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Technical Evaluation Report

Emergency Diesel Generator Technical Specifications Study Results

K. R. Hoopingarner

March 1991

Prepared for
Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
under Contract DE-AC06-76RLO 1830
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Pacific Northwest Laboratory
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ABSTRACT

The purpose of this report is to review technical specifications for emergency diesel generators in the context of new information developed in the Nuclear Plant Aging Research Program and the application of current NRC regulatory concepts and knowledge. Aging and reliability relationships related to the standard technical specifications are reviewed and supported by data and published information to ensure that conservative and beneficial specifications are identified. Where technical specifications could adversely influence aging and reliability, the technical issues and reasonable alternatives are identified for consideration.

This report documents and spans the technical progress from the published and approved regulatory documents to the current knowledge basis. This ensures that the technical bases for the technical specifications discussed are documented and relatively complete subject information is contained in one document.

The Pacific Northwest Laboratory (PNL) has participated in the Nuclear Plant Aging Research (NPAR) Program directed by the Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research, Division of Engineering. The NPAR study of emergency diesel generator aging was performed in two phases. In Phase I, plant operating experience, data, expert opinion and statistical methods were used to produce a new data base related to aging, reliability, and operational readiness of nuclear service diesel generators. Phase II was chiefly concerned with aging mitigation measures.

SUMMARY

The Pacific Northwest Laboratory (PNL) has been studying the aging of Emergency Diesel Generators (EDGs) for several years in support of NRC research efforts. Insights have been obtained indicating many opportunities exist for improved management of EDG systems including the influence of existing technical specifications. Technical specifications could be modified to yield significant safety benefits in the reduction of direct aging effects and increased system reliability. This would support the reliability improvements proposed in draft Regulatory Guide, 1.9, Revision 3, Section, Design, Qualification, Testing and Reliability of Diesel Generator Units Used as Class 1E Onsite Electric Power Systems Nuclear Power Plants.

Potential technical specification changes that would result in the most beneficial engine improvements for aging and reliability results are:

- Significantly reduce the number of total engine starts
- Reduce the load application rates for testing purposes and gradually add load to the engine
- Reduce the EDG testing loads to 90% of the continuous load rating or to the plant emergency unit load, whichever is less
- Increase the maximum EDG start time to 25 to 30 second range
- Make necessary changes to support the reliability emphasis of Regulatory Guide 1.9, Revision 3 and delete statistical emphasis
- Address fuel oil storage to permit station flexibility and the use of a larger fraction of stored fuel before replacement
- Eliminate many unnecessary and partially redundant tests and engine starts in the 18-month test period, as well as those due to false ESF signals
- Eliminate, where possible, short engine run times and excessive idle time.

The technical basis for changes to the technical specifications to avoid aging and improve reliability have been identified, researched and reported by the NPAR Program, Diesel Generator Task. The Electric Power Research Institute (EPRI) and the Nuclear Safety Analysis Center (NSAC), operated by EPRI,

have sponsored research and reported important results applicable to technical specification improvement. Another major contributor to the technical basis for potential improvements has been the NRC staff, Nuclear Management Resources Council, SAIC, and others working on engine reliability issues and the process of development of Regulatory Guide 1.9, Revision 3. The references for this report document additional technical information sources.

In NSAC/96 which is discussed in Section 4.1 in this report, the Nuclear Safety Analysis Center in their "NSAC Perspective" introduction cited fast starts, fast loading and the large number of tests as acting to increase diesel generator stress and wear. The PNL data confirms this list and adds excessive testing loads as another important stressor. The important concern is that these stressors are all imposed on the licensees by current NRC guidelines and technical specifications.

In the NPAR Program emergency diesel generator aging study, the overall objective was to provide information to assist regulatory organizations and plant operators to understand the role of aging in emergency diesel generators. The study was performed in two phases. Phase I provided general background material for this report. It defined which diesel generator system components fail and the causes of the observed failures. The principal accomplishment of Phase II was to develop information and recommendations to assist regulatory organizations and plant operators to improve diesel generator reliability and the management of aging. These activities have been performed with interaction with the NRC staff, industry, and code and standards committees.

The 10 to 12 second starting time followed by very rapid loading imposed by the typical plant technical specification has many negative technical safety implications. Recently, the NRC permitted a new, more realistic, approach for performing LOCA analyses. Under sponsorship of the Nuclear Safety Analysis Center (NSAC), studies were performed by General Electric and Westinghouse to investigate the safety implications of this more realistic analysis and calculation method for the emergency diesel generator starting time.

Both studies revealed that considerable relaxation of the current 10-second starting time requirements may be possible. The results of the BWR study indicated that the start time could be increased to 118 seconds for a typical BWR/6 without peak fuel temperatures exceeding the 2200°F limit. The results further show that for a 1600°F peak cladding temperature, the diesel generator start time can be 70 seconds. The PWR study concluded that a diesel start delay of 30 seconds was defendable with acceptable licensing calculations. Longer delays may be possible.

The most likely emergency electrical power need for nuclear power plants is the emergency developed for loss of offsite ac power (LOOP), but the plant remains fully functional otherwise. This is the chief mission for the Emergency Diesel Generator System. With over 1000 reactor years of operating history without a large-break event Loss of Coolant (LOCA) for primary water containment and with the recent 10 CFR 50 General Design Criterion 4 (leak-before-break) rulemaking, the PNL study results lead to a conclusion that the true mission envelope for the diesel-generator may be redefined with consequential benefits. The most realistic mission envelop appears to be:

- Reliability
  - very high, greater than 0.95 for each engine
- Duration
  - three to four days appears adequate
- Start Time
  - thirty seconds is an acceptable compromise with conservative margins. If Leak-Before-Break considerations are extended to the EDG system, a start time of 1 minute should be acceptable.
- Engine Load
  - The emergency ac electrical load for design should be in the range of 70 to 90% of the EDG continuous rating.
  - For testing, the load should be the emergency ac electrical load or 90% of the continuous rating, whichever is less.

Current NRC guidelines and technical specifications tend to focus on the hypothetical situation where both LOOP and LOCA events occur. Design considerations, engine purchase specifications, instrumentation logic, and periodic testing are all intended to mitigate this very rare postulated accident. Unfortunately, in doing so EDGs are subjected to many conditions that are harmful to aging and reliability concerns.

This report outlines a comprehensive analysis of the technical factors that apply to the Standard Technical Specifications and how safety may be positively influenced by considering certain modifications to these specifications. It attempts to integrate the EDG mission and reliability requirements into a balanced regulatory overview process and supply appropriate information allowing the NRC staff to select technical specifications options to achieve these goals. Because this document spans the technical progress from published and released regulatory documents to the present knowledge basis, some NRC current activities are discussed and presented. The purpose of this approach is to ensure that all applicable information needed for the technical specification improvement of the diesel generator system is included in this document.

CONTENTS

1.0 INTRODUCTION

The Pacific Northwest Laboratory (PNL) was selected to participate in the Nuclear Plant Aging Research (NPAR) Program by the Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research, Division of Engineering. The NPAR study of Emergency Diesel Generator (EDG) aging was performed in two phases. In Phase I, plant operating experience, data, expert opinion and statistical methods were used to produce a new data base related to aging, reliability, and operational readiness of nuclear service diesel generators. Phase II was chiefly concerned with aging mitigation measures. Phase I program results of assessments of aging experience have been published (Hoopingarner et al. 1987, Vol. 1 and 2). Methods for testing and aging mitigation (Hoopingarner et al. 1989) have been published as part of the Phase II work for the diesel generator task.

The purpose of this report is to review published technical specifications related to a new proposed management, testing and maintenance program for emergency diesel generators that was developed as a product of Phase II. Aging and reliability relationships to the Standard Technical Specifications are reviewed and supported by data and published information to ensure that beneficial specifications are identified. Where technical specifications could adversely influence aging and reliability, the technical issues and alternatives are also identified for consideration.

1.1 BACKGROUND

The historical approach taken by NRC for assuring diesel generator reliability had the objective of developing statistical data on the past fast starting and loading of the diesel generator units. This was supported by Standard Technical Specifications, that detailed the fast starting and loading conditions to be achieved. However, this approach provides no information on the long-term degradation of the performance of components and related systems which could lead to future failures and which could be corrected before an actual failure occurred or before a unit's reliability was compromised. The detection time to statistically determine unacceptable performance deterioration is considered to be excessive for regulatory purposes.

In 1977, Regulatory Guide 1.108 (Rev. 1) was issued and it defined a routine testing schedule that related the testing frequency to the number of failures being experienced. This guide requires the diesel generators to be "fast, cold" started at intervals of at least 31 days. If two failures are experienced in the last 100 valid tests, then the maximum test interval is decreased to 14 days. If three failures are experienced in the last 100 valid starts, the maximum test interval is further decreased to 7 days. Finally, if four or more failures are experienced in the last 100 valid tests, starting tests must be performed at least every three days. The requisites for a valid test are delineated in the guide. The thrust of this requirement was intended to encourage utilities with diesel generators with high failure rates to make improvements to avoid the high costs of frequent starting tests.

"Fast, cold" starting refers to plant technical specification requirements that the engine be started within approximately 10 seconds from ambient conditions and fully loaded in about 60 seconds. The start time and full-load time was not specified in Regulatory Guide 1.108 but was determined from admittedly conservative fuel cladding temperature calculations defined in 10 CFR 50, Appendix K. These requirements were then made a part of each plant's technical specifications.

The NRC has recognized the possibility of detrimental effects of the very testing that was originally meant to assure the diesel generators' reliability. In December of 1983, Generic Letter 83-41 was issued which requested licensees to provide information related to potential detrimental effects of "fast, cold" starts. This letter was followed by Generic Letter 84-15 in July 1984 which described changes in requirements to improve diesel generator reliability. This action requested that the licensees take action to reduce "fast, cold" starting tests and encouraged them to propose technical specification changes. The generic letter also described a goal-oriented reliability program developed by the staff and invited licensee comments on this program.

In response to these historical conditions, the NRC staff has in addition acted by the issue of Regulatory Guide 1.155, "Station Blackout" in August, 1988 which identifies a need for a reliability program. This reliability program for emergency diesel generators is designed to maintain and monitor reliability levels selected for compliance with the Station Blackout Rule 10 CFR 50.63 (6/68).

Regulatory Guide 1.9, Revision 3, "Section, Design, Qualification, Testing, and Reliability of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants" is in the final NRC approval process. It integrates into a single guide pertinent guidance previously addressed in Regulatory Guides 1.108, 1.9 Revision 2 and Generic Letter 84-15. Regulatory Guide 1.108 will be withdrawn after the issue of Regulatory Guide 1.9, Revision 3. The new guide is consistent with industry needs and with the recommendations contained in the NPAR study (Hoopingarner et al. 1989). Many prior operational and testing practices deleterious to engine reliability and life, such as cold fast starts, have been deleted from the new guide.

Although the NRC is moving away from frequent fast-starting requirements and allowing some slower loading testing, the technical specifications for the majority of U.S. nuclear power stations still define fast, cold starting and rapid loading for monthly tests of diesel generators. In addition, at the present time, most stations have not installed the necessary hardware modifications to permit both slower loading and fast-start response of the diesel-generator system.

The focus of the following sections in this technical evaluation report will be to review existing and proposed technical specifications and to ensure that balance and consistency are outlined in the consideration of specification details. The broad intent within the NRC to improve diesel generator reliability should be supported by Standard Technical Specifications that are defendable and also tend to reduce aging and reliability effects.

2.0 DIESEL GENERATOR TECHNICAL SPECIFICATIONS

The NPAR study developed information on the aging of diesel generator systems and the detailed causes of the observed degradation. It was relatively easy to develop the relationship between aging and reliability during the study, which is discussed in Section 2.2. It was much more difficult to obtain the data and information to link the provisions of standards, guides, and the Standard Technical Specifications to aging concerns.

This section presents a review of the content of an existing representative technical specification and a technical evaluation of it by expert diesel generator consultants. Aging and reliability relationships for presently known aging influences of selected technical specification provisions are discussed. This section concludes with a outline of potential beneficial technical changes that avoid or reduce aging stressors. The data and study results more often indicate the direction of beneficial changes rather than confirm numbers or absolute values of such changes.

2.1 REVIEW OF PRESENT SPECIFICATION CONTENT

Independent EDG experts have assisted the PNL staff during the performance of the Phase I and II NPAR studies related to diesel-generator aging. As a result, they were qualified to review the standard technical specifications and make judgments as to the aging influences of the present specification guidelines.

Three of these consultants were selected to review each current specification requirement and to determine the aging influence of these requirements. The direction given to the consultants was to evaluate each specification item and to make a judgment as to its most likely effect on known aging factors. The intended result was to place each specification requirement into a positive, negative, or neutral aging category. A positive category was defined as either preventing aging or detecting EDG deterioration without known harmful influences or testing conditions. A negative category would be where rapid wear, aging, or other deterioration could be reasonably projected as a consequence of the specification requirement. A neutral requirement is one were there is no aging influence on the hardware such as a requirement to report failures to the NRC, or to have a certain number of EDG units.

The NRC staff is presently involved in a program to improve the technical specifications, including those addressing emergency diesel generators. The technical specification review by the EDG consultants is intended to evaluate the aging and reliability influence of the present Standard Technical Specifications. Any proposed changes by the NRC staff can then be compared to existing specifications and the evaluation comments shown below by the consultants. This should give a sound technical basis to the improvement initiative for technical specifications.

For the purpose of this technical evaluation, the provisions of the ac portion of the Standard Technical Specifications are similar for all four common reactor vendor variations. The representative technical specification selected for review and comment is NUREG-0452, Standard Technical Specifications for Westinghouse Pressurized Water Reactors. Comments are limited to the Electrical Power Systems and the ac portion of it.

3/4.8.1 A. C. Sources from NUREG-0452

The following outline of the present specification paraphrases the requirements and lists the chief items cited. After each listing are the PNL staff and consultants comments. Copies of NUREG-0452 are readily available for comparison to the latest text.

SPECIFICATION OUTLINE

LIMITING CONDITION FOR OPERATION

3.8.1.1 Minimum operable ac sources are defined:

a. Two independent offsite circuits

b. Two independent diesel generators.

Comment: These were judged to be neutral for aging. However, the minimum amount of fuel may have aging and reliability considerations. This is addressed in Section 2.3.

Action

a. If one diesel or one offsite circuit is lost, surveillances 4.8.1.1.1.a and 4.8.1.1.2.a.4 are to be performed within an hour and each 8 hours thereafter, 72 hour time limit to progressively proceed to mode 3, and mode 4.

Comment: Surveillance 4.8.1.1.1.a judged to be neutral, surveillance 4.8.1.1.2.a.4 judged to be negative. A fast engine start has been shown to be harmful (Hoopingarner, et. al. 1989). Even a slower start with a prelube period has significant effects on certain components. All time periods specified are aging neutral.

b. If one diesel and one offsite circuit are lost, surveillances 4.8.1.1.1.a and 4.8.1.1.2.a.4 are to be performed within an hour and each 8 hours thereafter, 12 hour time limit to progressively proceed to mode 3 and 4.

Comment: Same as Action item a.

c. With one diesel inoperable in addition to a or b above:

   1. Verify that the remaining diesel and ac driven components are operable (implies 3 diesels if b is involved, since both b and c define that an EDG is lost)

   2. Verify that steam driven auxiliary feed pump is operable.

   Two hour time limit to be in mode 3 and 30 hours to be in mode 5.

Comment: All sections and time periods specified were judged to be aging neutral. This assumes that verification does not imply actual operations.

d. If two offsite circuits are lost, surveillance 4.8.1.1.2.a.4 is to be performed (if 3 offsite circuits are available otherwise the EDGs are operating to prevent station blackout) 24 hour time limit.

Comment: Same as action item a, where the plant has three or more offsite circuits. Does not apply for two offsite circuits.

e. If two diesels are inoperable, surveillance 4.8.1.1.1.a is to be performed within 1 hour and each 8 hours thereafter, 2 hour time limit to progressively proceed to modes 3 and 5.

Comment: Surveillance 4.8.1.1.1.a was judged to be positive.

SURVEILLANCE REQUIREMENTS

4.8.1.1.1 Each offsite independent circuit shall be:

a. Determined operable by breaker alignment and indicated power, each 7 days.

Comment: Was judged to be positive, and is an example of non-intrusive monitoring.

b. Demonstrated operable by actual use each 18 months (during shutdown).

Comment: Was judged to be positive overall, but it would cause some aging of the breakers. The 18 month period is appropriate to ensure that the alternate offsite power source will actually deliver power and that aging failures have not occurred. The frequency, at 18 months, is not enough to wear out the breakers.

4.8.1.1.2 Each diesel generator shall be demonstrated operable by:

a. Table 4.8.1 frequency and a staggered test basis defined.

TABLE 4.8-1. Describes the Test Schedule Frequency Related to the Number of EDG Failures in the Last 100 Valid Tests

for 0 and 1 failures the test frequency is 31 days
for 2 the test frequency is 14 days
for 3 the test frequency is 7 days
for 4 or more the test frequency is 3 days.

Comment: Test frequencies were judged to be negative. References: Beard J. T. September 1982, and Hoopingarner et. al. December 1989, further document the aging influence of too frequent testing.

1. check fuel level in engine day tank

2. check fuel level in storage tanks

3. check fuel transfer pump operation

4. fast start the EDG from ambient condition to rated speed within 10 to 12 seconds, achieving rated voltage and frequency.

5. fast load the EDG to greater than or equal to the continuous rating within the rated time (about 60 seconds), 1 hour operation minimum

6. check the alignment of the IE power breakers.

Comment: a.1,2,3 and 6 were judged to be positive. a.4 and 5 were judged to be negative. Fast starting and loading specified by a.4 and 5 as written have been recognized by the NRC and industry as being harmful and need reassessment for regulatory value.

b. After operation ≥1 hour and each month checking for and removing water from engine day tank(s).

Comment: Judged to be positive.

c. Once per 92 days and for new fuel, sample and test the fuel oil for water, sediment, viscosity and impurities.

Comment: Judged to be positive.

d. Once per 18 months during shutdown do the following:

1. inspect the diesel in accordance with procedures and manufacturer's recommendations

2. check the EDG capability to reject the largest emergency single load and maintain voltage and frequency without exceeding over-speed set points

3. check the EDG capability to reject the entire continuous load rating without an over-speed trip, maximum voltage also specified

Comment: Item d.1 was judged to be positive. d.2 and 3 were judged to be negative as written, but there is a positive governor checking role for a modified specification. This is discussed in Section 2.3.

4. simulate loss of offsite power and

   a. check the IE busses for load shedding

   b. check for successful EDG fast starting and fast loading with a run time of 5 minutes or greater, voltage and frequency are specified

5. check that with an ESF signal the EDG auto starts with a fast start. Voltage, frequency, and maximum time are specified as well as a 5 minute run time

6. with a simulated loss of one diesel and offsite power, check that d.4 specifications are achieved with the exception no run time is given

7. with both Loop and ESF signals

   a. check for proper load shedding form 1E busses

   b. check for fast starting and loading of the EDG while voltage and frequency are maintained for 5 minutes or more

   c. check that the EDG protective trips are automatically bypassed. Overspeed and generator differential current are an exception to the trip bypass

Comment: Items d.4 through 7 were judged to be negative as written. Tests involved in 4., 5., and 6 were considered to be unnecessary since specification item 7. appears to check these same items. Section 2.3 will discuss how the regulatory objectives of these tests can be achieved with fewer actual engine starts and other desirable changes.

8. check for a successful 24 hour test run with 22 hours greater than or equal to the continuous load rating and 2 hours at equal to or greater than the 2-hour load rating. A fast-start is specified along with voltage and frequency. Within 5 minutes of this test perform 4.8.1.1.2.d.7.b (another fast-start) surveillance

Comment: Judged to be negative. This specification, as written, requires the engine to operate in excess of 13 hours at the 2-hour rating. This is very harmful and exceeds the manufacturer's warranty and the Diesel Engine Manufacturing Association (DEMA) rating schedule. Refer to Section 2.3 for further discussion of this test specification.

9. check that the emergency loads do not exceed the engine 2000-hour rating

10. check the EDG capability to:

   a. synchronize with the offsite sources while loaded with the emergency power load

   b. transfer the emergency power load, and

   c. return to standby status

Comment: Items d.9 and 10 appear to be neutral for aging. They also appear to be completely unnecessary. The FSAR addresses specification item 9 and item 10 and they are tested each month since it is the only way to load the EDG units. The components tested in item 10 are chiefly non-safety related components.

11. check that while the EDG is in the test mode, an emergency signal causes the EDG to 1) go to standby and 2) the emergency loads are energized by offsite power

12. check that the fuel transfer pump transfers fuel to all diesels via cross-connection lines

13. check the accuracy, within 10% of the load sequencer intervals

14. check that the EDG lockouts function for:

    a. turning gear engagement

    b. emergency stops.

Comment: Items d.11 through 14 were judged to be positive, at least in the absence of aging effects.

e. Simultaneous EDG engine fast-starting test verifying rated speed and time specifications on a 10-year basis or after significant modifications.

Comment: Judged to be positive on the test frequency basis.

f. At least once per 10-years:

    1. drain and clean the fuel oil tanks

    2. perform a pressure test of the fuel oil system portion designed to ASME, Section 3, subsection NP, at 110% of design pressure.

Comment: Judged to be positive.

4.8.1.1.3 Reporting requirements are defined.

Comment: Reporting is neutral for aging and has no influence on the hardware.

2.2 AGING AND RELIABILITY RELATIONSHIPS

The NPAR diesel generator study was originally intended to develop data and information related to aging effects during the ongoing license period. This information was then intended to be used primarily by the NRC to mitigate aging and assist in formulating any required new regulatory actions. However, the investigators working on the study soon started getting information from NRC and industry sources indicating that standards, regulatory guides, technical specifications, and plant procedures all contributed to aging in various ways. The original concept that aging mitigation was primarily achieved through proper inspection, maintenance, and replacement has now been expanded to include modified technical specifications, standards, and regulatory guides.

Aging was the focal point of the NPAR study and reliability issues were chiefly being addressed for the diesel-generators by other groups. This concept worked for studies involving causes and effects of aging. Later when mitigation of aging was addressed, every useful corrective action proposed seemed to increase reliability. Looked at another way, if it did not increase reliability, it was not effective as an aging mitigation measure. The end result was open cooperation with the staff working on reliability issues and the use of the NPAR information in the reliability work.

After the linkage between aging and reliability was established and accepted, the interactions of applicable guides, standards, and the technical specifications with aging and reliability were studied. Regulatory Guide 1.108 was often cited by industry groups and individuals as a direct factor in excessive engine starts and the rapid engine loading leading to unexpected wear in certain engine components. The NRC staff increasingly joined in this judgment and conclusion. One end result was the development of a new draft regulatory guide to remove many of the provisions that induced aging effects. Draft Regulatory Guide 1.9, Revision 3 is expected to be released soon as an approved guide.

Many concerns addressed by Draft Regulatory Guide 1.9, Revision 3 can be only partly resolved by the guide, because of adverse details in current plant technical specifications. Current industry standards, and the technical specifications may be revised to complete the improvement envisioned for diesel generator management.

2.3 OUTLINE OF POTENTIAL BENEFICIAL CHANGES

This section is intended to outline the potential changes in emergency diesel generator operation that would result in less aging degradation or improved reliability. The technical bases for these potential improvements are also presented. The methodology used in this section applies the general information and data developed in the NPAR diesel generator task to the engine and generator hardware to reduce aging effects. That is, what physical changes would result in less wear and deterioration or conversely improved reliability.

The factors discussed in this section, if implemented, would result in less aging and wear in any diesel engine in any normal power production application. These same operational conditions have then been ranked, beginning with the most important, based upon data and experience from nuclear plant emergency diesel generators.

<u>Potential Improvements</u>

Beneficial changes with the most potential for reducing EDG aging and increasing reliability are as follows:

1. Significantly reduce the number of engine starts on a monthly or yearly basis.
2. Reduce the load application rates for testing purposes and gradually add load over a 15 minute period.
3. Reduce the EDG testing loads to 90% of the continuous load rating or to the plant emergency unit load, whichever is less.
4. Increase the maximum EDG start time to 25 to 30 second range for all engine operation demands.
5. Make necessary changes to support the reliability emphasis of Regulatory Guide 1.9, Revision 3 and delete statistical emphasis.
6. Address fuel oil storage to permit flexibility and a larger fraction of stored fuel use before replacement with new fuel.
7. Many unnecessary and partially redundant tests and engine starts in the 18-month period could be eliminated, as well as unnecessary engine starts due to false ESF signals.
8. Eliminate, where possible, short engine run times and excessive idle time.

Technical Basis for Potential Improvements

The technical basis for changes to the technical specifications to avoid aging and improve reliability have been identified, researched, and reported by the NPAR Program, Diesel Generator Task. The Electric Power Research Institute (EPRI) and the Nuclear Safety Analysis Center (NSAC) operated by EPRI also have sponsored research and reported important results applicable to technical specification improvement. Another major contributor to the technical basis for potential improvements has been the NRC staff and others working on engine reliability issues and the process of development of draft Regulatory Guide 1.9, Revision 3, "Selection, Design, Qualification, Testing, and Reliability of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants." The references listed include the research from these sources.

Engine Starts

Reduction of the number of engine starts as a goal has had strong technical support and NRC staff attention for some time (J. T. Beard, 1982). The French national utility (EDF) has implemented a goal to reduce the average number of EDG starts from about 60/year in 1985 to 15/year (A. F. Colas, 1988). Draft Regulatory Guide 1.9, Revision 3 provides for some reduction in the number of starts. The technical specifications may also be structured to further reduce the average number of engine starts by reducing or eliminating certain automatic engine starts (i.e., ESF signal) and test starts that partially duplicate other tests.

Starting the engine is a severe aging stressor for certain engine components such as the pistons and cylinder liners. During standby, oil drains away from the liners and the pistons, especially under warm standby conditions. During startup conditions lasting only seconds, these components may experience wear exceeding normal running wear rates equal to many hours of operation. Piston and cylinder liner scuffing are also more likely during startup conditions. Obviously, neither scuffing or high wear rates add to engine reliability.

Engine Loading Rate

Aging stressors associated with fast loading in response to accident signals are important. However, because of their frequency, the most important are those associated with the periodic testing mandated by regulations that simulate the starting and loading sequence that would be encountered during an emergency. Real emergency (unplanned) fast starts amount to only 2% of all starts, and the rest are tests (Nuclear Engineering International, 1987). Of the unplanned starts, only about one-half was followed by loading. On the average, there are only 5 incidents involving loss-of-offsite-power in the U.S. per year (EPRI 1987).

Rapid loading of the engines without allowing time for more normal thermal equilibration is very harmful to the engines. When the engine is called upon to deliver several megawatts of power in less than 60 seconds, the pistons thermally expand very rapidly. The cylinder liners are water cooled and expand much slower. The cylinder-piston clearance gap may then be lost causing metal-to-metal contact. This physical metal-to-metal contact can lead to piston/cylinder liner scuffing. Later under emergency power conditions, this scuffed metal can reach temperatures in the 600-700°F range, which can then initiate a crankcase explosion (Hoopingarner et al. 1989).

Reduction of Test Loads

The emergency diesel generators are perhaps the only large components of the plant safety related equipment that are routinely tested at much more than 100% of the emergency requirements. The relationship between high loads and wear is well known for typical piston engine applications. Engine manufacturers have indicated that aging and wear significantly increase after 95% of the continuous load rating is achieved.

The Diesel Engine Manufacturers Association (DEMA) has defined a "continuous rating" and a "2-hour rating" based on a 10% increase to the continuous rating. Non-nuclear customers, typically as good practice, load the engines to 80 to 90% of the continuous rating and rarely exceed these power levels.

This conservative use experience base, over decades of operation, is the basis for maintenance practices and the generally excellent reliability reputation of large diesel engines.

The nuclear industry often, in addition to the DEMA ratings, specifies special 2000-hour and 168-hour power ratings. Operators at nuclear stations may not fully understand the full implications of these ratings. The special engine ratings are intended by the manufacturers to specify the combination of loads and times which are to be followed by extensive engine disassembly to inspect for heat effects and unusual wear. It is equally important to note that these rating numbers are intended to represent the maximum loads and times in each power range. These two facts are not well known. The safety implications are that nuclear engines are routinely operated at high power levels and may unknowingly exceed rating limits and times without inspections being performed, as intended by the engine manufacturers.

<u>Increase of Start Time</u>

The maximum allowed EDG start time was established based on the emergency power needs of a coincident loss of offsite power (LOOP) and a loss of coolant accident (LOCA) plus a very conservative 10 CFR 50, Appendix K calculation of reactor core thermodynamics. The 10- to 12-second EDG starting time imposed by the typical plant technical specification is the result. There is no record of an actual LOOP and LOCA coincident event. In addition, the NRC has reduced the LOCA design applications and reconsidered the core thermodynamics calculation. Sections 4.0, Related Studies, and 5.1 LOCA Considerations supply additional details.

The increase of the maximum allowed EDG start time from about 10 seconds to about 30 seconds appears to be more conservative from the regulatory perspective. There are three benefits for this technical specification change. First, there is less risk of an overspeed trip and subsequent engine mission response loss. Second, significant reliability and engine performance improvements are obtained. Third, less aging and wear occurs.

Following the rapid acceleration to speed, an overspeed condition always occurs as the governor acts to gain control of the engine rpm. Often the result is an engine overspeed trip and the failure to support the intended EDG function to supply emergency power. Also this overspeed condition results in increased stresses in engine and generator components that can accelerate mechanical wear and loosen generator wiring.

An increase in the permitted starting time should improve reliability. To achieve a 10-second start the governor and fuel rack adjustments are not ideal for dependable running later when the engine is hot. This can lead to unacceptable surging, speed hunting, and other engine faults.

Support of Reliability Emphasis

Draft Regulatory Guide 1.9, Revision 3, currently in the final NRC release process, has a reliability emphasis rather than a statistical basis for regulatory guidance. This new guide was developed with assistance and information from EPRI, NUMARC, SAIC, NRC, and the EDG aging task of the NPAR Program (Lofgren et al. 1988, Vol. 1 and 2). Accelerated testing, rapid engine loading and certain other practices have been dropped since it was determined that such practices could not be supported (Hoopingarner et al. 1989). The intent of the new guidelines should be incorporated into any proposed technical specification changes.

Fuel Oil Storage

Current technical specifications require that about a seven-day fuel oil supply be on hand at all times for emergency use. This has important reliability and aging consequences as developed in the NPAR aging study. Briefly, this rather large amount of fuel oil is subject to several aging mechanisms and the current allowed use of fuel does not permit effective management. Reliability would be improved if the licensees were permitted to use a larger fraction of the fuel before replacement and they were encouraged to run the engines for longer time periods and use the oil at a faster rate.

One change that appears to be reasonable and practical for fuel oil management would allow greater management flexibility without any significant public risk change. It is to reduce the minimum fuel oil supply to about 3-4 days. This is ample for almost any conceivable emergency and allows enough time to organize additional supplies. A potential supply method, modern heavy-lift helicopters, could supply additional fuel for any additional emergency duration, and overcome adverse transportation problems.

Particulates and other standards allowed for new fuel are found in Federal Specification VV-F-800, ASTM D975 and other supporting standards. These specifications for new fuel are applied to fuel in long term storage, without any exceptions. For typical military applications fuel stored for more than 90 days is considered old fuel. Regulatory Guide 1.137, allows fuel to be stored for 10 years before cleaning out the tanks. With such long term storage some degradation should be provided for by perhaps allowing color changes, an increase in particulates (maybe twice or three times new fuel standards), and adding control of organic contaminants.

Unnecessary and Redundant Testing

Discussions with EDG consultants and engine manufacturers have provided information on qualification and periodic engine tests with marginal or nonexistent justification. The NPAR study also documented aging and the lack of observed benefits for some testing (Hoopingarner et al. 1988 and 1989). Candidates for tests that could be eliminated are:

- The engine hot restart test. This is not a problem area and does not need to be tested.
- The LOOP and ESF actuation signal start test is adequate and the separate LOOP and separate ESF signal start tests are redundant and provide no additional information.
- 18-month tests involving synchronizer and load transfer equipment are completely redundant and also test non-safety related functions. This equipment is used each month in performing the EDG surveillance testing and thus, it already tested adequately.
- The continuous (full) load rejection test is adequate and the less severe partial load rejection test is redundant and has almost no potential of revealing new information or problems that the full load test would not reveal.

Engine Run/Idle Time

The NPAR aging study documented results showing that some engine types are sensitive to running and idle time. Short-run times at full power have more aging effects than longer operating periods. Conversely, longer time at idle is more harmful (Hoopingarner et al. 1988 and 1989).

Helpful changes for reliability would include reducing the requirements for engine starting followed by a standby period and either the elimination of 5-minute test runs or incorporating such short tests into a longer test series. A simple change to eliminate the automatic engine start upon an ESF actuation signal would reduce both short-run and idle-run times since most of these signals are either false signals or test signals.

3.0 AGING INFORMATION AND APPLICATIONS TO TECHNICAL SPECIFICATIONS

In the NPAR Program emergency diesel generator systems were evaluated to 1) determine which components and subsystems were subject to aging, how they failed, and with what frequency, 2) determine the adequacy of surveillance, inspection, and trending methods, 3) assess the role of maintenance and other industrial practices in resolving aging effects, and 4) assess the role of regulatory practices, guides and technical specifications on aging. The overall objective of this study was to provide information to assist regulatory organizations and plant operators to understand the role of aging in emergency diesel generators.

The study to date was performed in two phases. Phase I, which was completed and provided general background material for this report, was concerned with defining which diesel generator system components fail and the principal causes of the observed failures. The principal objective of Phase II was to develop information and recommendations to assist regulatory organizations and plant operators in the improvement of diesel generator reliability and the management of aging influences. This activity has been performed with interaction with the NRC Staff, industry, and code and standards committees.

3.1 PHASE I DATA APPLICATIONS

This technical evaluation report applies the results of the Phase I activity of the Diesel Generator Aging Research Program which is reported in detail in (Hoopingarner et al. 1987). The principal issues addressed in Phase I included the following:

- Observable aging; failures, causes, and locations,
- important aging stressors including operations and regulatory effects, and
- potential corrective actions and mitigating measures.

The statistical analysis performed as part of the Phase I effort resulted in the identification of failures and ranking of the stressors identified in Tables 3.1 and 3.2 that can lead to the failure of diesel-generator

TABLE 3.1. Systems and Components Subject to Aging-Induced Failures Resulting In Loss of Function of Unit

Systems and Components	Percentage of Aging-Related Failures	
Instruments and Control Systems	26	
Governor		12
Control Air System		3
Wiring and Terminations		2
Sensors		2
Fuel System	15	
Engine Piping		7
Injector Pumps		5
Injectors and Nozzles		2
Starting System	10	
Starting Air Valve		5
Controls		2
Starting Motor		2
Cooling System	10	
Piping		3
Pumps		2
Heat Exchangers		2
Engine Structure	9	
Crankcase		3
Cylinder Liners		2
Main Bearings		2
Other Systems	30	

TABLE 3.2. Causes of Aging-Related Failures that Result in Loss of Function or Reliability

Failure Cause	Percentage of Aging-Related Failures
Adverse conditions - vibration, shock	32
Poor manufacture or construction quality control	23
Adverse environment - dust, humidity, etc	15
Human error - maintenance, operation	9
Poor design - wrong application or component	7
Other	15

components. Another valuable ranking of these stressors and their relative importance was obtained from an industry-wide workshop on diesel generator aging held under the auspices of the NPAR Program (Hoopingarner 1987, Vol. 2). Attending were representatives of U.S. utilities, vendors, contractors, consultants, and the national laboratories. One of the principal objectives of this workshop was to obtain the industry's perception of issues and problems regarding nuclear service diesel generators and to identify potential solutions.

The workshop attendees identified some of the same aging stressors as found in the statistical analysis of the data base and summarized in Table 3.2. However, they added other stressors and ranked them in a somewhat different order of importance as shown in Table 3.3. This table suggests that the principal stressors leading to the aging of diesel generator components are environmentally related. The second, third, and fourth most important stressors were, in order, maintenance practices, testing practices, and operating practices. It was apparent from the expressed concern about aging degradation factors, the workshop participants perceived that deterioration of diesel generator systems to be influenced by their normal operating environment, including the influence of guidelines and other regulatory requirements.

3.2 PHASE II AGING MITIGATION OPPORTUNITIES

Phase II activities were intended to develop information on aging mitigation and aging management opportunities for the diesel-generator system.

TABLE 3.3. Workshop Participant's View of Major Aging Stressors

Rank	Major Stressors
1.	Environmentally induced - dust, water, heat, oil, chemical, etc.
2.	Maintenance errors - inadequate training, etc.
3.	Fast starts and other regulatory induced factors
4.	Design inadequacy - wrong application, or poor component
5.	Operation induced - inadequate training and skills
6.	Vibration induced
7.	Fuel or lubricant degeneration
8.	Gasket, seal, or organic material degeneration
9.	Inadequate spares - quality, storage, ordering problems, data and specifications
10.	Corrosion
11.	Thermal stress
12.	Manufacturing or quality problems
13.	Fatigue not related to vibration
14.	Others

This has been done and the results have been published (Hoopingarner et al. 1983 and 1989). Many seminars and presentations have been given, outlining improvement possibilities and to carry out the technology transfer responsibilities defined in the task plan and requested by the NRC Project Manager. Fortunately, many improvement possibilities were developed by many individuals and groups within industry, the NRC staff and the PNL research task.

In NSAC/96 (Muralidharan 1986) discussed in Section 4.1 in this report, the Nuclear Safety Analysis Center in their "NSAC Perspective" introduction cited fast starts, fast loading and the large number of tests as acting to increase diesel generator stress and wear. The PNL data confirms this list and adds excessive testing loads as another important stressor. The important concern is that these stressors are all imposed on the licensees by current NRC guidelines and technical specifications. Fuel oil also ages, but it is not an engine stressor. However, reliability is affected and it is part of the specification and minor specification changes would permit better fuel oil management.

Based upon Phase I results, other input from the nuclear industry, and new Phase II research results, it was concluded that significant opportunities exist for reduction of aging effects and long-term improvement in diesel-generator system reliability. The key to this improvement in reliability and reduction in aging effects is 1) the reduction in the fast-starting, fast-loading, and heavy-loading stressors imposed by current guidelines and regulations, 2) the implementation of new recommended testing and trending procedures, and 3) the improvement of certain maintenance practices (Hoopingarner et al. 1989). The scope of this technical evaluation report is limited to the first key improvement recommended.

4.0 RELATED STUDIES

The 10- to 12-second starting time imposed by the typical plant Technical Specification is the result of 10 CFR 50, Appendix A, requirements which define a conservative approach to the calculation basis for a large-break loss of coolant accident (LOCA) with a coincident loss-of-offsite-power. Recently, the NRC outlined a new, more realistic, approach for performing LOCA analyses. Under sponsorship of the Nuclear Safety Analysis Center (NSAC), studies were performed by General Electric (Muralidharan 1986) and Westinghouse (Schwarz 1988) to investigate the implications of this more realistic analysis and calculation method for the emergency diesel generator starting time. Both studies revealed that considerable relaxation of the current 10-second starting time requirements may be possible.

4.1 SUMMARY OF BWR DIESEL STARTING TIME STUDY

The results of the BWR study indicated that the start time could be increased to 118 seconds in a typical BWR/6 without the peak fuel temperatures exceeding the 2200°F limit imposed by 10 CFR 50, Appendix K, for a combined LOCA and loss-of-offsite-power (LOOP). The results further show that for a 1600°F peak cladding temperature, the diesel generator start time can be 70 seconds.

Licensees have been required to use a set of guidelines established by the NRC and stated in Appendix K of 10 CFR 50. These guidelines have several built in arbitrary conservatisms. Recently, the NRC outlined in SECY-83-472 a new realistic approach for performing ECCS analysis and gave approval to General Electric to use this new approach in their SAFER/GESTR LOCA computer code. The results were published in (Muralidharan 1986) "Effect of Diesel Start Time on BWR/6 Peak Cladding Temperature Licensing Basis Sensitivity Calculations." This report addresses the sensitivity of peak cladding temperature that is determined using the realistic LOCA analysis approach outlined in SECY-83-472 for various diesel generator start durations.

SAFER/GESTR is an improved thermal-hydraulic code developed by General Electric Company and has been approved by the Nuclear Regulatory Commission

(NRC). Sensitivity/Analyses using this code, were performed to evaluate the changes in the fuel peak cladding temperature of a typical BWR/6 for various start-up durations of the Emergency Core Cooling System (ECCS), diesel/generators, and stroke-times of the associated injection valves.

4.2 SUMMARY OF PWR DIESEL STARTING TIME STUDY

In the PWR study, it was shown that the start time could be increased to 53 seconds in a typical Westinghouse four-loop plant without exceeding the 2200°F peak cladding temperature limit. The study further showed that the diesel start delay time could be increased from 10 seconds to 33 seconds with only a small increase in the peak cladding temperature (PCT) (from 1706°F to 1795°F).

The containment cooling effects of relaxed diesel start delay times were also evaluated in the study using the COCO computer code. When the maximum allowable diesel start delay times, as defined by the WCOBRA/TRAC large break LOCA analyses, were used in the containment integrity analyses, it was found that the peak containment pressure during the transient was well below the containment design pressure limit. However, the equipment qualification design envelope may be exceeded which limits the diesel start delay time to 45 seconds.

The Westinghouse study concluded that a diesel start delay of 30 seconds was defendable with currently accepted licensing calculations. Longer delays may be possible, but these would require the analysis of additional transients and improvements in analytical methods, particularly in the area of equipment qualification. The actual sensitivity of a given PWR design to diesel start delay time and the application of the results to regulatory and design limits would vary depending on the particular PWR considered. The reported calculations were done using the Appendix K revision of WCOBRA/TRAC computer code for a typical Westinghouse 4-loop PWR. The results were published in (Schwarz 1988) "The Effect of Diesel Start Time Delay on Westinghouse PWRs."

5.0 DIESEL GENERATOR MISSION ANALYSIS

The most likely backup electrical power need for nuclear power plants is when offsite ac power is lost, but the plant remains fully functional otherwise. This is the key need or mission for the Emergency Diesel Generator System. It is a single failure type of emergency condition, because a severe winter ice storm or severe winds (tornado) may disable both offsite power sources at the same time. In this case public safety is ensured if adequate ac power from any source is available in about a 5-minute time frame, since the undamaged plant is able to cope with an ac power loss for time periods of 10 minutes, or more, before damage to sensitive components would being.

A much less likely emergency electrical power need for nuclear power plants is the emergency developed when both offsite ac power is lost (LOOP event) and the plant develops a severe breach of the primary coolant boundary, or a LOCA event. Based on Section 4.0 information, ac power is needed in about 30 or more seconds for this combination of events. To put this in perspective, the U.S. nuclear power industry has never experienced a large-break loss of coolant event, with a collective exposure of over 1000 reactor-years of operation. It may be further assumed that after about 8 to 10 hours after a postulated LOCA event starts the plant will have been cooled down if normal power is available. If then a loss of ac power occurs, the emergency is essentially over as far as offsite risks to the public are concerned. In plain language, the risk is essentially non-existent for the combination LOOP and LOCA events.

It is interesting to observe that in contrast to the analysis presented in this report, that current NRC guidelines and technical specifications tend to ignore the loss of offsite power event and focus instead on the hypothetical situation where both LOOP and LOCA events occur together. Design considerations, engine purchase specifications, instrumentation logic, and periodic testing are all intended to mitigate this very rare postulated accident. Unfortunately, in doing so EDGs are subjected to many conditions that are harmful to aging and reliability concerns.

5.1 LOCA CONSIDERATIONS

A major change has been made to 10 CFR 50, General Design Criterion 4, which accepts leak-before-break analysis and detection for all large-diameter primary system piping. In essence, the LOCA event no longer has to be a design concern for piping hangers, supports, snubbers and the piping system. However, this LOCA event design relaxation has not been extended to the emergency diesel generator system, nor to equipment qualification. Therefore the present EDG system large-break LOCA operating conditions should be retained for EDG design requirements and qualification purposes. But, as discussed in the mission analysis and for aging concerns, there is little justification to continue with the routine testing of EDG equipment for fast-starting and rapid-loading capabilities associated with the large-break LOCA conditions.

5.2 STATION BLACKOUT CONSIDERATIONS

Diesel generator reliability has always been a concern of the NRC staff and previous U.S. regulatory administrations. In 1985, Generic Safety Issue GSI B-56, "Diesel Reliability" had the highest safety priority in NUREG-0933, "A Prioritization of Generic Safety Issues."

In response to these historical conditions, the NRC staff has acted by the issue of Regulatory Guide 1.155, "Station Blackout" in August, 1988 which identifies a need for a reliability program. This reliability program for emergency diesel generators is designed to maintain and monitor reliability levels selected for compliance with the Station Blackout Rule 10 CFR 50.63.

Regulatory Guide 1.9, Revision 3, "Section, Design, Qualification, Testing, and Reliability of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants" is in the final NRC approval process. It integrates into a single guide pertinent guidance previously addressed in Regulatory Guides 1.108, 1.9, Revision 2 and Generic Letter 84-15. Regulatory Guide 1.108 will be withdrawn after the issue of Regulatory Guide 1.9, Revision 3 which is consistent with industry guidance contained in NUMARC-8700, Appendix D. These two guides have resolved GSI B-56.

In Regulatory Guide 1.9, Revision 3 many prior operational and testing practices that were found to be harmful to engine reliability and life, such as cold fast starts, have been deleted. The development of this regulatory guide utilized information obtained through the NPAR Program, Diesel Generator Task. This same information should be applied to any revision of the plant Standard Technical Specifications.

5.3 SUMMARY OF MOST LIKELY MISSION RESPONSE NEEDS

With over 1000 reactor years of operation in U.S. regulatory history without a large-break LOCA event for primary water containment and with the recent 10 CFR 50 General Design Criterion 4 (leak-before-break) rulemaking, it may be concluded that the true mission envelope for the diesel-generator may be considered with consequential benefits. The most realistic mission envelope envisioned from the analysis of the NPAR diesel aging study data is:

- Reliability
  --very high, greater than 0.95 for each engine
- Duration
  --three to four days appears adequate
- Start Time
  --thirty seconds is an acceptable compromise with conservative margins. If Leak-Before-Break considerations are extended to the EDG system, within 1 minute should be acceptable.
- Engine Load
  --The emergency ac electrical load for the best practice design should be in the range of 70 to 90% of the EDG continuous rating.
  --For testing the load should be the emergency ac electrical load or 90% of the continuous rating, whichever is less.
- Start and Load Time
  --for design and qualification, about 100 seconds (BWRs)
  --for design and qualification, about 50 seconds (PWRs)
  --for routine testing, rapid loading should be avoided (recommended gradual loading over a time of 5 to 15 minutes or more)
  --for six months or outage testing, same as design and qualification time [if General Design Criterion No. 4 (leak-before-break) is further relaxed to include emergency power, fast-starts may be eliminated].

6.0 OTHER REGULATORY OPTIONS FOR SAFETY AND CONTROL

Regulatory bodies have responsibilities to exercise control to ensure public safety. In the nuclear industry regulators have options to exercise this control by use of various levels of overview. Conceptually, these levels may be viewed as a pyramid with the plant procedures at the bottom. The next levels are industry standards and guides, then regulatory guides, and finally technical specifications at the top of the pyramid. Of course this illustration could include many other types of NRC related documents such as FSARs, Notices, Bulletins, and others, but these do not seem to be true alternatives to the type of control information given in technical specifications.

It would be presumptuous for a technical evaluation report to specify which diesel generator concerns belong in each category of procedures, standards, regulatory guides, or technical specifications. However, it may be helpful to apply the insights and risk perceptions obtained in the diesel generator research study to indicate which general items belong next to the top and which are relatively unimportant and should be near the plant procedures at the bottom.

The general intent of the improvement program that the NRC is acting on for the Standard Technical Specifications is to simplify them and to eliminate requirements that have no important safety role. The EDG research on diesels also noted that plant personnel were aware of the increasing difficulties in making changes that would tend to improve safety, increasingly as the change progressed up the pyramid concept discussed above. Plant procedure changes took effort, but they were done most often. If the change affected a technical specification requirement, then it was rarely attempted, even when safety and reliability benefits may have appeared obvious to the plant personnel. The implication of this observation is that the NRC staff collectively can effectively increase safety by ensuring that regulatory control is placed at the right level and it is no higher than necessary.

6.1 TECHNICAL SPECIFICATIONS

The number of ac sources, their independence, and the limiting conditions for operations have the utmost importance and these control elements directly influence public risk. These are obvious illustrations for proper specification control elements. Other items with higher risk significance include the following:

- Engine load rating (i.e., continuous rating).
- Fuel oil gross tank capacity.
- Needed electrical output parameters, voltage, frequency, etc.
- Reliability category selected i.e., 0.95 or 0.975.
- Desired emergency EDG starting and loading times, electrical loads and sequence, fuel oil inventory levels, and related parameters.
- Desired EDG test conditions; startup, loading schedule and permitted prelube and post-test operation schedules.
- The scope of surveillance; daily, monthly, refueling and 10-year periods.

6.2 REGULATORY GUIDES AND INDUSTRY STANDARDS

Regulatory guides and industry standards are good options for items of lessor importance, these may include:

- engine qualification and design standards
- important definitions and scope diagrams for the system
- surveillance test details, test descriptions, and guidelines
- reliability improvement practices
- reliability measurement guidelines
- reporting requirements
- descriptions of EDG control logic needs.

6.3 PLANT PROCEDURES

Plant procedures are subject to rigorous approvals by the plant staff and are subject to additional NRC overview at the plant, region, and national levels. Plant procedures should supply the important supporting details for plant operations, maintenance, testing, and other EDG concerns. Examples of these control elements are:

- Tests of non-safety related equipment such as EDG frequency synchronization equipment and load transfer tests.
- Maintenance and test procedures.
- Test parameters for EDG condition monitoring, temperatures, pressures, and flows.
- Engine lockout, protective trips for plant equipment, and plant personnel safety concerns.

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