently forwarded to PG&E for review and was found acceptable.

- CAN3-Z299.3-85 required GE-L to develop an inspection and test plan, which was approved by PG&E, that included a scope of inspection to specify requirements for material certifications.

- Changes to GE-L's manufacturing procedures would require changes to GE-L's inspection and test plan, which PG&E would have to approve.

(2) Deficiency 50-323/91-202-02 (CLOSED)

This deficiency reflected PG&E's failure to include in its procurement documents to GE-L adequate technical and quality requirements for the mechanical components to ensure that the components and the diesel engine perform their safety-related function. Although PG&E later redefined the non-critical components referenced in its procurement documents as "mechanical components," the procurement documents were not revised to identify the technical and quality requirements of these components. PG&E's procurement documents considered the mechanical components (non-critical components) as parts that were not critical to the diesel engine and the 2-3 EDG set performing their safety-related function.

PG&E responded (DCL-92-009) that

- CG-P-Diesel made a distinction between critical and non-critical items so that special audit requirements could be specified for power train parts.

- CG-P-Diesel imposes the same requirements on all diesel engine components (power train and mechanical parts).

- PG&E considers the mechanical parts to be critical to the ability of the EDG to perform its intended safety-related function.

- Revision 2 to CG-P-Diesel was issued to GE-L (without revising the PO) to demonstrate that the same commercial quality requirements were imposed on all diesel engine components with the exception of the annual audit of subsuppliers.

The NRC staff considers these deficiencies closed because PG&E's compensatory actions have satisfied the concerns, specifically, PG&E's similarity evaluation (Spare and Replacement Parts Evaluation (RPE) M-6602, Attachment F, "Similarity Evaluation," Revision 2, dated April 24, 1992) identified and evaluated all design changes between the original five existing 1969 ALCO diesel engines at DCNPP and the new ALCO diesel engine manufactured by GE-L for the 2-3 EDG set.

2.2 Power Generator

By PO ZS-1539-AB-9, Revision 0, dated January 16, 1990, to P-EP, PG&E procured one 4.16-kV, 2600-kW, 60-Hz, 3-phase, 8-pole, 900-rpm, single-bearing, engine-driven, ac synchronous power generator. The generator was to be supplied as a design Class 1E basic component in accordance with PG&E's Engineers Material Memorandum (EMM) DC2-3322-BRH-E, Revision 0, dated January 5, 1990.

PEM is the sister company of, and the manufacturer for, P-EP. Both companies are subsidiaries of NEI Peebles Limited. P-EP provided the sales and technical services for all of the power generating equipment manufactured by NEI Peebles Limited and sold to U.S. customers.

In its acceptance of the PO from PG&E, P-EP accepted the responsibility to ensure overall compliance with all the applicable provisions of Appendix B to 10 CFR Part 50 and the reporting requirements of 10 CFR Part 21. Attachment A, "Specification for Supplier's Quality Assurance Program," Specification SP-D-Peebles (SP-D-Peebles), Revision 3, dated October 11, 1989, to PG&E's EMM required (1) that the supplier's

QA program for supplying equipment and components comply with the British Standards Institution's British Standard (BS) 5750, Part 1, Specification for Design/Development, Production, Installation, and Servicing, (ISO 9001-1987, Quality systems - Model for quality assurance in design/development, production, installation, and servicing), Part 2 and Part 3, and (2) that the supplier's QA program for supplying engineering services comply with Appendix B to 10 CFR Part 50 and ANSI N45.2-1971. In Section 3.0, "Quality Assurance Program (Edinburgh, Scotland)," SP-D-Peebles required that the supplier's QA program detail the procedures and methods used to ensure that all supplier's (PEM) activities satisfy the requirements of BS 5750, Part 1 (ISO 9001-1987) and Parts 2 and 3. In Section 4.0, "Quality Assurance Program (Cleveland Facility)," SP-D-Peebles required that the supplier (P-EP) ensure compliance with the applicable requirements of Appendix B to 10 CFR Part 50, ANSI N45.2-1971, and all other codes or standards referenced in the PO. SP-D-Peebles also imposed the requirements of numerous other ANSI nuclear standards, including ANSI N45.2.11-1974. Additionally, PG&E's PO for this safety-related generator, defined as a basic component in 10 CFR 21.3, invoked the reporting requirements of 10 CFR Part 21.

PG&E's generator is a complex component, composed of several critical parts that directly affect the ability of the generator to perform its design and safety-related functions (i.e., the credible failure mechanism or long-term degradation of the part could adversely affect the generator's ability to perform its safety-related function). PG&E selected and identified the generator's critical items in its PO.

PG&E's PO was modified and issued as Revision 1, February 2, 1990, to add Attachment F, "Critical Items Listing & Dedication Testing," to its EMM. Attachment F listed 14 critical items and their associated critical characteristics and required P-EP to verify PG&E-identified critical characteristics for each of the 14 critical items by performing tests. PG&E further required that the verification tests to be performed and their respective acceptance criteria be furnished to PG&E for approval before the materials and parts were installed or used.

Revision 2 to PG&E's PO, dated February 22, 1990, addressed specific data that P-EP was to provide to enable PG&E to perform the seismic analysis of the generator.

Revision 3 to PG&E's PO, dated February 6, 1991, included significant revisions to PG&E's EMM, SP-D-Peebles, Attachment A, and the critical items list of Attachment F. The EMM's Attachment F changed the list of critical items from 14 (shown in Revision 1) to 27 (in Revision 3). Several of the critical characteristics for those items that were to be verified by P-EP also changed, as described in Section 3.2.1.3 of this report. Table 1 (all tables are located at the end of this report beginning on page 145) provides a comparison of the critical items and their critical characteristics as expressed in Revisions 1 and 3 of the PO.

In the EMM, PG&E specified that the generator supplied by P-EP be identical (like for like) to PG&E's spare generator procured in 1986 and DCNPP's five existing generators from 1969. PG&E's basis for specifying an identical generator was that it had determined that the previously supplied generators met all applicable requirements including the NRC's quality and technical (including seismic DBE) requirements. PG&E's apparent strategy to demonstrate compliance with the requirements for suitability of safety-related equipment, including seismic DBE and any environmental qualification requirements, was to procure the generator on the basis of a like-for-like comparison with the 1969 generators, which were presumably fully qualified.

P-EP adapted PG&E's technical and quality procurement specifications into its own procurement specifications, including drawings, bills of material, and material specifications. In its procurement documents to PEM, P-EP either included or referenced its own documents. P-EP audited PEM's quality program and determined that, although it was not based on Appendix B to 10 CFR Part 50, PEM's program nevertheless met the applicable requirements of Appendix B to 10 CFR Part 50. P-EP attempted to indirectly invoke PG&E's requirements on PEM by imposing PEM's quality program in its procurement documents. With the notable exception of 10 CFR Part 21, no other NRC requirements or PG&E requirements were formally imposed on PEM, although PG&E's list of critical items and characteristics was informally transmitted to PEM by P-EP.

P-EP issued PO 16271 (shop order S-1128) to PEM on January 29, 1990, for PG&E's generator. For this generator, the PO specified that it be identical to the generator previously ordered by P-EP's PO 14673, dated February 25, 1986 (shop order S-1076, and job 259132), with some exceptions. The most significant exceptions were the phase rotation was changed per Drawing C-08991U; the pole insulation specification was changed from polyester resin to epoxy resin MV-20.9 per Specification EI-1.5.1; and the rotor pole assembly was changed per Drawing A-66843-7, Revision 2. P-EP's PO also imposed the reporting requirements of 10 CFR Part 21 on PEM. P-EP required that NEI Peebles Limited's QA program comply with Attachment A (SP-D-Peebles) of PG&E's EMM, and provided the generator's specifications for the tests to be witnessed, the applicable material specifications, the applicable manufacturing specifications, and the documentation requirements. P-EP's PO further required PEM to provide certification that PEM's manufacturing process complied with P-EP's and PEM's drawings and PEM's QA program, Issue 5, dated December 18, 1986. PEM's QA program was imposed because it was applicable to PG&E's 1986 spare generator.

The original issue of P-EP's PO to PEM did not identify the generator's critical items. Although P-EP issued several change orders to its PO during the fabrication, assembly, and test of PG&E's generator, P-EP failed to identify to PEM the generator parts that were specified by PG&E as critical items.
PEM completed and tested PG&E's generator during January and February 1991. PEM issued a certificate of conformance (COC) to P-EP on February 27, 1991, that certified the generator (serial no. 260274/1) was designed, manufactured, inspected, and tested in accordance with its quality program and the requirements of P-EP's PO 16271. On March 1, 1991, PEM shipped the completed generator to PG&E's contractor, GEC Alsthom of Toronto, Canada, for the final assembly and skid-mounting of the EDG set and the combined testing of the diesel engine, the generator, and the EDG's auxiliary systems. As required by PG&E's PO, when the generator for the 2-3 EDG set was delivered, P-EP provided PG&E with a COC that certified that the generator was produced in compliance with Appendix B to 10 CFR Part 50 and the reporting requirements of 10 CFR Part 21. This certification was based largely on P-EP's audit and determination that PEM's quality program was equivalent to Appendix B of 10 CFR Part 50. In its COC to PG&E dated March 27, 1991, P-EP certified that the generator complied with the provisions of PG&E's PO ZS-1539-AB-9 and added that the generator was the same in form, fit, and function, as the original generators supplied in 1969 (serial nos. 16908022–16908026).

2.3 Static Exciter-Voltage Regulator

By PO ZS-1539-AC-9, dated February 5, 1990, to Basler Electric Company of Highland, Illinois, PG&E procured two commercial grade SE-VRs and cabinets. The PO invoked PG&E's Specification EMM DC2-3342-BRH-E, Revision 0, dated January 29, 1990, which delineated specific performance requirements for the SE-VR equipment as well as several standards of the National Electrical Manufacturers Association (NEMA) and the Institute of Electrical and Electronics Engineers (IEEE). Attachment 1 to this EMM, "Series Boost – Static Exciter Regulator Specification for Diablo Canyon Emergency Diesel Generator Set – Brush-Type Synchronous Generator," specified that the SE-VR will provide ±1/2 percent voltage regulation on the generator over a range from the no-load condition up to, and including, the full-load steady-state condition.

The SE–VR consists of several CGIs that PG&E dedicated separately, using its RPE system for each component. To establish reasonable assurance that the SE–VR will perform its safety-related function, the interactions of the individual components must be determined. PG&E, however, had not developed an RPE that delineated the overall electrical requirements for the SE–VR system and the other related electrical components. Although the RPEs for the individual components contained specific design, material, and performance characteristics, including the instructions for verifying each of the characteristics identified, the individual RPEs failed to address the design and performance characteristics related to the synergy of the SE–VR components.

3 COMMERCIAL GRADE DEDICATION REVIEW

The team for this inspection evaluated PG&E's dedication activities for certain CGIs (e.g., the diesel engine, the SE–VR and cabinet, and certain I&C components, control panels, piping, and valves) and PG&E's additional verification activities for certain basic components (e.g., the power generator) to determine whether the results of all of these activities adequately ensure the suitability of those items for their intended safety-related functions and provide reasonable assurance of the quality and reliability of the 2-3 EDG set for its safety-related application at DCNPP2. To dedicate and qualify the commercial grade 2-3 EDG set, PG&E used the four acceptance methods described in EPRI NP-5652, "Guideline for the Utilization of Commercial Grade Items in Nuclear Safety-Related Applications (NCIG-07)," and the recommendations outlined in NUMARC 90-13, "Nuclear Procurement Program Improvements." EPRI NP-5652 described the four acceptance methods for CGIs as follows:

Method 1 – special tests and inspections
Method 2 – commercial grade survey of supplier
Method 3 – source verification
Method 4 – acceptable supplier/item performance record

The team's evaluation included reviewing PG&E's compensatory actions taken as a result of NRC findings identified during the inspections conducted at PG&E, P-EP, and PEM. This section describes the dedication methodologies and PG&E's activities, including the NRC findings and PG&E's compensatory actions taken for (1) the diesel engine, (2) the power generator, (3) the SE–VR, and (4) certain PG&E supplied items.

3.1 Diesel Engine

In its letter (DCL-91-067) dated March 27, 1991, to the NRC, PG&E provided an overall summary of its initial dedication approach for the diesel engine. During the 1991 NRC inspection of PG&E (IR 50-323/91-202), the team identified several concerns, characterized as unresolved items, with PG&E's initial dedication approach for the diesel engine. PG&E later revised its dedication methodology by reclassifying the acceptance methods applied to certain previously performed dedication activities and performing additional inspections and tests, described as post-modification tests, that PG&E had not previously included in its dedication of the diesel engine.

The team also reviewed certain portions of PG&E's RPE M-6602, Revisions 1 and 2, that documented PG&E's evaluation and dedication of the diesel engine for the 2-3 EDG set. The team's review consisted of evaluating (1) the distinctions PG&E made between the power train parts and the mechanical components, (2) the status of previous NRC inspection findings and PG&E's response to the NRC addressing the unresolved items and any additional information provided by PG&E during subsequent inspections, (3) PG&E's revised methodology for the dedication of the diesel engine, and (4) PG&E's compensatory actions taken for power train parts and mechanical components as a result of the NRC findings. These issues are described below.

3.1.1 Power Train Parts

PG&E's Design Specification 1539, described in Section 2.1 of this report, specified the criteria used to determine whether a diesel engine component or part was critical. The design specification also listed the critical components that are subject to the quality requirements specified in CG-P-Diesel. PG&E's criteria for determining if a component is critical was based on whether the functional performance testing by GEC Alsthom adequately demonstrated the components' properties or attributes regarding the effects of long-term degradation and cyclic fatigue. For example, if the functional performance testing will not demonstrate the adequacy of the component's properties or attributes to withstand the effects of long-term degradation and cyclic fatigue, then PG&E determined that the component was critical.

PG&E later defined (DCL-91-067) the critical components listed in the design specification as "power train parts." PG&E listed the power train parts in 14 groupings (a total of 424 parts):

- engine block
- crankshaft
- cylinder liners
- cylinder heads
- valves—air and exhaust
- valve inserts
- piston bodies
- piston caps
- connecting rods
- connecting rod nuts
- connecting rod bolts
- main bearings—shell
- main bearings—thrust
- camshafts

PG&E's further described the commercial grade dedication methodology for the diesel engine and the special quality requirements imposed on GE-L for critical components[1] (power train parts). The special quality requirements were that (1) GE-L shall evaluate all suppliers of power train parts to ensure their technical and quality capability to provide items or services, (2) GE-L's evaluation of suppliers shall be documented, and (3) GE-L's evaluation shall include an annual audit of the suppliers' facilities to assess the implementation of the suppliers' quality program in accordance with CSA's Standard CAN3-Q395 or equivalent.

For the commercial grade dedication and qualification of the diesel engine's power train parts, PG&E initially used acceptance Method 4 (acceptable supplier/item performance record) and qualified the use of this method by performing an audit of GE-L's facility in Montreal, Canada, December 12 through 15, 1989. The audit results, documented in Supplier Commercial Qualification Audit 89297S, addressed GE-L's ability to control changes in design, materials, and manufacturing processes, in accordance with the NRC's GL 89-02 and to validate the use of Method 4. Because of the concerns identified during its audit of GE-L, PG&E augmented its use of acceptance Method 4 for the initial dedication approach for power train parts with acceptance Methods 3 (source verification) and 1 (special tests and inspections).

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[1]PG&E did not attempt to distinguish between the term "critical component," as used in the design specification, and "critical part," as used in CG-P-Diesel; therefore, the terms were considered synonymous.

3.1.2 Mechanical Components

PG&E's Design Specification 1539 and CG-P-Diesel did not describe or define the non-critical parts (i.e., parts other than power train parts). However, PG&E's transmittal (DCL-91-067) described the remaining engine parts as mechanical components, which consisted of mechanical equipment associated with the diesel engine assembly up to the safety-related boundary, including individual parts of the engine, engine-mounted equipment (e.g., governor, fuel oil pressure control valve, lube oil pressure control valve, and piping), and skid-mounted auxiliary components (e.g., filters, strainers, lube oil pump, air start motors, and couplings). Thus all engine parts that were not identified as power train parts were considered to be non-critical components even though PG&E later defined these parts as mechanical components and evaluated them in its commercial grade dedication activities as diesel engine components critical to performing the engine's intended safety-related function.

PG&E selected 14 representative sample parts from the total population of 6316 parts that were not power train parts. On the basis of the 14 representative sample parts previously selected, PG&E defined 14 associated product types. The 14 product types of mechanical components listed below are intended by PG&E to represent the remaining engine parts, other than power train parts, which are referred to in the design specification and CG-P-Diesel as non-critical parts.

- engine-mounted rotating components
- skid-mounted rotating components
- special fasteners
- castings
- components from special manufacturing processes
- engine-driven or skid-mounted pumps
- precision-machined parts
- springs
- mechanical controlling devices
- heat exchanger
- commodity metallic
- commodity nonmetallic
- gaskets
- valves

PG&E's procurement documents referenced only critical components (power train parts) and non-critical components that were later defined as mechanical components. The PO, however, was not revised to identify the mechanical components or their safety-related function. For the mechanical components, the procurement documents did not provide their technical description or their technical and quality requirements. PG&E did not demonstrate its basis for considering the mechanical components, as described in the procurement documents, as parts that are not critical to the

EDG performing its intended safety-related function. Moreover, PG&E failed to evaluate the mechanical components to the same criteria used to evaluate and identify critical components (i.e., adequately demonstrating the properties or attributes that will withstand the effects of long-term degradation and cyclic fatigue).

PG&E initially used acceptance Method 4 to dedicate and qualify the diesel engine's commercial grade mechanical components. PG&E also supplemented acceptance Method 4 with acceptance Method 2 (commercial grade survey), performing Commercial Grade Survey 90216SS at GE-L's facility on September 17 through 20, 1990. The commercial grade survey was based on PG&E's 14 representative sample parts from the total population of 6316 mechanical components. Because of the concerns identified during its survey of GE-L, PG&E augmented its use of Method 2 with Methods 3 and 1.

3.1.3 Status of Previous Diesel Engine Dedication Inspection Findings

During its 1991 inspection of PG&E (IR 50-323/91-202), the NRC team identified several concerns (unresolved items) with PG&E's initial dedication approach for the diesel engine. The team reviewed PG&E's response to these concerns and considered additional information that PG&E provided during subsequent inspections. The results of this review are given below. For each case in which the NRC staff considers the concern unresolved (not closed), closure pending PG&E's successful completion of the post-modification tests, it is assumed that such tests will determine the adequacy of GE-L's design, materials, and manufacturing processes by subjecting certain components of the diesel engine to operating cycles in excess of the number of cycles where cyclic fatigue is expected.

3.1.3.1 Unresolved Item 50-323/91-202-01 (CLOSED)

The listing of power train parts in PG&E's transmittal (DCL-91-067) included valve inserts, connecting rod bolts, and connecting rod nuts, that were not listed in the design specification as critical components. However, PG&E did not revise the PO to include these components as critical components in its procurement documents and did not substantiate the components properties or attributes to withstand the effects of long-term degradation and cyclic fatigue. PG&E also failed to demonstrate that the list of power train parts included <u>all</u> parts that are required for the diesel engine to perform its safety functions.

In its letter (DCL-92-009), PG&E responded that

- It used the term "critical component" in the procurement documents because GE-L used this commercial terminology, which is understood to define a subset of components as safety-related.

- The items designated as "critical components" in the procurement documents are not the only items PG&E considers to be safety-related.

- The intent of the "critical components" definition, as used in the procurement documents, was to impose QA requirements for annual subsupplier audits beyond the QA requirements of CAN3-Z299.3-85.

- PG&E considered the valve inserts as part of the valve because they serve as the valve seating surface and the connecting rod nuts and bolts as part of the connecting rod because the nuts and bolts fasten the two-piece assembly of the connecting rod together.

The NRC staff considers this concern closed because PG&E's additional information about GE-L's use of the term "critical components" and its compensatory actions have satisfied the concern, specifically, PG&E's revised dedication approach for the diesel engine that considered all power train parts and mechanical components as critical components.

3.1.3.2 Unresolved Item 50-323/91-202-02 (NOT CLOSED)

PG&E evaluated several sources of performance history data to determine if documented failures of power train parts or mechanical components could be attributed to GE-L's manufacture of the diesel engine rather than to normal wear, adjustments of equipment, or poor maintenance and testing practices. PG&E's sources of performance history data and its evaluation of the data are discussed below.

- <u>DCNPP's ALCO Diesel Engine Failure History</u>

  PG&E reviewed the maintenance history for the five existing ALCO diesel engines at DCNPP and identified 33 mechanical-type component failures. Of these failures, only 3 could not be attributed to normal wear or maintenance and testing practices.

* NRC Bulletins and Information Notices (INs)

  PG&E reviewed 80 NRC bulletins and INs and identified two documents, INs 86-07 and 89-84, that were applicable to the performance history of DCNPP's diesel engines.

* Institute of Nuclear Power Operations (INPO) Nuclear Plant Reliability Data Systems (NPRDS) Data, and Significant Operating Experience Reports (SOERs)

  PG&E reviewed the NPRDS data and SOERs and identified a cracked cylinder head and two turbocharger failures as the only reported mechanical problems with ALCO diesel engines, or their auxiliary systems, that were not attributed to normal wear, adjustment of equipment, or poor maintenance and testing practices. PG&E concluded that these failures did not affect its commercial grade procurement and dedication of the diesel engine. The team, however, found that an ALCO diesel engine had experienced a cracked cylinder head that PG&E had not evaluated.

* EPRI NP-4264, "Failures Related to Surveillance Testing of Standby Equipment," Volume 2, "Diesel Generators"

  This document described EDG problems related to surveillance tests and recommended methods of alleviating those problems. The data covered just over 4 years (January 1979 through early 1983) and involved 136 EDGs and 585 failures. However, PG&E did not consider failures of other ALCO diesel engines that were not included in the 4-year period or other types of failures (e.g., failures related to unplanned demands) for ALCO diesel engines during the same timeframe.

* EPRI/NSAC (Nuclear Safety Analysis Center)-108, "The Reliability of Emergency Diesel Generators at U.S. Nuclear Power Plants"

  This report presents a 3-year survey (1983, 1984, and 1985) of EDG successes and failures to develop EDG reliability values that accurately indicate the contribution of EDG unreliability to plant risk. Each reported event was evaluated to determine if the EDG would have fulfilled its mission in a real emergency. For the purpose of determining the effect on plant risk, EDG reliability was considered during two phases of operation: the start phase and the load-run phase. However, PG&E did not consider other ALCO diesel engine failures that were not included in the 3-year survey (e.g., initial shakedown phase failures) or that reported other types of failures (e.g., surveillance test-related failures) for ALCO diesel engines during the same timeframe.

- PG&E's Survey of Industry-Wide Performance Data

  PG&E's independent survey of nuclear utilities with ALCO diesel engines to determine their reliability to start during surveillance testing for the years 1987 and 1988 failed to include all available reliability and performance data.

- Non-Nuclear Failure History of ALCO Diesel Engines

  PG&E determined that the best source of non-nuclear ALCO diesel engine failure history was GE-L's equipment bulletins. GE-L stated that equipment bulletins were issued to all customers if the problem was general and if it resulted in a design change. PG&E determined that 12 of the 88 GE-L equipment bulletins reviewed were applicable to PG&E's commercial grade dedication of the Model 18-251-F diesel engine.

- The Government Industry Data Exchange Program (GIDEP)

  As a member of this government-sponsored information exchange program that includes data on material problems, PG&E searched the GIDEP data base, but did not identify any failures of ALCO diesel engines.

- PG&E's Supplier Commercial Qualification Audit 89297S

  PG&E audited GE-L's facility in Montreal, Canada, December 12 through 15, 1989, to address GE-L's ability to control changes in design, materials, and manufacturing processes in accordance with NRC GL 89-02 and to validate the use of acceptance Method 4. PG&E's procurement document, CG-P-Diesel, invoked additional design controls that are not prescribed by QA program standard CAN3-Z299.3-85. During the audit, PG&E identified seven deficiencies in GE-L's quality program and its implementation and issued an audit finding report (AFR) for each deficiency.

  PG&E followed up by visiting the GE-L facility June 26-29, 1990, to assess GE-L's corrective actions to the AFRs. During the followup visit, PG&E accompanied GE-L's staff on its followup visit to Auburn Technologies Incorporated (ATI) of Auburn, New York, to verify ATI's corrective actions taken for four deficiencies that were identified by GE-L during its audit of ATI on January 10, 1990. ATI was GE-L's major subsupplier of power train parts. Before GE-L bought out Bombardier Inc., ATI and GE-L were the same company. ATI is a machining and assembly facility that provided GE-L with the power train parts listed in Table 2.

PG&E noted that ATI purchased the connecting rod nuts and connecting rod bolts in large volumes and verified them at receipt inspection, before adding them to its inventory. However, traceability was not maintained and material certifications were not available. Although material certifications were available for the power train parts listed in Table 2, PG&E concluded that the validity of the material certifications was indeterminate because ATI had not audited its subsuppliers.

GE-L's audit of ATI and the results of its followup visit identified weaknesses in GE-L's ability to control changes to design, materials, and manufacturing processes. Moreover, PG&E's audit and followup of GE-L's corrective actions substantiated the identified weaknesses in GE-L's quality program. Therefore, PG&E failed to demonstrate that GE-L adequately controlled changes in design, materials, and manufacturing processes necessary to support the use of acceptance Method 4 as the basis for the commercial grade dedication.

The team found that PG&E's evaluation of several of the sources of performance history data contained weaknesses, such as not representing industry-wide performance history because of either omissions in the specific source or gaps in the collective timeframe of the data. Additionally, PG&E did not substantiate that GE-L adequately controlled changes in design, materials, and manufacturing processes necessary to support the use of acceptance Method 4 as the basis for the commercial grade dedication. Moreover, the weaknesses in PG&E's performance history data evaluation were such that it was questionable whether industry-wide data could be established to adequately substantiate PG&E's use of acceptance Method 4 even when supplemented by other methods of commercial grade dedication.

PG&E responded (DCL-92-009) that

- Revision 1 of RPE M-6602 identifies five failures from the history review of DCNPP's existing five EDGs, whereas the preliminary RPE reviewed by the NRC identified only three failures; however, these failures did not relate to a specific weakness in the design and manufacturing controls imposed by GE-L.
- The cracked cylinder head that NRC identified as not evaluated by PG&E was identified in PG&E's preliminary RPE, but was erroneously attributed to the wrong facility.

- It recognizes that the EPRI and NSAC reports have limitations, such as timeframe and exclusion of certain types of failures; however, the cornerstone of the Method 4 evaluation for the dedication of the 2-3 EDG is the failure history of the existing five DCNPP EDGs.

- The scope of PG&E's survey regarding reliability of ALCO diesel engines is being expanded to include the data identified in the report. However, the responses received to date have not shown any data that would invalidate the Method 4 conclusions.

- The applicable equipment bulletins that PG&E reviewed verified that the improvements recommended had been incorporated into the 2-3 EDG design.

- To compensate for the ATI weaknesses identified, PG&E incorporated acceptance Methods 3 and 1 into verification activities for all parts supplied to GE-L by ATI.

3.1.3.3 Unresolved Item 50-323/91-202-03 (NOT CLOSED)

The mechanical components consisted of a total population of 6316 parts, which included, as a single item, those components and parts purchased by GE-L as subassemblies. In August of 1990, PG&E developed a matrix identifying critical characteristics for a selected number of parts from the 6316 mechanical components to provide specific technical input for the commercial grade survey. PG&E used the following selection criteria to identify the mechanical components to be included in the matrix: (1) the subsupplier; (2) the product type, complexity, and function; (3) the construction process; (4) industry experience with fraudulent items; and (5) the performance history. This activity resulted in PG&E's selection of 14 representative mechanical components, which PG&E correlated to the ALCO Model 18-251-F, "Renewal Parts List No. 943," dated July 1982, to determine if the 14 sample mechanical components previously selected would adequately represent all of the diesel engine's 6316 mechanical components. This activity resulted in PG&E defining 14 product types that were represented by the 14 mechanical components that were previously selected. The 14 product types and the 14 representative mechanical components and each part's associated critical characteristics, as identified in PG&E's commercial grade survey plan, are described in Table 3.

The 14 product types of mechanical components did not represent an established batch or lot homogeneity, particularly with respect to the control of critical characteristics, mechanical components furnished by the same subsupplier, and mechanical components with traceability to subsuppliers with an acceptable quality program, verified through audit or survey. In its selection of the 14 mechanical components to be used for the commercial grade survey, PG&E failed to demonstrate that

- The mechanical component selected adequately represented all of the other mechanical components within the product type or adequately established a basis for accepting the remaining mechanical components in each product type (e.g., the piston rings, selected to represent the "casting" product type, were used to accept the water and air piping elbows and the lube oil strainer; the fuel injection pump, selected to represent the "engine-driven skid-mounted pump" product type, was used to accept the lube oil pump and jacket water pump; the fuel injectors, selected to represent the "precision machined part" product type, were used to accept the push rods, piston pin assemblies, and the fuel pump rack control assemblies, including lifters, control shafts, and associated parts).

- The critical characteristics identified for the 14 representative mechanical components adequately represented all of the properties or attributes essential for the sample mechanical components, and all other mechanical components in the product type, to perform their design functions directly applicable to the EDG's ability to perform its intended safety function.

- The critical characteristics of the 14 representative mechanical components ensured that the part, and all other mechanical components in the product type, were technically identical to the mechanical components in DCNPP's five existing ALCO diesel engines and that the bases of the original seismic qualification were maintained.

PG&E responded (DCL-92-009) that

- PG&E's selection criteria provided a much more comprehensive review of the GE-L quality program implementation by specifically selecting a representative variety of manufacturing and procurement activities. Therefore, based on the control over critical characteristics of a representative sample verified during the commercial grade survey, PG&E established that programmatic controls over design, materials, and manufacturing processes had been implemented.

- PG&E supplemented areas in which weaknesses were identified by the commercial grade survey by incorporating acceptance Methods 3 and 1 into its verification activities.

- The basis for identifying the differences between the design of the original EDGs and the 2-3 EDG was an issue that was identified in the survey as requiring further documentation. PG&E will review these differences to determine if additional equipment testing is necessary to substantiate the overall component quality given that the change from the original five EDGs limits the applicability of Method 4 dedication to these components.

3.1.3.4 Unresolved Item 50-323/91-202-04 (NOT CLOSED)

PG&E evaluated five quality program elements and their associated quality criteria from Appendix B to 10 CFR Part 50 during its commercial grade survey of GE-L (i.e., design control; procurement control; identification and control of material, parts, and components; inspection and test; and control of nonconformances). The commercial grade survey of the 14 selected mechanical components identified several deficiencies in GE-L's quality program and its implementation that PG&E had not identified during its Supplier Commercial Qualification Audit 89297S and its followup visits to GE-L and ATI.

In its transmittal (DCL-91-067), PG&E claimed that the survey showed GE-L had an excellent commercial program for the production of diesel engines. PG&E also stated that its approach to the commercial grade survey would provide reasonable assurance that the diesel engine meets the PO requirements.

However, in Attachment R, "Engineering Resolution to Open Items Identified in Commercial Grade Survey 90216SS," to RPE M-6602, PG&E did not establish an adequate basis for accepting the 14 mechanical components chosen for the commercial grade survey because it did not adequately evaluate the findings of the survey with regard to the specific critical characteristics of the mechanical components selected for the survey. In Attachment R, PG&E stated that the radiator and the lube oil cooler, 2 of the 14 mechanical components selected for the survey, were purchased, received, and installed by GEC Alsthom and that resolution of the open survey issues for these items was contingent on GE-L's audit of GEC Alsthom. PG&E's procurement documents, however, showed that GE-L was responsible for the overall design and performance of the completed EDG assembly, in addition to supplying the diesel engine. Therefore, GE-L had the design responsibility for the radiator and lube oil cooler, which were not evaluated by PG&E during the survey. PG&E also failed to demonstrate its basis for using GE-L's audit of GEC Alsthom as its commercial grade survey of GE-L for the radiator and lube oil cooler.

PG&E's commercial grade survey failed to substantiate that GE-L's quality program was adequate to control the 14 selected mechanical components and raised concerns about the adequacy of the quality program to control the remaining mechanical components that were not evaluated during the survey. The survey identified deficiencies in GE-L's quality program and its implementation that also adversely affect the power train parts.

PG&E responded (DCL-92-009) that

- The purpose of the commercial grade survey was to identify any areas of GE-L's commercial quality program that could be taken credit for in the dedication, not to use the commercial grade survey as the sole basis of dedication.

- When the commercial grade survey identified inconsistencies or weaknesses (e.g., receipt inspection documentation, subsupplier design change reviews), PG&E performed additional inspections, tests, and source verification (Methods 3 and 1) to ensure complete dedication of all items (e.g., inspection of sampling of EDG parts before assembly, detailed review of design changes between the original five EDGs and the 2-3 EDG).

3.1.3.5 Unresolved Item 50-323/91-202-05 (NOT CLOSED)

As part of its response to the NRC staff, presented during a meeting in Rockville, Maryland on July 15, 1991, PG&E provided a reference document identified as Attachment XI, "Summary of Unique Safety Related Engine and Auxiliary System Mechanical Parts and Their Independent Verification." This document appeared to be part of RPE M-6602 and listed parts from the ALCO Model 18-251-F, "Renewal Parts List No. 943," dated July 1982, included in Attachment Q to RPE M-6602. The notes to the listing showed that power train parts were independently inspected and tested for configuration and material acceptability according to the requirements of Section I of PG&E's Inspection Plan DC-271, dated August 23, 1990. The inspection plan divided PG&E's source verification activities into the following three sections of activities:

<u>Section I</u> – Source verification activities consisted of dimensional and documentation checks that were identified as inspections for configuration in Attachment D to DCL-91-067. The critical characteristics chosen by PG&E for this portion of its source verification activities are given in Table 4. However, because PG&E did not include the engine block in this portion of its source verification activities, the critical characteristics for the engine block (described in Table 3) were not included in these configuration inspections.

Section II – Source verification activities during GE-L's manufacture of the diesel engine consisted of the following PG&E witness points:

- engine block and base welding
- engine block machining
- cylinder liner hydrostatic test
- engine block assembly
- crankshaft deflection
- inspection of cylinder head section
- torquing activities
- bumping clearance
- engine test
- lube oil and fuel oil analysis

Section III – Source verification activities during assembly of the diesel engine, generator, and auxiliary systems and associated piping by GEC Alsthom consisted of the following PG&E witness points:

- skid welding and heat treatment
- instrument tubing installation
- pressure tests
- critical piping and fastener dimensions
- radiator alignment checks
- system cleanliness and flushing
- electrical connections
- painting
- the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) symbol stamp on the applicable air receivers
- break-in test
- final running test and inspection
- diesel auxiliaries test
- final packaging

However, DC-271 did not include (1) the GE-L quality control elements to be verified by PG&E during the source verification activities and that were specific to the power train part's critical characteristics, (2) the surveillance methods or verification activities to be performed, and (3) an evaluation to determine the adequacy of the suppliers' (GE-L and GEC Alsthom) controls that were verified during the source verification activities.

PG&E responded (DCL-92-009) that

- The quality control elements required by CG-P-Diesel are addressed by Method 2 and the associated audits and surveys.
- The source inspectors are cognizant of the QA program requirements and have documented their review in source inspection reports of applicable areas such as verification of measurement and testing equipment calibration.
- The evaluation of the adequacy of the supplier's controls are not performed by inspection personnel, but are performed by design engineering personnel using the documented inspection reports.

3.1.3.6 Unresolved Item 50-323/91-202-06 (NOT CLOSED)

PG&E selected specific dimensional measurements as the critical characteristics of the power train parts. PG&E did not demonstrate its bases for determining that these dimensions (critical characteristics) were relevant to (1) the credible failure modes of the power train parts and the parts' ability to perform their safety-related functions and (2) the properties or attributes of the power train parts necessary to withstand the effects of long-term degradation and cyclic fatigue.

The results of PG&E's dimensional source verification (Method 3) activities identified numerous dimensional deficiencies in many of the power train parts. PG&E accepted these dimensional deviations without evaluating their effect on the properties or attributes of the power train parts to withstand long-term degradation and cyclic fatigue. Moreover, PG&E accepted these dimensional deviations, in part, on the basis of the quality activities of GE-L and ATI, even though PG&E's audits and surveys of both organizations identified significant deficiencies in their respective quality programs that were directly applicable to the power train parts. Additionally, where the source verification activities consisted of dimensional verifications that were accepted with identified deviations from the design specification and the drawings, PG&E did not substantiate or confirm that GE-L adequately controlled the quality of the manufacturing processes for power train parts. The purpose of PG&E's source verification activities was intended to demonstrate reasonable assurance that the power train parts meet the quality and reliability requirements of Appendix B to 10 CFR Part 50.

PG&E did not provide reasonable assurance that the technical bases for the critical characteristics chosen and verified during the source verification activities adequately (1) ensure that the power train parts and the diesel engine will perform their safety-related function, (2) ensure that the power train parts have the properties or attributes necessary to withstand the effects of long-term degradation or cyclic fatigue, and (3) ensure that the power train parts are technically identical to the critical components of DCNPP's five existing ALCO diesel engines and, therefore, maintains the bases of the original seismic qualification.

PG&E responded (DCL-92-009) that

- The purpose of source verification (Method 3) for the power train parts was not to provide complete verification activities to dedicate these parts independent of the other three dedication methods.

- The verification activities conducted under Methods 3 and 1, in conjunction with the associated engineering evaluations, provide reasonable assurance that these subsupplier components are adequate by verifying the various subsupplier activities (e.g., verify machining by dimensional check and verify material by chemical analysis of selected elements and hardness verification).

- The assurance that these parts have the attributes necessary to withstand the effects of long-term degradation or cyclic fatigue is not provided by these inspections alone. The GE-L design process and performance history in conjunction with the testing done under Methods 3 and 1 provide reasonable assurance that these components can withstand the effects of concern as have the equivalent components in the existing five diesels.

- As a result of concerns regarding GE-L documentation of the bases for subsupplier design modifications identified during the commercial grade survey, PG&E is identifying those components that are not technically identical to the existing five EDGs so that it can assess the effect on the dedication of those components.

3.1.3.7 Unresolved Item 50-323/91-202-07 (NOT CLOSED)

The reference document provided in PG&E's response of July 15, 1991, as discussed in Section 3.1.3.5 of this report, indicated that power train parts were independently inspected and tested for configuration and material acceptability according to the requirements of PG&E's Inspection Plan DC-271. The inspection plan divided PG&E's source verification activities into the three groups discussed. However, in the inspection plan, PG&E did not address its Method 1 special test and inspection activities and did not demonstrate a plan for these activities.

PG&E's transmittal (DCL-91-067) identified the following integrated functional-performance tests to be performed for the diesel engine and the completed 2-3 EDG set:

break-in test	rated rejection test
performance test	margin test
control and alarm test	acceleration test
diesel auxiliaries test	dead load·pickup test
rated load test	starting capacity test

The break-in test for the diesel engine was completed at GE-L's facility on February 11, 1991. GEC Alsthom performed the remaining integrated functional-performance tests listed above at its facility in Toronto, Canada, after the diesel engine, the emergency synchronous generator, and the diesel engine's auxiliary systems and associated piping were skid mounted and the EDG had been completely assembled. However, PG&E did not demonstrate the acceptance criteria specific to the critical characteristics to be verified during the functional-performance testing, and the documentation requirements for the inspection and test results. PG&E did not identify a documented plan to control and prescribe the special tests and inspections that GEC Alsthom will perform, and the test methods and inspection techniques that GEC Alsthom will use to confirm the acceptability of the functional-performance tests.

PG&E responded (DCL-92-009) that

- DC-271 was developed to address the specific PG&E witness points during engine manufacture and dimensional verifications of power train parts; it was not intended that this plan identify all the special testing activities to be performed for the dedication of the 2-3 EDG.

- The special tests outlined in RPE M-6602 were based on nondestructive verification of the critical characteristics of material and material strength and incorporated to provide reasonable assurance that the material strength and subsupplier materials used met the GE-L material specification requirements.

- The documented plan for the testing was generated by GE-L and was reviewed and approved by PG&E before GEC Alsthom started testing.

3.1.3.8 Unresolved Item 50-323/91-202-08 (NOT CLOSED)

The special tests and inspection activities for the power train parts consisted of selected material testing of power train parts, as identified in Attachment E to DCL-91-067. PG&E stated that the applicable GE-L material specifications or drawings were used as the acceptance criteria for all material tests, even though PG&E did not demonstrate a plan to perform the special test and inspection activities, as discussed in Section 3.1.3.7 above. The critical characteristics chosen by PG&E for the special tests and inspection activities are described in Table 4.

PG&E selected specific chemical elements from the allowable constituents specified in the material specifications as the critical characteristics of the power train parts. PG&E did not demonstrate its bases for determining that these chemical elements (critical characteristics) were relevant to (1) the credible failure modes of the power train parts and the ability of the parts to perform their safety-related functions and (2) the properties or attributes of the parts necessary to withstand the effects of long-term degradation and cyclic fatigue.

The results of PG&E's special tests and inspection activities identified numerous deviations in the chemical composition and hardness, or strength, in many of the power train parts. PG&E accepted these deviations in material requirements without evaluating their effects on the properties or attributes of the parts to withstand long-term degradation and cyclic fatigue. Moreover, PG&E accepted these deviations in material requirements, in part, on the basis of material certifications that were not traceable to the power train parts and that were not verified by audit or survey of GE-L's or ATI's subsupplier. In other instances, PG&E accepted the power train parts without material certifications and without performing a comprehensive material test to ensure that the part complied with the material specifications required by the design specification.

Additionally, where the special tests and inspection activities consisted of an analysis of a specific chemical element or hardness that was accepted with identified deviations from the material specifications required by the design specification, or without material certifications, or without verified material traceability, PG&E did not substantiate or confirm that GE-L adequately controlled the material used to manufacture the power train parts. The purpose of PG&E's activities was intended to demonstrate reasonable assurance that the power train parts meet the quality and reliability requirements of Appendix B to 10 CFR Part 50.

PG&E failed to demonstrate reasonable assurance that the technical bases for the special tests and inspection activities (1) ensure that the power train parts and the diesel engine will perform their safety-related function, (2) ensure that the power train parts have the properties or attributes necessary to withstand the effects of long-term degradation or cyclic fatigue, and (3) ensure that the power train parts are technically identical to the critical components of DCNPP's five existing ALCO diesel engines and maintain the bases of the original seismic qualification.

PG&E responded DCL-92-009 that

- The purpose of the special tests and inspections (Method 1) for the power train parts was not to provide complete verification activities to dedicate these parts independently of the other three dedication methods.

- The verification activities conducted under Methods 3 and 1, in conjunction with the associated engineering evaluations, provide reasonable assurance that these subsupplier components are adequate by verifying the various subsupplier activities (e.g., verify material by nondestructive chemical analysis of selected elements and hardness verification).

- The assurance that these parts have the attributes necessary to withstand the effects of long-term degradation or cyclic fatigue is not provided by these inspections alone. The GE-L design process and performance history, in conjunction with the testing done under Methods 3 and 1, provide reasonable assurance that these components can withstand the effects of concern as have the equivalent components in the existing five diesels.

- As a result of concerns regarding GE-L documentation of the bases for subsupplier design modifications identified during the commercial grade survey, PG&E is identifying those components that are not technically identical to the existing five EDGs so that it can assess the effect on the dedication of those components.

3.1.4 Revised Engine Dedication Methodology

During its meeting of February 20, 1992, in Rockville, Maryland, with representatives of the NRC to discuss the open issues from previous inspections, PG&E presented a revised approach for its dedication of the diesel engine. PG&E's new approach was developed to address the team's concerns regarding the performance history of the engine and the long-term degradation and cyclic fatigue of certain critical parts of the diesel engine.

PG&E's revised dedication approach changed the relationship of two acceptance methods (Method 2, commercial grade survey of supplier, and Method 4, acceptable supplier/item performance record) by supplementing both methods with its review of design changes, thereby attempting to establish the similarity of the diesel engine for the 2-3 EDG to DCNPP's five existing ALCO diesel engines. The revised approach also clarified that PG&E's evaluation of the diesel engine was performed by redefining its use of Method 1, special tests and inspections, and Method 3, source verifications. Specifically, PG&E revised the dedication methodology for the diesel engine by (1) applying acceptance Method 2 to the dedication of the power train parts (originally, Method 2 applied only to mechanical components); (2) redefining the material tests and verification activities (performed by PG&E in its original dedication approach as acceptance Method 1 activities) as compensatory actions for the weaknesses identified during its commercial grade survey of GE-L; and (3) applying acceptance Method 1 to only certain types of special inspections and testing activities. The revised dedication approach changed PG&E's dedication methodology for the mechanical components by limiting the use of acceptance Method 1 for only the diesel engine break-in test at GE-L, the integrated functional-performance tests at GEC Alsthom, and the post-modification tests at DCNPP2.

PG&E's revised dedication approach and its use of the four acceptance methods for CGIs is described below.

3.1.4.1 Method 4 — Acceptable Supplier/Item Performance Record

The team found that PG&E's evaluation of and conclusions with regard to several of the sources of performance history data contained weaknesses that were directly related to the 2-3 EDG set and its safety-related performance history, as described in Section 3.1.3.2 of this report. Moreover, the weaknesses identified in PG&E's performance history data were of such a nature to question whether industry-wide data could be established that would adequately substantiate PG&E's use of acceptance Method 4 as its overall basis for the commercial grade dedication of the diesel engine.

In its revised approach, PG&E did not consider Method 4 as the overall basis for the commercial grade dedication of the diesel engine, but rather as an acceptance method that contributed to the basis that established the similarity of the diesel engine for the 2-3 EDG to the diesel engines on DCNPP's five existing EDGs. To successfully support the use of Method 4 in its revised dedication approach (that resulted in diminishing the import of Method 4 on the overall dedication of the diesel engine), PG&E committed to complete its survey of the performance of ALCO diesel engines in the nuclear industry and perform the detailed design review of GE-L's design changes with respect to DCNPP's five existing ALCO diesel engines. This design review also supports PG&E's use of Method 2, commercial grade survey of supplier, as described below.

PG&E identified GE-L's design changes to certain power train parts and mechanical components that were used in DCNPP's five existing ALCO diesel engines. Because of these design changes, PG&E's use of acceptance Method 4 as part of its original bases for the dedication of the diesel engine, was no longer applicable to the following critical items:

- exhaust pipe expansion joint
- cylinder pressure indicator valve
- lube oil pump relief valve
- oil catcher
- lubricating oil regulating valve
- camshaft with gear
- crankshaft and extension shaft
- exhaust manifold and shroud
- cylinder block
- turbosupercharger
- valve levers, support and casings
- safety door
- cylinder head
- fuel injection equipment
- governor linkage
- governor drive
- generator connection
- lube oil pump
- radiator fan drive
- engine/generator skid
- lube oil filter
- air start motor lubricator
- air start motor
- lube oil check valve
- fuel oil filter
- engine base with screens and covers
- camshaft thrust bearing and flywheel
- fuel pump control shafts and levers
- turbo exhaust outlet adapter
- overspeed trip
- micro switch assembly
- water pump
- piston, connecting rod and cylinder liner
- fuel pump support, cross-head lifters and covers
- air manifold pressure regulating valve
- fuel oil booster pump and drive
- gaskets, and various commodity items

However, PG&E stated that dedication of the CGIs listed above will be accomplished by use of acceptance Method 2 with compensatory actions. Method 3, source verification, and Method 1, special tests and inspections, as utilized in PG&E's revised dedication approach, also are applicable to the dedication of the CGIs listed above.

3.1.4.2 Method 2 — Commercial Grade Survey of Supplier

Although acceptance Method 2 is a means by which PG&E can take credit for a supplier's commercial quality controls by confirming that the design, material, and performance characteristics of an item are adequately controlled, PG&E did not specify the supplier's acceptable commercial quality controls in its procurement documents for certain components. For example, PG&E did not specify quality requirements (1) to ensure the adequacy of the design, material, and performance characteristics of certain components necessary for the EDG to perform its intended safety-related function and (2) to ensure that certain components were technically identical to the mechanical components of DCNPP's five existing ALCO diesel engines, thus maintaining the bases of the original seismic qualification.

In its revised dedication approach, PG&E used acceptance Method 2 to contribute to its bases that established the similarity of the diesel engine for the 2-3 EDG to DCNPP's five existing ALCO diesel engines. Although PG&E's original dedication approach applied acceptance Method 2 only to the mechanical components supplied by GE-L, its revised dedication approach applied acceptance Method 2 in such a way as to ensure that the supplier's commercial quality controls were adequate to control the design, material, and performance characteristics for (1) the completed diesel engine supplied by GE-L, (2) certain power train parts supplied by ATI, (3) the support skid assembly supplied by Nicholls-Radtke Limited, and (4) the assembled 2-3 EDG set supplied by GEC Alsthom. PG&E's use of acceptance Method 2 for CGIs is described below.

(1) Assessment of GE Locomotive

In its original dedication approach, PG&E described its audit of GE-L (Commercial Qualification Audit 89297S, December 12-15, 1989) as an assessment of GE-L's ability to control changes in design, materials, and manufacturing processes in accordance with NRC GL 89-02 to validate the use of acceptance Method 4. The audit identified seven deficiencies in GE-L's quality program and its implementation. PG&E issued an audit finding report for each deficiency.

In its revised dedication approach, PG&E considered the audit as contributing to its acceptance Method 2 evaluation of the diesel engine, specifically applicable to the power train parts. PG&E's compensatory actions for the findings identified during its programmatic assessment of GE-L are given below.

- PG&E accompanied GE-L on its audits of ATI, Nicholls-Radtke Limited, and GEC Alsthom.

- PG&E verified the certificates for certain power train parts supplied by GE-L's subsuppliers that were not audited by GE-L annually, as required by PG&E's PO.

- PG&E performed a survey of GE-L (Commercial Grade Survey 90216SS, September 17 through 20, 1990).

The team reviewed PG&E's commercial grade survey of GE-L and found that PG&E's selection of the 14 product types of mechanical components (described in Table 3 and used to conduct commercial grade survey 90216SS) failed to represent an established batch or lot homogeneity (particularly with respect to the control of critical characteristics), mechanical components furnished by the same subsupplier, and mechanical components with traceability to subsuppliers with an acceptable quality program verified through an audit or survey. The team's findings are described in Section 3.1.3.3 of this report.

During its survey, PG&E evaluated five quality program elements and their associated quality criteria from Appendix B to 10 CFR Part 50 (i.e., design control; procurement control; identification and control of material, parts, and components; inspection and test; and control of nonconformances). The survey of the 14 selected mechanical components identified several deficiencies in GE-L's quality program and its implementation, as described in Section 3.1.3.4 of this report.

PG&E stated that it was not appropriate for its original dedication approach to characterize and use acceptance Methods 3 and 1 as compensatory actions for the weaknesses identified during its Method 2 commercial grade survey of GE-L. For the activities performed by PG&E on the power train parts and previously identified by PG&E as acceptance Methods 3 and 1, PG&E redefined those activities in its revised dedication methodology as Method 2 compensatory actions, described in Section 3.1.5 of this report.

For the findings identified during its commercial grade survey of GE-L, PG&E, in its revised dedication approach for the diesel engine, described the following Method 2 compensatory actions:

- To substantiate the adequacy of GE-L's design controls and to support PG&E's seismic analysis of the 2-3 EDG (to ensure that the diesel engine and its critical components are technically identical to the critical components of DCNPP's five existing ALCO diesel engines and maintain the bases of the original seismic qualification), PG&E will perform a detailed design review of GE-L's design changes with regard to DCNPP's five existing ALCO diesel engines.

- To provide added assurance that GE-L's subsuppliers provided quality parts for PG&E's diesel engine, PG&E performed additional inspections and tests on power train parts and mechanical components (e.g., the inspections and tests performed on a sample of mechanical components described in Section 3.1.3.3 of this report and in Table 3). These inspections and tests consist of activities performed to verify part number, configuration, damage, and material. PG&E documented the results of its Method 2 compensatory actions in RPE M-6602, Attachment X, "Inspection Plan DC-271," Section I, for the configuration and material verifications of the power train parts and RPE M-6602, Attachment Z, "QC Surveillance Plan No. 6602-1," for the configuration and material verifications performed on a sample of the mechanical components. The specific details of PG&E's Method 2 compensatory actions for power train parts and mechanical components are described in Section 3.1.5 of this report.

- To ensure that all nonconformances for PG&E's diesel engine contain sufficient justification for the acceptance of certain parts, PG&E reviewed all of GE-L's reports of material nonconformances.

- To ensure (a) the adequate verification of the design, material, and performance characteristics of certain components of the EDG that are necessary for the diesel engine to perform its intended safety-related function and (b) the properties or attributes of certain components are capable of withstanding the effects of long-term degradation and cyclic fatigue, PG&E, used acceptance Method 1 in its revised dedication approach. PG&E's acceptance Method 1 activities included the diesel engine break-in tests by GE-L, the integrated functional-performance tests by GEC Alsthom, and the post-modification tests. The post-modification tests, described in Section 3.1.4.4(3) of this report, provide for (a) performing the tests described in PG&E's revised dedication approach as post-modification functional tests and (b) evaluating the adequacy of GE-L's design, materials, and manufacturing processes by subjecting certain components of the diesel engine to operating cycles in excess of the number of cycles where cyclic fatigue is expected. These tests are described in PG&E's revised dedication approach as post-modification preoperational endurance tests.

(2) Assessment of Auburn Technologies Incorporated

ATI was a machining and assembly facility and GE-L's major subsupplier of power train parts. For PG&E's 2-3 EDG diesel engine, ATI supplied GE-L with the power train parts listed in Table 2. During the followup visit to GE-L in June 1990, PG&E accompanied GE-L's staff on its followup visit to ATI to verify ATI's corrective actions taken for four deficiencies identified during GE-L's audit of ATI on January 10, 1990.

The team found that GE-L's audit of ATI and the results of its followup visit failed to close the previously identified weaknesses in GE-L's ability to control changes to design, materials, and manufacturing processes. Moreover, PG&E's audit and followup of GE-L's corrective actions substantiated the identified weaknesses in GE-L's quality program. Therefore, PG&E failed to demonstrate that GE-L adequately controlled changes in design, materials, and manufacturing processes, as described in Section 3.1.3.2 of this report.

During GE-L's followup audit of ATI, PG&E reviewed GE-L's POs to ATI, witnessed magnetic particle (MT) nondestructive examination (NDE) of a connecting rod, witnessed the induction heat treatment of a camshaft, randomly verified the calibration of certain measurement and test equipment (M&TE), and reviewed material test reports for certain power train parts. GE-L's review of its POs to ATI identified that in addition to the power train parts listed in Table 2, ATI had also supplied the damper, certain gears, and the turbocharger for PG&E's diesel engine.

To compensate for ATI's weaknesses identified by GE-L's audit and to provide assurance that all of the parts supplied by ATI meet GE-L's specifications, PG&E incorporated in its original dedication approach the use of acceptance Methods 3 and 1 in the verification activities for all power train parts supplied to GE-L by ATI.

According to PG&E, this confirmed the adequacy of ATI-supplied power train parts. These verification activities were incorporated into PG&E's RPE M-6602 and its source surveillance plan. However, to provide added assurance that GE-L' subsuppliers provided quality parts for PG&E's diesel engine, in accordance with its revised dedication approach, PG&E performed additional inspections and tests for configuration and material. The results of these inspections were documented in PG&E's RPE M-6602, Attachment Z, "QC Surveillance Plan No. 6602-1." In its revised dedication approach, PG&E considered all of its previously performed verification activities to be acceptance Method 3 activities although some of these were considered acceptance Method 1 activities in PG&E's original dedication approach.

(3) Assessment of Nicholls-Radtke Limited

GEC Alsthom procured the fabrication and assembly of the support skid structure for the 2-3 EDG from Nicholls-Radtke Limited (NRL). GEC Alsthom provided NRL with GE-L's drawings and specifications for the support skid structure that specified that the fabrication of the support skid structure comply with the CSA's Standards W59, "Welded Steel Construction," and W47.1, "Certification of Companies for Fusion Welding of Steel Structures." According to PG&E, the CSA Standard W59 was similar to the American Welding Society's (AWS's) Standard ANSI/AWS D1.1, "Structural Welding Code," and that CSA Standard W47.1 contained the requirements for the qualification of welders and welding procedure specifications.

In August 1990, PG&E performed an audit of NRL to ensure that the skid would be manufactured in accordance with GE-L's requirements. PG&E's audit addressed NRL's ability to properly control the manufacturing processes for welding procedure qualification; welder qualification; visual acceptance criteria for welds; weld filler metal procurement and its traceability, storage, and control; and postweld heat treatment (i.e., stress relief heat treatment). PG&E's audit identified the following concerns; which would require NRL to take corrective actions:

- NRL's welding procedure specification failed to specify the preheat requirements for plate sections with thickness in excess of 1 1/2-inches (3.81-cm).
- GE-L's drawings failed to provide adequate fabrication detail for the welding joints that included groove weld splices.

- NRL's visual inspection acceptance criterion for completed welds were based on a standard for pipe welds as opposed to acceptance criterion for plate welds, as used in the skid's fabrication.

- For welding electrodes, NRL failed to establish a procedure to control the temperature of the electrode storage oven, the maximum allowed exposure time for an electrode removed from its storage oven, and the rebaking practices for electrodes before their return to a storage oven.

To address these concerns, PG&E developed an inspection plan for the fabrication and assembly of the support skid structure that identified hold and witness points that allowed PG&E to verify certain NRL fabrication activities and GEC Alsthom revised its inspection plan to reference NRL Engineering Standard 89044, which contained the proper criteria for visual inspection of weldments and weld filler metal (electrode) storage requirements.

(4) **Assessment of GEC Alsthom**

GEC Alsthom was GE-L's subsupplier that assembled the 2-3 EDG set and performed the integrated functional-performance tests of the completed EDG set that included the diesel engine, power generator, and its auxiliary systems. In October 1990, GE-L, with assistance from PG&E, performed an audit of GEC Alsthom's QA program. GE-L's audit of GEC Alsthom, based on the requirements of CSA Standard CAN3-Z299.3-85, resulted in the following findings, as referenced in GE-L's corresponding corrective action reports (CARs).

CAR 1 — GEC Alsthom failed to establish documented instructions for manufacturing, assembly, and inspection activities.

CAR 2 — GEC Alsthom failed to include the electrical and pressure instruments in its calibration program for M&TE and segregate the M&TE items calibrated for use on the 2-3 EDG from those M&TE items not approved for use on the 2-3 EDG.

CAR 3 — GEC Alsthom failed to establish a procurement program that complied with the requirements of CSA Standard CAN3-Z299.3-85 and also failed to properly maintain its approved suppliers list.

GE-L's followup audit of GEC Alsthom in March 1991, resulted in closing CAR 2, however, CARs 1 and 3 remained open. In May 1991, PG&E accompanied GE-L during its audit of GEC Alsthom's assembly of the 2-3 EDG and witnessed GEC Alsthom perform the integrated functional-performance tests on the completed EDG. During the audit, GE-L identified the following additional deficiencies.

CAR 4 – GEC Alsthom failed to establish controls that ensured the correct drawing revision was used during the fabrication and assembly of the 2-3 EDG. Drawings were identified that did not incorporate the outstanding document review requests, were not approved, and did not list revisions in the drawing index.

CAR 5 – GEC Alsthom failed to document the current status of the assembly operations via its inspection and test plan and other supporting documents for the assembly of the 2-3 EDG's components were either incomplete or were not developed or were not retrievable and auditable.

CAR 6 – GEC Alsthom's quality control inspectors failed to properly document that certain inspections were performed.

CAR 7 – GEC Alsthom failed to develop the necessary assembly instructions for certain complex assembly activities and other assembly instructions were not followed.

CAR 8 – GEC Alsthom failed to approve the special processes performed by a certain subcontractor.

CAR 9 – GEC Alsthom failed to establish adequate document control measures as evidenced by the fact that documentation for inspections, tests, design, procurement, and supplier qualifications were either lost, misplaced, or not developed.

CAR 10 – GEC Alsthom's improper tagging and segregation of safety-related items during storage and assembly resulted in its failure to properly control the identification of safety-related items supplied by GE-L, PG&E, and other suppliers.

CAR 11 – GEC Alsthom failed to provide indoctrination and training of newly hired shop personnel that were performing activities during the assembly and tests of the 2-3 EDG that affect its quality.

CAR 12 – GEC Alsthom failed to properly evaluate and qualify certain subsuppliers, provide documentation that substantiated the qualification of certain subsuppliers on its approved vendors list, and ensure that all subsuppliers maintained a quality program that complied to CSA Standard CAN3-Z299.3-85.

CAR 13 – GEC Alsthom performed work on nonconforming components without either documenting the nonconformance on a discrepant material report or approving the discrepant material report and its disposition. Nonconforming items were dispositioned as "use-as-is" without an adequate engineering basis.

In order to address the deficiencies identified during GE-L's audits of GEC Alsthom's assembly of PG&E'S 2-3 EDG, GEC Alsthom developed two separate comprehensive reinspection plans. The first plan was developed to ensure that PG&E's 2-3 EDG was assembled in accordance with GE-L's specifications, and the second plan was developed to verify the quality of all components and parts procured by GEC Alsthom. These reinspection plans, with concurrence by GE-L and PG&E, were developed as Method 2 compensatory action for the CARs described above.

To ensure that PG&E's 2-3 EDG was assembled in accordance with GE-L's specifications, GEC Alsthom developed a reinspection plan applicable to all of the critical components of the EDG assembly on the basis of its review of the assembly drawings and GE-L and PG&E's concurrence. GEC Alsthom's reinspection efforts were divided into twelve areas of the completed 2-3 EDG assembly, as listed below.

machinery arrangement	fan drive assembly
jacket water system	lube oil system
starting air system	turbocharger air system
fuel oil system	pressure gage tubing
radiator compartment	conduit arrangement
skid assembly	protection devices

For each of these areas, GEC Alsthom developed a set of inspection requirements that referenced specific inspection sheets for each component or part in each area of reinspection. The inspection sheets included the identification of the component, the acceptance criteria for the reinspection effort, and the M&TE used in the reinspection effort. GEC Alsthom's reinspection effort consisted of the activities listed below.

- verifying part numbers of installed components
- verifying part dimensions and their installation
- verifying the material grade of bolts and capscrews
- performing visual inspections for cleanliness and workmanship
- performing ultrasonic (UT) NDE of the shaft on the radiator fan
- verifying the torque requirements for certain bolts
- verifying the alignment and installation fit-up of certain components
- performing UT NDE of certain weldments
- verifying the adequacy of the electrical and instrumentation systems
- performing other visual inspections

To resolve the deficiencies identified by GE-L and described in CARs 3, 9, and 12 above (i.e., GEC Alsthom procured parts and services from subsuppliers that were not audited or qualified according to GEC Alsthom's quality program), GEC Alsthom developed a specific reinspection plan. The inspection plan for these parts that were not properly audited and qualified prescribed GEC Alsthom perform additional inspections to ensure the quality of the parts and provide justification for not qualifying the parts (e.g., the part was used only during the integrated functional-performance tests or the part would be dedicated by PG&E). GEC Alstom's reinspection plan for these parts consisted of performing hardness measurements, verifying certain dimensions, performing chemical analysis of certain materials, performing UT NDE on certain shafts, verifying personnel qualifications for UT NDE technicians, verifying M&TE calibrations, and performing visual inspections of certain weldments.

PG&E also developed RPE M-6602, Attachment AV, "QC Surveillance Plan 6602-2," to document the completion of those inspections required for the dedication of the 2-3 EDG assembly that could not be completed during the manufacture and assembly of the diesel engine, power generator, and auxiliary systems. These inspections could not be completed because the items to be inspected were not accessible for inspection at GEC Alsthom's facility (i.e., removed or packaged for shipment).

The results of GEC Alsthom's compensatory actions and reinspection efforts were reviewed and approved by GE-L and PG&E as noted on each of the completed inspection sheets. However, the team determined that even though GEC Alsthom's compensatory actions appeared to be comprehensive, the compensatory actions were not guided by PG&E's commercial grade dedication process adopted for other components or parts of the 2-3 EDG that were procured as CGIs. Specifically, the design, material, and performance characteristics for each part were not identified by GEC Alstom or verified to ensure the suitability of these parts for their intended safety-related functions and did not provide reasonable assurance of the quality and reliability of the 2-3 EDG set for its safety-related application at DCNPP2.

To ensure the adequacy and quality of GEC Alsthom's assembly of PG&E's 2-3 EDG set, including the diesel engine, power generator, and its auxiliary systems, PG&E applied acceptance Method 1, special tests and inspections, in its revised dedication approach. Included in PG&E's Method 1 activities intended to ensure the adequacy of GEC Alsthom's assembly were the tests described in PG&E's revised dedication approach as post-modification functional tests and as post-modification preoperational endurance tests (see Section 3.1.4.4(3)).

3.1.4.3 Method 3 — Source Verifications

In its original dedication approach for the diesel engine, PG&E used acceptance Method 3, witnessing GE-L perform quality activities that were intended to confirm that GE-L adequately controlled the quality requirements for power train parts and acceptance Method 1 verifying selected design, material, and performance characteristics of power train parts. By combining the use of Methods 3 and 1, PG&E intended to confirm that the power train parts meet their design specifications and their design, material, and performance characteristics to ensure the parts will perform their safety-related function.

However, for those activities previously categorized as acceptance Method 3 activities, PG&E redefined them in its revised dedication approach as Method 2 compensatory actions. Additionally, in its revised dedication approach for the diesel engine, PG&E stated that it was not appropriate for its original dedication approach to characterize and use acceptance Method 3 as compensatory actions for the weaknesses identified during its commercial grade survey of GE-L.

According to the revised dedication approach, PG&E's acceptance Method 3 activities for the 2-3 EDG were based on GE-L's inspection and test plans developed for the manufacture of the diesel engine and the assembly of the EDG by GEC Alsthom and reviewed and approved by PG&E. PG&E documented the results of all of its source verification activities in source inspection reports that are contained in RPE M-6602, Attachment Y, "Source Inspection Reports and Associated Engineering Responses."

To provide added assurance that the diesel engine was assembled according to GE-L's specifications, PG&E incorporated the source inspection witness points for certain activities and documented reviews in GE-L's inspection and test plans. PG&E's witness points during manufacture of the diesel engine are given below.

- engine block and base welding
- cylinder liner hydrostatic test
- inspection of cylinder head sections
- engine test
- block machining
- block assembly
- crankshaft deflection
- torquing activities
- bumping clearance
- lube oil and fuel oil analysis

PG&E also developed Sections II and III of Inspection Plan DC-271 (see Section 3.1.3.5) to further implement its acceptance Method 3 activities. PG&E's activities described in Section I of DC-271 consist of configuration and material verifications of power train parts. These verifications are defined by PG&E as Method 2 compensatory actions and are not within the scope of Method 3.

According to its revised dedication approach, PG&E's Method 3 activities at GEC Alsthom were intended to monitor all phases of the assembly of the 2-3 EDG. PG&E's witness points during the assembly of the EDG are given below.

- skid welding and heat treatment
- critical piping and fastener dimensions
- electrical connections
- painting
- break-in test
- final running test and inspection
- instrument tubing installation
- pressure tests
- radiator alignment checks
- system cleanliness and flushing
- ASME BPVC symbol stamp for applicable air receivers
- diesel auxiliaries test
- final packaging

3.1.4.4 Method 1 — Special Tests and Inspections

In its revised dedication approach for the diesel engine, PG&E changed the application of acceptance Method 1. PG&E's original dedication approach used acceptance Method 1 for the break-in test performed by GE-L, the functional-performance test performed by GEC Alsthom, and the additional tests (i.e., to verify the material and material strength for the power train parts and 10 percent of the mechanical components) that PG&E performed as a result of concerns raised during its commercial grade survey of GE-L. In its revised dedication approach, PG&E stated that it was not appropriate for its original dedication approach to characterize and use acceptance Method 1 as compensatory actions for the weaknesses identified during its commercial grade survey of GE-L. Therefore, PG&E applied acceptance Method 1 to only those activities defined as (1) the diesel engine break-in tests performed by GE-L, (2) the integrated functional-performance tests performed by GEC Alsthom, and (3) the tests described in PG&E's revised dedication approach as post-modification functional tests and post-modification preoperational endurance tests. These acceptance Method 1 activities are described below.

(1) Diesel Engine Break-in Tests

The functional break-in test, witnessed by PG&E and completed by GE-L on February 9, 1991, was performed to demonstrate that the assembled diesel engine was operable and to verify the engine's load and no-load performance. Specifically, GE-L performed 14 separate performance-runs of the diesel engine that were conducted with the engine in a no-load condition and a loaded condition using GE-L's test-generator. For these performance-runs, GE-L ensured the calibration of its test equipment used to verify the adequacy of the engine's instrumentation, coolant flow through the water-jacket, operating temperatures, operating pressures, bearing temperatures, and fluid levels in all systems.

For the no-load performance-runs with the water-jacket coolant at its normal operating temperature, GE-L ran the engine for 5-, 10-, and 30-minute intervals with engine speeds from 400 rpm, up to and including its rated speed of 900 rpm. After each no-load performance-run test, GE-L performed a visual inspection of the engine's piston skirts, cylinder liners, connecting rods, lube oil filters, and strainers.

For the performance-runs with the engine loaded, GE-L ran the engine at its rated speed of 900 rpm for 1 hour with the engine loaded at 25 percent of its full-load rating of 3632 hp (908 hp); 1 hour with the engine loaded at 50 percent of its full-load rating (1816 hp); 2 hours with the engine loaded at 75 percent of its full-load rating (2724 hp); 2 hours with the engine loaded at 100 percent of its full-load rating; and 1 hour with the engine loaded at 110 percent (10-percent overload) of its full-load rating (3995 hp). Following each performance-run test with the engine loaded, GE-L performed the same inspections performed after each no-load performance-run test described above.

(2) **Integrated Functional-Performance Tests**

GEC Alsthom mounted the engine from GEL, the generator from P-EP/PEM, and portions of the auxiliary systems on a skid of GE-L's design (fabricated by Nicholls-Radtke, Ltd.) and conducted functional performance testing on the diesel engine-power generator unit at its facility in Toronto, Canada, before shipping the assembled EDG to DCNPP2. GEC Alsthom ran these tests using some shop equipment of its own, so not all the equipment that would eventually become part of the 2-3 EDG system at DCNPP2 was tested by GEC Alsthom. The RPE for the diesel engine, RPE M-6602, Revision 2, Section VIII, "Special Tests and Inspections," under "Functional Testing at GEC Alsthom in Toronto," and the RPE for the ac synchronous generator, RPE E-7505, Revision 0, Attachment 1, under the heading "GEL Functional Testing," stated that this series of testing was performed in accordance with GE-L's Procedure 50D77481, "Electrical Test Specification," and briefly described the following testing.

- control and alarms test
- break-in test (reperformance of GE-L's break-in testing)
- diesel auxiliaries test
- rated load test
- load rejection test
- margin tests (acceleration, dead load pickup, and starting capacity – 100 fast starts)

<u>Note</u>: The testing sequence given in the RPEs M-6602 and E-7505 (i.e., 1-hour stabilization at full load, 22-hour full-load run at 2600 kW, and a 2-hour 110-percent overload capacity run at 2860 kW) was inconsistent with Section 4.6 of Procedure 50D77481 in which the order was 2-hour stabilization, 2-hour overload, 22-hour full load. During post-exit meeting conversations with the team, PG&E confirmed the test sequence, used during the portion of the post-modification tests that repeats this test, will be the test sequence prescribed in the applicable RPEs.

The parts of the system installed at the site that were not tested at GEC Alsthom include the SE-VR cabinets and some associated cabling, the governor system (electric control and mechanical actuator), and certain portions of auxiliary systems that were not skid mounted and such components as the starting air supply system. Therefore, in addition to confirming the results of various tests, the post-modification testing must include testing of these previously not tested components. Although the post-modification tests include repeating some of the GEC Alsthom tests, some portions of those tests, such as the 100 fast starts, are not to be repeated. PG&E will credit portions of the GEC Alsthom-performed tests to provide part of its verification of certain critical characteristics and/or to serve as compensatory actions.

The general critical characteristics of the EDG system, as described in PG&E's field change (FC) M-16128, "Post-Modification Functional Tests," Revision 0, dated June 10, 1992, as described in Table 5, were availability within the required time, capability of supporting loads for a design-basis accident (DBA), lost/rejected load speed stability, load sequencing voltage stability/recovery, and load sequencing frequency stability/recovery. These characteristics were to be verified by various combinations of tests, some of which were included in the GEC Alsthom tests, such as the starting capacity test, acceleration test, dead load pickup test, rated load test, and load rejection test.

In RPE M-6602, Revision 2, for the diesel engine, the engine's critical characteristics were given in terms of the characteristics of individual critical items of the power train parts and mechanical components. A table in the RPE originally correlated verification of these critical characteristics as a group for the various critical items to one or more of the four general acceptance methods, but not to specific tests. However in describing the four acceptance methods used, in Section VIII, "Special Tests and Inspections," the GEC Alsthom test series was described. Without a detailed correlation of critical characteristics to specific tests and inspections, the team reviewed GEC Alsthom's test procedure against Revision 0 of PG&E's Post-Modification Test Procedure (PMT) 21.12, "Diesel Generator 2-3 Site Acceptance Tests," dated December 1, 1992, and Revision 0 of PMT 21.13, "24 Hour Load Test of Diesel Generator 2-3 and Support Systems," dated November 23, 1992, and confirmed that certain portions of the GEC Alsthom tests were to be repeated as part of the post-modification tests with the most notable exception of the 100 fast starts. Although the parts of the GEC Alsthom testing that actually involved components (mostly skid mounted) that would ultimately remain part of the final installation at the DCNPP2 site, for the most part, and would be retested under the post-modification tests, the 100 fast starts performed in Toronto were being relied upon as the sole basis for verifying the ability of the engine, the generator, and the air start motors (only) to reliably achieve multiple consecutive starts.

The RPE for the ac synchronous generator, RPE E-7505, Revision 0, included a table that listed the generator's critical items and its critical characteristics. The table indicated that PG&E was relying on the functional testing at PEM and at GEC Alsthom (called "GEL" in the table), in lieu of supplier qualification to verify the adequacy of the slip ring mounting sleeve insulators and all generator terminations and connections. In addition, verification of virtually all of the critical characteristics was to be supported by some part of the post-modification tests, whether by monitoring certain parameters (e.g. vibration) during the run or by inspection and/or electrical testing, or both, following it.

The GEC Alsthom test document, GE-L Standard Manufacturing Practice 50D77481, "Electrical Test Specification," dated March 25, 1991 (of which revision dated September 6, 1991, was submitted to and reviewed by the team) described the functional performance testing of the skid-mounted engine-generator unit at GEC Alsthom. Attached to the procedure was Appendix I, which was supposed to contain the test results. Review of these documents resulted in the following observations.

The procedure did not always provide acceptance criteria or tolerances on test values where appropriate. The data in Appendix I were often taken without any stated acceptance criteria, but no out-of-specification values were noted where acceptance criteria were stated. Often, individual results were expressed merely as "OK," as opposed to documenting objective evidence (raw data). This is illustrated by the following:

Step 3.1, "HI-POT TEST," called for applying 1000 Vac (for 1 minute) to each wire from the skid to the control panel (before connecting to the panel) to ground, but no acceptance criterion was given, either in terms of minimum insulation resistance or maximum allowable leakage current. A so-called hi-pot (short for high potential) test (also called dielectric withstand) normally subjects the insulation to a test voltage of twice rated voltage plus 1000 volts (dc). However, the specification of 1000 Vac could not be evaluated because neither the prescribed test equipment, service voltage, nor voltage rating of the various wires listed were stated. The step listed 26 separate devices whose wires were to be tested, including the governor, magnetic pickups, and thermocouples. Then the instructions excepted the wires from these three types of devices, but did not state how they should be checked, if at all. Although the step required checking all wires (with noted exceptions), the data printed in Appendix I for this step indicated only a single reading of 5.4 milliamperes (ma) and a single "*Megger*" reading of >200 megohms. These results were not fully consistent with the procedure, vague as it was, nor with each other. A "*Megger*" (which is a registered trademark of Biddle Instruments, Inc.) would be expected to give a reading in terms of megohms (typically at 500 or 1000 Vdc), but this test was not specified. A 5.4 ma reading (presumably ac-RMS) with 1000 Vac applied continuously is most probably what is known as "charging current" and is indicative of the capacitive impedance to ground of the system and of no gross insulation breakdown, as opposed to actual leakage (as would be measured by a dc hi-pot test). This value might be acceptable for control circuits, but may be excessive for leakage-sensitive circuits such as instrument leads. It was therefore not clear what test instruments were actually used, what the results were for each wire, and whether the results were meaningful and satisfactory for the various applications.

As with the engine, it is apparent that the GEC Alsthom testing will ultimately serve to provide additional margin in support of dedication of the generator and its ancillary systems because most of the testing will be repeated during the post-modification tests. The team found this to be an acceptable approach, because the specific concerns identified above would be addressed during the post-modification tests when the discrepant portions of the tests are repeated.

(3) Post-Modification Tests

During the meeting in Rockville, Maryland, on February 20, 1992, to discuss the open issues from the NRC inspections at PG&E, P-EP, and PEM, PG&E presented a revised methodology, or approach, for the dedication of the diesel engine. PG&E's revised dedication approach was developed to address the team's concerns regarding the performance history of the engine and the long-term degradation and cyclic fatigue of certain critical parts of the diesel engine. At the meeting, the NRC staff suggested that PG&E consider additional endurance testing in combination with a breakdown and inspection of specific parts of the engine and power generator. At the conclusion of the meeting, PG&E agreed to develop, in consultation with GE-L, a program for supplemental endurance testing of the 2-3 EDG.

On March 26, 1992, PG&E met in Rockville, Maryland, with representatives of the NRC to discuss post-installation endurance tests to be conducted on the 2-3 EDG. At the meeting, PG&E agreed to conduct post-test inspections of certain critical components of the diesel engine and power generator and agreed to document its test and inspection plan in a letter submittal to the NRC.

By letter (DCL-92-092) dated April 17, 1992, PG&E transmitted to the NRC its plan for the preoperational endurance testing of the 2-3 EDG and stated that the purpose of the testing was to further augment the basis for the commercial grade dedication of the EDG. PG&E added that this additional testing will facilitate resolution of the open issues identified during the NRC's inspection of PG&E and the issues raised during the inspections of PE-P and PEM. In its plan, PG&E identified the specific testing to be conducted, the equipment monitoring to be performed during the testing, the criteria to be used for evaluating component malfunctions or failures, and the inspections to be performed following completion of testing.

During its exit meeting with PG&E's staff on June 5, 1992, the team noted that PG&E's procedures that specified the requirements of the post-installation test and inspections were not complete and considered this an open item.

By letter (DCL-92-218) dated October 9, 1992, PG&E transmitted documentation associated with the open items identified during the team's inspection, including the documentation issued to specify the 2-3 EDG post-modification test requirements. Specifically, Enclosure 1 to PG&E's letter contained FC M-16128, "Post-Modification Functional Tests," Revision 0, dated June 10, 1992, to PG&E's Design Change Notice (DCN) DC2-EM-44405, Revision 1, of PG&E's Design Change Package (DCP) DCP-M-44405 and PMT-21.16, "Diesel Generator 23 Preoperational Endurance Test," dated October 5, 1992. DCP-M-44405 documents the installation of the 2-3 EDG at DCNPP2, the changes to the facility brought about by the installation of the 2-3 EDG, and PG&E's description and safety evaluation, as required by 10 CFR 50.59.

PG&E pointed out that the additional onsite testing of the 2-3 EDG at DCNPP2 is preoperational testing as distinguished from post-installation testing. The testing will be conducted using a temporary load bank, not actual plant loads. However, PG&E stated that the temporary load bank will be capable of simulating the resistive and reactive loads necessary to adequately test the EDG. The post-modification functional tests and the post-modification preoperational endurance tests are described separately below.

Post-Modification Functional Tests

PG&E's FC M-16128 provided for the following additional tests to be included in PG&E's basis for dedication of certain components that were dedicated individually through their respective RPEs:

- the engine break-in tests in accordance with GE-L's Standard Manufacturing Practice 50D77481, "Electrical Test Specifications," dated March 25, 1991, described in Section 3.6, "No Load Tests," Section 3.7, "Load Adjustment Test," Section 3.8, "KWS (relay) Setting," and Section 3.9, "Stability"

- the multiple start tests, using each air start receiver separately with and without turbo air assist, to verify that the sizing criteria for the air start receivers were met in the final configuration of the air start system

- the starting test defined by IEEE Standard 387-1984, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," Section 6.3.1

- the load acceptance tests defined by IEEE Standard 387-1984, Section 6.3.2, with the use of the load bank

- the rated load tests defined by IEEE Standard 387-1984, Section 6.3.3

- the load rejection tests defined by IEEE Standard 387-1984, Section 6.3.4, with the short-time rated load defined as 110 percent of the EDG's full load

- the electrical load tests defined by IEEE Standard 387-1984, Section 6.3.5

- the subsystem tests defined by IEEE Standard 387-1984, Section 6.3.6, for the subsystems defined in Section 7.5.1.4

- the load capability tests defined by IEEE Standard 387-1984, Section 7.2.1

- the start and load acceptance tests defined by IEEE Standard 387-1984, Section 7.2.2; NRC RG 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants," Revision 1, dated August 1977; and Draft RG 1.9, "Selection, Design, Qualification, Testing, and Reliability of Diesel Generator Units used as Onsite Electric Power Systems at Nuclear Power Plants," proposed Revision 3, dated November 1988 (The tests consist of 23 valid starts of the diesel engine that meet the requirements of IEEE Standard 387-1984. For each valid start, the EDG should pick up a single load ≥50 percent of its rated load and continue to run until the lube-oil system temperature equals 170 °F (±10 °F). In accordance with Section 7.2.2.4 of IEEE Standard 387-1984, three additional starts shall be performed. For all future diesel engine starts after the completion of these tests, the starts are counted as start attempts that are recorded and evaluated where failures may occur.)

- the margin tests defined by IEEE Standard 387-1984, Section 7.2.3

- the start and load to 110 percent of its rated load and run for 1 hour with the priming system fuel oil solenoid valve blocked and verified open and the throttling valve on the return to the priming tank fully open

- the 200-hour preoperational endurance testing defined by PMT-21.16 described below

- the heat balance and flow balance tests of the jacket water cooling system as directed by GE-L

PG&E's FC M-16128 also described the critical characteristics of the 2-3 EDG assembly and certain components of the assembly that are dedicated through individual RPEs and the successful completion of the post-modification tests. For the critical characteristics of the assembly and certain components, FC M-16128 identified the methods used to verify the critical characteristics and the acceptance criteria. The critical characteristics of the 2-3 EDG assembly are described in Table 5 while the critical characteristics of the specific components are described elsewhere in this report.

Post-Modification Preoperational Endurance Tests

During the meeting with PG&E on February 20, 1992, in Rockville, Maryland, the NRC staff suggested that PG&E perform an endurance test consisting of 25 8-hour runs (200 hours) on the EDG. During the followup meeting on March 26, 1992, in Rockville, Maryland, PG&E presented to the NRC staff a draft plan to conduct an endurance test of the 2-3 EDG. By letter (DCL-92-092) dated April 17, 1992, PG&E transmitted to the NRC its plan for the preoperational endurance testing of the 2-3 EDG and stated the purpose of the testing was to further augment the basis for its commercial grade dedication of the EDG. PG&E determined that the number of cycles that corresponds to the minimum ratio of the fatigue strength versus tensile strength, for a compilation of materials used in the diesel engine that are subject to cyclic fatigue, occurred at 1-million (10^6) cycles. PG&E also concluded that no matter how many cycles were performed beyond 10^6 cycles, fatigue failure was not expected to occur. PG&E'S preoperational endurance test plan provides for running the EDG a number of operating cycles, ≈10-million (10^7) cycles, that is significantly greater than for which the fatigue limit of 10^6-cycles is expected to occur (based on 200 hours at 900 rpms).

By letter (DCL-92-218) dated October 9, 1992, PG&E transmitted documentation associated with the open items identified during the team's inspection, including PMT-21.16. PG&E stated that the purpose of PMT-21.16 is to demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test as described in DCL-92-092. PG&E added that the additional testing will facilitate resolution of the open issues identified during the NRC's inspections of PG&E, P-EP, and PEM. The essential elements of the post-modification preoperational endurance tests are given below.

- The 200-hour endurance test is comprised of 25 8-hour segments. During each 8-hour segment, the 2-3 EDG will be run at 2600-kW (100 percent of its rated load) for 7 hours. For the remaining 1 hour in each segment, the 2-3 EDG will be run at a step reduction in load that is equal to or greater than the largest single plant load. Testing of the 2-3 EDG at 100 percent of its rated load will generate the greatest stress on the unit while simulating required emergency operation. The step reduction in load will simulate the most severe load change expected during emergency operations. After completion of the 200-hour test, a 2-hour run will be performed with the EDG load equal to or greater than 110 percent of the rated load (2860 kW).

- Monitoring of the endurance test will include all instrumentation required by Section 6.2.1.(2)(b) of IEEE Standard 387-1984. Vibration monitoring shall be provided to trend vibration data from the lube oil pump, fuel oil pump, jacket water pump, and the free end of the power generator. An engine analyzer will be used to trend the engine's performance at 100 percent of its rated load from data gathered by the engine analyzer on a cylinder-by-cylinder basis. Electrical data (i.e., voltage, frequency, current, and power factor) for the power generator will be monitored during the test. Lube oil samples for analysis will be taken before the start of the endurance test, every 24 hours of diesel engine run time during the tests, and after the completion of the endurance test. Also monitored during the endurance test are the consumption of the fuel oil and lube oil and the differential pressures across the fuel oil and lube oil filters.

- After the diesel engine receives a start signal, the 2-3 EDG shall accelerate to 900 rpm in ≤10 seconds and the voltage and frequency shall be 4160 volts (±420 volts) and 60 Hz (±1.2 Hz) in 13 seconds. The 2-3 EDG shall demonstrate its capability to reject the largest single load while maintaining 4160 volts (±420 volts) and a frequency of 60 Hz (±3 Hz) and reject a full-load without tripping and exceeding 4580 volts during and following the load rejection.

- Successful completion of the test requires completion of a cumulative run time of 200 hours. Failures during operation of the 2-3 EDG that are not considered valid failures or for which component replacement can be accomplished by substitution of an item that was dedicated by a specific RPE shall not require restart of the endurance test. For any item replaced during the test, an evaluation shall be conducted to assess the potential impact of the failure on the qualification of other components of the 2-3 EDG. The criterion used to evaluate tests failures or malfunctions are those contained in Section C.2.e. of RG 1.108, Revision 1. The acceptance criterion for equipment monitoring instrumentation are prescribed in GE-L's operating and maintenance manual. The acceptance criterion for the vibration monitoring shall be the demonstration of stable readings with respect to increases in vibration levels between the initial data collected and the data collected during the final runs of the endurance tests.

Following completion of the 200-hour endurance test, PG&E shall perform certain inspections of the diesel engine and power generator. The essential elements of the post-testing inspections are given below.

- Inspect all 18-cylinders of the diesel engine with a fiberscope or boroscope. Inspect, in-situ, the main bearing clearance for all main bearings and remove and inspect two main bearing lower shell sections. Disassemble and inspect one power assembly (i.e., cylinder head, piston, connecting rod, and connecting rod bearing) from each quadrant of the diesel engine. Inspect, in-situ, the cylinder liners of all 18 cylinders. The acceptance criteria for measured parameters are prescribed in GE-L's operating and maintenance manual and for those items subject to visual inspection, PG&E will rely on the judgment of GE-L's representative.

- Inspect the diesel engine and power generator utilizing the visual inspection requirements prescribed in PG&E's Surveillance Test Procedure (STP) M-81, "Diesel Engine Generator Inspection," Revision 1, dated September 23, 1991, as specified for the 18-, 36-, 54-, 72-, 90-, and 108-month surveillance and inspection intervals.

- Inspect the critical items of the power generator with a fiberscope or boroscope and perform electrical tests of certain critical items, as described in Table 6. For the power generator's critical items not listed in Table 6, their adequacy and qualification will be verified by monitoring the electrical parameters of the power generator during the 200-hour endurance tests (i.e., the power generator's voltage, wave shape of the voltage, electrical losses and efficiency, load excitation, voltage regulation, temperature rise, and other machine parameters).

3.1.5 Compensatory Actions for Power Train Parts and Mechanical Components

For the verification activities performed by PG&E on power train parts that were originally identified by PG&E as acceptance Methods 3 and 1, PG&E, in its revised dedication approach, redefined those verification activities as acceptance Method 2 compensatory actions. For the power train parts, the critical design and material characteristics PG&E selected and verified as acceptance Method 2 compensatory actions are described in Table 4.

During its acceptance Method 2 commercial grade survey of GE-L (PG&E identified certain weaknesses in GE-L's quality program and its implementation), PG&E performed inspections and tests on a representative mechanical component selected from the 14 product types of mechanical components, as described in Section 3.1.2 of this report. In its original dedication approach, PG&E considered these verification activities as part of its acceptance Method 2 activities. However, in its revised dedication approach, PG&E defined these activities as Method 2 compensatory actions. For the representative mechanical component, the critical design and material characteristics PG&E selected and verified as Method 2 compensatory actions are described in Table 3.

The team's review and evaluation of PG&E's Method 2 compensatory actions performed on the individual power train parts and the representative mechanical components are described below.

3.1.5.1 Evaluations of Power Train Parts

In its Inspection Plan DC-271 (see in Section 3.1.3.5), PG&E selected specific dimensional measurements as the critical characteristics of the power train parts. However, for the power train parts PG&E did not demonstrate its bases for determining that these dimensions (critical characteristics) were relevant to the part's credible failure modes and ability to perform its safety-related function and to the part's properties or attributes necessary to withstand the effects of long-term degradation and cyclic fatigue. The critical design characteristics chosen by PG&E for dimensional verification during its Method 2 compensatory actions for power train parts are described in Table 4.

As described in Sections 3.1.3.6 and 3.1.3.8 of this report, PG&E failed to demonstrate reasonable assurance that the technical bases for the critical characteristics chosen and verified during (1) the source verification activities and (2) the special tests and inspection activities (which became part of the Method 2 compensatory actions) ensured that the power train parts and the diesel engine will perform their safety-related function and that the parts have the properties or attributes necessary to withstand the effects of long-term degradation or cyclic fatigue.

The comments below represent a summary of the team's evaluation of PG&E's Method 2 compensatory actions performed on the selected power train parts. Closure of the issues is pending PG&E's successful completion of its post-modification tests that are intended to (1) demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test, described in Section 3.1.4.4(3) of this report; (2) facilitate the resolution of the unresolved items and nonconformances identified during the NRC's inspections of PG&E; (3) demonstrate reasonable assurance that the parts will perform their safety-related function; and (4) demonstrate that the parts have the properties or attributes necessary to withstand the effects of long-term degradation or cyclic fatigue by subjecting certain parts to the operating cycles in excess of the number of cycles where cyclic fatigue is expected.

(1) Engine Block

Attachment AQ, "Method 2 Compensatory Actions for Block," of RPE M-6602, Revision 2, documents PG&E's actions. PG&E procured two engine blocks with serial nos. 14 and 15. One of the engine blocks will be used in the completed diesel engine and the other will be a spare. The engine block was manufactured by welded construction and consisted of forgings and low-carbon steel plates that were manufactured in accordance with the American Society for Testing and Materials (ASTM) A-36. The saddle, the main bearing caps, and the foundation plate were manufactured in accordance with the American Iron and Steel Institute (AISI) AISI-1021, -1045, and -1018, respectively. GE-L identified nine structural members of the engine block that it considered critical to the engine block's function but, for only four of the nine structural members, PG&E selected critical material characteristics of the material and its strength . The nine structural members are listed below; those tested by PG&E are identified with an asterisk.

saddle*	main bearing cap*
camshaft bearing	top deck plate*
middle deck plate	foundation plate*
inside wall	outside wall
rib plate	

PG&E witnessed only a sampling of GE-L's verification activities during its Method 2 compensatory actions, and PG&E's inspection plan did not address all of the critical characteristics identified by GE-L in its Engineering Evaluation DE-35692.

GE-L's QA Reports M-03202 and M-03203 state that the material used to manufacture the middle deck plate, water plate, and the inside wall section, were different from the material required by the design specification and drawings. The reports further state that the material supplied had a higher tensile strength than the material required. However, GE-L's evaluation of the material used did not address (a) the increased hardness associated with the higher tensile strength, (b) the substituted material's susceptibility to the effects of long-term degradation and cyclic fatigue, or (c) the differences between the chemical and mechanical properties of the two materials.

GE-L's welding program, used to assemble the engine block, did not comply with the requirements of the CAN3-Z299.3-85 QA program standards, imposed by PG&E's PO, GE-L had no program for the qualification of personnel performing welding and failed to document the individuals' welding performance qualifications, as identified during PG&E's audit of GE-L. Although PG&E identified GE-L's weakness regarding welding and welder performance qualification, PG&E did not witness any of the actual engine block fit-up or welding. PG&E chose to witness only a sampling (30 percent) of GE-L's NDE of the completed engine block weldments, using the MT NDE examination method, and only six weldments using the UT NDE examination method.

GE-L did not have material certifications for several of the structural members. Material traceability for the structural members with material certifications was not adequate because the basis of the material certifications had not been verified by GE-L performing an audit or survey of its supplier.

The main bearing cap was purchased to AISI-1045, which specifies a carbon content range of 0.43 to 0.50 percent. PG&E used filings from the main bearing cap to determine its carbon content by performing an x-ray fluorescence analysis. The chemical composition test report showed a carbon content of only 0.386 percent (±0.008 percent), which was below the 0.43-percent minimum specified for AISI-1045 material. PG&E based its acceptance of the material on an evaluation that determined the minimum carbon limit for the main bearing cap was 0.39 percent by including the tolerance of ±0.03 percent, which is equal to the measured carbon content value of 0.386 percent, rounded off to the next higher value, or 0.39 percent.

Although some material specifications for the engine block specified fine grain material, PG&E did not perform any special test and inspection activities to verify material grain size. When material traceability was not substantiated by a material certification or verified by audit or survey of the subsupplier, PG&E's material tests were not adequate to identify the material used in its engine block or confirm that the material met GE-L's design specification.

GE-L performed the hydrostatic test of the engine block without documented procedures that identify and control the test parameters.

(2) **Crankshaft**

Attachment AL, "Method 2 Compensatory Actions for Crankshaft," of RPE M-6602, Revision 2, documents PG&E's actions. As Method 2 compensatory action for GE-L's failure to audit National Forge Company, the manufacturer of the crankshaft, PG&E conducted independent verifications of the crankshaft's critical characteristics identified as dimensions, material, and material strength.

The dimensional verifications of the crankshaft included verifying the diameter at the main bearing locations, diameter at the crankpin journals, length at the center of each crankpin, length at the thrust bearing face, and diameter at the spigot fit. All dimensions were found to be acceptable with the exception of the spigot diameter that was undersized by 0.001 inch (0.0254 mm). The deviation was evaluated and determined to have no effect on the engine's operation.

The crankshaft material was analyzed using the x-ray fluorescence technique and determined to be acceptable based on the chemical composition of certain elements. Specifically, the contents of manganese, chromium, and molybdenum were determined to be within the specified range permitted by the material specifications. However, according to PG&E the content of the other alloying elements including carbon, phosphorus, sulphur, silicon, and vanadium was not checked because a sample of material needed for a wet chemistry analysis was not available. The adequacy of the material strength was determined by a hardness test that measured values in excess of the 165 minimum Brinell hardness number (BHN) of the specification requirement.

(3) **Cylinder Liners**

Attachment AI, "Method 2 Compensatory Actions for Cylinder Liner," of RPE M-6602, Revision 2, documents PG&E's actions. The cylinder liner is a cast iron cylindrical shell with an inner diameter of approximately 9 inches (22.86 cm) and a length of about 2 feet (60.96 cm), with a flange at the upper end to facilitate installation. The cylinder liner forms the pressure boundary of the combustion chamber over which the pistons move; the cylinder head forms the upper portion of the boundary and the piston itself forms the lower boundary. The diesel engine contains 18 cylinder liners, one for each cylinder.

PG&E's source verification activities for the 36 cylinder liners manufactured (18 of which were spares) showed that five cylinders liners did not satisfy the inside diameter requirement, three cylinders liners did not satisfy the outside diameter requirement at the top land, and three cylinders liners did not satisfy the liner flange thickness requirement. Although the dimensions of the cylinder liners had previously been checked and found acceptable by ATI, PG&E stated that the following factors may have contributed to the apparent dimensional deficiencies:

- a change in the cylinder liner temperature at the time of the second measurement
- use of a different measuring device
- performance of the second measurement at a different location on the cylinder liner

PG&E concluded that the apparent oversized and undersized dimensions did not affect the proper functioning or installation of the cylinder liners and that no programmatic quality problem existed. Although the cylinder liners were found acceptable, PG&E did not demonstrate an engineering evaluation to substantiate the acceptance of the cylinder liners with dimensional deviations from its design requirements and to analyze the dimensional deviations of the cylinder liners with regard to their effects on long-term degradation and cyclic fatigue. PG&E tested all cylinder liners, using Procedure QCP-10.7 to verify material chemistry and checked for weight (density), magnetism, visual appearance, spark test, and system scientific test to determine whether the material characteristics were consistent with those required for a non-specific cast iron. Even though the material specification noted that the maximum contents of sulphur and phosphorus were mandatory requirements, PG&E did not determine the specific elemental composition of sulphur and phosphorus, or for carbon, silicon, manganese, chromium, and molybdenum.

To determine the material strength, L-hardness values were measured at five locations of each cylinder liner and averaged and corrected to a single BHN. All hardness values were in the range of 190 to 269 BHN, which met the acceptance criteria.

Although PG&E determined that the results for the cast iron and chromium plating analyses were acceptable, PG&E failed to establish an adequate technical basis to substantiate its conclusions and did not evaluate the effects of long-term degradation and cyclic fatigue on the cylinder liners with regard to the chemical elements that were not analyzed.

These discrepancies were addressed by GE-L in its document, titled "Engineering Evaluation of Cylinder Liners," dated April 22, 1992. GE-L identified a problem with the low pit depth and density on the internal chrome plating of the cylinder liners. PG&E reviewed and concurred with the proposed corrective actions in its letter to GE-L dated May 29, 1991. The letter also requested the results of the boroscope inspections, visual inspections after testing, and lube oil analysis be forwarded to PG&E in writing for review and approval before the final shipment of the 2-3 EDG. GE-L included these results in its "Engineering Evaluation of the Cylinder Liners." The evaluation concluded that the low pit depth and density in the installed cylinder liners will not affect the engine's capability to perform its design function.

GE-L's chemical analysis report for the cylinder liner material identified the specific elemental composition, such as the maximum contents of sulphur and phosphorus, required in the material specification. Minor deviations in the chemical composition requirements were identified and documented in GE-L Nonconformance Reports M-03204, M-03208, M-03209, M-03210, M-03211, M-03212 and M-03213. Deviations from the acceptance limits for manganese and silicon data were noted for some ladle analysis samples. PG&E's engineering evaluation of these nonconforming material reports was addressed in PG&E Memorandum (file No. 420DC) dated August 20, 1991. This evaluation concluded that if the microstructure and hardness of the parts were evaluated and found acceptable, then the minor deviations from the chemical requirements should not be a problem. PG&E's approval of this evaluation, as documented in PG&E letter to GE-L dated September 26, 1990, provided the basis for the release of the hold point on assembly of the cylinders.

The GE-L engineering evaluation of measurement discrepancies concluded that they were acceptable and will not affect equipment operation. PG&E reviewed and concurred with this evaluation.

The team's review of the supporting documentation substantiates PG&E conclusion regarding cylinder liner material acceptability. However, the effects of long-term degradation and cyclic fatigue were not evaluated.

(4) Cylinder Heads

Attachment AK, "Method 2 Compensatory Actions for Cylinder Heads," of RPE M-6602, Revision 2, documents PG&E's actions. The cylinder head is a cast iron block that forms the upper boundary of the cylinder and contains the inlet and exhaust valves that control the ingress of combustion air and the egress of the products of combustion. The cylinder head also provides the penetration for fuel oil injection into the cylinder. The cast iron block is machined to a thickness of approximately 10 inches (25.4 cm) with a cross-sectional area of approximately 11 inches x 8 1/2 inches (27.44 cm x 21.54 cm). The cylinder head is bolted to the engine block, forming a pressure containing seal with the cylinder liner.

PG&E used GE-L's manufacturing drawings to verify the following dimensional requirements:

- The "x" and "y" coordinates of the bore locations for the valve guides were measured using a coordinate measuring machine (CMM). (In its IR M-8 dated September 7, 1990, PG&E documented observing the calibration and set up of the CMM and the subsequent measurement of the cylinder head critical dimensions.) Of the 18 cylinder heads measured, 5 had at least one oversized dimension.

- The "x" and "y" coordinates of the hole locations for the mounting bolts were measured using the CMM. Dimensional discrepancies were found with all 18 cylinder heads.

- The overall length, width, and thickness of the cylinder heads were measured. Dimensional discrepancies were found with the air and exhaust flange location on 11 cylinder heads.

PG&E's source verification activities identified several dimensional deficiencies with many of the cylinder heads. Although GE-L Engineering Evaluation DE-35692, "Engineering Evaluation of Cylinder Heads," dated January 7, 1991, considered the worst-case discrepancies, the evaluation concluded that the cylinder head parts were acceptable and the discrepancies found will not affect the engine's operation. GE-L also determined that the discrepancies were not the result of a programmatic weakness. PG&E did not evaluate the effects of the dimensional deviations with regard to long-term degradation and cyclic fatigue.

The license performed special tests, documented in Laboratory Test Report 420DC-90.838, to verify the material chemistry of the cylinder heads relative to cast iron. Material filing samples were taken from 9 of the 18 cylinder heads (50-percent sample size). The samples were analyzed by the x-ray fluorescence, combustion-iodate titration, and combustion-infrared techniques. The analysis determined that (a) the content of silicon was below the minimum allowable for each sample, (b) the manganese was below the minimum allowable for eight of the nine samples, (c) the chromium was below the minimum allowable for five of the nine samples, and (d) the nickel was below the minimum allowable for four of the nine samples. The carbon and molybdenum contents were acceptable.

Material hardness test results, documented in MP M-56.18, "Equotip Hardness Testing of Steels and Stainless Steels," dated August 8, 1990, determined that material hardness was in the acceptable range permitted by ALCO Specification 31P5400.

Although each of the chemical elements that were found to be outside the allowable limits were addressed in the test report, PG&E concluded that the cylinder head material meets the general chemical composition typical for Grey Cast iron. PG&E's review and acceptance of the engineering evaluation for the cylinder head is documented in PG&E letter to GE-L dated January 8, 1991. This letter provided approval to GE-L for the release of the hold-point on assembly of the cylinder heads.

Although PG&E accepted all of the cylinder heads, determining that the associated analytical error precluded excluding the material on the basis of measured values, PG&E failed to establish an adequate technical basis for its conclusions, and did not evaluate the long-term degradation and cyclic fatigue effects on the cylinder heads with regard to the material discrepancies, specifically those elements where the discrepancy measured exceeded the analytical error tolerance.

(5) **Valves — Air and Exhaust**

Attachment AO, "Method 2 Compensatory Actions for Air and Exhaust Valves," of RPE M-6602, Revision 2, documents PG&E's actions. The air and exhaust valves controls the proper sequence of the ingress of fresh combustion air and the egress of the products of combustion from the cylinders during the engine cycle. The air and exhaust valves were manufactured by Eaton Corporation and consisted of a stainless steel head (commercial designation 21-4N) welded to an alloy steel stem. PG&E's source verification of Eaton's activities, as described in its IR M-18, consisted of verifying the following:

- the diameter of the stem and seat
- the overall length of the head and stem assembly
- the UT NDE of the flash welded bi-metallic joint between the head and stem, in accordance with GE-L's ALCO Manufacturing Specification 31P5773
- the liquid penetrant (PT) NDE of the surface of the valve, in accordance with GE-L's ALCO Manufacturing Specifications 31P5670 and 31P5651
- the chemical analysis of one intake valve and four exhaust valves using an alloy analyzer

GE-L's UT examination required the use of a specific setup valve standard for calibrating sensitivity rather than a flat-bottomed hole standard. PG&E observed that the setup valve standard was less sensitive than the flat-bottomed hole standard because the flat-bottomed hole standard would establish rejection criteria based on a 0.030-inch (0.0762-cm) flaw diameter in contrast to a 0.050-inch (0.127-cm) flaw diameter for the setup valve standard. Although GE-L used the less sensitive rejection criteria, PG&E accepted the air and exhaust valves without addressing this concern.

PG&E analyzed the chemical content of all exhaust valves and determined that the incorrect material was supplied and, therefore, rejected all 36 of the original exhaust valves. For the replacement exhaust valves, PG&E verified the material chemistry of only three valves. PG&E witnessed this activity and the dimensional inspections, UT and PT NDE, of all valves at Eaton's facility and documented its activities in IR M-12, dated September 14, 1990. Material hardness measurements were taken on the stem, tip, and core of the sample valves were found acceptable, as documented in Eaton's metallurgical laboratory audit checklists and PG&E accepted all three replacement valves.

In addition, Eaton's letter dated November 13, 1990, stated that all supplied exhaust and intake valves were inspected for head and stem material using a material analyzer and that the valves conformed to the requirements of the material specification. Thus PG&E accepted the remaining exhaust valves.

However, since Eaton also had inspected and found acceptable the 36 original exhaust valves that were subsequently rejected by PG&E, PG&E did not adequately substantiate its basis for sampling only 3 valves and accepting the balance of replacement exhaust valves based on the results of the three valves sampled.

(6) Valve Inserts

Attachment AP, "Method 2 Compensatory Actions for Valve Inserts," of RPE M-6602, Revision 2, documents PG&E's actions. Valve inserts are mounted in the cylinder head to form a hard seating surface for the air and exhaust valves and ensure a leak-tight cylinder during the compression and combustion phases of the engine cycle. GE-L purchased the air and exhaust valve inserts to ALCO Purchasing Practice 31P5441, which required the valve inserts to be high-temperature cast alloy material. PG&E's source verification Inspection Plan DC-271 specified witnessing of the dimensional checks of all valve inserts to verify compliance with GE-L's drawings and the air and exhaust valve insert checklists. The Method 2 compensatory actions include verification of configuration by dimensional and visual inspections and destructive chemical composition testing on a sample of valve inserts.

Although the dimensional inspections of the 36 air valve inserts and the 36 exhaust valve inserts, documented in IR M-7, determined that all dimensions were in compliance with the GE-L specification, PG&E verified only the outside diameter and thickness of the air and exhaust valve inserts. PG&E did not verify all other dimensions (e.g., inside diameter and length) specified by GE-L's drawings and required by the inspection plan, as critical dimensions that effect long-term degradation and cyclic fatigue of the valve inserts.

The total number of valve inserts in the engine is 72. However, because of the destructive nature of the material testing, chemical analysis was performed on eight valve inserts (four air valve inserts and four exhaust valve inserts taken from the spares supplied as part of PG&E's purchase order) using the x-ray fluorescence method and combustion-infrared techniques. Although, the test results concluded that the eight valve inserts sampled met the chemical requirements of Stellite #3 cobalt alloy for the elements that were analyzed, PG&E did not verify the samples for silicon content even though the ALCO specification stipulated the content shall not exceed 1.5 percent and minimum hardness of 50 Rockwell "C" (RC).

(7) Piston Bodies

Attachment AJ, "Method 2 Compensatory Actions for Pistons," of RPE M-6602, Revision 2, documents PG&E's actions. The piston body, or the main portion of the piston, is an aluminum alloy casting approximately 11 1/2-inches long and 9 inches in diameter (29.21 cm and 22.86 cm). A piston pin assembly attaches the connecting rod to the piston body. The piston cap is attached at the upper end to form the piston assembly. Attachment F, "Similarity Evaluation for Method 4 and Seismic Qualification," of RPE M-6602, Revision 2, noted that the piston assembly was changed from the original 1969 design of a valve-pocketed, dished-top, steel-capped type piston assembly to the new design of an 11.5:1 ratio Mexican-hat-type piston assembly. The piston assembly contains five rings, two of which are located on the piston body. PG&E's source verification Inspection Plan DC-271 specified witnessing the dimensional checks of the overall length, diameter, bottom oil ring location, and top compression ring location.

PG&E found that all of the dimensional measurements verified were within the tolerance values specified, except for the location of the bottom oil ring on the no. 15 piston body, which was out of tolerance by 0.003 inch (0.0762 mm). ATI had previously inspected and accepted the piston bodies without identifying any dimensional discrepancies. In waiver AS2929, GE-L stated that the degree of deviation in the groove location with regard to the size and location of the oil drain holes will not affect the fit or function of the piston body. Although the PG&E accepted the piston bodies on the basis of GE-L's Engineering Evaluation DE-35692, PG&E did not evaluate the dimensional deviations of the piston bodies with regard to the effects of long-term degradation and cyclic fatigue.

PG&E analyzed the material chemistry of 9 of the 18 piston bodies, using the x-ray fluorescence technique. It determined that the material was acceptable. However, PG&E analyzed only six of the elemental constituents; did not analyze the material chemistry content for chromium, magnesium, and silicon. For the chemical composition of the piston bodies, the elemental constituents that were tested were within the specified range. PG&E concluded that the correct correlation of the elemental constituents tested to their allowed limits resulted in a high probability that the remainder of the elemental constituents were as specified.

PG&E also measured the hardness of all 18 piston bodies using the Equotip technique that resulted in L-hardness values in the range of 435 to 449, which were converted to 104 to 109 BHN. These hardness values were below the minimum acceptance value of 115 BHN specified in the purchase order to ATI. Although the measured BHN values were below the minimum acceptance level, PG&E concluded that the BHN values were within the allowed deviation range of the BHN conversion table. By including the BHN conversion table accuracy tolerance, PG&E concluded that the measured BHN hardness values indicated that the piston bodies were thermally treated and the measured BHN values were acceptable.

(8) Piston Caps

Attachment AJ, "Method 2 Compensatory Actions for Pistons," of RPE M-6602, Revision 2, documents PG&E's actions. The piston cap forms the upper portion of the piston assembly and is constructed from a steel forging with machined grooves for three compression rings. The piston cap is subjected to the effects of loads and thermal stresses encountered when the fuel and air mixture explodes during the compression phase of the combustion cycle. Each piston cap is approximately 3-inches thick and 9 inches in diameter (7.62 cm and 22.86 cm) and is fastened to the piston body by a central stud and nut arrangement.

The dimensional measurement verifications were taken with the piston caps assembled to the piston bodies. PG&E found all dimensions verified to be within the tolerances specified on the design drawings.

PG&E analyzed the material chemistry, using the x-ray fluorescence technique, of material filings taken from each of the 18 piston caps. Although PG&E did not analyze the piston caps for silicon content and found 4 piston caps with carbon contents below the minimum requirements of the material specification, PG&E accepted all 18 piston caps. In response to the carbon content deficiencies noted in several piston caps, PG&E, by letter dated August 20, 1991, referenced the American Society of Metals Handbook, Vol. 1, Ninth Edition, Table 7, "Alloy Steel Product Composition Tolerances - Bars, Billets, Blooms, and Slabs," which recognized a carbon content analysis tolerance of ±0.02-percent weight. This tolerance, taken to its extremes, would expand the carbon content allowed from a range of 0.28 to 0.33 percent, as specified, to a range of

0.26 to 0.35 percent. PG&E concluded that considering the tolerance allowed and the allowed error associated with the chemical analysis of percent carbon in each piston cap provided adequate assurance that the material met the requirements of the material specification

PG&E also measured the hardness of the piston caps using the Equotip method on the center post and the upper rim that resulted in L-hardness values of 285 to 321, which were converted to acceptable values of 30 to 35 RC.

(9) **Connecting Rods**

Attachment AF, "Method 2 Compensatory Actions for Connecting Rods," of RPE M-6602, Revision 2, documents PG&E's actions. The connecting rods provide the mechanical linkage between the piston assembly and the crankshaft and are used to convert the translational motion of the piston assembly to the rotational motion of the crankshaft. ATI manufactured the connecting rods from steel forgings that are approximately 2-feet (0.608-m) long, 8-inches (20.32-cm) wide at the crankpin bore, and 5-inches (12.7-cm) wide at the piston pin bore. The diesel engine contains 18 connecting rods, 1 for each cylinder.

In the connecting rod check list of Attachment X, "Inspection Plan DC-271," Revision 1, of RPE M-6602, Revision 1, dated April 10, 1992, PG&E stated that, for the 36 caps and main connecting rods, the following critical dimensions shall be verified:

- the piston-end pin bore center to the crankshaft-end pin bore center shall be 21.00 to 20.995 inches (53.34 to 53.327 cm)
- the diameter at the piston-end (with bushing) shall be 3.7555 to 3.7520 inches (9.5389 to 9.53 cm)
- the diameter at crankshaft-end (without bearing) shall be 6.411 to 6.412 inches (16.2839 to 16.2864 cm)
- the bolt hole locations at the centerline shall be 1.562 to 1.563 inches (3.967 to 3.970 cm) and 7.624 to 7.626 inches (19.364 to 19.370 cm)

PG&E verified the dimensions of the 36 connecting rods (18 are spares) using the CMM. The dimensional verification of the connecting rods and caps are documented in IR M-6. Of the 16 connecting rods identified with dimensional deficiencies, 15 connecting rods had diameter dimensional deficiencies at the pin bore on the crankshaft end.

However, GE-L's factory repair service procedure defined an acceptable bore dimension to be in the range of 6.4105 to 6.4130 inches (16.2826 to 16.2890 cm), which is a greater range than that specified in GE-L's design drawing (6.411 to 6.412 inches (16.2839 to 16.2864 cm)). PG&E accepted the connecting rods on the basis of the bore dimensional range given in the repair service procedure (used to repair worn connecting rods), even though the dimensional deficiencies that were found are relative to the design requirements for new connecting rods. PG&E did not verify the centerline locations of the bolt holes used to mechanically join the connecting rod cap with the connecting rod, which forms the attachment to the crankshaft. The tolerance for the bolt hole location was ±0.0001 inch (±0.00254 mm).

Although ATI had previously checked and accepted the dimensions of the connecting rods, PG&E stated that the following factors may have contributed to the apparent dimensional deficiencies:

- a change in connecting rod temperature at the time of the second measurement
- use of a different measuring device
- performance of the second measurement at a different location on the connecting rods

PG&E concluded that the dimensional deficiencies did not affect the proper functioning or installation of the connecting rods and that no programmatic quality problem existed. Although the connecting rods were found acceptable, PG&E did not substantiate acceptance of the deficient connecting rods relative to their design requirements and did not analyze the effects of dimensional deviations on long-term degradation and cyclic fatigue.

PG&E chemically analyzed material filings from 9 of the 18 connecting rods using the x-ray fluorescence technique. The material chemistry analysis showed that the chromium content was excessive for all nine connecting rods tested and, for three of the connecting rods tested, the constituent elements of manganese and nickel did not comply with the material specification requirements of AISI E-86B45. Only the molybdenum content was verified to be correct. Of all the elements analyzed, chromium was the only element that consistently tested at higher levels and no explanation was given for the high measurements, except that the x-ray fluorescence instrument was prone to large errors. PG&E also did not verify the material chemistry for carbon, silicon, and boron. However, PG&E determined that the material chemistry was acceptable, despite the elemental constituent composition discrepancies, and accepted the connecting rods because the associated analytical error of the x-ray fluorescence instrument was greater than the amount of the elemental constituent composition discrepancies.

In its Attachment AF, PG&E stated that for the connecting rods to fail metallurgical evaluation (hardness requirements), the Brinell values would have to be below 285. The team recognized that conversions between hardness scales introduced additional errors. However, PG&E accepted connecting rod 531 with a 282 BHN and no chemical analysis was performed, and connecting rod 1206 with a hardness of 284 BHN and a chemical analysis that identified high contents of nickel and chromium. PG&E's analysis did not address these specific deviations. Although, for 14 of the 18 connecting rods tested, the material hardness values were below the minimum acceptability value, PG&E accepted the connecting rods based on the degree of accuracy in using the Equotip conversion chart.

(10) Connecting Rod Nuts

Attachment AH, "Method 2 Compensatory Actions for Connecting Rod Nut," of RPE M-6602, Revision 2, documents PG&E's actions. Connecting rod nuts are used to fasten the lower end of the connecting rod to the connecting rod cap, which forms the mechanical attachment to the crankshaft. The nuts are 1 3/8 inches (3.4925 cm) in diameter with 7/8–14 NF-3 threads.

PG&E's inspection plan specified the verification of the nut diameter and thread parameters (thread-pitch and the number of threads per inch) for all of the 144 nuts required for the diesel engine. The connecting rod nuts were taken from GE-L's existing inventory. Initially, 75 percent of the nuts tested for thread-pitch failed. The acceptance criteria for the nuts were provided in GE-L Drawing 21-A-72008, Revision E, which specified the acceptable inside diameter of the nuts shall be 1.365 to 1.385 inches (3.4671 to 3.5179 cm) and the acceptable thread-pitch shall be 7/8–14 NF-3 threads. The measured diameters ranged from 1.371 to 1.377 inches (3.4823 to 3.4975 cm). The 40 nuts that met the thread-pitch requirements also met the diameter requirements. In "Engineering Evaluation of Connecting Rod Nuts Dimensions," dated December 19, 1992, GE-L stated that the failure of 75 percent of the nuts to meet thread tolerance requirements indicated that the manufacturer of the nuts for the connecting rod had programmatic problems and that GE-L could not rely on Industrial Nut's manufacturing and inspection process for nuts having NF-thread requirements. GE-L evaluated a thread class change for each application where NF threads were actually specified.

Although it found the connecting rod nuts acceptable, PG&E did not demonstrate its basis for accepting the connecting rod nuts that were not verified or evaluate the effects of long-term degradation and cyclic fatigue on the connecting rod nuts.

PG&E chemically analyzed spare nuts to avoid destruction of parts to be used in its diesel engine. A sample size of 10 percent was selected for testing. PG&E's analysis determined that the connecting rod nuts were AISI E-4140H, complying with all elements of the material specification with the exception of sulphur. The sulphur content for all test specimens but one exceeded the 0.025-percent maximum level. PG&E tested only 8 nuts rather than the 14 to 15 that would be required to meet the requirement of a 10 percent sample size.

As documented in Attachment AH, PG&E verified the material strength of the connecting rod nuts by performing hardness measurements using the Equotip device to determine an L-hardness value that was converted to RC. The measured values were within the range of 26 to 37.5 RC and acceptable. PG&E tested a sample size of 28 nuts – 8 initially, supplemented by another batch of 20. However, the total sample size was smaller than that specified for examination.

GE-L's audits of ATI showed that the connecting rod nuts were procured in large volumes and commingled with existing inventory after acceptance so that traceability to a specific PO or material certification was not maintained. PG&E failed to evaluate this condition in its acceptance of the connecting rod nuts.

PG&E, therefore, failed to establish an adequate basis for accepting the connecting rod nuts and failed to evaluate the effects of the material deficiencies on long-term degradation and cyclic fatigue.

(11) **Connecting Rod Bolts**

Attachment AG, "Method 2 Compensatory Actions for Connecting Rod Bolts," to RPE M-6602, Revision 2, documented PG&E's actions. GE-L's dimensional verification of the 144 original bolts supplied by ATI found that the bolts did not have the required taper. In its technical engineering evaluation, "DE-35692: PG&E 18-Cylinder – Engineering Evaluation of Connecting Rod Bolts," in Attachment AG to RPE M-6602, GE-L described the rejection of the 144 original bolts and their replacement. GE-L's chemical analysis and hardness testing of the new bolts resulted in accepting the replacement connecting rod bolts.

(12) **Main Bearings - Shell**

Attachment AM, "Method 2 Compensatory Actions for Main Bearing, Shell," of RPE M-6602, Revision 2, documents PG&E's actions. These actions and results are the same as those described below for the main thrust bearings.

(13) **Main Bearings - Thrust**

Attachment AN, "Method 2 Compensatory Actions for Main Bearing, Thrust," of RPE M-6602, Revision 2, documents PG&E's actions for the main thrust bearings, including configuration verification by dimensional and visual inspections and nondestructive testing of material.

PG&E's IR M-6 documented the inspection and acceptance of the dimensional, surface finish, and blow-hole limitation criteria.

The material chemistry of the two main thrust bearings consist of a half-bearing shell with a steel back and one or more layers of a lead-bronze lining material, with an overlay of lead, tin, and copper. The certificate of conformance from GE-L's subsupplier stated that these material requirements were met. However, the independent chemical analysis verified only that the outer layer was lead and that lead was the maximum element present. The material test method for lead identification was selected to provide verification of the subsupplier's material certification without damaging the part. PG&E's metallurgical evaluation concluded that the presence of lead adequately demonstrated that the main thrust bearings represent the general class of bearing material alloys containing lead. The post-modification preoperational endurance tests, in lieu of more specific analysis, should demonstrate that acceptable material properties were provided in the main bearings – shell and thrust.

(14) Camshafts

Attachment AE, "Method 2 Compensatory Actions for Camshaft," of RPE M-6602, Revision 2, documents PG&E's actions. The camshafts extend along the length of the engine with one located on each side. The camshafts consist of eccentrically arranged cams, or lobes (one intake lobe and one exhaust lobe for each cylinder), and concentric bearing journals. The radial orientation of the lobes provide the proper sequencing motion of the push rods that activate the rocker arms, causing the intake air and exhaust valves to open and close. The lobe arrangement on the shaft determines the firing order of the cylinders, while the contour of each lobe controls the time and rate of the valves opening and closing. The camshaft is a forged steel, segmented unit (10 total segments per engine, 5 in the left camshaft and 5 in the right camshaft), and is approximately 15-feet long and 4 1/2 inches in diameter (4.56-m long and 11.43-cm diameter) at the bearing journals.

ATI manufactured three camshaft assemblies to ensure that two correct camshaft assemblies would be available for the diesel engine. PG&E's inspection plan identified the "longest tolerance dimension" as a critical characteristic. The longest tolerance dimension was found to exceed the allowable dimension on three camshaft segments. Although the dimensions of the camshaft segments had been previously checked and accepted by ATI, PG&E stated that the following factors may have contributed to the apparent dimensional deficiencies:

- a change in camshaft segment temperature at the time of the second measurement
- use of a different measuring device
- performance of the second measurement at a different location on the camshaft segments

PG&E concluded that the apparent dimensional deviations did not affect the function or installation of the camshafts and that no programmatic quality problem existed. Although PG&E found all of the camshaft segments acceptable, PG&E did not evaluate the bases for accepting the camshafts with dimensional deviations from their design requirements and did not analyze the effects of dimensional deviations on long-term degradation and cyclic fatigue.

PG&E chemically analyzed material filings taken from the end flange of one of the camshaft segments. In Attachment F, "Similarity Evaluation of Method 4 and Seismic Qualification," to RPE M-6602, Revision 2, PG&E noted that the camshaft material had been upgraded from hot-rolled steel 81602, heat treatment 81602fv-9, AISI E-1050, chromium (normalized) hot-finished rounds to hot-rolled steel 81800, heat treatment 81800fv-9, AISI E-1080, (normalized) hot-finished rounds. The material chemistry verification, as compared to the material specification for AISI E-1080, showed that the manganese content met the specification requirement. Although PG&E concluded that the camshaft material met the material specification for the elements analyzed, PG&E did not evaluate any other elemental components, except for chromium, which was identified as a trace element. PG&E, therefore, failed to establish an adequate technical basis for accepting the camshafts and failed to evaluate the effects of the deficiencies on long-term degradation and cyclic fatigue of the camshafts.

The material strength was verified by PG&E performing hardness tests at five lobe locations on each camshaft assembly. An average L-hardness value was determined and converted to RC values. The values were within the acceptance criteria and therefore acceptable.

3.1.5.2 Evaluations of Mechanical Components

As described in Sections 3.1.3.3, 3.1.3.4, and 3.1.4.2 of this report, PG&E's commercial grade survey (90216SS, September 17 through 20, 1990) identified several weaknesses in GE-L's controls for purchasing, receipt inspections, and inprocess inspections of mechanical components. The 14 product types and the 14 representative mechanical components (from the total population of 6316 mechanical components, described in Section 3.1.2 of this report) and each part's associated critical characteristics, as identified in PG&E's commercial grade survey plan, are described in Table 3.

Because of the concerns identified during its commercial grade survey of GE-L, PG&E described, in RPE M-6602, Attachment Z, "QC Surveillance Plan No. 6602-1," Revision 0, dated November 6, 1990, its original dedication approach for the mechanical components, including augmenting its use of acceptance Method 2 with acceptance Methods 3 and 1 (revised to Method 2 compensatory actions, as described in Section 3.1.4.2(1) of this report). Attachment AR, "Summary of Unique Safety Related Engine Parts and Their Independent Verification," of RPE M-6602, Revision 2, also documents PG&E's verification activities for certain mechanical components.

The results of PG&E's activities documented in Attachments Z and AR of RPE M-6602 were intended to verify the adequacy of GE-L's standard practices for purchasing, receipt inspections, and inprocess inspections. However, the findings of PG&E's commercial grade survey did not substantiate that GE-L established reasonable assurance of the quality and adequacy of the 14 representative mechanical components surveyed and raised additional concerns regarding the quality and adequacy of the remaining mechanical components that were not evaluated during the survey.

The comments below represent a summary of the team's evaluation of PG&E's Method 2 compensatory actions performed on the representative mechanical components. Closure of the issues is pending PG&E's successful completion of its post-modification tests that are intended to (1) demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test, described in Section 3.1.4.4(3) of this report; (2) facilitate the resolution of the unresolved items and nonconformances identified during the NRC's inspections of PG&E; (3) demonstrate reasonable assurance that the parts will perform their safety-related function; and (4) demonstrate that the parts have the properties or attributes necessary to withstand the effects of long-term degradation or cyclic fatigue by subjecting certain parts to the operating cycles in excess of the number of cycles where cyclic fatigue is expected.

(1) Turbocharger

The turbocharger was PG&E's representative part from the product type category, "Engine-Mounted Rotating Component." The turbocharger is a mechanical device that improves the diesel engine's power output by providing supplemental air input to the diesel engine cylinders. The turbocharger is mounted on the upper portion of the engine and is driven by engine exhaust gases.

PG&E performed the following compensatory actions:

- verified the catalog number, serial number, part number, and the nameplate data per the bill of material to ensure the correct turbocharger was procured and received
- inspected for damage
- witnessed fit-up during installation to ensure proper mounting configuration
- checked dimensions per GE-L specification and drawings

- verified the ASME BPVC symbol stamp on the turbocharger's air receivers

- monitored the inlet and outlet pressures for the turbocharger to ensure the integrity of the turbocharger's casing-to-flange joint

- checked for leaks at the after-cooler, the air receiver outlet strainer, the air receiver, the turbocharger itself, the clamp for the air filter sleeve, the sleeve for the air filter, the cooling water outlet hose connection, and the O-ring gasket for the lube oil drain

- witnessed the functional-performance test of the diesel engine, including verifying the turbocharger's intake-air temperature at ≈110 °F (43.3 °C), exit-air temperature at ≈1120 °F (604.4 °C), and exhaust gas temperature at ≈910 °F (487.7 °C)

(2) Air Start Motor

The air start motor was PG&E's representative part from the product type category, "Skid-Mounted Rotating Component." PG&E's RPE M-6602 identified part number, configuration, function, and workmanship as critical characteristics of the air start motor. Checklist 2 of Attachment Z, "QC Surveillance Plan 6602-1," augmented by Inspection Plan DC-271, documented in Attachment X, "Inspection Plan DC-271," to RPE M-6602, Revision 2, provided instructions for inspection and verification of the critical characteristics with the exception of function. The final results of PG&E's inspection and verification activities were not available to the team.

(3) Cylinder Head Studs

The cylinder head studs were PG&E's representative part from the product type category, "Special Fastener." Checklist 3 of Attachment Z lists the acceptance criteria and instructions for verifying the configuration and materials of the cylinder head studs. The compensatory actions for the cylinder head studs, as specified in Checklist 3, provided for inspection of the studs for damage, critical external dimensions, hardness, markings, thread-pitch, and part number. Although PG&E Inspection Plan 6602-1 listed cylinder head studs as the representative part for the category, Checklist 3 of Attachment Z failed to document the verification of cylinder head studs. The team found that the dedication of the cylinder head studs was incomplete because the compensatory actions were not complete.

(4) **Piston Rings**

The piston rings were PG&E's representative part from the product type category, "Casting." Checklist 4 of Attachment Z and PG&E's laboratory test results (Report 420DC-90.956 dated December 7, 1990) documented PG&E's verification of the piston rings and their compliance to ALCO Specification 31P5450, dated March 9, 1983. Checklist 4 specified that all parts representing the category shall be inspected for damage, dimensions, hardness, material markings, and part number. Checklist 4 documented the inspection results of 40 compression rings and their conformance to Catalog 2421029-1 and GE-L Drawing 4272046-1F. PG&E checked for hardness and found acceptable three fire rings and three compression rings. However, it did not perform a material analysis or document the results of the dimensional verifications. The configuration inspections, required by Attachment Z and documented in Checklist 4, were to be based on the sampling standard MIL-STD-105D for sampling performed on a homogeneous lot. The standard was used as a guide for the piston rings. However, PG&E did not use the recommended sample size for the piston rings tested and did not establish a homogeneous lot by either the date of manufacture, heat or lot traceability, or manufacturer's COC.

(5) **Radiator**

The radiator was PG&E's representative part from the product type category, "Components from Special Manufacturing Process." PG&E identified the critical characteristics for the radiator as part number, configuration, dimensions, workmanship, functional testing and operability, and special manufacturing processes. In its commercial grade survey of GE-L, PG&E stated that quality and technical requirements were imposed on the subsupplier of the radiator, Young Radiator Company. PG&E witnessed the company perform dimensional inspections of the three radiators and a hydro-leak test of the radiator pressurized with air and submerged in water. The radiators tested were acceptable.

(6) **Fuel Injection Pump**

The fuel injection pump was PG&E's representative part from the product type category, "Engine-Driven or Skid-Mounted Pump." PG&E identified critical characteristics for the fuel injection pump as part number, configuration, dimensions, workmanship, and functional testing and operability. PG&E's five original 1969 diesel engines were supplied with "Bosch" 9-mm rack-type injection pumps; however, PG&E's 2-3 EDG engine was supplied with a "Lucas Bryce" 18-mm injection pump, part FCQAB180A0565. PG&E considered the change in fuel injection pump an engineering upgrade.

(7) **Fuel Injector**

The fuel injector was PG&E's representative part from the product type category, "Precision Machined Part." PG&E identified the critical characteristics for the fuel injector as part number, configuration, dimensions, workmanship, functional testing and operability, and material. Also, during the post-modification preoperational endurance tests, PG&E will monitor the combustion pressure and temperature. PG&E's five original 1969 diesel engines were supplied with "Bosch" 0.400-mm, 157° spray-angle nozzles; however, PG&E's 2-3 EDG engine was supplied with a "Lucas Bryce" 145° spray-angle nozzle. The fuel injector nozzle design change was necessary to accommodate the piston cap design modification to a Mexican-hat-type configuration. PG&E considered these changes an engineering upgrade. Attachment F, "Similarity Evaluation for Method 4 and Seismic Qualification," of RPE M-6602, Revision 2, documents the changes in design between the original five 1969 diesel engines and the 2-3 EDG engine.

(8) **Valve Spring**

The valve spring was PG&E's representative part from the product type category, "Spring." PG&E identified the critical characteristics for the valve spring as part number, configuration, dimensions, workmanship, material, and mechanical properties. Checklist 8 of Attachment Z and PG&E's test report dated January 14, 1991, documented PG&E's verification of the valve spring and its compliance to ALCO Specification 31P5606, dated April 6, 1948.

Checklist 8 specified that all parts representing this category shall be inspected for damage, free length, markings, number of coils, and part number. Checklist 8 documented the inspection results for 13 out of 75 engine springs and their conformance with GE-L Drawing 46A72023-1V.

PG&E, however, did not document the results of the dimensional verifications and only tested two valve springs to verify their compliance with the chemical and hardness requirements of the specification. The configuration inspections, required by Attachment Z and documented in Checklist 8, were to be based on the sampling standard MIL-STD-105D for sampling performed on a homogeneous lot. The team standard was used as a guide for the valve springs. However, PG&E did not use the recommended sample size for the valve springs tested and did not establish a homogeneous lot by either the date of manufacture, heat or lot traceability, or manufacturer's COC.

(9) **Governor**

The governor was PG&E's representative part from the product type category, "Mechanical Controlling Device." PG&E identified the critical characteristics for the governor as part number, configuration, dimensions, workmanship, and functional testing and operability. The team's evaluation of the governor consisted of the Woodward Governor Company (WGC) Model EG-B13C governor (mechanical portion) and the overspeed trip mechanism (mechanical portion). The governor system and the overspeed trip system also have electrical portions that were dedicated separately and will be discussed separately. PG&E originally dedicated the mechanical governor with RPE M-6602 for the diesel engine, but later dedicated it by a separate RPE, M-7514.

Section 7 of RPE M-6602, Revision 2, April 24, 1992, contained items 18, 23, 32, 41, and 58 that concerned governor problems or failures and formed (originally) the major basis of its dedication. PG&E evaluated items 18 and 23 as requiring no further action because the failures were the result of error by DCNPP2 site personnel and normal wear, respectively. Item 58 was a problem with governor settings and adjustments for which PG&E stated no additional action was required. However, item 32 was the replacement of a governor on the 1-2 EDG engine as a result of a "nut lost in the assembly." PG&E described this as not being a part failure or manufacturing defect, stating that no action was required, but it did not explain how the nut became lost or address the consequences of its loss. The referenced maintenance document, SWF MM-1-83-136 dated May 24, 1983, indicated that the governor was replaced and the removed governor opened to look for a lost nut reported on Nuclear Plant Problem Report (NPPR) DC1-83-TI-P0289 dated April 21, 1983. The NPPR revealed that during the replacement of the

1-2 EDG shutdown solenoid operated valve (SOV) coil per DCN DC1-U-E-314, the SOV was found to be defective and the nut, lockwasher, and face-plate that secure the coil to the SOV were missing. The nut, and later the lockwasher, were found in the bottom of the governor. The document indicated that the face-plate was presumed not to have been installed because it was never found.

Such failures could result in losing engine speed control if loose parts fouled the governor mechanism as well as disabling the SOV shutdown function if the coil came loose from the SOV during engine operation. Although the PG&E's evaluation did not explain why this problem did not pose a problem for 2-3 EDG, the team's discussion with WGC indicated that this problem had been corrected several years ago by fixing the nut, lockwasher, and face-plate to the SOV coil with epoxy resin. Discussion with the DCNPP2 site diesel engine system engineer indicated that the problem had been corrected on the other engine governors (that had not been refitted with epoxied SOVs) by the use of Loc-Tite thread sealant per the manufacturer's recommendations at the time. The problem will be solved for the 2-3 EDG because it will have a new governor with epoxied SOV parts.

Item 41 dealt with the speed indication on the mechanical governor not corresponding to speed setting knob movement. The offending governor was replaced, but PG&E did not determine the cause of the problem. PG&E stated that no additional action was required without explaining why this failure was not a problem for the governor of the engine of the 2-3 EDG. The referenced document, NPPR DC0-85-TN-P0054, merely stated what the indication was and the item referenced a maintenance document that covered governor replacement. It was not clear from the available documents how or if this potential failure mode was evaluated further and resolved for the governor of the 2-3 EDG (not to mention the other five).

RPE M-6602 also addressed in Section 7.F, a search of the GIDEP data base for references to ALCO diesels or their parts and no failures were identified. However, the team was concerned that by constraining the data base search parameters to only the name "ALCO," references to components listed by their manufacturers' names (e.g., Woodward Governor, Ingersoll-Rand, etc.) would not have been captured. In response to this concern, PG&E searched three GIDEP reports issued in August, November, and December 1991, but found no references for manufacturer: "Woodward." However, PG&E committed to search the whole GIDEP failure history data base for references to Woodward and incorporate the results into RPE M-6602, Revision 2, Minor Change 1.

The rest of the dedication of the Woodward EG-B13C mechanical governor was described in a separate RPE, M-1043. On May 15, 1992, PG&E issued a new RPE, M-7514, Revision 0, which superseded M-1043. It was not clear which (if any) RPE covered dedication of the governor output or fuel control linkage and the starting air booster assembly.

The safety function of the governor stated in RPE M-7514 was simply to control engine speed. PG&E did not mention the detailed elements of that function such as providing 10-second automatic startup on loss of normal vital ac power, controlling engine speed under changing load conditions (as severe as the largest possible step change as the last load to be added) within specified dynamic response times and within maximum overshoot limits, and providing one means (usually as a backup) of overspeed (or other casualty) engine shutdown. PG&E also did not address the operation of the centrifugal flyweight-controlled subgovernor upon loss of EG-A control signal.

In RPE M-7514 PG&E characterized drift and slow response as "the most credible," as opposed to all credible failure modes; both are valid. The following, however, were not addressed: (a) failure of the auto start air booster assembly to function as designed, (b) failure of the booster to retain starting air pressure, (c) failure of the booster to release fuel rack control upon reaching set speed/removal of starting air pressure, (d) failure of the shutdown SOV to dump governor internal hydraulic oil pressure and effect engine shutdown when energized, and (e) failure of the SOV to close upon deenergization. The effects of the two recognizes failure modes were incorrect voltage and frequency output. The effects of the unlisted failure modes (a—e above) were, of course, not addressed.

RPE-7514 listed the critical characteristics of markings and identification, speed control, and responsiveness. These critical characteristics were consistent with the listed safety function and failure modes, but would not support all the listed safety functions or other germane, but not listed, safety functions and failure modes discussed above. The verification method for speed control was performance of a "normal start and hot restart test." The verification method for responsiveness was performance of the normal start, hot restart, and load rejection tests. These tests are prescribed by STP M-9A (December 18, 1991) and STP M-9D (February 21, 1992). The description of these tests in terms of the acceptance criteria in the RPE neither covered the situation of the addition of heavy loads, such as during a load sequence test, nor the centrifugal flyweight-controlled subgovernor operation upon loss of EG-A control signal.

The dedication methodology for the governor system as described in the current revisions of PG&E's documents would not be adequate to properly verify the governor's suitability of application on the 2-3 EDG at DCNPP2. Nevertheless, the post-modification tests, including comprehensive preoperational tests (assuming load sequencing and loss of EG-A control are addressed), and the endurance run, pending satisfactory results of post-run inspections, could resolve these issues.

PG&E dedicated the Woodward EG-A electric governor control unit, under RPE E-6800, Revision 1, May 15, 1992, including the control box, motor-operated speed control potentiometer, and the resistor box. Attachment 1 to RPE E-6800 documented the critical characteristics of the safety functions and verification methods for these three items. The safety function of the control box was to provide control for the engine to operate at preset speed, but this somewhat complex component's failure modes were simplistically stated as open or short circuit, neither of which nonspecific conditions would predict the effects with any certainty. Short or open circuits could occur at many locations and produce different effects. The function of the motor-operated speed-setting potentiometer, was "to adjust the speed reference voltage to the necessary level set by the EG-A control unit." The failure modes were incompletely given as motor stalls or limit switches do not open/close, with the effect of "inhibits the EG-A control unit to adjust the required speed setting." Only the function and failure modes and effects analysis (FMEA) of the resistor box made sense. The critical characteristics of model number, terminal configuration/numbering, base dimensions, mounting configuration, and "material similarity and batch homogeneity (visual only)" were stated to have been verified for all the items during panel fabrication before the components were installed, but materials similarity was not adequately verified by "visual inspection of all accessible components of all items." Also, the term "batch homogeneity" has little meaning for these types of items and indicates a superficial analysis of the circumstances. Even if it did, there was no way to determine batch or lot traceability because PG&E did not establish if lots or batches exist, nor did it address any unique identifiers such as serial numbers.

The only meaningful similarity, relevant to this dedication, would be similarity to the same components on the other five EDGs, which was not stated as a requirement. The technical basis of the verification tests specified was unclear and some of the tests appeared to be of questionable value or validity. There was little resemblance to the checks specified in Woodward EG-A Instruction Manual 37706N. For example, it was not clear what value there was in merely checking continuity of the primary windings of the load sensor input transformers without verifying turns ratio, operating voltages, linearity, etc., or the value of measuring insulation resistance of terminals to ground with a 12-Vdc power supply. Even if insulation resistance could be meaningfully measured at 12 Vdc, that voltage would be inappropriate for some of the terminals that had 120-Vac inputs. The meaning of measuring the resistance between terminals 13 and 24 on the EG-A control box was not clear when there were several parallel branch circuits connected (if the potentiometer is connected). Also, the description of this resistance test calls for removal of the terminal 23-to-24 jumper. However, according to the EG-A control unit schematic diagram in Manual 37706N, this jumper must be installed for 60-Hz operation. It remains to be determined whether subsequently performed procedures ensure reinstallation of this jumper.

The existing dedication plan for the electric control portions of the governor system did not adequately address all critical characteristics. The remaining concerns may be resolved by satisfactory results from the post-modification tests.

(10) **Lube Oil Cooler**

The lube oil cooler was PG&E's representative part (and the only part) from the product type category, "Heat Exchanger." PG&E identified the critical characteristics for the lube oil cooler as part number, configuration, dimensions, workmanship, material, and special manufacturing. The lube oil cooler is a skid-mounted heat exchanger that removes heat from the engine circulating lubricating oil to maintain proper lube oil temperature during engine operation. The lube oil cooler was manufactured by McRae Engineering Equipment, Inc.

PG&E performed the following compensatory actions:

- reviewed the purchase order requirements before manufacture
- verified the part number and the proper ASME BPVC symbol stamping
- visually inspected for workmanship and dimensional verification
- witnessed the hydrostatic testing of both the tube- and shell-sides of the lube oil cooler

- witnessed the functional testing of the lube oil cooler's performance parameters and leak checks of the associated piping system

(11) Exhaust Manifold Studs

The exhaust manifold studs (total 4824) were PG&E's representative parts from the product type category, "Commodity-Metallic." PG&E identified the critical characteristics for the exhaust manifold studs as part number, configuration, dimensions, workmanship, material, and mechanical properties. Checklist 11 of Attachment Z and PG&E's test report, dated January 14, 1991, documented PG&E's verification of the manifold studs and their compliance to ALCO Specification 31P5606, dated April 6, 1948.

Checklist 11 specified that all selected parts representing this category shall be verified by witnessing fit-up during installation. Only certain selected parts were inspected for damage, markings, material analysis, diametral verification, and length measurement. PG&E documented the inspection results in Checklist 11. No documented verification of any of the required attributes for exhaust manifold studs existed because the exhaust manifold studs were not among the parts tested and were not visually inspected during engine assembly. The configuration inspections, required by Attachment Z and documented in Checklist 11, were to be based on the sampling standard MIL-STD-105D for sampling performed on a homogeneous lot. The standard was used as a guide for the exhaust manifold studs. However, PG&E did not use the recommended sample size for the exhaust manifold studs tested and did not establish a homogeneous lot by either the date of manufacture, heat or lot traceability, or manufacturer's COC.

(12) Flex Hose

The flex hose was PG&E's representative part from the product type category, "Commodity-Nonmetallic." PG&E identified the critical characteristics for the flex hose as part number, configuration, dimensions, workmanship, functional testing and operability, and material. Checklist 12 of Attachment Z and PG&E's test report, dated January 14, 1991, documented PG&E's verification of the flex hose.

Checklist 12 specified that items such as hoses, O-rings, and other rubber parts are considered normal wear items and therefore not subject to long-term degradation and cyclic fatigue. Checklist 12 also specified verification activities for the flex hoses consist of witnessing fit-up during installation and visually inspecting for damage and part number. A design change in the turbocharger's cooling water outlet connection was identified as the reason for improper fit-up of the flex hose. PG&E incorporated inspection of the new design flex hose into Inspection Plan DC-271. PG&E noted no deficiencies in the 11 of 21 parts that were inspected in this category. However, because material was specified as a critical characteristic and to determine flex hose integrity, PG&E included the results of the integrated functional-performance tests as its basis, in part, for acceptance of the flex hose as well as the successful completion of the post-modification tests.

(13) **Valve Cover Gasket**

The valve cover gasket was PG&E's representative part from the product type category, "Gasket." PG&E identified the critical characteristics for the valve cover gasket as part number, configuration, dimensions, workmanship, and material. The configuration inspections, required by Attachment Z were based on the sampling standard MIL-STD-105D for sampling performed on a homogeneous lot. The standard was used as a guide for the valve cover gasket. However, PG&E did not use the recommended sample size for the valve cover gasket and did not establish a homogeneous lot either by date of manufacture, heat or lot traceability, or manufacturer's COC.

(14) **Fuel Oil Pressure Valve**

The fuel oil pressure valve was PG&E's representative part from the product type category, "Valve." PG&E identified the critical characteristics for the valve cover gasket as part number, configuration, dimensions, workmanship, and functional testing and operability. Although PG&E's verification of the fuel oil pressure valve should have been documented in Checklist 14 of Attachment Z, PG&E stated that it was unable to witness GE-L's verification activities for the fuel oil pressure valve or for the lube oil pressure relief valve. Therefore, it incorporated documented verification activities for the air start motor lubricators into Inspection Plan DC-271 as alternate representative parts.

3.2 Power Generator

P-EP's facility, originally known as Electric Products Incorporated, supplied, under various names, over 120 power generators to the nuclear industry. Electric Products Incorporated was purchased by Portec, Inc. in 1969, and was known as the Electric Products Division of Portec, Inc. Portec sold the company in 1979 to Parson Peebles, a subsidiary of Northern Engineering Industries Limited (NEI) in England. NEI is a wholly owned subsidiary of the Industrial Power Group of Rolls-Royce. The Cleveland facility was known at that time as Parson Peebles Electric Products, Inc. After Parson Peebles' purchase of the Cleveland facility, NEI reorganized its Parson Peebles operations under the name of NEI Peebles Limited and the Cleveland facility became NEI Peebles—Electric Products, Inc. (P-EP). P-EP's manufacturing facility in Cleveland was closed September 1984 and the power generator work was moved to NEI Peebles Limited's Pilton Works facility in Edinburgh, Scotland, known as Peebles Electrical Machines (PEM).

This background information affects PG&E's procurement and dedication of the power generator because DCNPP's five existing emergency ac power generators (serial nos. 16908022–16908026), installed on EDGs 1-1, 1-2, 1-3, 2-1, and 2-2, were procured in 1969 from the Electric Products Division of Portec, Inc., and manufactured in the Cleveland facility. PG&E procured a spare generator (serial no. 38604851) in 1986 from P-EP, specifying that it be identical (i.e., like for like) to DCNPP's five 1969 generators. However, PEM manufactured the 1986 spare power generator in its Pilton Works in Edinburgh, Scotland.

By PO ZS-1539-AB-9, Revision 0, dated January 16, 1990, to P-EP, PG&E procured one 4.16-kV, 2600-kW, 60-Hz, 3-phase, 8-pole, 900-rpm, single-bearing, engine-driven, ac synchronous generator. The generator was to be supplied as a design Class 1E basic component in accordance with PG&E's Engineers Material Memorandum (EMM) DC2-3322-BRH-E, Revision 0, dated January 5, 1990. In the EMM, PG&E required that the generator be identical to PG&E's 1986 spare generator and DCNPP's five 1969 generators on the basis that the previously supplied generators had already been determined to have met all applicable requirements. PG&E's apparent strategy to demonstrate compliance with the requirements for safety-related equipment suitability, including DBE and any environmental qualification requirements, was to procure the generator on the basis of a like-for-like comparison.

In its acceptance of the PO from PG&E, P-EP accepted the responsibility to ensure overall compliance with all the applicable provisions of Appendix B to 10 CFR Part 50 and the reporting requirements of 10 CFR Part 21. As a result of the team's inspection of P-EP on August 5 through 9, 1991 (IR 99900772/91-01, dated January 15, 1992), the most significant inspection finding identified was that P-EP failed to demonstrate reasonable assurance that the items specified as critical by PG&E met the quality and reliability requirements of Appendix B to 10 CFR Part 50 and that the critical characteristics of such items had been adequately verified and that the items are capable of performing their design and safety-related functions. Specifically, P-EP failed to demonstrate that the critical characteristics of the following had been verified: (1) the items specified as critical that the manufacturer (PEM) of the power generator procured as commercial grade and (2) the stator coil's resistance temperature detectors, slip rings, adhesives, and the mounting sleeve insulator for the slip rings that P-EP procured as commercial grade.

The team also identified as nonconformances other elements of P-EP's quality program and its implementation that failed to meet NRC requirements. For example, P-EP failed to establish adequate measures for, and to implement adequate control of, its external design interface with PEM. Therefore, on the basis of nonconformances identified during its inspection of P-EP, the team concluded that additional inspections were necessary and conducted an inspection of PEM on September 23 through 27, 1991.

As a result of the team's inspection of PEM (IR 99901065/91-01, dated February 13, 1992), the most significant inspection finding identified was that PEM failed to demonstrate reasonable assurance that certain critical items (1) met all of PEM's procurement specifications to its suppliers of commercial grade material, (2) met all of P-EP's procurement specifications to PEM, (3) met all PG&E's requirements imposed on P-EP, and (4) met all the applicable NRC quality and technical requirements. Specifically, there was inadequate documented evidence that all the critical characteristics of such items were identified and adequately verified to ensure the items are capable of performing their safety-related functions. Examples of the critical items that were not adequately dedicated include the rotor pole magnet wire wrapped with varnished insulation tape that was specified to be unvarnished, the Bakelite electrical separation ring that was used as a load-bearing component part of the rotor shaft support assembly without an engineering basis for the design, and certain other commercial grade materials, parts, and equipment described in the report (IR 99901065/91-01) that were accepted on the basis of unvalidated certificates of conformance from PEM's commercial suppliers.

The team also identified other elements of PEM's quality program and its implementation that did not meet NRC requirements. For example, PEM had not established adequate measures for, nor implemented adequate control of, its external design interface with P-EP.

In its letter (DCL-92-034) dated February 12, 1992, responding to the deficiencies identified during the team's inspection of P-EP (IR 99900772/91-01), PG&E replied that its evaluations, conducted during its audits of P-EP and PEM, identified the same nonconformance issues discussed in the IR. Attachment 2, "NEMP 12.4 Evaluation," Revision 1, to Enclosure V, "PG&E Engineering Evaluation of P-EP for Purchase of Sixth Generator," to PG&E's letter provided an itemization of the issues and PG&E's compensatory actions taken to resolve the findings. Revision 1 to PG&E's NEMP 12.4 evaluation incorporated (1) 10 CFR Part 21 reports for P-EP, (2) the results of PG&E's followup on its audit findings, (3) the results of PG&E's independent testing of adhesive, and (4) the results of P-EP's final design change and procedure equivalency review. PG&E added that it was formulating a plan, in conjunction with P-EP, to address the team's concerns relative to the adequacy of the documentation and completeness of P-EP specification and procedure equivalency and design change reviews performed to resolve the concerns with respect to the lack of program requirements for the P-EP/PEM interface.

In its letter (DCL-92-126) dated May 22, 1992, responding to the deficiencies identified during the team's inspection of PEM (IR 99901065/91-01), PG&E replied that, on the basis of its discussions with the team on May 6, 1992, it had revised the NEMP 12.4 evaluation to cover any new issues from the team's inspection of PEM rather than submit a response to the NRC similar to that issued with its earlier letter (DCL-92-034) for the team's inspection of P-EP. Accordingly, Enclosure 1 to PG&E's letter contained Revision 2 to the NEMP 12.4 evaluation dated May 22, 1992. In addition, Enclosure 2 to PG&E's letter contained RPE E-7505, Revision 0, dated May 22, 1992, for the qualification of the generator. According to PG&E, RPE E-7505 more clearly documents PG&E's activities taken as compensatory actions for the findings identified during its audit of P-EP and PEM and the NRC inspections of P-EP and PEM.

RPE E-7505 also incorporated the post-modification preoperation endurance tests (described in Section 3.1.4.4(3) of this report) as a PG&E verification activity. PG&E's letter also stated that credit for this testing and resolution of the PG&E audit findings and the team's inspection issues, in conjunction with other PG&E verification activities, described in RPE E-7505, constitute its bases for the qualification of the power generator for the 2-3 EDG. The RPE also identifies the following activities that remain for PG&E to complete to qualify the generator: (1) the completion of P-EP's identification of all design changes from the design of the ordinal five EDGs (necessary for the seismic qualification of the generator), (2) the completion of P-EP's re-review of its equivalency evaluation of the P-EP/PEM specifications and procedures, (3) the testing by P-EP/PEM to resolve its use of the lightly varnished wire for the rotor pole magnet wire instead of the unvarnished wire that was specified, and (4) PG&E's successful completion of the post-modification tests.

This section describes the team's review of (1) the status of previous P-EP and PEM inspection findings and PG&E's response to the NRC addressing these findings and any additional information provided by PG&E during subsequent inspections and (2) PG&E's compensatory actions taken to resolve these issues regarding the power generator for its 2-3 EDG.

3.2.1 Design Control

P-EP maintained the overall engineering and design control responsibility, in addition to providing sales and services support, for the generators and other power generating equipment procured by the U.S. nuclear industry. However, PEM's engineering and design organization performed independent design activities. The team evaluated the design activities of P-EP and PEM in the areas described separately below.

3.2.1.1 Design-Bases Documentation

The team reviewed P-EP's and PEM's control of the generator's engineering design basis that would be necessary to establish the like-for-like relationship of the new generator to the design basis of the generators previously supplied. Specifically, the team reviewed the synergistic effect of the changes that were made to the original engineering design bases since 1969 to determine what, if any, effect those changes had on PG&E's like-for-like procurement requirement.

P-EP's design-basis reconciliation to the original 1969 design consisted of a drawing change review dated June 24, 1991. P-EP's review encompassed the drawings associated with PG&E's generator since 1984, including all revisions. However, P-EP's reconciliation of design changes for the generator was documented and verified only to 1984 when the manufacturing facility closed in Cleveland, Ohio. Therefore, neither P-EP nor PEM could substantiate that the new generator was like-for-like to PG&E's five existing 1969 generators. In its design-basis reconciliation, P-EP failed to demonstrate that the established design control measures were commensurate with those applied to the original design and that the original design basis had been correctly translated into revised specifications, drawings, procedures, and instructions.

3.2.1.2 Design Interface

A significant design interface existed between P-EP and PEM. Although P-EP maintained the overall responsibility for the generator's engineering and design control, PEM's engineering and design organization functioned completely independent of P-EP's organization and it performed certain independent design activities. P-EP provided its design drawings, procedures, and material specifications to PEM, and PEM's engineering organization translated them into PEM specifications, drawings, procedures, and instructions to fabricate and assemble PG&E's generator. This process also included converting dimensions and tolerances from English values to their metric equivalents.

The measures established in Section 3, "Design Control," of P-EP's QAM-100 did not provide for adequate procedures between P-EP and PEM for the review, approval, release, distribution, and revision of documents involving their respective design interface. This deficiency appeared to have resulted from the "sister company" relationship of P-EP and PEM, and the daily interface of their respective staffs. Although PEM issued Departmental Procedure (DP) 03A004, "Processing of Engineering Change," Revision 0, dated December 17, 1990, it did not affect P-EP's control of the design interface activities during most of the fabrication and assembly of PG&E's generator. Moreover, P-EP failed to establish reasonable assurance that PEM's procedure adequately controlled the design interface activities that were P-EP's responsibility.

Equivalency evaluations of PEM's procedures and material specifications used to fabricate and assemble PG&E's generator were completed by a P-EP's engineering staff in July 1991 and reviewed by P-EP's QA manager in August 1991. (The generator was completed by PEM in February 1991.) P-EP performed these evaluations to ensure that PEM correctly translated the design bases into procedures and material specifications.

PEM-produced documents were not reviewed or approved by P-EP before use, and PEM-initiated engineering changes were not controlled by documented procedures until December 1990. The measures established in Section 4, "Design Control," of PEM's QMV1 did not provide for adequate procedures between PEM and P-EP for the review, approval, release, distribution, and revision of documents involving their respective design interface. This deficiency appeared to have resulted from the "sister company" relationship of PEM and P-EP and the daily interface of their respective staffs. Although PEM issued DP 03A004, Revision 0, it did not affect PEM's design interface activities during most of the fabrication and assembly of PG&E's generator.

PEM performed equivalency evaluations of its drawings, procedures, and material specifications to P-EP's drawings, procedures, and material specifications and initiated design changes, as required. The equivalency evaluations were not auditable because PEM's equivalent procedures or material specifications were not always available for comparison to P-EP's procedures or material specifications and the evaluations consisted of only a brief summary of the procedures or material specifications. P-EP's equivalency evaluations failed to adequately document the critical requirements or acceptance criteria compared during the evaluation and the results of the evaluation or bases to support P-EP's conclusion that the documents were equivalent.

3.2.1.3 Selection of Critical Items

Dedication is the selection and review for and verification of suitability of application to ensure the adequacy of critical parameters (characteristics) of CGIs that are to be used in safety-related applications. PG&E's generator is a complex component composed of several critical parts that directly affect the ability of the generator to perform its design and safety-related functions. The credible failure mechanism or long-term degradation of the part could adversely affect the generator's ability to perform its safety-related function. PG&E was aware that its generator was actually to be manufactured by P-EP's sister company, PEM, and became involved in the dedication of CGIs by selecting the critical parts of the generator and specifying their critical characteristics.

Attachment F (described in Section 2.2 of this report) to PG&E's PO to P-EP listed 14 critical items and their associated critical characteristics and required P-EP to verify PG&E-identified critical characteristics for each of the 14 critical items by performing tests. PG&E further required that P-EP's verification tests and their respective acceptance criteria be furnished to PG&E for approval before the materials and parts were installed or used. P-EP subsequently passed to PEM the responsibility for procuring seven of the items and verifying their critical characteristics. However, P-EP did this indirectly by identifying only those items it would procure and supply to PEM as safety-related items. P-EP transmitted PG&E's list of items and their critical characteristics to PEM without making it a part of or referencing it in P-EP's PO.

In its PO to PEM, P-EP identified the material specifications applicable to certain parts of the generator and required PEM to supply certificates of analysis, test reports, or certificates of conformance for those materials and parts. The material specifications specified such items as materials, identification, ordering information, approved suppliers, and storage requirements. In many cases, the material specification contained an approved suppliers list that included specific products, listed by trade name, that P-EP had approved as meeting the material specification.

The team immediately identified three concerns with these actions that were distinct from other procurement and technical issues discussed in Sections 2.2 of this report: (1) PG&E's selected critical items were not made a formal part of P-EP's PO for procurement of the generator from PEM; (2) the listed critical items (including their critical characteristics) did not correspond to P-EP's material specifications and other requirements specified in the PO; and (3) P-EP did not amend its PO to PEM to address the revisions to PG&E's PO.

Revision 3 to PG&E's PO included significant revisions to Attachment F that changed the list of critical items from 14 (shown in Revision 1) to 27 (in Revision 3). Several of the critical characteristics for those items that were to be verified by P-EP also changed. In other changes imposed by the revision, certain subassemblies that were previously identified as critical items were divided into individual parts of the subassembly and listed separately. For example, brushes and brush holders were identified as item 7 in Revision 1 and the critical characteristics were identified as size and shape and final generator test for resistance, material, and contact pressure; however, Revision 3 listed the brushes and the brush holder separately as items 20 and 19, respectively, and listed configuration as the only critical characteristic for both items. Table 1 provides a comparison of the critical items and their critical characteristics as expressed in Revisions 1 and 3 of the PO. These changes were the result of discussions between the staffs of PG&E and NEI-Peebles at QA audit meetings held in Cleveland during December 1989 and in Edinburgh during October 1990.

P-EP's generic FMEA was applicable to all rotating electrical machinery produced and was part of P-EP's technical documentation that demonstrated the generator's compliance with the requirements of the IEEE Standard 323, "Qualifying Class 1E Equipment for Nuclear Power Generating Stations," and Standard 344, "Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations." The FMEA included the credible failure mode for each individual part of the generator assembly and a criticality level was assigned to the part on the basis of the effect of the part's credible failure mode on the ability of the generator to perform its safety-related function.

According to P-EP, PG&E's PO did not impose qualification of the generator to the requirements of IEEE Standards 323 or 344 and PG&E did not procure P-EP's FMEA documentation for use in the selection of critical items or their critical characteristics. P-EP also stated that the extent of its involvement in PG&E's selection of critical items and their critical characteristics was limited to only an agreement with PG&E to perform testing necessary to verify the critical characteristics of the critical items identified by PG&E in Attachment F of Revision 1 to its PO.

Both P-EP and PEM reported that they had not been involved in PG&E's selection of the critical items or their critical characteristics listed in Revision 3 of PG&E's PO. Furthermore, PG&E's generator was completed when Revision 3 was issued; therefore, neither P-EP nor PEM considered Revision 3 during its design, procurement, and manufacturing activities.

Because of the minimal involvement of P-EP's engineering organization in PG&E's selection of critical items and their critical characteristics listed in Revision 1, the team was concerned that PG&E's selected list of critical items may not have been sufficiently comprehensive to ensure that all items were included, specifically, those items with a credible failure mode or that, in a degraded condition, could adversely affect the generator's ability to perform its design and safety-related function. The team reviewed P-EP's generic FMEA and discussed the technical bases for the critical items and their critical characteristics with the engineering staffs of both P-EP and PEM to determine whether PG&E's Revision 1 list of 14 critical items or its Revision 3 list of 27 critical items included all parts that are critical to the generator's ability to perform its design and safety-related function.

According to P-EP's FMEA, the generator's two major design parameters with regard to the effects of long-term degradation and cyclic fatigue were its operating temperatures and cyclic loading or high vibration forces. On the basis of these design parameters, criticality levels 1 or 2 were assigned in the FMEA to critical items such as the stator windings, leads and their connections, rotor pole windings, roller bearings, rotor shaft, coil supports, and slip rings. From its review of P-EP's generic FMEA documentation, the team determined that PG&E's lists of critical items did not adequately envelope all of the generator's critical parts having a design or safety-related function (i.e., the slip-ring mounting sleeve insulator and the temperature and vibration indicating devices, as discussed below).

Slip-Ring Mounting Sleeve Insulator

The generator was designed with a brush and slip-ring assembly to carry dc excitation voltage to the field coils mounted on the rotor shaft. The slip-ring assembly was concentrically mounted on the rotor shaft. P-EP incorporated a slip-ring mounting sleeve insulator in its design to prevent establishing a current path to ground between the slip-ring assembly and the rotor shaft. The mounting sleeve insulator consisted of a tube of insulating material, with ≈0.25-inch (0.65-cm) wall thickness, installed between the shaft and the slip-ring assembly. P-EP's generic FMEA documentation indicated that, if the mounting sleeve insulator between the slip-ring assembly and the rotor shaft failed, dc excitation voltage would be lost and result in catastrophic failure of the generator. In addition, a short-to-ground failure in the insulator could occur from wear or erosion, establishing a current path to ground. However, PG&E did not identify the slip-ring mounting sleeve insulator as a critical item.

Temperature and Vibration Indicating Devices

P-EP provided six resistance temperature detectors (RTDs) to monitor the generator's stator coil operating temperatures and provide a conservative indication of the generator's overall temperature. The operating temperatures of the generator, including localized thermal stresses, affect the stability of the insulation and adhesive materials (e.g., thermal breakdown, aging, fatigue, and wear), which directly affect the fragility of unisotropic structures (e.g., rotor windings) during the installed life of the generator. A limit of 105 °C rise over an ambient temperature of 40 °C for the maximum generator operating temperature (145 °C) was established in P-EP's design basis. Although the RTDs were included in PG&E's Revision 1 list of critical items, they were not included in the Revision 3 list of critical items. RTDs were not provided to monitor the temperature of the shaft's single roller bearing, even though the roller bearing and its operating temperature were identified in P-EP's FMEA as critical items.

In addition to high temperature, fatigue from cyclic loading or high vibration forces on the generator also may directly affect the performance and reliability of the single roller bearing. The roller bearing may be subjected to cyclic loading or high vibration forces caused by an unbalanced rotor shaft, the diesel engine with its crankshaft directly connected to the generator's rotor shaft, and other sources from the skid-mounted EDG assembly.

original design and that the original design basis had been correctly translated into revised specifications, drawings, procedures, and instructions. PG&E's purchase order required that the new generator for DCNPP2 be identical (i.e., like for like) to DCNPP's five existing operating generators (original 1969 design basis) and its 1986 spare generator. However, P-EP's design-basis reconciliation and verification of the design changes for PG&E's generator were documented and verified only to the 1984 timeframe; when the Cleveland manufacturing facility was closed. Thus, P-EP did not perform an adequate design-basis reconciliation or verification of the generator's design changes to ensure the adequacy of the design, and the effects of those changes on the generator's overall design.

In Section IV of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it had participated in P-EP's audit of PEM and asked P-EP to submit a description of all design changes, material changes, and discrepancy reports since the manufacture of DCNPP's five existing power generators. Further, PG&E said it would review P-EP/PEM drawings to determine all related drawing change request (DCRs) and discrepancy reports (DRs) to establish equivalency between all manufacturing procedures and material specifications listed in P-EP's PO to PEM. PG&E will document the results of its evaluation in RPE E-7505, Attachment 3.

(2) **Nonconformance 99900772/91-01-02 (NOT CLOSED)**

P-EP failed to demonstrate that the results of PEM's design translation activities were equivalent to the design requirements specified by P-EP. P-EP provided its design drawings and specifications to PEM because PEM manufactures P-EP's generators. PEM's engineering organization translated P-EP's design specifications into its own PEM specifications, drawings, procedures, and instructions. The documents produced by PEM were not reviewed or approved by P-EP before use, and PEM-initiated design changes that were not controlled by documented procedure until December 1990, when PEM issued Departmental Procedure DP03A004, "Processing of Engineering Change," well after the design activities for PG&E's generator were completed. Although P-EP performed equivalency evaluations of PEM's procedures and material specifications used to fabricate and assemble PG&E's generator, P-EP did not adequately document the critical requirements or acceptance criteria compared during the equivalency evaluation and the results of the equivalency evaluation or other bases to support P-EP's conclusion that PEM's procedures and specifications were equivalent.

During the installed life of the generator, subtle damage to the generator may occur from short-to-ground or asynchronous events (e.g., paralleling the generator out-of-phase) that cause significant forces on the stator coils and rotor pole windings. P-EP indicated that PG&E's generator was designed to withstand short-to-ground events that produce magnetic forces on the stator coils, which were mechanically supported by the stator frame's welded structure. The end sections of the stator coils, however, were installed in a cantilevered arrangement with stiffeners to support the coils and prevent or minimize their distortion. An asynchronous event may produce centrifugal forces on the rotor pole windings of sufficient magnitude to cause separation of the windings and an unbalanced rotor shaft. P-EP stated that the generator was not constructed to withstand an asynchronous event. However, PG&E did not identify vibration indicating devices as critical items.

For a complex assembly such as a generator, the selection of critical items and the determination of their critical characteristics would require the involvement of both PG&E's and supplier's engineering staffs. Although in Revision 3 of its PO, PG&E revised the introductory statement of Attachment F, in part, to state that this listing was based on discussions between the staffs of PG&E and NEI-Peebles at QA audit meetings held in Cleveland, Ohio, during December 1989 and in Edinburgh, Scotland, during October 1990, PEM and P-EP considered this interface activity to be limited to those critical items identified in Revision 1 to PG&E's PO, and they believed the interface activity was nonexistent for the critical items identified in Revision 3 of the PO. Furthermore, PEM and P-EP had completed PG&E's generator when Revision 3 was issued; therefore, Revision 3 was not considered during the design, procurement, and manufacturing activities of the generator.

3.2.1.4 Status of Previous Design Control Inspection Findings

During its inspections of P-EP and PEM the NRC team identified several nonconformances with P-EP/PEM's design control for PG&E's power generator. The team reviewed PG&E's response to the NRC addressing these nonconformances, including additional information provided by PG&E during subsequent inspections. The results of the team's review are given below.

(1) Nonconformance 99900772/91-01-01 (NOT CLOSED)

P-EP, in its design-basis reconciliation and verification of changes that affect the design of PG&E's 1990 generator to the design basis for the original 1969 generator, failed to demonstrate that the changes in the design were controlled commensurate with the design controls applied to the

In Section IV of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it asked P-EP to perform an equivalency evaluation between specifications and procedures. P-EP examined 70 procedures and specifications that resulted in 42 equivalency evaluations. PG&E found most of P-EP's equivalency evaluations adequate. However, PG&E said it would reverify equivalency for those evaluations that had inadequate documentation for the rotor shaft, magnet wire, lead wire, and roller bearing. Further, PG&E said it would review P-EP/PEM drawings to determine all the related DCRs and DRs to establish equivalency between all manufacturing procedures and material specifications listed in P-EP's PO to PEM. PG&E will document the results of its evaluation in RPE E-7505, Attachment 3.

(3) Nonconformance 99901065/91-01-01 (NOT CLOSED)

PEM failed to demonstrate that the results of its design translation activities were equivalent to the design requirements specified by P-EP. P-EP provided its design drawings and specifications to PEM because PEM manufactures P-EP's generators. PEM's engineering organization translated P-EP's design specifications into its own PEM specifications, drawings, procedures, and instructions. The documents produced by PEM were not reviewed or approved by P-EP before use, and PEM-initiated design changes were not controlled by documented procedure until December 1990 when PEM issued Departmental Procedure 03A004, "Processing of Engineering Change," well after the design activities for PG&E's generator were completed. Although PEM performed equivalency evaluations of its drawings, procedures, and material specifications used to fabricate and assemble PG&E's generator, PEM did not adequately document the critical requirements or acceptance criteria compared during the equivalency evaluation and the results of the equivalency evaluation or other basis to support PEM's conclusion that its drawings, procedures, and material specifications were equivalent to P-EP's. Therefore, PEM failed to establish adequate measures to control its design interface activities and to demonstrate adequate design equivalency evaluations.

In Section V of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it asked P-EP to perform an equivalency evaluation between specifications and procedures. P-EP examined 70 procedures and specifications that resulted in 42 equivalency evaluations. PG&E found most of P-EP's equivalency evaluations adequate. However, PG&E said it would reverify equivalency for those evaluations that had inadequate documentation for the rotor shaft, magnet wire, lead wire, and roller bearing. Further, PG&E said it would review P-EP/PEM drawings to determine all the related DCRs and DRs to establish equivalency between all manufacturing procedures and material specifications listed in P-EP's PO to PEM. PG&E will document the results of its evaluation in RPE E-7505, Attachment 3.

The NRC staff considers these nonconformances unresolved. The closure is pending PG&E's successful completion of (1) the design review between the original five and the sixth generator from 1984 to 1969, including verification of design changes for the stator frame to complete the seismic evaluation, (2) the reverification of equivalency of the P-EP/PEM procedures and material specifications, and (3) the post-modification tests, described in Section 3.1.4.4(3) of this report, that evaluate the adequacy of P-EP/PEM's design, materials, and manufacturing processes by subjecting certain components of the power generator to operating and transient conditions.

3.2.2 Selection and Review for Suitability

P-EP supplied the generator to PG&E as a basic component that complied with the quality requirements of Appendix B to 10 CFR Part 50; therefore, P-EP was responsible for establishing reasonable assurance that the generator and its critical items will perform their respective design and safety-related functions. P-EP procured 7 of the 14 items listed in Revision 1 of PG&E's PO (or 10 of the 27 items listed in Revision 3) and supplied them to PEM for installation in the generator assembly. PEM procured the 7 remaining critical items listed in Revision 1 of PG&E's PO (or 17 of the 27 items listed in Revision 3) from its subsuppliers in Europe. PEM was qualified as a subsupplier to P-EP through P-EP's audits of PEM dated September 30, 1985, and August 7 through 9, 1989. P-EP stated that its audits qualified PEM to supply components and parts produced to a quality program equivalent to the requirements of Appendix B to 10 CFR Part 50 and in compliance with the reporting requirements of 10 CFR Part 21. The critical items procured by P-EP and PEM are identified in Table 1 of this report. The team evaluated the selection and review for suitability activities of P-EP and PEM as described separately below.

3.2.2.1 Selection and Review for Suitability by P-EP

P-EP's procurement practice consisted of purchasing items from subsuppliers that were selected on the basis of their performance history, which was determined through the general knowledge and experience of P-EP's staff. The performance history data that was documented and verified during the manufacture of PG&E's generator did not establish an adequate basis for the qualification of the subsuppliers of critical items. Most of P-EP's subsuppliers were not audited to verify that their measures to control design, processes, and material changes were adequately implemented. Therefore, the critical items procured by P-EP for PG&E's generator were procured as CGIs. The POs for these items did not impose any quality requirements or the reporting requirements of 10 CFR Part 21 on the subsupplier.

P-EP's commercial grade dedication program was governed by Procedure DED-100, implemented on August 2, 1991. The program was not in effect during the procurement and commercial grade dedication of the critical items supplied to PEM for use in PG&E's generator. P-EP considered its standard material receiving activities adequate to dedicate CGIs, on the basis of its understanding of commercial grade dedication requirements that existed before P-EP's development and implementation of DED-100. The commercial grade dedication activities performed by P-EP for the items procured and supplied to PEM for PG&E's generator were, therefore, not controlled by documented instructions or procedures.

Although P-EP agreed to perform the testing necessary to verify the critical characteristics of the items identified in Revision 1 of PG&E's PO as critical, P-EP did not identify all the items critical to the generator's ability to perform its intended safety-related function or perform a technical evaluation of the items identified in Revision 1 of PG&E's PO to determine the adequacy of PG&E's list of critical characteristics. For the critical characteristics selected by PG&E, P-EP failed to demonstrate their relevance to the properties or attributes of the item necessary to withstand the effects of long-term degradation, to the credible failure mode of the item, and to the ability of the item to perform its safety-related function. Consequently, an evaluation of P-EP's generic FMEA identified additional critical characteristics for certain items that were not identified or verified by P-EP during its commercial grade dedication activities and that were not identified by PG&E in its Revision 1 to the PO. P-EP also failed to demonstrate that PEM's dedication activities, for critical items procured by PEM as commercial grade, resulted in reasonable assurance that the generator and its critical items will perform their respective design and safety-related functions.

3.2.2.2 Selection and Review for Suitability by PEM

PEM's procurement practice consisted of purchasing items from suppliers that were selected on the basis of their performance history (similar to Method 4, acceptable supplier/item performance record), which was determined through the general knowledge and experience of PEM's staff. Although this procurement practice is commonplace for European manufacturers, the NRC placed conditions on its acceptance of this method to dedicate CGIs. In its Generic Letter 89-02 the NRC stated that supplier/item performance history was an acceptable method to dedicate CGIs provided (1) the established historical record is based on industry-wide performance data that is directly applicable to the item's critical characteristics and its intended safety-related application and (2) the supplier's measures to control changes in design, materials, and manufacturing processes have been adequately implemented as verified by audit.

Most of PEM's suppliers, however, were not audited to verify that their measures to control design, processes, and material changes were adequately implemented. The performance history data that were documented and verified were not demonstrated to be industry wide and directly applicable to the item's critical characteristics or its intended safety-related application. For the most part, the POs to the suppliers of these items did not impose any quality and technical requirements and none imposed the reporting requirements of 10 CFR Part 21. Therefore, the critical items for PG&E's generator PEM procured as commercial grade from suppliers whose ability to adequately control changes in design, materials, and manufacturing processes had not been substantiated to support the use of Method 4 as an acceptable portion of PEM's commercial grade dedication activity.

3.2.2.3 Status of Previous Selection and Review for Suitability Inspection Findings

During its inspections of P-EP and PEM the NRC team identified several nonconformances with P-EP/PEM's design control for PG&E's power generator. The team reviewed PG&E's response to the NRC addressing these nonconformances, including additional information provided by PG&E during subsequent inspections. The results of the team's review are given below.

(1) **Nonconformance 99900772/91-01-03 (NOT CLOSED)**

P-EP failed to adequately verify the properties or attributes of certain materials, parts, and equipment that were used in the fabrication and assembly of PG&E's generator and that also directly affect the generator's ability to perform its intended design and safety-related function. Specifically, P-EP failed to ensure the suitability (a) of the stator coil's resistance temperature detectors, slip rings, adhesives, and mounting sleeve insulator for the slip rings and (b) of the materials, parts, and equipment PEM procured.

In Section IV of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it had participated in P-EP's audit of PEM and that it would review and approve the dedication evaluations performed by P-EP. Further, PG&E said it would review P-EP/PEM drawings to determine all the related DCRs and DRs to establish equivalency between all manufacturing procedures and material specifications listed in P-EP's PO to PEM. PG&E will document the results of its evaluation in RPE E-7505, Attachment 3.

(2) **Nonconformance 99901065/91-01-02 (NOT CLOSED)**

PEM failed to adequately verify the properties or attributes of certain materials, parts, and equipment that were used in the fabrication and assembly of PG&E's generator and that also directly affect the generator's ability to perform its intended design and safety-related function. Specifically, PEM failed to ensure the suitability of (a) the rotor pole magnet wire wrapped with varnished insulation tape that was specified to be unvarnished, (b) the Bakelite electrical separation ring that was used as a load-bearing component part of the rotor shaft support assembly without an engineering basis for the design, and (c) certain materials, parts, and equipment that were accepted based on certificates of conformance from PEM's suppliers that were not audited to verify that their measures to control design, processes, and material changes were adequately implemented. Therefore, PEM failed to establish adequate measures for the selection and review for suitability of CGIs and to demonstrate an adequate dedication of these items.

In Section V of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it performed independent testing and review of selected suppliers, as described in RPE E-7505, Attachment 4, "Compensatory Actions for Subsupplier Issues." Further, PG&E said it would review P-EP/PEM drawings to determine all the related DCRs and DRs to establish equivalency between all manufacturing procedures and material specifications listed in P-EP's PO to PEM. PG&E will document the results of its evaluation in RPE E-7505, Attachment 3.

The NRC staff considers these two nonconformance unresolved. Closure is pending PG&E's successful completion of (1) the design review between the original five and the sixth generator from 1984 to 1969, including verification of design changes for the stator frame to complete the seismic evaluation, (2) the reverification of equivalency of the P-EP/PEM procedures and material specifications, and (3) the post-modification tests, described in Section 3.1.4.4(3) of this report.

(3) **Unresolved Item 99901065/91-01-01 (NOT CLOSED)**

P-EP provided the material specification for the rotor pole magnet wire to PEM in PO 16271, which specified that magnet coil wire be provided in accordance with P-EP Material Specification MW-25.3, "Magnet Wire – Round, Square, or Rectangular – Unvarnished Fused Polyester Glass Covering, With or Without Enamel Undercoat, Class F (155 °C)," dated June 24, 1977. PEM procured the wire from its supplier by PO EM31035 (original), dated April 27, 1990. In its PO, PEM specified that "rotor copper–unvarnished double dacron glass insulated square magnet wire" be used. PEM also listed material specifications that corresponded to those in MW-25.3 and required certification, by a COC, of the chemical composition of copper, the conductor resistivity, and the insulation dielectric "stress" (strength). The COC, written in French, stated that the material was *Fil de cuivre guipé 2 DAGLAS Imprégné Classe F*... (which means copper wire wrapped with double dacron glass, impregnated, Class F). PEM accepted the wire and used it to wind the rotor poles. However, the team noted that the French word, *imprégné,* means impregnated and that fiber insulation material is commonly impregnated with varnish, indicating that the insulation would not have been unvarnished as specified. Accordingly, the PEM engineers confirmed that the supplied wire had been varnished. Therefore, the wire did not meet the P-EP material specification nor the PEM PO requirement for unvarnished insulation.

PEM immediately informed P-EP of the deviation; whereupon, P-EP reportedly indicated to PEM that P-EP would perform a deviation evaluation (pursuant to 10 CFR Part 21) regarding the varnished insulation, including an evaluation of the compatibility of the varnish with, and its effects on the adhesion properties of, the other materials (such as epoxy adhesive) used in the assembly of the rotor poles. The results of P-EP's and PEM's evaluations of this deviation were not reported to the team before the exit meeting with PEM on September 27, 1991.

In Section V of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that the failure to note that the wire was varnished, vice unvarnished as specified, was an error in the incoming inspection rather than a failure to identify a design change. Further, PG&E stated that to ensure the varnished wire is acceptable, P-EP would be conducting additional tests and that RPE E-7505, Sheet 25, Limitation 3 would track completion and evaluation of the testing. In Section VII of Revision 2 of the NEMP 12.4 evaluation, PG&E stated that it considered the varnished rotor pole magnet wire to be acceptable pending successful completion of P-EP testing, resolution of the equivalency of the wire (RPE E-7505, Sheet 25, Limitation 2), and satisfactory completion of the post-modification tests.

On November 17, 1992, PG&E transmitted to the NRC the results of the P-EP testing of the adhesion properties of the varnished insulation of the rotor pole magnet wire as installed in the power generator using the same type of adhesive. Both the adhesive and the varnish are reported to be epoxy compounds, noted for strength of the secondary bonds. The actual testing was apparently conducted by a French laboratory under contract to the wire manufacturer. The results of the test was translated to English. The report stated that the calculated/expected shear loading on the bonds between rotor pole windings and layers of windings at 125 percent overspeed averaged 30.44 psi (209.87 kPa); whereas, the bonds between test fixtures of both the unvarnished DAGLAS and the epoxy-varnished DAGLAS insulation material held at a test loading that produced 1740 to 1885 psi (11.99 to 12.99 MPa) shear stress. Although the test was conducted at room ambient temperature, the report also stated that previous testing had demonstrated that the bond strengths improved at higher temperatures. The report noted that the specification had been written when some varnishes were of an inferior phenolic type whereas epoxy resin varnish was used on the rotor pole magnet wire in this machine. The report cited current industry standards that allowed the use of varnished magnet wire and concluded that the wire was acceptable in light of the satisfactory production electrical tests and overspeed tests.

The NRC staff considers this concern unresolved. The winding configuration will produce tensile stresses while rotating that were neglected in the testing and analysis. The geometry of the rotor pole suggests that they would be considerably less than the shear stress and the margin between calculated stress and test stress was so large that this simplification should not invalidate the test. However, closure is pending PG&E's successful completion of the post-modification tests and no detection of delamination of the winding layers during inspections.

3.2.3 Special Processes

P-EP's facsimile transmittal to PEM, dated February 11, 1987, provided the instructions for fitting the dovetail rotor pole assemblies to the rotor spider assembly, even though P-EP did not have a documented procedure that prescribed this activity. PEM incorporated these instructions into Engineering Standard R-6097, "Assembly Procedure for Wound Rotors of Class 1E Generators Having Dovetail Poles." P-EP did not approve PEM's procedure or perform an equivalency evaluation because it did not have a documented procedure to compare to PEM's procedure.

P-EP Drawing C-66827, "Rotor Pole Assembly," Revision 2, specified the use of Brazing Specification EB-4.4 for the fabrication of the rotor pole stampings. P-EP did not perform an evaluation to determine the equivalency of PEM's Brazing Procedure R-6092, "Preparation and Procedure for Brazing Copper/Copper Alloy Rotor Bars to Short Circuiting Rings for Use in Normal Industrial Environments," Issue 1, Revision 0, dated December 7, 1990. In addition, P-EP did not perform an equivalency evaluation of Peebles Power Transformers Procedure 5275, "Process Specification Responsible Department Fabrication," dated March 26, 1987. PEM used this procedure as a broad-based procedure that allowed the user to choose between several welding and brazing processes and joint geometries.

PG&E's generator was designed with eight field coils mounted on the rotor. Each field coil consisted of 404 turns of magnet wire that were wound on a laminated-steel rotor pole core with high permeability. The application of a dc excitation voltage, supplied from the brush and slip-ring assembly, will cause the field coils to generate a magnetic field. In combination with the rotation of the rotor shaft, this field generates the output voltage. An electrically shorted or open field coil winding may result in the failure of the generator to perform its intended design and safety-related function. The field coil windings also are subjected to centrifugal forces from the rotation of the shaft and the resulting mechanical stresses that may affect the integrity of the field coil windings.

PEM's Manufacturing Procedure R-6096, "Manufacturing Procedure for Strip-On-Flat Field Coils Wound Directly Onto Laminated Poles for use In Class 1E Generators," Revision 0, dated January 4, 1991, stated that spliced joints in the magnet wire were permissible where a continuous length of magnet wire was not available during field coil (rotor pole) fabrication. In the event that the amount of magnet wire available on a single spool was not sufficient to complete the coil winding operation, or where the magnet wire was damaged or broken during the manufacturing process, PEM's Procedure R-6096 permitted making a brazed-joint spliced connection in the field coil winding. If the fabrication and brazing of such a joint is not adequately controlled by procedural guidance and proper quality techniques, the results may be a mechanically weak spliced connection or a high electrical resistance at the brazed joint, which may not be readily detectable after completing the field coil winding.

P-EP stated that, to its knowledge, no spliced connections were made during the fabrication of the field coils and produced a COC that indicated that a sufficient quantity of magnet wire per spool was ordered for each field coil assembly. The COC, however, did not establish reasonable assurance that PEM had not made spliced connections as a result of damage to the magnet wire during the winding process, and P-EP did not demonstrate documented verification that PEM did not perform spliced connections.

PEM Manufacturing Procedure R-6096 did not produce the guidance or the precautionary statements contained in P-EP Production Specification R-6028. P-EP did not perform an equivalency evaluation of PEM's procedure. PEM's manufacturing procedure did not include quantitative or qualitative acceptance criteria for spliced connections such as resistance measurements and tensile strength tests following the brazed-joint splicing operation.

Nonconformance 99900772/91-01-04 (NOT CLOSED)

P-EP failed to demonstrate that the activities affecting quality (to fit the dovetail rotor pole assemblies to the rotor spider assembly, to perform the brazing required to fabricate the rotor spider assembly, and to perform brazed-joint spliced connections in the field coil winding) were documented or accomplished in accordance with instructions, procedures, or drawings that contained quantitative or qualitative acceptance criteria and were equivalent to those specified by P-EP.

In Section IV of Revision 2 of the NEMP 12.4 evaluation, PG&E responded that it had participated in P-EP's audit of PEM and that, according to P-EP, the lack of detailed instructions for the dovetail rotor pole assembly is not an issue that would jeopardize the function of the generator because this procedure is considered standard shop practice. If the rotor pole were not assembled correctly, the result would be excess vibration and the functional testing of the generator, particularly the overspeed portion of the testing, verifies that these assembly operations were conducted correctly. P-EP performed engineering evaluations to address equivalency of the PEM's brazing procedures for the rotor spider assembly and brazed-joint spliced connections in the field coil winding and concluded that the procedures are acceptable and that no spliced connections were made in field coil windings. The adequacy of documented instructions for the assembly of the generator will be verified by the compensatory actions described in RPE E-7505 (i.e., functional testing, source inspection, and PG&E's audit participation) and the satisfactory completion of the post-modification test.

The NRC staff considers this nonconformance unresolved. Closure is pending PG&E's successful completion of the reverification of equivalency of the P-EP/PEM procedures and material specifications, and the post-modification tests, described in Section 3.1.4.4(3) of this report.

3.2.4 Critical Item Evaluations

Although P-EP considered its standard material receiving activities adequate to dedicate CGIs, the commercial grade dedication activities performed by P-EP for the items procured and supplied to PEM were not controlled by documented instructions or procedures before P-EP's development and implementation of DED-100. Therefore, the team also reviewed the procurement documentation for the critical items procured by PEM and evaluated the extent to which the PG&E-listed critical characteristics (as well as others) listed in Table 1 were ultimately verified by PEM. A summary of P-EP/PEM's commercial grade dedication activities for a sample of the critical items specified by PG&E in Attachment F to Revision 1 and, where applicable, Revision 3 of its PO to P-EP is given below.

3.2.4.1 Evaluations of the Critical Items Supplied by P-EP

P-EP supplied the generator to PG&E as a basic component that was supposed to comply with the requirements of Appendix B to 10 CFR Part 50. Therefore, P-EP was responsible for establishing reasonable assurance that the generator and its critical items will perform their safety-related functions. PG&E selected and specified the critical items and their critical characteristics for its generator, and P-EP agreed to perform the steps necessary to verify PG&E-specified critical characteristics. P-EP did not demonstrate that PG&E's critical characteristics were relevant and complete to the design characteristics, credible failure modes, and ability of the item to perform its safety-related function and did not identify the properties or attributes necessary to withstand the effects of long-term degradation and cyclic fatigue. P-EP also failed to demonstrate in all cases that its own and PEM's dedication activities, for critical items procured by P-EP and PEM as commercial grade, resulted in establishing reasonable assurance that the critical characteristics chosen by PG&E were adequately verified.

The comments below represent a summary of the results of the team's evaluation of P-EP/PEM's dedication of and PG&E's compensatory actions performed on a sample of the generator's critical items listed in Table 1. Closure of the issues is pending PG&E's successful completion of its post-modification tests, described in Section 3.1.4.4(3) of this report, that are intended to (1) demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test; (2) facilitate the resolution of the unresolved item and nonconformances identified during the NRC's inspections of P-EP and PEM; (3) demonstrate reasonable assurance that the parts will perform their safety-related function; and (4) demonstrate the adequacy of P-EP/PEM's design, materials, and manufacturing processes by subjecting certain components of the power generator to operating and transient conditions.

(1) Insulators

PG&E identified the critical characteristics of the 5-kV insulators for the main generator output terminal box as dielectric strength, size, and weight in Revision 1 of its PO and dielectric strength and configuration in Revision 3. The acceptance criterion for the insulators' dielectric strength was not obtained from the supplier.

The insulators (Westinghouse Style 1581-772, Class A30) were procured by P-EP and some of their critical characteristics (i.e., dimensions and weight) were verified before shipment to PEM. A supplier's certification of dielectric strength was not obtained and P-EP did not measure this parameter. P-EP did, however, measure the insulation resistance at 2500 Vdc and issue a COC to PEM.

PEM conducted a dielectric withstand ("hi-pot") test at 9500 Vac, consistent with the applicable requirements in the National Electrical Manufacturers Association (NEMA) Standard MG1-1987. However, analysis of the test circuit for high voltage testing of generator insulators may not be conclusive for all individual insulating components. If the field circuit is tested with a megohmeter ("Megger") at 500 Vdc from a dc field terminal to ground, then the field lead cable insulation is in series with the insulating grommet or bushing; the field winding insulation is in series with the shaft bearing insulator; and the slip-ring insulator also is in series with the shaft bearing insulator. Therefore, if it were desired to verify that those series components were individually satisfactory, additional test points would need to be chosen (e.g, from shaft to ground and/or from brush rigging terminals to ground) to ensure that at some point, all the components have been alone in a parallel branch circuit. However the tests already made, while not verifying the insulation integrity of all the individual components, did demonstrate satisfactory overall insulation of the rotor and stator.

(2) **Insulating Bushings**

P-EP purchased insulating bushings for the generator housing lead wire penetrations to prevent chafing of the lead wire insulation during operation. The critical characteristics of the insulating bushings were identified by PG&E as size and shape and included thread outside diameter (OD) and length, and overall OD, inside diameter (ID), and length. The bushings are made of Grade XX SALI tubing, which is a phenolic material.

P-EP verified their dimensions, including the thread OD, thread length, bushing OD, ID, and overall length. However, P-EP did not verify their dielectric strength or concentricity.

(3) **Insulating Materials**

The insulating materials were installed on the stator's so called "diamond" (shape) coil windings. PG&E identified thickness as the critical characteristic. P-EP procured the following insulation materials and sampled the amount indicated:

mica paper tape. . . . . . 6 of 60 rolls sampled
mica paper tape. . . . . . 6 of 60 rolls sampled
B-stage mica paper tape. . 7 of 162 rolls sampled
B-stage mica wrapper . . . 4 of 4 rolls sampled

P-EP verified the thickness of the insulating material on the rolls sampled and found the results of its verification activities acceptable. However, P-EP did not verify (1) the batch or lot homogeneity of the insulation material to ensure that each batch or lot was sampled and traceable to each batch or lot and (2) the material constituents of the insulating materials or their properties or attributes with regard to the generator's design-basis operating temperature requirements.

To compensate for inadequate material verification of insulating materials during generator construction, PG&E proposed to verify adequate performance of the generator insulation system by conducting dielectric withstand tests at about 9.5 kV in accordance with DCNPP Electrical Maintenance Procedure MP E-54.2, "High Voltage Testing of Electrical Equipment." Satisfactory results of these tests following the completion of the post-modification tests will demonstrate that the insulation material used and its installation provided an acceptable (and adequately durable) insulation system for the generator. This test also is performed every 18 months as part of STP M-81G, "Diesel Engine Generator Inspection." In addition, the generator is operationally tested at least quarterly and is in a mild environment at other times.

(4) **Bearing Seal**

The bearing seal is a felt disc installed on the rotor shaft. PG&E identified the critical characteristics as thickness, shape, and texture in Revision 1 of its PO and as configuration and texture in Revision 3. P-EP verified the seal's dimensions, including OD, ID, thickness, and shape. P-EP believed the determination of acceptability of the felt bearing seal's texture was a matter of judgment. However, P-EP did not consider that the different "weights" of oil-seal felt have different porosity and lubricant holding properties.

(5) Brushes and Brush Holders

The brushes and brush holders were installed on a brush holder stud and positioned above the slip rings on the rotor shaft. PG&E identified the critical characteristics as size, shape, final generator test to verify resistance, material, and contact pressure.

The brushes and their wire leads and terminal connections were installed in the brush holders. PG&E identified the critical characteristic as configuration. P-EP verified the brushes' dimensions, including height, length, and width. P-EP did not, however, verify the material constituents, wire lead size or type, wire lead terminal connections, and electrical resistance of the brushes.

PG&E identified the critical characteristic of the brush holders as configuration. P-EP verified the dimensions, including the opening size for the brush, and overall shape of the brush holders. P-EP did not, however, verify the spring tension on the brushes, the technical and quality requirements, or the critical characteristics of the Grade X Spaudite Bakelite cylinder (bushing) that fits over the brush holder stud and functions as the insulator for electrical separation between the brush holder and the generator frame.

(6) Stator Resistance Temperature Detectors (RTDs)

The stator RTDs were installed in the stator coil assembly. PG&E identified the critical characteristics as shape, size, shop test for continuity, resistance, and insulation. Although continuity and resistance were listed separately as characteristics for several items without further explanation, the team noted that if a quantitative value for resistance was desired then continuity would be demonstrated without performing a separate test. Specifying continuity in addition to resistance would, therefore, normally be considered redundant. However, PG&E did not specify the temperature at which the shop test for resistance was to be conducted or the linearity requirements over the test range. P-EP failed to demonstrate documented dedication and verification activities for the commercial grade stator RTDs.

(7) Current Transformers and Test Switches

The current transformers and test switch form a sensing device. PG&E identified the critical characteristics of current transformers (CTs) as configuration, mounting, insulation, resistance, and continuity. P-EP verified the CTs' dimensions, including the height, the length measured at the feet, the length of the body, location of mounting holes, weight, insulation resistance, and continuity. The acceptance criterion for the dielectric strength (or alternatively for insulation resistance) of the CTs was not obtained from the manufacturer. P-EP found the results of its verification activities acceptable. However, it was not clear from the documentation if P-EP verified (a) the electrical loads supplied by the CTs or if the CTs supplied a current to the static exciter voltage regulator or instrumentation and protective circuits, (b) the required ratio of the primary to secondary currents, and/or (c) the secondary winding resistance. In addition, it was not clear if P-EP had verified the temperatures at which the required values of these parameters should be met.

The NEMP 12.4 evaluation, Revision 2, stated that these characteristics were not required to be verified because the CTs had been ordered under a specific catalog number (General Electric JCB-3, catalog No. 753X21G8); therefore, the electrical characteristics were "included in the verification process." However, unvalidated commercial catalog information is not an acceptable method for verification of critical characteristics of CGIs for safety-related service. Nevertheless, on the basis of the foregoing discussion, the compensatory actions outlined in RPE E-7505, and extensive testing at PEM, it appears the CTs will be acceptable for service after satisfactory completion of the post-modification tests.

Review of RPE E-7505 revealed that this issue was addressed in Section B of Attachment 4, but that for the CTs, it merely restated the assertion that height, width, length, mounting holes, weight, insulation resistance, and continuity had been verified. The team reviewed a copy of the PEM test data sheets (identified by GO 260274, Serial 260274/1), dated February, 13, 1991, from the extensive factory testing. Data Sheet 7 contained CT data taken during the testing at PEM, which consisted of secondary winding resistance tests performed at 23 °C, secondary insulation resistance at 1000 V, voltage withstand for 72 seconds, and a turns ratio test. However, the sheet showed no acceptance criteria or tolerances for any of the test parameters. Also having stated that the effective CT turns ratio was supposed to be 600 to 5, and indicating a test current of 600 amps, the value shown presumably for CT output was not 5 amps as expected, but 600 amps for all three CTs. It was not clear if this was an error or if the CTs had been read using some kind of shop test stand meter that was supposed to read 600 amps, presumably with a 5-amp input. It was also not clear what adjustment may have been made to obtain the desired reading, or what the range of adjustment of this instrument was compared to the one to be installed at DCNPP2. It was therefore difficult without having acceptance criteria or even knowing the service conditions/system parameters, to evaluate the raw test data.

In Revision 1 of its PO to P-EP, PG&E identified the CT test switches as critical items and identified their critical characteristics as configuration, dielectric strength, and continuity. Although it had not been clear if P-EP had measured the dielectric strength of the CT test switches, PG&E's P-EP NEMP 12.4 evaluation, Revisions 1 and 2, on page 54, stated that P-EP had verified the dielectric strength by an insulation resistance test. Attachment H to Revision 1 of the NEMP 12.4 evaluation consisted of copies of the original P-EP dedication evaluations, including sheets 1 through 6 of 6 of Test/Inspection Report S-1128-5, dated July 18, 1990. Sheet 1 specified the acceptance criteria for the States, Type "SJK" CT test switches' dimensions (cover size and location of mounting holes), weight, dielectric strength (actually specified insulation resistance at 500 Vdc of greater than 1000 megohms), and continuity. The actual test data were recorded on Sheet 2. It showed insulation resistance readings of >50 gigohms between adjacent terminals on one end of each of the seven poles with the blades down and the same values from line-to-load-side terminals of poles 5, 6, and 7 with the blades up. These results appeared to be acceptable and consistent with the schematic diagram of the particular switch configuration under test included on the data sheet. The continuity data was actually expressed as pole or contact resistance (although measured with a multimeter having a 0.1-ohm minimum reading), showing 0.0 ohms line-to-load for all poles with blades down, and 0.0 ohms between the CT secondary shorting terminals with blades up. The data appeared to be satisfactory and consistent with the terminal/schematic diagram, confirming the make-before-break CT secondary shorting action of the switch.

(8) Slip-Ring Assembly

The slip-ring assembly was installed on the rotor shaft. PG&E identified the critical characteristics as configuration and materials. However, P-EP failed to demonstrate documented dedication and verification activities for the commercial grade slip-ring assembly.

(9) Adhesives

The epoxy adhesive (resin) was applied during the forming of the rotor pole windings. PG&E identified the critical characteristic as material. P-EP Shop Order S-1128 required the use of epoxy resin instead of a polyester resin (polyester resin was used for PG&E's five existing EDGs) because an environmental qualification report showed that the performance characteristics of epoxy resin were acceptable and it was an acceptable substitute for the polyester resin. P-EP, however, did not establish similarity of the commercial grade epoxy resin purchased to the epoxy resin described in the environmental qualification report. P-EP also failed to demonstrate documented dedication and verification activities for the commercial grade epoxy resin.

RPE E-7505 consolidated the information gathered in support of dedication of the individual critical items and outlined the compensatory actions for deficiencies in the dedications, referencing various other documents as necessary, such as the Peebles NEMP 12.4 evaluation.

Attachment "L" to PG&E's Peebles NEMP 12.4 evaluation (Revision 2) documented PG&E's evaluation of this issue, stating that although P-EP agreed to supply the resin specimen for compensatory testing, P-EP took the position that it was not needed because of the rotor pole winding clamps and because of the satisfactory results of the 25-percent overspeed testing. PG&E adopted this position and summarized the evaluation of this concern and the compensatory testings in Section E of Attachment 4 to RPE E-7505. It states that PG&E's Technical and Ecological Services Laboratory (TESL), as documented in TESL Test Report 500-91.65, Revision 1, dated March 21, 1991, tested a sample of resin from ostensibly the same batch as that used in building the generator at PEM. According to the TESL Test Report 500-91.65, Revision 1, dated March 21, 1991 (in Attachment "L"), a sample of Morton Thiokol/Armstrong Products type A-701, one-part epoxy resin, identified as being from batch number GA0309 performed successfully in bonding acceptance tests per ASTM D-1002-72 and per Morton Thiokol, Inc., Test Procedure APTM 40-1285. Attachment L to

NEMP 12.4 also contained a copy of an undated COC from Cox Sales Company that referenced an Order 16651 (whose order is not indicated), identified the product as A-701, identified the batch number as GA0309, and referenced NEI Specification MV-20.9. The COC certified that the material was "produced in accordance with standard production specifications" and stated that "production records for each lot are on file with the manufacturer, Morton International. However, Attachment L did not contain documentation to establish traceability of the tested batch number to the resin used in the generator, nor did it provide information about Morton-Thiokol's batch homogeneity.

(10) Slip-Ring Sleeve Insulator

The slip-ring mounting sleeve insulator was installed between the shaft and the slip-ring assembly and provided not only the electrical separation of the slip-ring assembly and the rotor shaft, but also formed the mounting structure for the slip-ring assembly. PG&E did not identify the slip-ring mounting sleeve insulator as a critical item. P-EP's material routing incoming order review of April 12, 1990, showed that P-EP supplied the slip-ring mounting sleeve insulator to PEM as a commercial grade stock item. Additionally, P-EP Drawing A-29412, "Slip Ring Mounting Sleeve Insulator," Revision 3, dated December 20, 1967,showed an obsolete material specification for the sleeve insulator. P-EP stated it would update the drawing. P-EP failed to demonstrate documented dedication and verification activities for the commercial grade slip-ring mounting sleeve insulator.

(11) Vibration Indicating Devices

The vibration indicating device is used to detect high vibration resulting from various sources, including an asynchronous event. However, PG&E elected not to procure permanent vibration monitoring devices for the generator since they were not considered to be items critical to the reliable, long-term operation of the generator. PG&E took other steps to ensure that the generator was and is operating within the limits for vibration established by the manufacturer.

During the initial generator testing by PEM, vibration measurements were taken to determine conformance to the NEMA Standard MG1-1987, which specifies a maximum displacement peak-to-peak of 0.003 inch (0.0076 cm). Measurements were made both before and after overspeed testing in the transverse, vertical, and axial directions at both the driver end and non-driver end of the generator shaft. The test results indicated a maximum peak-to-peak displacement of 0.0028 inch (0.0071 cm).

The generator was again tested while assembled to the diesel engine at GEC Alsthom and also will be tested during the post-modification tests at DCNPP2, during which time vibration of the generator will be monitored with portable instrumentation. PG&E does not plan to include automatic synchronization capability equipment, which was not provided for the other five diesel generator units currently installed at DCNPP.

3.2.4.2 Evaluations of the Critical Items Supplied by PEM

Even though PEM had completed PG&E's generator before Revision 3 of the PO was issued and reported that Revision 3 was not considered during the design, procurement, and manufacturing activities of the generator, PEM acknowledged that certain items specified in Attachment F of Revision 3, although not listed in Attachment F of Revision 1, had been considered critical to the generator's ability to perform its intended design and safety-related function and, therefore, included in PEM's commercial grade dedication and verification activities.

The comments below represent a summary of the results of the team's evaluation of P-EP/PEM's dedication of and PG&E's compensatory actions performed on a sample of the generator's critical items listed in Table 1. Closure of the issues is pending PG&E's successful completion of its post-modification tests, described in Section 3.1.4.4(3) of this report, that are intended to (1) demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test; (2) facilitate the resolution of the unresolved item and nonconformances identified during the NRC's inspections of P-EP and PEM; (3) demonstrate reasonable assurance that the parts will perform their safety-related function; and (4) demonstrate the adequacy of P-EP/PEM's design, materials, and manufacturing processes by subjecting certain components of the power generator to operating and transient conditions.

(1) Lead Wire

In Revision 1 of its PO to P-EP, PG&E identified lead wire (Attachment F, item 1) as a critical item and specified the critical characteristics as dielectric strength, number of strands, the markings on the cable, and the insulation thickness. However, in Revision 3 of PG&E's PO only configuration was specified as the critical characteristic for lead wire (Attachment F, item 16). PEM had specified the lead wire to be used for dc field leads (the segment from the brush-rigging to the external terminal box) without guidance from P-EP. In all the pertinent documentation provided by P-EP, the team could not identify any wire suitable for this application. The only document that may have referred to this wire specified wire of insufficient ampacity for this application. Therefore, PEM chose what appeared to be a suitable type of wire and procured it in a similar manner to other lead wire used for this generator. However, the wire was procured without apparent knowledge or consent of P-EP, and PEM did not verify the critical characteristics specified by PG&E.

(2) Magnet Wire

In Revision 1 of its PO to P-EP, PG&E identified magnet wire (Attachment F, item 4) as a critical item. This insulated copper wire is wound in a coil of turns or windings (approximately 450 for this machine) around each of eight (for this 60-Hz, 900-rpm machine) laminated steel rotor poles. Each rotor pole creates a constant magnetic field from the direct current flowing in its windings, which induces alternating current in the stator windings (coils) as each pole passes the stator windings. A prime mover (in this case the diesel engine) turns the rotor shaft, which causes relative motion between the magnetic field of the rotor poles and the stator windings, inducing generator voltage and current. The generator is synchronous because the frequency of the output voltage and current is directly proportional to the speed of rotation of the rotor.

P-EP provided the material specification for the rotor pole magnet wire to PEM in PO 16271. The P-EP PO specified that magnet coil wire be provided in accordance with P-EP Material Specification MW-25.3, as described in Section 3.2.2.3(3) of this report.

However, the wire received from PEM's supplier did not meet the P-EP material specification or the PEM PO requirement for unvarnished insulation (see Section 3.2.2.3(3) of this report). In addition, PEM had no documented analysis addressing the use of varnished insulation tape in this application and no information from P-EP regarding the basis for the specification of unvarnished insulation. Accordingly, PEM immediately informed P-EP of the deviation. P-EP agreed to perform a deviation evaluation (pursuant to 10 CFR Part 21) regarding the varnished insulation, including an evaluation of the compatibility of the varnish with, and its effects on the adhesion properties of, the other materials (such as epoxy adhesive) used in the assembly of the rotor poles.

In Revision 1 of its PO to P-EP, PG&E identified the critical characteristics of the magnet wire as size and shape, resistance, and insulation dielectric strength. Although these characteristics were critical, PG&E omitted other pertinent material properties of the magnet wire, such as mechanical strength and allowable bend radius, as well as characteristics of the insulation system, such as thermal capability. These characteristics were not merely manufacturing considerations because they could affect generator reliability given the stresses involved during normal operation of the generator, let alone the additional stresses from asynchronous events, adverse extremes of the normal service environment, or a DBE, such as seismic excitation. Although some of these characteristics may ultimately have been addressed by P-EP's material specification and final testing, PG&E had not identified them as critical.

Both the COC from PEM's supplier and the test report certify that the material met all specifications, but there was no basis for acceptance of the COC. PEM did not survey its suppliers and did not conduct independent testing to verify the accuracy of the COC or the test report. As a result, PEM accepted and used nonconforming material. This is one of several examples of PEM accepting a COC at face value with no audits, surveys, or verification testing to verify the validity of the COC.

(3) Leads to Coil Terminations

In Revision 1 of its PO to P-EP, PG&E identified the leads to coil terminations (Attachment F, item 11) as critical items and specified the critical characteristics as brazing and weld materials. Revision 3 of PG&E's PO did not include the leads to coil terminations as critical items, although PEM's engineering staff agreed with the team that the leads to coil terminations were critical. Moreover, PEM pointed out that all connection and termination joints were critical to the generator's ability to perform its design and safety-related function.

The completed generator assembly contains several connections and terminations that can be classified into one of the following three types:

- brazed, high-temperature silver-solder joints that connect the magnet wires of the rotor poles to cable leads

- overlapped compression joints that connect copper conductors to copper conductors (e.g., the stator coil windings to other stator coil windings and the stator coil windings to the copper conductors of the parallel rings) or copper conductors to cable leads (e.g., the copper conductors of the parallel rings to the cable leads that run to the generator's main terminal box)

- crimped joints that connect cable leads to lugs (e.g., ring-tongue terminals used for bolted terminations)

PG&E identified the leads to coil terminations as critical items with critical characteristics listed as brazing and weld materials, even though weld materials are not used to perform brazing operations. PEM used brazed connections only to connect the magnet wires of the rotor poles to cable leads that run along the surface of the rotor shaft to the slip-ring assembly. However, PG&E did not identify the generator's other connections and terminations as critical items, even though PEM considered them to be critical.

PEM did not establish a documented procedure to control the high-temperature silver-solder brazing operation. PEM, however, did have skilled craft with several years of experience to make the brazed joints. PEM failed to document qualification of the brazing materials and methods used, inspection of the brazed joints, or verification that the joints were adequate and met expected quality and technical requirements.

To control the overlapped compression joints in the stator assembly, PEM developed Procedure R 6081, "Compression Jointing of Copper Conductors Within a Stator Winding Using AMP Products," dated November 20, 1990. PEM prepared trial joints for the overlapped compression joints that connect the stator coil windings to each other and the stator coil windings to the parallel ring to establish the fabrication parameters for the same type of compression joints to be performed during the manufacturing of the generator.

However, PEM failed to document the results of the test and inspection of the qualifying trial joints. PEM also failed to document objective evidence of any inspection or verification to ensure that the joints made during fabrication were adequate and met expected quality and technical requirements.

PEM did not establish a documented procedure to control the crimped joints that connect the cable leads to ring-tongue terminal lugs that form bolted connections at the terminal box for the cable leads that run from the stator's parallel rings, at the slip-ring assembly for the cable leads that run along the rotor shaft from the rotor poles, and at the brush-rigging assembly and the field terminal box for the cable leads that connect those two items. In addition, PEM failed to document objective evidence of its inspection or verification of the crimped joints to ensure that the joints were adequate and met expected quality and technical requirements.

(4) Roller Bearing

PEM procured a single spherical roller bearing for the generator as a CGI from the manufacturer, FAG (UK) Limited. PG&E identified the roller bearing (Catalog No. 22226EAS-M-C3) as a critical item with critical characteristics of part number and configuration. However, the manufacturer provided a bearing with a forged cage rather than a steel cage. Further evaluation indicated that the cage material is not important since that component is not load-bearing and many different materials are acceptable for the cage. The remaining critical characteristics were verified to be acceptable.

However, PG&E did not identify as critical characteristics the physical and chemical properties of the materials of construction for the load-bearing parts of the bearing, namely, the rollers and the inner and outer races. Furthermore, PEM did not audit the manufacturer to determine if there were adequate material controls applied to ensure that the proper materials were used. PG&E indicated that the overall adequacy of the roller bearing, including materials of construction, would be demonstrated by the successful completion of the post-modification tests.

(5) **Rotor Shaft**

In Revision 1 of its PO to P-EP, PG&E identified the rotor shaft (Attachment F, item 13) as a critical item and specified dedication would be required by factory test, without specifying what should be included in the test. However, in Revision 3 of its PO, PG&E specified the rotor shaft's (Attachment F, item 1) critical characteristics as material, configuration, and integrity.

In its PO to PEM, P-EP required that the rotor shaft forging comply with Material Specification MS-70.42, "Shaft Forging, Carbon Steel (Not Recommended for Welded Lands) Used for All Flanged Shafts and All Shafts Over 10-Inch Diameter," dated November 10, 1972. MS-70.42 specified the shaft material comply with ASTM A-470, Class 1, "Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts." However, P-EP's Drawing C-67400-1, "Shaft, Single Bearing, Forged, Flanged for Alco Engine," Revision 7, dated November 19, 1990, specified that the shaft material comply with ASTM A-292, Class 1. The team determined that ASTM A-292 was superseded by ASTM A-469, "Vacuum-Treated Steel Forgings for Generator Rotors," and that P-EP Drawing C-67400-1 had not been revised to reflect ASTM A-469 for generator rotor shafts instead of the obsolete A-292 specification. The issue of concern is that PEM did not document a reconciliation of the apparent conflict between the material specified in the drawing and the material specified in MS-70.42. Neither PEM nor P-EP documented the basis or rationale for ordering the generator's rotor shaft to a material specification intended for turbine rotors and shafts (ASTM A-470) as opposed to the material specification for generator rotors (ASTM A-469).

ASTM A-469 required a permeability test of the rotor shaft be performed in accordance with ASTM A-341, "Test Method for DC Magnetic Properties of Materials Using DC Permeameters and the Ballistic Test Methods," or ASTM A-773, "Test Method for DC Magnetic Properties of Materials Using Ring and Permeameter Procedures with DC Electronic Hysteresigraphs." ASTM A-470 did not require a permeability test of the rotor because the specification was intended for turbine rotors. Moreover, a permeability test was not performed or documented in PEM's inspection records for the rotor shaft. Neither P-EP nor PEM evaluated the necessity to determine the rotor shafts permeability; therefore, the proper material and its characteristics were not adequately verified by PEM.

PEM ordered the rotor shaft from La Forgia di Bollate s.p.a. of Milan, Italy. PEM's PO specified "shaft forging to Drawing B-67405-1, to be rough turned condition, material spec: ASTM A-470-77, Class 1, also BS-970 080 M40," even though PEM did not document an equivalency evaluation between ASTM A-470-77, Class 1, and BS-970 080 M40. La Forgia di Bollate issued its COC, dated December 6, 1990, to PEM and certified that the rotor shaft complied with PEM's Drawing B-67405-1 and Material Specification BS-970 080 M40. The COC also certified the shaft was UT NDE according to the requirements of ASTM A-418, "Ultrasonic Inspection of Turbine and Generator Steel Rotor Forgings," and reported that "no noteworthy defect was found, positive results." The shaft was shipped to Weir Engineering Services, Alloa Works, located in Alloa, Scotland, where PEM procured the final shaft machining in accordance with Drawing C-67400-1. Weir Engineering Services issued a COC to PEM that certified that the shaft had been inspected and conformed to Drawing C-67400-1. PEM performed a dimensional verification of the shaft to Drawing C-67400-1 during receipt inspection to ensure the configuration characteristic of the rotor shaft.

Only UT straight beam NDE was performed on the rotor shaft, which may not detect shallow internal discontinuities (i.e., cracks or tears and bursts that occur during the processing of ingots or billets) immediately below the surface of the rotor shaft. Although PG&E identified integrity as a critical characteristic of the rotor shaft, PEM did not perform a MT examination, which would detect these discontinuities, even though certain conditions peculiar to forgings require the use of more than one NDE method to provide reasonable assurance of the integrity of the rotor shaft forging.

(6) Stator and Rotor Core

In Revision 1 of its PO to P-EP, PG&E identified the stator and rotor core as a critical item (Attachment F, item 14) and specified their critical characteristic as factory testing (electrical losses). However, in Revision 3 of PG&E's PO the stator core and rotor pole were omitted as a critical item and stampings were identified (Attachment F, item 2) with the critical characteristics of configuration and material. The stator core and rotor pole stampings are addressed separately below.

Stampings — Stator

In PO 16271 to PEM, P-EP specified that stator core stampings (electrical steel) be provided in accordance with P-EP Material Specification MS-70.77, "Steel-Electrical Sheet - Fully Processed." The MS-70.77 revision of February 14, 1991, allowed PEM-built core steel material for machines to be purchased according to PEM Specification R 8046, "Electrical Core Steel For Rotating Machines, Coated On Both Sides With An Insulating Resin Or Varnish," and stated that "Grade 310-50-A5...is universally acceptable under MS-70.77."

PEM procured the material from Joron Steel by PO EM31024 (original, estimated date February 1990). PEM's PO specified "stator core steel to purchase standard R 8046, Grade 310-50-A5" and required test certificates for the chemical composition of steel and insulation resistivity.

Joron procured the steel from EBG in Germany. EBG provided a test report indicating the steel core loss, but not the chemical composition or insulation resistivity. Joron subsequently provided the test report to PEM with some additions (coil numbers, contract number, and purchase order number).

Although PEM specified testing for both chemical composition and insulation resistivity in its PO to Joron, it accepted the material without either of those tests being performed. This is another example of PEM accepting material from a supplier who has not met the PO requirements without generating a discrepancy report. In addition, although Revision 1 of PG&E PO required factory testing for electrical losses, PEM did not pass this on to its supplier. Even though EBG provided the results of the factory test for electrical losses to PEM through Joron, there was no basis for accepting the EBG test report because PEM did not audit its suppliers.

Stampings — Rotor Pole

In its PO to PEM, P-EP specified that rotor pole stampings (pole iron) be provided in accordance with P-EP Material Specification MS-70.38, "Steel - Hot Rolled Pole Steel." The MS-70.38 revision of February 14, 1991, allowed rotor pole steel material to be Tensiloy 250 for PEM-built machines.

PEM issued PO EM31042 to British Steel Corporation requesting Tensiloy 250 steel. The PO required test certificates for chemical composition, mechanical properties (tensile, yield, percent-elongation), and dc permeability.

Although Revision 1 of PG&E's PO identified "losses" (presumably referring to ac hysteresis) as a critical characteristic, PEM recognized that to be inappropriate for dc rotor pole stampings, even though it did not notify P-EP, because the critical characteristics of rotor pole stampings are mechanical and dc permeability. Thus, even though PEM did not pass on the "losses" requirement to its supplier, PEM did specify the correct critical characteristics. PEM's supplier, British Steel Corporation, did supply a certificate of magnetic testing (dc permeability) that identified the product as Tensiloy 250 and provided results of mechanical and dc permeability testing. Chemical composition of the steel was not provided. Again, PEM accepted the test certificate without an adequate basis since no audits of British Steel Corporation had been performed.

(7) **Stator RTDs**

In Revision 1 of its PO to P-EP, PG&E identified the stator RTDs as critical items, but P-EP did not invoke or provide a material specification for the RTDs. However, P-EP PO 16271 to PEM included, in the description of the generator, "6 embedded 10-ohm detectors," which indicated that P-EP supplied the RTDs to PEM for PG&E's generator. However, PEM issued PO JA30241 (original) (date not discernible on copies) to Carel Components Ltd. for eight stator winding RTDs 10-ohms at 25 °C, 3 wire 6-inch long x 11/32 inch wide x 0.50 inch thick (15.24-cm long x 0.873-cm wide x 1.27-cm thick), which showed that PEM had procured the RTDs that were actually installed in the generator. Carel subsequently procured the RTDs from its subsupplier, Minco Products, Inc. Although the original PO from PEM did not specify the insulation material, PEM modified its PO in a telex to Carel, dated March 28, 1990, which Carel acknowledged by letter dated March 29, 1990. The modification specified the Minco part number in accordance with the catalog description. The Minco part number identified the model number (including element type, insulation class and thickness, and lead wire size), length, lead wire insulation, width, number of lead wires, and lead wire length. PEM did not require a COC from Carel in its original or revised (by telex) PO.

Revision 1 of PG&E PO inadequately identified the critical characteristics of the stator RTDs as only size and shape; Revision 3 did not identify the stator RTDs as critical items at all. Although Revision 1 of PG&E PO did require a shop test for RTD continuity, resistance (but no associated temperature), and insulation, PEM identified none of these characteristics to Carel in PO JA30241. Minco shipped the RTDs on May 4, 1990, and PEM received them on May 15, 1990. According to the PEM record of a telephone conversation of September 14, 1990, to Carel, PEM requested a COC for the RTDs. Minco issued a COC (undated) to Carel, which was then provided to PEM certifying that the RTDs met the specifications as defined by the PO (i.e., part number). PEM performed its standard receipt inspection, verifying dimensions and shop testing for insulation resistance. In addition, PEM stated that its standard practice was to test RTDs during stator winding and also during testing of the completed generator. However, PEM test records did not indicate the expected values and tolerance for the RTD resistance with regard to temperature and the temperature at which the RTD resistance was measured was not recorded. Therefore, it was difficult to determine if the measured value was within the expected range.

PEM receipt inspectors did not always have all applicable documents available. PEM receipt inspectors were supposed to verify that incoming materials met the PO specifications by checking the delivered material against a copy of the PO. In this case, the PO was changed by telex to specify a part number and the receipt inspector was not provided a copy of the change notification. Therefore, the receipt inspector was not able to verify that the correct part number was received. Checking against the PO could have led to accepting incorrect material because Minco provides two different classes of RTDs that are identical except for the body material and the PO did not specify body material.

(8) Stator Coils

Although Revision 1 of PG&E's PO inappropriately omitted the stator coils as critical items, Revision 3 did identify stator coils (Attachment F, item 15) as critical items with critical characteristics of configuration, chemical composition, and coating insulation. Nevertheless, in PO 16271 to PEM, P-EP invoked Material Specification MW-25.5 for the stator coil magnet wire. The MW-25.5 revision of May 10, 1982, "Magnet Wire - Round, Square, or Rectangular Class H (180 °C)," provided detailed specifications, including codes and standards to be met for the copper wire, enamel first insulation coating, and packaging. ANSI Standard C7.9 (for square or rectangular soft or annealed copper wire) and ASTM B-3 (for soft or annealed copper wire) were among the standards called for. In addition, MW-25.5 listed approved suppliers and the trade names of their products to meet the material specification. One approved magnet wire of the type available to PEM was listed in MW-25.5 as "Polythermaleze 2000," manufactured by Phelps Dodge.

PEM procured the stator magnet wire from its supplier, ISM, by PO EM31003. In its PO, PEM appropriately specified the material by trade name as well as by description (stator copper 0.256-inch wide x 0.102-inch thick (0.650-cm x 0.259-cm) insulated with polythermaleze 2000 enamel). The PO listed material specifications corresponding to those specified in MW-25.5 with the exception of ASTM B-3, which was not contained in any of the other specifications listed.

PEM (PO EM31003) required a test certificate for chemical composition of copper, electrical resistivity, and insulation dielectric strength and a COC attesting to conformance with the NEMA Standard Publication MW1000, "Thermal Classification and Insulation Voltage Withstand Level for the Type of Wire Specified." ISM subsequently supplied the material to PEM with a test certificate from ISM's subsupplier, SAFI-CONEL, and an ISM COC. However, PEM could produce no documentation that could connect the SAFI-CONEL test certificate to the PEM purchase order.

Although Revision 3 to PG&E's PO was issued less than 1 month before the generator was shipped, P-EP passed it on to PEM, and PEM tried to dedicate the stator coil wire in accordance with the new revision. However, PG&E inadequately listed the critical characteristics of the stator coils as configuration, chemical composition, without specifying particulars for the latter two. PEM's dedication methodology, apart from final testing, consisted of invoking P-EP's material specifications through PO requirements for its supplier, but the material and/or documentation received did not always meet these requirements.

PEM PO EM31003 to ISM required a test certificate indicating the chemical composition of the copper, electrical resistivity, and insulation dielectric strength. ISM supplied a COC attesting that the wire met the required specifications and also supplied a test certificate from SAFI-CONEL, but the test certificate addressed only the insulation dielectric strength. PEM apparently had not received any test certificates indicating the chemical composition of the copper or the insulation resistivity, and there was no documented basis for acceptance of the COC. PEM had not surveyed ISM or SAFI-CONEL and did not provide independent testing to verify the accuracy of the COC or the test report.

PEM maintained that it should not be held responsible for inadequate dedication of an item after the fact. The team determined that, although PEM accepted and used the stator coil wire without an adequate COC and test report, this did not constitute a deviation from the P-EP PO or PG&E PO because Revision 1 to PG&E PO did not specify the stator coil wire as a critical item and Revision 3 was issued well after the generator had been assembled.

However, of greater concern were the issues of controlling and surveying suppliers, identifying nonconforming material, and holding suppliers accountable for nonconformances. At the time of the inspection, PEM was not in the practice of auditing or surveying its suppliers; therefore, its basis for accepting COCs from its suppliers was inadequate. In addition, PEM accepted and used material for which the COC certified that PO requirements had been met when, in fact, the requirements had not been met. In the stator coil procurement, the material supplier certified that PO specifications were met but did not furnish test certificates as required by the PO. PEM neither held the supplier (ISM) accountable nor documented this as a supplier noncompliance for future reference.

During the team's inspection of PEM (IR 99901065/91-01), a tour of the material receiving area, review of documents, and interviews with PEM personnel generally supported PEM's claim that it inspected all incoming material for compliance with PO requirements. Nonconforming material was quarantined until the engineering staff determined disposition. If PEM's engineering staff determined the material to be unacceptable, it would be rejected (returned to the supplier) and a discrepancy report would be prepared. Discrepancy reports were to be reviewed on a routine basis to evaluate supplier performance. If, however, the material were to be evaluated by PEM's engineering staff as acceptable as is, no discrepancy report would be issued, even if the material (or the documentation) did not meet all the PO requirements. However, this practice, with regard to discrepancy reports, would not identify and track the performance of vendors who may occasionally, or even routinely, provide marginally acceptable materials or incomplete or inadequate documentation.

(9) **Bearing Bracket**

In its PO to P-EP, PG&E identified the bearing bracket (Attachment F, item 4) as a critical item and specified its critical characteristics as only configuration and material. PG&E's generator was a single bearing design. One end of the generator's rotor shaft was supported by a spherical roller bearing and bearing bracket assembly while the other end of the rotor shaft was flanged for mounting to the diesel engine.

PEM Drawing RA-14896, "Non-Drive End Roller Bearing Bracket Kit," Revision 0, dated February 16, 1990, was the design drawing for the bearing bracket assembly. The assembly consisted of a spherical roller bearing, the bearing bracket hub, the bearing seal, the bearing cover, and the insulation ring.

The bearing bracket hub (part no. 30767-0274, Drawing B-66863-1) was a welded assembly of two concentric machined rings. The ID of the inner ring of the bearing bracket hub abutted the OD of the roller bearing and held the roller bearing in place, laterally, on the rotor shaft. This ring was machined with ports to lubricate (grease) the bearing. Welded to the OD of the inner ring was a mounting ring, with a smaller L-shaped cross section attached to the inner ring by a continuous 3/8-inch (0.952-cm) fillet weld on both sides. The mounting ring was drilled to accommodate eight bolt holes, equally spaced circumferentially.

PEM procured this fabricated assembly from its supplier as a CGI. PEM Material Specification MS-70.14 specified that the material for both rings comply with BS-4360, Grade 43A. However, the supplier did not provide PEM with a COC for the material or the fabrication. Although PEM's receipt inspection appeared to consist of a visual inspection for workmanship, the results of the inspection were not documented. In addition, PEM failed to specify any NDE of the continuous fillet welds that form critical load-bearing members of the support assembly of the bearing-end of the rotor shaft.

The insulation ring (Drawing A-64934-A) provided the electrical separation between the bearing bracket assembly and the generator frame. The ID of the 0.437-inch (1.109-cm) thick (±0.010-inch/0.0254-cm) insulation ring was fitted over a portion of the L-shaped mounting ring on the bearing bracket hub. The OD of the insulation ring appeared to be larger than the OD of the mounting ring and, therefore, the insulation ring stood proud of (extended beyond) the mounting ring. This configuration required the insulation ring to abut directly to the generator frame in such a way that it appeared to constitute a load-bearing component part of the support assembly for the bearing end of the rotor shaft. PEM's Material Specification MI-5.3, specified the material for the insulation ring as C.B. Bakelite. The insulation ring also was drilled to accommodate eight bolt holes, equally spaced circumferentially, that aligned with the bolt holes in the mounting ring. The eight bolts (5/8-inch (1.587-cm) hex-head) placed through the holes in the mounting ring and the insulation ring were attached to the generator frame and formed the supporting attachments for the bearing end of the generator.

PEM procured the fabricated (ID and OD cut to size and the bolt holes drilled) insulation ring from its supplier as a CGI. However, the supplier did not provide PEM with a COC for the material or the fabrication. Although PEM's receipt inspection appeared to consist of a visual inspection for workmanship, the results of the inspection were not documented. Neither P-EP nor PEM demonstrated an engineering basis for the design of the insulation ring in combination with the mounting ring of the bearing bracket hub, which used the insulation ring as a load-bearing component part of the support assembly of the bearing end of the rotor shaft.

Therefore, PEM's inspection or verification of the commercial grade bearing bracket hub and insulation ring failed to demonstrate reasonable assurance that the parts were adequate and met expected quality and technical requirements.

Although not specifically a component part of the bearing bracket assembly, the brush-rigging was attached to the bearing bracket assembly by using a threaded stud. To form the electrical separation between the brush-rigging and the bearing bracket assembly (and, therefore, the rotor shaft), the stud was installed inside a mounting tube insulator. The material for the mounting tube insulator was specified in Drawing A-18405 as Grade X Spaudite Bakelite. PEM agreed that the tube insulator was a critical item, even though no critical characteristics were identified by either PG&E or P-EP and PEM did not perform any dedication activities to ensure that the tube insulator met expected quality and technical requirements.

The continuous fillet welds that tie the outer ring to the inner ring were not identified as a critical characteristic and were not NDE inspected. While the primary function of the bearing bracket is to provide lateral support for the roller bearing, thrust loads also may be imposed thereby subjecting the fillet welds to lateral stresses. PG&E indicated that the adequacy of these welds will be determined by visual inspection following completion of the post-modification tests.

(10) **Stud — Threaded Rod**

Eight threaded rod studs are utilized during assembly of the generator rotor to align and compress the steel stampings. The rods are 7/8 inch diameter (2.222 cm), about 3-feet long (0,912 m), and are threaded for 3 inches (7.62 cm) at each end to accommodate a nut. The rods were procured by PEM from Dunblane Light Engineering, Limited who in turn obtained them from NUMAC Precision Engineering with the material supplied by Bright Steel through Albion Steel. Both of the firms are listed in the British Registry.

The critical characteristics were identified as dimensions, material of construction, and tack welding of the nuts following assembly. During the NRC inspection at PEM, it was learned that a material substitution had been made by PEM's supplier because the specification called for ASTM A-108 while BS-970, Grade 605 M36 was actually supplied. P-EP and PEM compared the two material properties and found them acceptable. PEM accepted a COC from the supplier despite the fact that the firms were not audited and the procurement was commercial grade. The firms were, however, listed on the British Registry. The nut material, verification of the torquing pressure applied during assembly, and inspection of the adequacy of the tack welding of the nuts were critical characteristics that had not been verified for acceptability.

P-EP has indicated that the torquing pressure and adequacy of the tack welding of the nuts are not critical to reliability since, as noted above, the threaded rods are only used as an aid during the rotor assembly process. The primary means of retaining the final assembly configuration is use of the head rings and welded rivets. The threaded rods are maintained in place during the life of the generator by tack welding the nuts to preclude accidental disassembly.

PG&E determined that the threaded rods were acceptable for their intended function during assembly of the rotor stampings. In that regard, it appears that the rods may have been incorrectly identified as critical parts initially. PG&E indicated that, since the rods are retained in the final generator assembly, the post-modification tests and subsequent inspection will demonstrate the acceptability of the installation.

(11) **Spider End Rings**

In its PO to P-EP, PG&E identified the spider end rings (Attachment F, item 7) as critical items and specified their critical characteristic as configuration. The generator's spider end rings (one on each end of the rotor spider assembly) consisted of a head ring with eight mounting-lug ribs welded in an equally spaced configuration that extended radially from the axis of the head ring.

PEM Drawing B-66865, "#408 Pole Rotor Spider Head," Revision 4, dated February 6, 1970, prescribed the assembly of the head ring and the eight mounting-lug ribs. The ID of the head ring was concentrically fitted over the rotor shaft and abutted the spider stamping assembly. The OD of the head ring was smaller than the circumference formed by the eight threaded studs that held the spider stampings in a compressed assembly. Each head ring was produced with eight penetrations, equally spaced circumferentially to accommodate the eight rivets that extended through the spider stamping assembly and were welded to the head rings on each end. Eight mounting-lug ribs were attached to each head ring (1/4-inch (0.635-cm) fillet welds on each side of the mounting-lug ribs) in an equally spaced arrangement so that the ribs extended radially from the rotor's axis. The mounting-lug ribs were drilled and tapped to accommodate the bolted attachments of the rotor end ring and the generator's fan assembly.

PEM procured the spider end rings from its supplier as commercial grade fabricated assemblies. Although PEM's supplier provided a COC for the spider end rings, the COC failed to address NDE or visual inspection of the mounting-lug attachment welds, which form the critical load-bearing members of the support assembly for the generator's fan assembly. PEM's receiving inspection appeared to consist of a visual inspection for workmanship; however, the results of the inspection were not documented.

PG&E claims that the functional testing of the generator by PEM and subsequent testing at GEC Alsthom in which overspeed testing was performed, subjected these welds to greater stresses than they will experience during normal operation and that visual inspection following the post-modification tests will provide final evidence of acceptability.

When the team questioned why two generator fans (one at each end of the rotor) were not considered critical items, PG&E responded that the fans are not critical to generator operation because a fan failure would result in a slightly higher operating temperature, which is acceptable for a reasonable period of time. No documented analysis of this response was made available.

(12) Short Circuit Bars

In its PO to PEM, P-EP specified that damper bars (short circuit bars or rotor bars) of hard-drawn oxygen-free copper be provided in accordance with P-EP Material Specification MC-80.6, "Copper - Hard Drawn Oxygen Free or Deoxidized - Bar Rods and Shapes." However, the MC-80.6 revision of February 14, 1991, allows damper bars to meet BS-1433, Grade 103C.

Therefore, PEM issued PO JA30274 to Thomas Bolton & Johnson Ltd. for, "copper rods 1/2-inch (1.27-cm) diameter x 34 inches (86.36 cm) long to conform to ASTM B-187 high conductivity round bar to BS-1433, 1970, hard drawn, designation C103." The PO required test certificates for chemical composition, tensile strength, percent elongation, and conductivity, hardness, and embrittlement tests.

Revision 3 of PG&E's PO identified the short circuit bars (damper bars) as critical items with critical characteristics of configuration and material. Bolton provided the material to PEM with a test certificate specifying all applicable requirements. Once again, PEM accepted the COC from Bolton without an adequate basis.

PG&E has indicated that final acceptance of the adequacy of manufacture and installation of the short circuit bars will be verified during the inspections following the completion of the post-modification tests.

(13) Rivets

In its PO to P-EP, PG&E identified the rivets (Attachment F, item 13) as critical items and specified their critical characteristic as configuration. The eight rivets were placed through the rotor spider assembly and extended its entire axial length. The ends of the rivets penetrated the head ring of the spider end ring assembly and were chamfered to facilitate performing a groove weld that joined the rivet to the head ring of the spider end ring assembly.

PEM Drawing RE-1734, dated November 15, 1990, prescribed the details for the 7/8-inch (2.222-cm) diameter x 35-5/8-inch (90.4875-cm) long rivets made from material complying with BS-970, PT1 (1983), Grade 605 M36, Condition T. PEM, in conjunction with P-EP, performed an equivalency evaluation of the material specified, compared the material actually used, and determined that the material used was acceptable, even though the technical basis to support that determination was not adequately documented. PEM's receiving inspection appeared to consist of a visual inspection for workmanship; however, the results of the inspection were not documented. PEM failed to specify any NDE examination of the groove welds that attach the rivets to the head ring of the spider end ring assemblies, which form load-bearing members of the support assembly for the generator's fan assembly.

(14) Stator Frame

In its PO to P-EP, PG&E identified the stator frame (Attachment F, item 18) as a critical item and specified the critical characteristic as configuration. The stator frame formed the structural support for the stator and the completed generator assembly.

P-EP Drawing D-66825-1, Revision 3, dated November 17, 1970, described the construction details of the stator frame. Although P-EP's stator frame drawing was furnished to PEM, PEM's engineering staff found that portions of the stator frame drawing were too difficult to read and properly interpret and noted that the drawing did not specify certain critical fabrication details, such as the length and pitch of the increments of intermittent fillet welds that join structural members.

P-EP's drawing, which was originally prepared by the Electric Products Division of Portec, Inc., specified the structural details of the stator frames in PG&E's five existing 1969 generators, which were qualified with respect to DCNPP's seismic requirements. PG&E required the new 2-3 generator to be identical to PG&E's 1986 spare generator and DCNPP's five 1969 generators in an apparent attempt to demonstrate compliance with the requirements for safety-related equipment suitability, including seismic and any environmental qualification requirements. However, PEM's new drawing consisted of some design changes from the original drawing in areas where the original was not clear or the details were not specified and, therefore, constituted changes to the original design.

PEM's new drawing for the frame was not reviewed and approved by P-EP and no evaluation was performed or documented to establish that the new drawing of the frame design was identical to the frame design of the previous frames supplied to PG&E. Fabrication of the stator frame to PEM's new drawing did not ensure that the stator frame was identical to the original seismically qualified 1969 stator frames. Of particular concern is the acceptability of the length and pitch of the intermittent fillet welds that join the structural members of the frame. At the time of this inspection, these review activities by P-EP had not been completed.

3.3 Static Exciter-Voltage Regulator

The SE-VR provides and controls the current to the field winding of the generator as necessary to maintain the generator voltage to within 1/2 percent from no-load to full-load steady-state conditions. The SE-VR is designed to operate in one of two modes: in the isochronous mode as an independent source (its primary DBE mode), or in the droop mode when in parallel with the 4160 Vac system.

PG&E purchased two SE-VR cabinets from Basler Electric. The cabinets included the actual metal cabinets as well as various components and subassemblies that Basler mounted in them. PG&E assumed responsibility for wiring the various subassemblies to each other and to DCNPP2's Class 1E electrical system under its QA program. PG&E-approved drawings had been completed for this purpose.

In order to dedicate the commercial grade Basler panels and equipment for safety-related Class 1E application, PG&E wrote several RPEs for various components and subassemblies within the panels. Individual RPEs were written for the contactors (RPE E-6789), rectifier diodes (RPE E-6790), current boast transformers (RPE E-6795), voltage regulator assemblies (RPE E-6802), high-voltage chassis (RPE E-6806), and the actual cabinet (RPE M-7027). No generic RPE was written to cover the system oriented performance of this equipment. The team identified the following concerns:

- RPE E-6795 for the current boast transformers did not list as a critical characteristic the linearity or turns ratio of the transformers, nor did it provide for their verification.

- The individual RPEs did not contain provisions for evaluating drift of potentially critical system or individual component parameters such as the automatic voltage setting used to establish a reference voltage for the voltage regulator during generator isochronous operation or the control/alarm functions supplied by the digital tachometer under RPE E-6652.

- The individual RPEs did not address system or component performance under all required ambient temperature conditions. The diesel generator room design temperature is 120 °F (48.9 °C) (with temperatures up to 128 °F (53.3 °C) possible during worst case extreme conditions); whereas the Basler SE-VR instruction manual lists the operating temperature for this equipment as 104 °F maximum (40 °C); yet there was no documented evaluation of the operation of this equipment outside of its stated design operating temperature.

In its letter (DCL-92-218) to the NRC, PG&E submitted several requested documents, including Field Change Notice FC-M-16128 to Design Change Package DCP-M-44405, dated June 10, 1992. The section titled "Correlation of Site Pre-operational Testing to Sixth Diesel Dedication Activities," listed the generic (system) critical characteristics for the sixth diesel assembly and several individual components by RPE with the specific portions of the PMT program being relied upon to verify them. The system critical characteristics are discussed briefly in Section 3.1.4.4(2) of this report. Many of the verification tests will be repeated as part of the post-modification tests. The field change notice also states that testing in accordance with IEEE Standard 387 and NRC RG 1.9 testing, and 23 more fast starts will be performed as part of the verification of these system critical characteristics.

Subsequent to the this inspection, PG&E submitted the following detailed procedure for the post-modification tests: PMT 21.12, "Diesel Generator 2-3 Site Acceptance Tests," Revision 0, dated December 1, 1992; PMT 21.13, "24 Hour Load Test of Diesel Generator 2-3 and Support Systems," Revision 0, dated November 23, 1992; and PMT 21.16, "Diesel Generator 2-3 Preoperational Endurance Test," Revision 0, dated October 5, 1992. Satisfactory results of these tests, including post-modification test inspections should provide reasonable assurance that the SE—VR and associated equipment will reliably perform its intended safety functions.

Quality Evaluation (QE) Q0009781, Enclosure 2 to DCL 92-218, addressed the concerns stated above regarding (1) specification and verification of current booster transformer turns ratio and linearity, (2) set point drift, and (3) high ambient temperature effects. In the QE, PG&E stated that Revision 1 to RPE E-6795 would be issued to require verification of proper turns ratio and linearity of the current booster transformers. With regard to set point drift, PG&E contended that set point drift is a relatively long-term phenomenon and explained that, in accordance with NRC GL 82-09 concerning qualification equipment in a mild environment, PG&E's established surveillance, maintenance, and set point programs, supported by the performance history of similar equipment for the other five EDGs on site, were intended to cover set point drift; therefore, it was not considered as a failure or degradation mode that needed to be addressed by dedication.

With regard to high ambient temperature effects on the operation of the SE—VR and associated equipment, the QE included detailed calculations of the increase in electrical resistance that would be caused by the design ambient temperature of 120 °F (48.9 °C) and its effect on various items of electro-mechanical components, particularly the numerous relays potentially affected. PG&E concluded in each case that the temperature would not unacceptably affect component operation. This approach is acceptable with the following two exceptions: (1) decreases in insulation resistance were not considered and (2) the effect on the time-current characteristic curve of the thermal overload trip function of the Westinghouse-type FHB36100A molded-case circuit breaker was not considered. PG&E is tracking closure of these concerns through Action Requests (ARs) A0268259-AE-15 and A0268259-AE-16.

3.4 PG&E Supplied Items

The team also performed a review for PG&E's dedication activities associated with the procurement of I&C components used for EDG operation and control. These items were typically procured as CGIs from various suppliers that PG&E had not audited or placed on its approved suppliers list.

The comments below represent a summary of the results of the team's evaluation of PG&E's dedication of certain PG&E supplied I&C components and valves. Closure of the issues is pending PG&E's successful completion of its post-modification tests, described in Section 3.1.4.4(3) of this report, that are intended to demonstrate the capability of the 2-3 EDG to perform a 200-hour endurance test and demonstrate reasonable assurance that the parts will perform their safety-related function.

3.4.1 RPE E-6652 — Digital Process Tachometer

PG&E procured the Airpax digital process tachometer from MANCO as a CGI. This tachometer is used to measure the diesel engine speed and control various diesel functions and interlocks. The tachometer contains internal circuits that are used to energize control relays JWPR and SPR and timer FST. The circuits control the turbo-boost valves, the field shutdown timer, and the air start motor circuitry.

The RPE listed as critical characteristics part number and homogeneity, dimensions, set points on relay outputs, set points on analog outputs, and hysteresis settings. Validation of these critical characteristics included visual examination, insulation resistance testing, and functional testing with a frequency generator. No specific evaluation was performed for the potential error introduced regarding differences in set point drift between assumed values and actual equipment specifications. PG&E stated that the required accuracy of these circuits was not high as they are used to verify general functions such as "engine running." Based on the limited accuracy requirements for these circuits and the inherent accuracy of digital type solid state equipment, the team agreed that for this instrument a specific evaluation of drift would not be required as part of the dedication process. However, PG&E should evaluate drift, where critical, as part of the dedication process.

3.4.2 RPE E-6796 — Power Relays

PG&E procured the Potter and Brumfield PRD and PM series power relays from Basler Electric and Potter and Brumfield as CGIs. The relays control the generator field flashing and the generator field starting and voltage shutdown. The RPE listed as critical characteristics dimensions, batch homogeneity, coil pickup and dropout voltages, contact voltage drop, insulation resistance, and functional operation of the relay contacts. Validation of these critical characteristics was to be accomplished by visual inspection and bench testing. Seismic qualification was by similarity to similar relays tested in an identically fabricated panel and tested by Wyle Labs. The team was concerned that the test procedure for verifying adequate pickup voltage allowed the shop test to be performed at any temperature from -40 °F to 150 °F (-4.44 °C to 65.55 °C). The maximum specified pickup voltage was listed as 102 Vac for the PRD series relays and 94 Vdc for the PM series relays. No reference was made in the RPE as to the calculated minimum voltage expected during worst-case system conditions and under what temperature conditions this voltage could occur. As a result, the testing performed according to the RPE did not adequately verify the critical functions of the relays. Consequently, PG&E provided the actual test data for the relays, which showed that adequate margin existed between the actual relays performance and the test procedure acceptance criteria. However, the control of the test conditions (temperature) by the shop test procedure was inadequate.

3.4.3 RPE J-7370 — Solenoid Valves

PG&E procured the ASCO turbo-boost air assist solenoid valves from Leighton Stone Corporation as a CGI. These solenoid valves open to allow air flow to the turbocharger on an engine start signal. The ASCO valves are similar but not identical to the ASCO valves used with the other five diesel generators. The new valves have a maximum rating of 250 psi versus 300 psi for the valves currently installed on the other diesel engines. No statement of the system-specific requirements was contained in the RPE. The RPE listed critical characteristics as part number, coil continuity, valve body material, leakage, and operability. Verification was by continuity test, pressure leak test, operability bench test, and a material verification by QCP 10.7. The team noted that PG&E had implemented various system design changes as a result of using the 250 psi (1723.5 kPa) versus the 300 psi (2068.2 kPa) rated valves.

3.4.4 RPE V-6651 — Isolating Transformer

PG&E procured the instruments to isolate the transformer from SCI-CALTROL as CGIs. The isolating transformer provides isolation of the remote tachometers from Class 1E circuitry. No deficiencies were identified with this RPE.

4 SEISMIC QUALIFICATION REVIEW

The seismic qualification of the 2-3 EDG was performed by establishing its similarity with the existing five EDGs at DCNPP and by using the qualification data obtained earlier to qualify the 2-3 EDG. However, in areas where the 2-3 EDG differed substantially from the other diesels or where similarity could not be established, PG&E performed additional tests and/or calculations to demonstrate compliance with acceptance criteria. In its review of the seismic qualification of the 2-3 EDG, the team focused on PG&E's bases and approach to establish the similarity of the 2-3 EDG with the five existing EDGs at DCNPP. In addition, the team reviewed in detail the tests and calculations performed specifically for the 2-3 EDG's seismic qualification. These included tests and calculations relative to skid-mounted auxiliary components, floor-mounted mechanical components, electrical components and cabinets, panel-mounted I&C equipment, electrical and electro-mechanical components. As a result of the review, the team identified a number of concerns and requested additional information. These concerns, which are discussed below, have since been resolved.

The mathematical model for the five existing EDGs at DCNPP consists of four parts: the skid frame, generator, engine, and radiator. The mathematical models of these different components are sufficiently detailed to determine the critical high-stress locations of the components. Thus, for example, the skid frame model considers the stiffness of the ribs in the I-beam of the frame, as well as anchor bolts and seismic stays; the generator model allows for the determination of the relative motion between the rotor and stator. In the engine model, the various subcomponents (e.g., the turbocharger, governor, and air intake silencer) are modeled as lumped masses at appropriate locations. Certain subcomponents, though not explicitly modeled, are included in the mathematical model. Appropriate nodes in the model represent items such as lube oil pumps, coolers, strainers, filters and heaters. The fuel oil day tank, air start system and its subcomponents, radiator system and subassemblies are similarly represented. To account for the key differences between the existing five EDGs and the 2-3 EDG, PG&E revised the input data for the mathematical model; the model itself was not changed. The team reviewed the revised input and found it to be appropriate and consistent with the design drawings of the 2-3 EDG.

The response accelerations were approximately the same for the engine and the generator. However, the acceleration levels for the radiator were significantly different, and PG&E performed a structural evaluation of the radiator to reconcile the differences. PG&E also, performed response spectra analysis to obtain global forces, acceleration, and moments. The results of the analysis verified the structural integrity of the engine, radiator, and skid anchorage. PG&E performed a time history analysis to obtain amplified response spectra at various locations on the engine where devices such as valves, switches, and gauges are mounted. PG&E used an envelope of the amplified response spectra during shake-table tests for the seismic qualification of the valves, switches, and other devices. The control and excitation cabinets are floor mounted in the turbine building while the contactor cabinets are wall mounted. Therefore, PG&E used appropriate horizontal and vertical required response spectra in the shake-table tests of these cabinets.

A summary of critical stresses for the main components of the 2-3 EDG is provided in Table 7. Except for skid anchor bolts, certain engine bracket welds, and supports for the radiator, substantial margins of safety exist to accommodate a safe shutdown earthquake (SSE) at other critical locations on the engine and generator. The stress evaluation of the anchor bolts of the skid beam indicate that all stresses are well within the allowable values for the ASME SA-193, Grade B7 material of the anchor bolts.

The highest interaction ratio of 0.08, based on a conservative linear estimation, occurs on an engine bracket. The shear forces applied to the engine during a seismic DBE are resisted by the bracket. The critical section is located at the bracket chock weld near the free end (Sheet 153 of Calculation SQE-24.1). The team reviewed the calculations and found them acceptable. The structural evaluation of the supports for the new radiator assembly indicates that the margin of safety is 1.86. The staff reviewed the stress analysis including the finite element model of this component and found it acceptable. The new radiator has three cores, as opposed to two cores in the existing radiators of the five EDGs at DCNPP. There are four brackets located on the sides of the radiator that are attached to vertical tube supports. These tube supports are welded to the skid at one end and connected to the ceiling of the radiator housing at the other end. PG&E used its structural analysis program (SAP 90) in the evaluation of the support system. The analytical model simulated the tube and shell members in sufficient detail to accurately predict the response of the assembly to various loading combinations. The results of the analysis indicate that the maximum stresses occur in the vertical tube supports and are within the code allowables.

A number of the 2-3 EDG skid-mounted ancillary components were determined to have acceleration responses similar to those of the five existing EDGs. The team reviewed the stress summaries of the following components, which are based on the calculations performed for the five existing EDGs, and found them acceptable.

lube oil cooler
gear box mounting
lube oil strainer
jacket water expansion tank
turbocharger
lube oil heater
diesel fuel oil day tank

PG&E obtained a number of items, such as pressure control valves and switches, as CGIs. In order to allow these items to be used in a seismic Class 1 application, PG&E contracted with Wyle Laboratories to have the required testing performed (documented in Report 54275, dated April 1991). In these tests, which involved five operating basis earthquakes (OBEs), two SSEs and fragility tests, the test response spectra enveloped the required response spectra over all frequencies. The team audited the seismic evaluation of the following valves and switches and found the test results satisfactory.

pressure control valve (Model E-55-15328)
pressure switch (UEC Model JG-156-9536)
pressure control valve (Fisher Model 67SS-3)

The team also reviewed the following relevant DCNs and FCNs to assess the potential impact of these modifications on the seismic qualification of the affected components.

- DC2-EM-44047, Revision 1, for the installation of clean-out ports on the fuel oil day tanks
- DC1-SJ-45026, Revision 0, for the replacement of existing dial-readout float-style indicators with a standpipe-type level indicator
- DC2-SM-44096, Revision 0, for the addition of new sample valves
- DC1-EP-43722, Revision 0, for the modification of a pipe support to reduce the vibration of the starting-air tubing
- FC-C-15878, Revision 0 and 1, for the modification of the main lead terminal box to allow for top enter of the cables into the box, and to relocate an existing switch box
- FC-M-16112, Revision 0, for the replacement of existing anchor bolts (located at the base of the fuel oil priming pump) and mounting bolts made of ASTM A-307, Grade B with ASMT A-307, Grade A material
- FC-E-16099, Revision 0, for the replacement of vendor-supplied lead termination box with a larger box

The concerns raised by the staff relative to the Crosby relief valve testing discussed in Wyle Reports 54275 and 54275-1, were resolved by PG&E's response to the team's request for additional information. The team was concerned about the relief valves lifting (travel of the valve disk from its closed position allowing a pressure discharge) at the maximum system pressure of 250 psi (1723.5 kPa). The relief valve lifting experience at 250 psi (1723.5 kPa) was valve popping, which did not indicate a potential for the loss of large volumes of air from the air receivers. No valve popping was observed at pressures below 200 psi (1378.8 kPa). The capacity of the air receivers, when pressurized to 200 psi (1378.8 kPa), is considered to be sufficient to ensure several starts of the EDG. Therefore, the team considered the test results acceptable.

Another team concern was the chatter observed during testing the fuel oil transfer switches. Fuel oil transfer switch chatter could result in cycling of the fuel oil transfer pump during a seismic event if the spurious signals resulting from chatter erroneously started or stopped the pump. However, the effect on the availability of fuel to the EDG would be minimal during the short duration of a seismic event. Therefore, on this basis, the team considered these test results acceptable.

5 EXIT MEETING

On May 1, 1992, the NRC inspection team conducted an interim-exit meeting with members of PG&E's management and staff and reported its progress in evaluating PG&E's dedication and compensatory actions taken for the 2-3 EDG. On June 5, 1992, the team conducted its closing-exit meeting for this inspection with members of PG&E's management and staff. Persons attending the interim- and closing-exit meetings are listed in Appendix A. Throughout the inspection, the team met with PG&E's management and staff to discuss the team's concerns. During the closing-exit meeting, the team summarized the scope of the inspection and its concerns.

During its closing-exit meeting, the team identified certain concerns that required additional information and evaluation by PG&E. The team also noted that PG&E's procedures specifying the requirements of the post-modification test and inspections were not complete. At the exit meeting, PG&E's management stated that it would provide any additional clarification or information that would facilitate the team's final evaluation of PG&E's dedication and compensatory actions. Therefore, the team agreed to evaluate related PG&E documents submitted after the closing-exit meeting.

6 SUMMARY

For the final documentation necessary to resolve the remaining open items identified in this report, PG&E is completing its evaluations and documenting the results in the appropriate RPEs. PG&E listed certain limitations for its RPEs for the diesel engine (M-6602) and the power generator (E-7505) that, when completed and incorporated into the respective RPE, conclude the dedication process. The open items (limitations) associated with PG&E's final documentation for the RPEs are identified below, including any additional specific issues identified by the team.

(1) Diesel Engine

The following documentation will be incorporated in RPE M-6602, Revision 2, via Minor Change 1:

- Final documentation of PG&E's comparison of the renewal parts lists for the lube oil low level switch, special fuel oil crossover fitting, radiator fan drive system, and the mechanical stop for the fuel rack.
- Final documented closure of all GE-L corrective action reports for GEC Alsthom, including review of auxiliary system drawings. Closure of this issue is tracked by ARs A0220633-AE-6 and A0239775.
- Final inspection report transmitting the completed Inspection Plan DC-271.
- Completed QC Surveillance Plan 6602-2
- Completion of the post-modification tests by DCNPP2. Closure of this commitment is tracked by AR A0234893-AE-2.
- GE-L's engineering evaluation for the AMOT temperature control valve, governor, fuel oil nipple, final liner plating, connecting rod (Revision 1), and camshaft (Revision 1).
- For the Woodward EG-B13C mechanical governor (RPE M-7514), described in Section 3.1.5.2(9) of this report, PG&E committed to search the GIDEP failure history data base for references to Woodward and incorporate the results into RPE M-6602. For the electric control portions of the governor system, the remaining concerns will be resolved by PG&E's satisfactory completion of the post-modification tests.

(2) Power Generator

The following documentation will be incorporated in RPE E-7505, Revision 1, via Minor Change 1:

- Completion of design change review between the original five 1969 generators and the 1984 generator, tracked by AR A0201157, including verification of design changes for the stator frame to ensure that the stator frame was identical to the original seismically qualified 1969 stator frames.

- Reverification of equivalency documentation for the 2-3 generator by P-EP, including verification of equivalency issues associated with the rotor shaft, magnet wire, lead wire, and roller bearing.

- Completion of special testing by PEM of the lightly varnished rotor pole magnet wire used in the generator assembly (described in Section 3.2.2.3(3) of this report). For the rotor pole magnet wire special testing, closure is pending PG&E's successful completion of the post-modification tests and no detection of delamination of the winding layers during inspections.

- Completion of the post-modification tests by DCNPP2. Closure of this commitment is tracked by AR A0234893-AE-2.

(3) Static Exciter-Voltage Regulator

With regard to high ambient temperature effects on the operation of the SE—VR and associated equipment, PG&E's evaluation will include (a) decreases in insulation resistance that were not previously considered and (b) the effect on the time-current characteristic curve of the thermal overload trip function of the Westinghouse-type FHB36100A molded-case circuit breaker that was not previously considered. Closure of these issues is tracked by ARs A0268259-AE-15 and A0268259-AE-16.

When these open items associated with final documentation for the RPEs are completed and incorporated into the RPEs and the ARs are completed, PG&E will have successfully concluded the dedication process. PG&E is not requested to submit these completed documents to the NRC staff. However, these documents are subject to verification during future NRC inspections.

Although this IR documents several concerns identified during the inspections of PG&E, P-EP, and PEM, the team believes that PG&E may resolve the specific technical issues identified during these inspections by successful completion of its compensatory actions taken as a result of the inspection findings and the post-modification tests, described in Section 3.1.4.4(3) of this report. The post-modification tests will determine the adequacy of 2-3 EDG's design, materials, and manufacturing processes by subjecting certain components of the EDG to operating cycles in excess of the number of cycles where cyclic fatigue is expected and to operating and transient conditions that will resolve the team's concerns that remain open.

Table 1

PG&E's Selected Critical Characteristics
for the Power Generator's Critical Items

Critical Items	PG&E's PO Revision	Attachment F Item No.	Critical Characteristics
ITEMS PROCURED BY PEM:			
Lead wire	1	1	Dielectric strength Number of strands Marking on cable
	3	16	Configuration
Magnet wire	1	4	Size and shape Resistance Insulation Dielectric strength
	3	3	Material Insulation Dielectric strength
Copper bus (in terminal box)	1	10	Size Resistance Silver plating
Lead to coil terminations	1	11	Brazing Weld materials
Roller bearing	1	12	Size/type Visual inspection Catalog number Tolerances
	3	6	Part number Configuration
Shaft casting	1	13	PEM test
	3	1	Material Configuration Integrity
Stator and Rotor core	1	14	PEM test (losses)
Stampings	3	2	Configuration Material

Table 1 Continued

Critical Items	PG&E's PO Revision	Attachment F Item No.	Critical Characteristics
Stator coils	3	15	Configuration Chemical composition Coating insulation
Bearing bracket	3	4	Configuration Material
Stud-threaded rod	3	5	Dimensions Material Welding
Spider end rings	3	7	Configuration
Pole end rings	3	8	Configuration Material
Short circuit bars (damper bars)	3	9	Configuration Material
Pole head	3	10	Configuration
Tapered keys	3	11	Configuration Materials Hardness
Rotor wedge	3	12	Material
Rivets	3	13	Configuration
Insulating washers	3	14	Configuration Material Dielectric strength
Stator frame	3	18	Configuration
ITEMS PROCURED BY P-EP:			
Insulators (5 kV in terminal box)	1 3	1 22	Dielectric strength Size and weight Dielectric strength Configuration
Insulating bushings (lead wires through motor case)	1 3	3 24	Size and shape Configuration

Table 1 Continued

Critical Items	PG&E's PO Revision	Attach-ment F Item No.	Critical Characteristics
Insulating material (sheets, tape, & rings)	1 3	5 26	Thickness Thickness
Bearing seals (felt)	1 3	6 23	Thickness and shape Texture Configuration Texture
Brushes and brush holders	1	7	Size and shape Final generator test: resistance, material, and contact pressure
• Brushes	3	20	Configuration
• Brush holder	3	19	Configuration
Stator resistance temperature detectors (RTDs)	1	8	Shape and size Shop test: continuity, resistance, and insulation
Current transformer and test switch	1	9	Size and weight Dielectric strength Continuity
• Current transformer	3	21	Configuration Mounting Insulation Resistance Continuity
• Current transformer test switch	3	25	Configuration Dielectric strength Continuity
Slip-rings	3	17	Configuration Material
Adhesives	3	27	Material

Table 2

Diesel Engine Power Train Parts
Supplied by Auburn Technologies Incorporated

Power Train Parts	Auburn Technologies Inc.'s Subsupplier
Cylinder liners	Lynchburg Foundry—liners Chromium Corporation—chrome plating and acid etch
Camshaft assemblies (right and left side)	Copperweld
Piston bodies	Alcoa—aluminum body
Piston caps	Ladish—steel caps
Connecting rods	Voest-Alpine
Connecting rod bolts	
Connecting rod nuts	

Table 3

PG&E's Selected Critical Characteristics for the Representative Parts From the Diesel Engine's Mechanical Components; Verified as Method 2 Compensatory Actions

Product Types	Representative Parts and Subsuppliers	Critical Characteristics
Engine-mounted rotating equipment	Turbocharger—ATI	Part No. Configuration Dimensions Workmanship Functional testing and operability
Skid-mounted rotating component	Air start motor—Ingersoll Rand	Part No. Configuration Dimensions Workmanship Functional testing and operability
Special fastener	Cylinder head stud—GE-L manufactured from commodity purchased bar stock	Part No. Configuration Dimensions Workmanship Material Mechanical properties
Casting	Piston rings—Kaydon Ring & Seal	Part No. Configuration Dimensions Workmanship Material Mechanical properties
Components from special manufacturing process	Radiator—Young Radiator	Part No. Configuration Dimensions Workmanship Functional testing and operability Special manufacturing

Table 3 Continued

Product Types	Representative Parts and Subsuppliers	Critical Characteristics
Engine-driven or skid-mounted pump	Fuel injection pump—Lucas Bryce	Part No. Configuration Dimensions Workmanship Functional testing and operability
Precision machined part	Fuel injector—Lucas Bryce	Part No. Configuration Dimensions Workmanship Functional testing and operability Material
Spring	Valve spring—Associated Spring	Part No. Configuration Dimensions Workmanship Material Mechanical properties
Mechanical controlling device	Governor—Woodward Governor	Part No. Configuration Dimensions Workmanship Functional testing and operability
Heat exchanger (this product type contains only one part)	Lube oil cooler—McRae Engineering	Part No. Configuration Dimensions Workmanship Material Special manufacturing
Commodity—metallic	Exhaust manifold stud—Erie Bolt	Part No. Configuration Dimensions Workmanship Material Mechanical properties

Table 3 Continued

Product Types	Representative Parts and Subsuppliers	Critical Characteristics
Commodity—nonmetallic	Flex hose—Aeroquip	Part No. Configuration Dimensions Workmanship Functional testing and operability Material
Gasket	Valve cover gasket—Joints-Etanches .Supply	Part No. Configuration Dimensions Workmanship Material
Valve	Fuel oil pressure control valve—Fulflo	Part No. Configuration Dimensions Workmanship Functional testing and operability

Table 4

PG&E's Selected Critical Characteristics
From the Diesel Engine's Power Train Parts;
Verified as Method 2 Compensatory Actions

Power Train Parts (14)	Critical Characteristics	
	Source Verification	Special Test and Inspections
Engine block	Fabrication welding: • weld fusion • weld continuity	Material/material strength: • top deck plate • saddle • foundation plate • main bearing cap
Crankshaft	Dimensions: • diameter at bearing and crankpin journals • length at thrust bearing face • length at center of crankpin	Material/material strength
Cylinder liners	Dimensions: • inside diameter after plating • outside diameter at top land • thickness of liner flange	Material/material strength Chrome plating internal surfaces
Cylinder heads	Dimensions: • overall length • overall height • location of four valve guide bores • location of seven bolt holes • bolt hole size	Material/material strength
Valves–air and exhaust	Dimensions: • overall length • diameter at stem • diameter at seat Fusion of stem to seat Surface continuity for stem and seat	Material

Table 4 Continued

Power Train Parts (14)	Critical Characteristics	
	Source Verification	Special Test and Inspections
Valve inserts	Dimensions: • outside diameter • thickness	Material
Piston bodies	Dimensions: • overall length • diameter • bottom oil ring location • top compression ring location	Material/material strength
Piston caps	Dimensions: • diameter at the top • top compression ring location	Material/material strength
Connecting rods	Dimensions: • center piston pin bore to center crankpin bore • diameter of piston end with bushing • diameter at crankshaft end without bearing • location of bolt hole centerline	Material/material strength
Connecting rod nuts	Dimensions: • diameter • thread pitch • threads per inch	Material/material strength
Connecting rod bolts	Dimensions: • overall length • diameter at shank • pitch diameter at each end • major diameter at big end • threads per inch • thread taper	Material/material strength

Table 4 Continued

Power Train Parts (14)	Critical Characteristics	
	Source Verification	Special Test and Inspections
Main bearings — shell	Dimensions: • thickness at center • two thickness 5/8-inches from the parting line • free spread diameter • surface finish • blow-hole limitation	Material
Main bearings — thrust	Dimensions: • thickness at center • two thickness 5/8-inches from the parting line • free spread diameter • overall width • inside width • surface finish • blow-hole limitation	Material
Camshafts	Dimensions: • longest length with a tolerance dimension • diameter at bearing location	Material/material strength

Table 5

Critical Characteristics of the 2-3 EDG Assembly

Critical Characteristics	Verified By	Acceptance Criteria
Available within a time consistent with the requirements of engineered safety feature (ESF) or shutdown system loads under normal and accident conditions.	IEEE-387 tests Acceleration test Dead load pickup test Starting capacity test	Starts and accelerates to rated speed and voltage in less than 10 seconds.
Capable of supporting rated load required to provide power to operate the required ESF systems to mitigate a design-basis accident.	IEEE-387 tests Rated load test Dead load pickup test	Stable operation at rated load of 2600 kW.
Speed is maintained during recovery from transients caused by disconnection of the largest single load.	IEEE-387 tests Rated load test Load rejection test Dead load pickup test RG 1.9 test and 23 starts	Speed does not exceed 75-percent of the difference between nominal speed and the overspeed trip set point of 115 percent of nominal speed, whichever is lower.
Nominal voltage is restored during load sequencing.	IEEE-387 tests Rated load test Load rejection test Dead load pickup test RG 1.9 test and 23 starts	Voltage is within 10 percent of nominal in less than 40 percent of each load sequence time interval; no less than 75 percent of nominal voltage during loading.

Table 5 Continued

Critical Characteristics	Verified By	Acceptance Criteria
Nominal frequency is restored during load sequencing.	IEEE-387 tests Rated load test Load rejection test Dead load pickup test RG 1.9 test and 23 starts	Frequency within 2 percent of nominal in less than 40 percent of each load sequence time interval; no less than 95 percent of nominal frequency during loading.

Table 6

Inspections and Tests of the Power Generator Following the Post-Modification Tests

Critical Items	Inspection and Tests Attributes
Lead wire	Visual inspection for surface damage
Lead-to-coil terminations	Visual inspection of lugs, crimps, splices and brazing for signs of overheating
Stator coils	Visual inspection for cracks and discoloration
Bearing bracket	Visual inspection for fretting Electrical inspection: megger bearing support to end-bell (500 V)
Stud-threaded rod	Visual inspection of weld for cracks
Spider end rings and pole end rings	Visual inspection of welds for cracks
Short circuit bars (damper bars)	Visual inspection for cracks and discoloration
Rotor wedges	Visual inspection for tightness-looseness
Rivets	Visual inspection of weld for cracks
Stator frame	Visual inspection for surface damage and broken welds
Insulators (5 kV in terminal box)	Electrical inspection: megger (2500 V)
Insulating bushings (lead wires through motor case)	Visual inspection for damage
Bearing seals (felt)	Visual inspection for extrusion of grease
Brushes and brush holders	Visual inspection for damage
Current transformers and current transformer test switch	Electrical inspections: megger transformer primary (2500 V); megger transformer secondary (500 V); megger test switch adjacent contacts (500 V)
Slip-rings	Visual inspection for deformity
Pole windings	Electrical inspection: voltage drop across the rotor poles (120 V, 60-Hz ac)

Table 6 Continued

Critical Items	Inspection and Tests Attributes
ISSUES RAISED DURING INSPECTIONS OF P-EP AND PEM:	
Insulation ring (electrical separation between the bearing bracket assembly and generator frame)	Visual inspection of weld for cracks
Slip-ring mounting sleeve insulator	Electrical inspection: megger slip ring to ground (500 V)
Insulation cylinder (electrical separation between the brush holder and generator frame)	Electrical inspection: megger brush to ground (500 V)

Table 7

Summary of Critical Stresses for the Main Components of the 2-3 EDG Set

Location	Load Case	Stress/ Interaction Ratio (IR)	Margin of Safety*	Allowable
Skid beam (W24x94)	SSE	IR=0.11	9.0	1.0
Skid anchor bolts	SSE	IR=0.80	1.25	1.0
Cross beam (W14X53)	SSE	IR=0.27	3.7	1.0
Engine bracket	SSE	IR=0.12	8.3	1.0
Engine hold down bolts (engine tensile force)	OBE	8.3 ksi (f_t)	6.0	50.0 ksi
	SSE	24.4 ksi (f_t)	2.8	70.0 ksi
Engine bracket chock weld (engine shear force)	OBE	5.8 ksi (f_s)	3.1	18.0 ksi
	SSE	15.0 ksi (f_s)	2.2	33.84 ksi
Support for the radiator (third core critical) tube 2x3	SSE	21.8 ksi	1.86	40.6 ksi
Support for the radiator (third core critical) 3/4 inch bolt	SSE	IR=0.13	7.7	1.0
Generator hold down bolts	OBE	IR=0.08	25.0	1.0
	SSE	IR=0.17	5.9	1.0

*Margin of safety = allowable stress (factor) ÷ actual stress (factor).

APPENDIX A

PERSONS CONTACTED

The U.S. Nuclear Regulatory Commission staff participating in the inspection of the commercial grade procurement and dedication of the emergency diesel generator for Diablo Canyon Nuclear Power Plant Unit 2 and the PG&E personnel contacted during both inspection periods are listed below and designated as • – persons attending the entrance meetings; † – persons attending the interim-exit meeting; * – persons attending the closing-exit meeting.

<u>April 27 through May 1, 1992</u>

Pacific Gas and Electric Company:

•		Aaron, Douglas S.	Director, Procurement Support, Nuclear Operations Support (NOS)
•	†	Anderson, Richard C.	Manager, Nuclear Engineering and Construction Services (NECS)
•	†	Barham, Michael L.	Parts Supervisor, NOS
•	†	Clark, Rich	Assistant Project Engineer, NECS
	†	Dobrzensky, Michael	Supervising Engineer, Project Quality Assurance (PQA)
•	†	Farradj, Usama	Group Leader, Safety Systems Group, Mechanical Systems (MS), NECS
	†	Fetterman, Thomas	Group Supervisor, Electrical Engineering, NECS
•	†	Hardesty, Dan	Safety Systems Group, MS/NECS
•		Hoch, John B.	Manager, Nuclear Safety and Regulatory Affairs (NSARA)
•	†	Kahler, Edwin R.	Group Leader, Procurement Design Engineering Group, Equipment Qualification Group (EQG), Nuclear Engineering (NE), NECS
•	†	Kar, Anil K.	Electrical Engineer, NECS
	†	Locke, R. F.	Lawyer, PG&E Law Department
•		Love, Brian F.	Quality Assurance Engineer, PQA
•	†	Nicholson, Alan	Regulatory Compliance Engineer, NSARA
	†	Sexton, James A.	Manager, Quality Assurance
•	†	Tomkins, James E.	Director, NSARA
•	†	Walters, Ed	Replacement Part Evaluations Group, MS/NECS
•	†	Young, Jay C.	Director, PQA

U.S. Nuclear Regulatory Commission:

	†	Alexander, Stephen D.	Environmental Qualification & Test Engineer, Reactive Inspection Section 2 (RIS2), Vendor Inspection Branch (VIB), Division of Reactor Inspection and Licensee Performance (DRIL), Office of Nuclear Reactor Regulation (NRR)
•	†	Gleaves, William C.	Mechanical Engineer, RIS1/VIB/DRIL/NRR
	†	Haass, Walter P.	Senior Reactor Engineer, Special Projects Section, VIB/DRIL/NRR
•	†	Matthews, Steven M.	Team Leader, RIS1/VIB/DRIL/NRR
	†	Norrholm, Leif J.	Branch Chief, VIB/DRIL/NRR
	†	Potapovs, Uldis	Section Chief, RIS1/VIB/DRIL/NRR
•	†	Regan, Christopher M.	Mechanical Engineer, Project Directorate V, Division of Reactor Projects, NRR
•	†	Wagner, William J.	Reactor Inspector, Division of Reactor Safety, Region V

June 1 through 5, 1992

Pacific Gas and Electric Company:

•	*	Anderson, Richard C.	Manager, NECS
•	*	Chu, Winnie	Equipment Dynamic Analysis Group, EQG/NE/NECS
	*	Clark, Rich	Assistant Project Engineer, NECS
	*	deUriarte, Thomas G.	Director, NSARA
•	*	Dobrzensky, Michael	Supervising Engineer, PQA
	*	Elsalaymeh, Rabah	Group Leader, Electrical and I&C Replacement Part Evaluations Group, NECS
•	*	Farradj, Usama	Group Leader, Safety Systems Group, MS/NECS
	*	Fujimoto, Warren	Vice President, Nuclear Technical Services
•	*	Hardesty, Dan	Safety Systems Group, MS/NECS
•	*	Hoch, John B.	Manager, NSARA
	*	Kahler, Edwin R.	Group Leader, Procurement Design Engineering Group, EQG/NE/NECS
•	*	Kar, Anil K.	Electrical Engineer, NECS
•	*	Khan, Mohsin R.	Group Leader, Equipment Dynamic Analysis Group, EQG/NE/NECS

	*	Lee, Wayne K.	Quality Engineer, Engineering Quality Services
•	*	Nicholson, Alan	Regulatory Compliance Engineer, NSARA
	*	Tidrick, Gary	Supervising Engineer, NE/EQG/NECS
•	*	Tomkins, James E.	Director, NSARA
•	*	Walters, Ed	Replacement Part Evaluations Group, MS/NECS
•	*	Young, Jay C.	Director, PQA

U.S. Nuclear Regulatory Commission:

•	*	Alexander, Stephen D.	Environmental Qualification & Test Engineer, RIS2/VIB/DRIL/NRR
•		Haass, Walter P.	Senior Reactor Engineer, Special Projects Section, VIB/DRIL/NRR
•	*	Jacobson, Jeffrey B.	Acting Section Chief, RIS2/VIB DRIL/NRR
	*	Kirsch, Dennis	Technical Assistant, Region V
•	*	Matthews, Steven M.	Team Leader, RIS1/VIB/DRIL/NRR
	*	Norrholm, Leif J.	Branch Chief, VIB/DRIL/NRR
	*	Potapovs, Uldis	Section Chief, RIS1/VIB/DRIL/NRR
	*	Rajan, Jai Raj N.	Mechanical Engineer, EMEB/NRR

these documents are subject to verification during future NRC inspections.

In accordance with Section 2.790(a) of Title 10 of the Code of Federal Regulations (10 CFR), a copy of this letter and the enclosure will be placed in the NRC's Public Document Room.

Should you have any questions concerning this inspection, we will be pleased to discuss them with you. Thank you for your cooperation during this inspection.

Sincerely,
/S/
Jack W. Roe, Director
Division of Reactor Projects III/IV/V
Office of Nuclear Reactor Regulation

Enclosure:
Inspection Report No. 50-323/92-201
cc w/enclosure: See next page

LETTER TO PG&E, SUBJECT: INSPECTION OF THE PROCUREMENT AND COMMERCIAL GRADE DEDICATION OF THE SIXTH (NO. 2-3) EMERGENCY DIESEL GENERATOR SET FOR DIABLO CANYON NUCLEAR POWER PLANT UNIT 2 (INSPECTION REPORT NO. 50-323/92-201)

OFC	DFIPS/ADM	DRIL/VIB	DRIL/VIB	DRIL/VIB	DRIL/VIB	DRIL/SIB
NAME	DGable	SMMatthews	SDAlexander	WCGleaves	WPHaass	JBJacobson
DATE	2/01/93*	2/01/93*	2/04/93*	12/28/92*	1/06/93*	12/29/92*
COPY	Yes	Yes	Yes	Yes	Yes	Yes

OFC	DET/EMEB	DRP/PD5	DRS/RGNV	DRIL/VIB	DRIL/VIB	NRR/DRIL
NAME	JNRajan	CMRegan	WJWagner	UPotapovs	LJNorrholm	RPZimmernan
DATE	1/28/93*	1/05/93*	1/22/93*	2/04/93*	2/04/93*	2/05/93*
COPY	Yes	Yes	Yes	Yes	Yes	No

OFC	NRR/DRIL	NRR/SELB	DRP/PD5	NRR/DRP
NAME	CERossi	CHBerlinger	TQuay	JWRoe
DATE	2/08/93*	2/05/93*	2/10/93*	2/10/93
COPY	Y N	Y N	Y N	Y N

DISTRIBUTION:
RIDS-IE:09/Central Files/50-323
PDR
DRIL R/F
VIB R/F

* - SEE PREVIOUS CONCURRENCE
[1] - FRosa concurred on the previous inspection (50-323/91-201).