

October 4, 1989

Docket Nos. 50-275  
and 50-323

Mr. J. D. Shiffer, Vice President  
Nuclear Power Generation  
c/o Nuclear Power Generation, Licensing  
Pacific Gas and Electric Company  
77 Beale Street, Room 1451  
San Francisco, California 94106

Dear Mr. Shiffer:

DISTRIBUTION:  
Region V (4)  
Docket File  
NRC & LPDRs  
PDV Reading  
GHolahan  
MVirgilio  
JLee  
HRood  
OGC  
DHagan  
EJordan

RBarrett  
NChokshi  
TMeek (8)  
WandaJones  
JCalvo  
ACRS (10)  
GPA/PA  
OC/LFMB  
FRosa  
JKnight  
JKnox  
GKelly

SUBJECT: ISSUANCE OF AMENDMENTS (TAC NOS. 73109 AND 73110)

The Commission has issued the enclosed Amendment No. 44 to Facility Operating License No. DPR-80 and Amendment No. 43 to Facility Operating License No. DPR-82 for the Diablo Canyon Power Plant (DCPP), Units 1 and 2, respectively. The amendments change the combined Technical Specifications (TS) in response to your application dated May 12, 1989, as supplemented by letters dated May 11, July 3, July 18, and September 5, 1989 (Reference LAR 89-05).

The amendments revise the TS for DCPP to change the diesel generator (DG) allowed outage time (AOT) from 72 hours to 7 days. Prior to installation of the sixth DG, this change would apply only to the swing diesel generator (DG 1-3) for performance of preplanned preventive maintenance. After the sixth DG is installed and operational (scheduled for December 1991), the 7-day AOT would apply to all DGs.

A copy of the related Safety Evaluation is enclosed. Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

original signed by Harry Rood

Harry Rood, Senior Project Manager  
Project Directorate V  
Division of Reactor Projects - III,  
IV, V and Special Projects  
Office of Nuclear Reactor Regulation

Enclosures:

1. Amendment No. 44 to DPR-80
2. Amendment No. 43 to DPR-82
3. Safety Evaluation
4. BNL Report

cc w/enclosures:  
See next page

DRSP/PD5  
JLee  
09/11/89

DRSP/PD  
HRood  
09/11/89

DREP/PD5  
RJBarrett  
09/11/89

OGC  
09/13/89

DRSP/PD5  
GKnox  
09/02/89

DOEA/BC:TSB  
JCalvo  
09/26/89

8910180111 891004  
PDR ADDOCK 05000275  
FDC



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

October 4, 1989

Docket Nos. 50-275  
and 50-323

Mr. J. D. Shiffer, Vice President  
Nuclear Power Generation  
c/o Nuclear Power Generation, Licensing  
Pacific Gas and Electric Company  
77 Beale Street, Room 1451  
San Francisco, California 94106

Dear Mr. Shiffer:

SUBJECT: ISSUANCE OF AMENDMENTS (TAC NOS. 73109 AND 73110)

The Commission has issued the enclosed Amendment No. 44 to Facility Operating License No. DPR-80 and Amendment No. 43 to Facility Operating License No. DPR-82 for the Diablo Canyon Power Plant (DCPP), Units 1 and 2, respectively. The amendments change the combined Technical Specifications (TS) in response to your application dated May 12, 1989, as supplemented by letters dated May 11, July 3, July 18, and September 5, 1989 (Reference LAR 89-05).

The amendments revise the TS for DCPP to change the diesel generator (DG) allowed outage time (AOT) from 72 hours to 7 days. Prior to installation of the sixth DG, this change would apply only to the swing diesel generator (DG 1-3) for performance of preplanned preventive maintenance. After the sixth DG is installed and operational (scheduled for December 1991), the 7-day AOT would apply to all DGs.

A copy of the related Safety Evaluation is enclosed. Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

A handwritten signature in cursive script that reads "Harry Rood".

Harry Rood, Senior Project Manager  
Project Directorate V  
Division of Reactor Projects - III,  
IV, V and Special Projects  
Office of Nuclear Reactor Regulation

Enclosures:

1. Amendment No. 44 to DPR-80
2. Amendment No. 43 to DPR-82
3. Safety Evaluation
4. BNL Report

cc w/enclosures:  
See next page

Mr. J. D. Shiffer  
Pacific Gas and Electric Company

Diablo Canyon

cc:

Richard F. Locke, Esq.  
Pacific Gas & Electric Company  
Post Office Box 7442  
San Francisco, California 94120

NRC Resident Inspector  
Diablo Canyon Nuclear Power Plant  
c/o U.S. Nuclear Regulatory Commission  
P. O. Box 369  
Avila Beach, California 93424

Ms. Sandra A. Silver  
660 Granite Creek Road  
Santa Cruz, California 95065

Bruce Norton, Esq.  
c/o Richard F. Locke, Esq.  
Pacific Gas and Electric Company  
Post Office Box 7442  
San Francisco, California 94120

Mr. Peter H. Kaufman  
Deputy Attorney General  
State of California  
110 West A Street, Suite 700  
San Diego, California 92101

Dr. R. B. Ferguson  
Sierra Club - Santa Lucia Chapter  
Rocky Canyon Star Route  
Creston, California 93432

Managing Editor  
The County Telegram Tribune  
1321 Johnson Avenue  
P. O. Box 112  
San Luis Obispo, California 93406

Chairman  
San Luis Obispo County Board of  
Supervisors  
Room 270  
County Government Center  
San Luis Obispo, California 93408

Ms. Nancy Culver  
192 Luneta Street  
San Luis Obispo, California 93401

Regional Administrator, Region V  
U.S. Nuclear Regulatory Commission  
1450 Maria Lane, Suite 210  
Walnut Creek, California 94596

Michael M. Strumwasser, Esq.  
Special Assistant Attorney General  
State of California  
Department of Justice  
3580 Wilshire Boulevard, Room 800  
Los Angeles, California 90010

Mr. John Hickman  
Senior Health Physicist  
Environmental Radioactive Mgmt. Unit  
Environmental Management Branch  
State Department of Health Services  
714 P Street, Room 616  
Sacramento, California 95814



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

PACIFIC GAS AND ELECTRIC COMPANY  
DIABLO CANYON NUCLEAR POWER PLANT, UNIT 1  
DOCKET NO. 50-275  
AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 44  
License No. DPR-80

1. The Nuclear Regulatory Commission (the Commission) has found that:
  - A. The application for amendment by Pacific Gas & Electric Company (the licensee), dated May 12, 1989, as supplemented by letters dated May 11, July 3, July 18, and September 5, 1989 complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR Chapter I;
  - B. The facility will operate in conformity with the application, the provisions of the Act, and the regulations of the Commission;
  - C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;
  - D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and
  - E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.


2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and paragraph 2.C.(2) of Facility Operating License No. DPR-80 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A and the Environmental Protection Plan contained in Appendix B, as revised through Amendment No. 44, are hereby incorporated in the license. Pacific Gas & Electric Company shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan, except where otherwise stated in specific license conditions.

3. This license amendment becomes effective at the date of its issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

  
George W. Knighton, Director  
Project Directorate V  
Division of Reactor Projects - III,  
IV, V and Special Projects  
Office of Nuclear Reactor Regulation

Attachment:  
Changes to the Technical  
Specifications

Date of Issuance: October 4, 1989



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

PACIFIC GAS AND ELECTRIC COMPANY  
DIABLO CANYON NUCLEAR POWER PLANT, UNIT 2  
DOCKET NO. 50-323  
AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 43  
License No. DPR-82

1. The Nuclear Regulatory Commission (the Commission) has found that:
  - A. The application for amendment by Pacific Gas & Electric Company (the licensee), dated May 12, 1989, as supplemented by letters dated May 11, July 3, July 18, and September 5, 1989 complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR Chapter I;
  - B. The facility will operate in conformity with the application, the provisions of the Act, and the regulations of the Commission;
  - C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;
  - D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and
  - E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.


2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and paragraph 2.C.(2) of Facility Operating License No. DPR-82 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A and the Environmental Protection Plan contained in Appendix B, as revised through Amendment No. 43, are hereby incorporated in the license. Pacific Gas & Electric Company shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan, except where otherwise stated in specific license conditions.

3. This license amendment becomes effective at the date of its issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

  
George W. Knighton, Director  
Project Directorate V  
Division of Reactor Projects - III,  
IV, V and Special Projects  
Office of Nuclear Reactor Regulation

Attachment:  
Changes to the Technical  
Specifications

Date of Issuance: October 4, 1989

ATTACHMENT TO LICENSE AMENDMENT NOS. 44 AND 43  
FACILITY OPERATING LICENSE NOS. DPR-80 and DPR-82  
DOCKET NOS. 50-275 AND 50-323

Replace the following pages of the Appendix "A" Technical Specifications with the attached pages. The revised pages are identified by Amendment number and contain vertical lines indicating the areas of change. Overleaf pages are also included, as appropriate.

Remove Page

3/4 8-1  
3/4 8-2  
3/4 8-3  
3/4 8-4  
B 3/4 8-1  
B 3/4 8-2

Insert Page

3/4 8-1  
3/4 8-2  
3/4 8-3  
3/4 8-4  
B 3/4 8-1  
B 3/4 8-2



### 3/4.8 ELECTRICAL POWER SYSTEMS

#### 3/4.8.1 A.C. SOURCES

##### OPERATING

#### LIMITING CONDITION FOR OPERATION

---

3.8.1.1 As a minimum, the following A.C. electrical power sources shall be OPERABLE:

- a. Two independent circuits (one with delayed access) between the offsite transmission network and the Onsite Class 1E Distribution System, and
- b. Three separate and independent diesel generators,\* each with:
  1. A separate engine-mounted fuel tank containing a minimum volume of 200 gallons of fuel, and
  2. Two supply trains of the Diesel Fuel Oil Storage and Transfer System with a combined storage of 31,023 gallons of fuel for one unit operation and 52,046 gallons of fuel for two unit operation.

APPLICABILITY: MODES 1, 2, 3, and 4.

##### ACTION:

- a. With one offsite circuit of the above required A.C. electrical power sources inoperable, demonstrate the OPERABILITY of the remaining A.C. sources by performing Specification 4.8.1.1.1a. within 1 hour and at least once per 8 hours thereafter. If each of the diesel generators have not been successfully tested within the past 24 hours demonstrate its OPERABILITY by performing Specification 4.8.1.1.2a.2) separately for each such diesel generator within 24 hours. Restore the offsite circuit to OPERABLE status within 72 hours or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.
- b. With a diesel generator of the above required A.C. electrical power sources inoperable, demonstrate the OPERABILITY of the A.C. offsite sources by performing Specification 4.8.1.1.1a within 1 hour and at least once per 8 hours thereafter; and if the diesel generator became inoperable due to any cause other than preventive maintenance or

---

\*For a five diesel generator configuration, OPERABILITY of the third (common) diesel generator shall include the capability of functioning as a power source for the required unit upon automatic demand from that unit.

## ELECTRICAL POWER SYSTEMS

### LIMITING CONDITION FOR OPERATION

#### ACTION (Continued)

testing, demonstrate the OPERABILITY of the remaining OPERABLE diesel generators by performing Specification 4.8.1.1.2a.2) within 24 hours\*; restore the diesel generator to OPERABLE status within 7 days\*\* or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

- c. With one offsite circuit and one diesel generator of the above required A.C. electrical power sources inoperable, demonstrate the OPERABILITY of the remaining A.C. sources by performing Specification 4.8.1.1.1a. within 1 hour and at least once per 8 hours thereafter; and if the diesel generator became inoperable due to any cause other than preventive maintenance or testing, demonstrate the OPERABILITY of the remaining OPERABLE diesel generators by performing Specification 4.8.1.1.2a.2) within 8 hours; restore at least one of the inoperable sources to OPERABLE status within 12 hours or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours. Restore the other A.C. power source (offsite circuit or diesel generator) to OPERABLE status in accordance with ACTION a. or b., as appropriate with the time requirement of that ACTION statement based on the time of initial loss of the remaining inoperable A.C. power source. A successful test of diesel OPERABILITY per Specification 4.8.1.1.2a.2) performed under this ACTION statement for OPERABLE diesels or a restored to OPERABLE diesel satisfies the diesel generator test requirement of ACTION a. or b.
- d. With one diesel generator inoperable in addition to ACTION b. or c. above verify that:
  1. All required systems, subsystems, trains, components and devices that depend on the remaining OPERABLE diesel generators as a source of emergency power are also OPERABLE, and
  2. When in MODE 1, 2, or 3 that at least two auxiliary feedwater pumps are OPERABLE.If these conditions are not satisfied within 2 hours be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

---

\*This test is required to be completed regardless of when the inoperable diesel generator is restored to operability.

\*\*For a five diesel generator configuration, the inoperable diesel generator shall be returned to OPERABLE status within 72 hours. However, once per calendar year, the third (common) diesel generator may be inoperable for up to 7 days for preplanned preventive maintenance and testing provided one unit is in Mode 5 or 6 and the other four diesel generators are OPERABLE. Surveillance Requirements 4.8.1.1.1a and 4.8.1.1.2a.4 shall be performed within 48 hours prior to removal of Diesel Generator 3 from service. During the 7 day period the remaining four diesel generators shall be verified OPERABLE at least once per 24 hours (in addition to any testing required by Table 4.8-1). In the event these conditions are not met, the unit in Mode 1, 2, 3, or 4 will be placed in HOT SHUTDOWN within 12 hours and COLD SHUTDOWN within the following 24 hours. The provisions of Technical Specification 3.0.4 do not apply.

## ELECTRICAL POWER SYSTEMS

### SURVEILLANCE REQUIREMENTS

4.8.1.1.1 Each of the above required independent circuits between the offsite transmission network and the Onsite Class 1E Distribution System shall be:

- a. Determined OPERABLE at least once per 7 days by verifying correct breaker alignments, indicated power availability, and
- b. Demonstrated OPERABLE at least once per 18 months during shutdown by:
  - 1) Transferring 4 kV vital bus power supply from the normal circuit to the alternate circuit (manually and automatically) and to the delayed access circuit (manually), and
  - 2) Verifying that on a Safety Injection test signal, without loss of offsite power, the preferred, immediate access offsite power source energizes the emergency busses with permanently connected loads and energizes the auto-connected emergency (accident) loads through sequencing timers.

4.8.1.1.2 Each diesel generator\* shall be demonstrated OPERABLE:

- a. In accordance with the frequency specified in Table 4.8-1 on a STAGGERED TEST BASIS by:\*\*
  - 1) Verifying the fuel level in the engine-mounted fuel tank,
  - 2) Verifying the diesel starts from ambient condition and accelerates to at least 900 rpm in less than or equal to 10 seconds. The generator voltage and frequency shall be  $4160 \pm 420$  volts and  $60 \pm 1.2$  Hz within 13 seconds after the start signal. The diesel generator shall be started for this test by using one of the following signals:
    - a) Manual, or
    - b) Simulated loss of offsite power by itself (Startup bus undervoltage), or
    - c) A Safety Injection actuation test signal by itself.

\*For a five diesel generator configuration, tests of Diesel Generator 3 to satisfy the frequency specified in Table 4.8-1 and in Surveillance Requirement 4.8.1.1.2b for one unit may be counted in determining whether the frequency specified in Table 4.8-1 and in Surveillance Requirement 4.8.1.1.2b for the other unit is satisfied. Unit-specific portions of this Surveillance Requirement for Diesel Generator 3 shall be performed on an alternating schedule with signals from Units 1 and 2.

\*\*All diesel generator starts for the purpose of this surveillance test may be preceded by an engine prelube period. Further, all surveillance tests, with the exception of once per 184 days, may also be preceded by warmup procedures (e.g., gradual acceleration and/or gradual loading > 150 sec) as recommended by the manufacturer so that the mechanical stress and wear on the diesel engine is minimized.

## ELECTRICAL POWER SYSTEMS

### SURVEILLANCE REQUIREMENTS (Continued)

---

- 3) Verifying the generator is synchronized, loaded to greater than or equal to 2484 kW in less than or equal to 60 seconds, and operates for greater than or equal to 60 minutes,
  - 4) Verifying the diesel generator is aligned to provide standby power to the associated emergency busses,\* and
  - 5) Verifying the diesel engine protective relay trip cutout switch is returned to the cutout position following each diesel generator test.
- b. At least once per 18 months during shutdown\*\*, by:
- 1) Subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service;
  - 2) Verifying that the load sequence timers are OPERABLE with each load sequence timer within the limits specified in Table 4.8-2;
  - 3) Verifying the generator capability to reject a load of greater than or equal to 508 kW while maintaining voltage at  $4160 \pm 420$  volts and frequency at  $60 \pm 3$  Hz;
  - 4) Verifying the generator capability to reject a load of greater than or equal to 2484 kW without tripping. The generator voltage shall not exceed 4580 volts during and following the load rejection;
  - 5) Simulating a loss of offsite power by itself, and:
    - a) Verifying de-energization of the emergency busses and load shedding from the emergency busses, and
    - b) Verifying the diesel starts on the auto-start signal, energizes the emergency busses with permanently connected loads within 10 seconds, energizes the required auto-connected loads through sequencing timers and operates for greater than or equal to 5 minutes while its generator is loaded with the permanent and auto-connected loads. After energization of these loads, the steady state voltage and frequency of the emergency busses shall be maintained at  $4160 \pm 420$  volts and  $60 \pm 1.2$  Hz during this test.

---

\*For a five diesel generator configuration, this may be the associated bus in the other unit if that unit is in MODE 1, 2, 3 or 4.

\*\*For a five diesel generator configuration, these surveillance requirements can be performed on the third (common) diesel generator with only one unit shutdown.

### 3/4.8 ELECTRICAL POWER SYSTEMS

#### BASES

#### 3/4.8.1, 3/4.8.2, and 3/4.8.3 A.C. SOURCES, D.C. SOURCES, and ONSITE POWER DISTRIBUTION

The OPERABILITY of the A.C. and D.C. power sources and associated distribution systems during operation ensures that sufficient power will be available to supply the safety-related equipment required for: (1) the safe shutdown of the facility, and (2) the mitigation and control of accident conditions within the facility. The minimum specified independent and redundant A.C. and D.C. power sources and distribution systems satisfy the requirements of General Design Criterion 17 of Appendix A to 10 CFR Part 50.

The ACTION requirements specified for the levels of degradation of the power sources provide restriction upon continued facility operation commensurate with the level of degradation. The OPERABILITY of the power sources is consistent with the initial condition assumptions of the safety analyses and is based upon maintaining sufficient redundancy of the onsite A.C. and D.C. power sources and associated distribution systems OPERABLE during accident conditions coincident with an assumed loss-of-offsite power and single failure of one onsite A.C. source. The A.C. and D.C. source allowable out-of-service times are based on Regulatory Guide 1.93, "Availability of Electrical Power Sources," December 1974 except for the allowed outage time associated with Action Statement b. of Specification 3.8.1.1. This allowed outage time was changed to be consistent with the recommendation of Diablo Canyon Power Plant Diesel Generator Allowed Outage Time Study, May 1989. When one diesel generator is inoperable, there is an additional ACTION requirement to verify that all required systems, subsystems, trains, components and devices, that depend on the remaining OPERABLE diesel generators as a source of emergency power, are also OPERABLE, and that at least two auxiliary feedwater pumps are OPERABLE. This requirement is intended to provide assurance that a loss-of-offsite power event will not result in a complete loss of safety function of critical systems during the period one of the diesel generators is inoperable. The footnote to Action Statement b. allows the third (common) diesel generator to be inoperable for up to 7 days for preplanned preventive maintenance and testing provided one unit is in Mode 5 or 6. Compensatory measures are required including verification that the remaining diesel generators are OPERABLE. The term, verify, as used in both of these contexts means to administratively check by examining logs or other information to determine if certain components are out-of-service for maintenance or other reasons. It does not mean to perform the surveillance requirements needed to demonstrate the OPERABILITY of the component.

The OPERABILITY of the minimum specified A.C. and D.C. power sources and associated distribution systems during shutdown and refueling ensures that: (1) the facility can be maintained in the shutdown or refueling condition for extended time periods, and (2) sufficient instrumentation and control capability is available for monitoring and maintaining the facility status.

The design of the 125-volt D.C. distribution system is such that a battery can have associated with it a full capacity charger powered from it associated 480-volt vital bus or an alternate full capacity charger powered from another 480-volt vital bus. Technical Specification 3.8.2.1 ACTION c. limits operation in the latter configuration to 14 days. Technical Specification 3.8.3.1 requires either charger be OPERABLE.

The Surveillance Requirements for demonstrating the OPERABILITY of the diesel generators are in accordance with the recommendations of Regulatory

## ELECTRICAL POWER SYSTEMS

### BASES

---

#### A.C. SOURCES, D.C. SOURCES, and ONSITE POWER DISTRIBUTION (Continued)

Guides 1.9, "Selection of Diesel Generator Set Capacity for Standby Power Supplies," March 10, 1971, 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants," Revision 1, August 1977, where applicable, and 1.137 "Fuel Oil Systems for Standby Diesel Generators," Revision 1, October 1979, where applicable. For the five diesel generator configuration, the third (common) diesel generator is designed to respond to a Safety Injection Signal from either Unit 1 or Unit 2. If the capability to respond to a Safety Injection Signal from one unit is maintained during surveillance testing on the other unit, then the third (common) diesel generator shall be considered to be OPERABLE for that unit.

The Surveillance Requirements for demonstrating the OPERABILITY of the batteries are based on the recommendations of Regulatory Guide 1.129, "Maintenance Testing and Replacement of Large Lead Storage Batteries for Nuclear Power Plants," February 1978, and IEEE Std 450-1980, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations."

Verifying average electrolyte temperature above the minimum for which the battery was sized, total battery terminal voltage onfloat charge, connection resistance values and the performance of battery service and discharge tests ensures the effectiveness of the charging system, the ability to handle high discharge rates and compares the battery capacity at that time with the rated capacity.

Table 4.8-3 specifies the normal limits for each designated pilot cell and each connected cell for electrolyte level, float voltage and specific gravity. The limits for the designated pilot cells float voltage and specific gravity, greater than 2.13 volts and 0.015 below the manufacturer's full charge specific gravity or a battery charger current that had stabilized at a low value, is characteristic of a charged cell with adequate capacity. The normal limits for each connected cell for float voltage and specific gravity, greater than 2.13 volts and not more than 0.020 below the manufacturer's full charge specific gravity with an average specific gravity of all the connected cells not more than 0.010 below the manufacturer's full charge specific gravity, ensures the OPERABILITY and capability of the battery.

Operation with a battery cell's parameter outside the normal limit but within the allowable value specified in Table 4.8-3 is permitted for up to 7 days. During this 7-day period: (1) the allowable values for electrolyte level ensures no physical damage to the plates with an adequate electron transfer capability; (2) the allowable value for the average specific gravity of all the cells, not more than 0.020 below the manufacturer's recommended full charge specific gravity ensures that the decrease in rating will be less than the safety margin provided in sizing; (3) the allowable value for an individual cell's specific gravity ensures that an individual cell's specific gravity



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION  
RELATED TO AMENDMENT NO. 44 TO FACILITY OPERATING LICENSE NO. DPR-80  
AND AMENDMENT NO. 43 TO FACILITY OPERATING LICENSE NO. DPR-82  
PACIFIC GAS AND ELECTRIC COMPANY  
DIABLO CANYON NUCLEAR POWER PLANT, UNIT NOS. 1 AND 2  
DOCKET NO. 50-275 AND 50-323

1.0 INTRODUCTION

By letter dated May 12, 1989, as revised by letter dated July 3, 1989 and supplemented by letters dated May 11, July 3, and September 5, 1989 (Reference LAR 89-05), Pacific Gas and Electric Company (PG&E or the licensee) requested amendments to the combined Technical Specifications (TS) appended to Facility Operating License Nos. DPR-80 and DPR-82 for the Diablo Canyon Power Plant (DCPP), Unit Nos. 1 and 2, respectively.

The original letter of May 12, 1989 requested that the allowed outage time (AOT) for any diesel generator (DG) be changed from 72 hours to 7 days. This request was supported by a probabilistic risk assessment (PRA) which was described in PG&E's submittal of May 11, 1989. In the May 12, 1989 amendment request, PG&E stated that it planned to install a sixth diesel generator at Diablo Canyon, thereby superseding the current five-diesel arrangement, in which there is one "swing" diesel that is shared between the two units. After the sixth diesel is installed, each unit will be served by three dedicated diesels, thus eliminating the need for a swing diesel generator. The sixth diesel is scheduled to be installed at the fourth refueling outage for Unit 2, which is currently planned for the fall of 1991.

The proposed amendments were discussed in a meeting between the NRC staff and PG&E on May 23, 1989 in Rockville, Maryland. As a result of the discussions at the meeting and subsequent telephone discussions with the staff, PG&E modified that part of its proposed TS change that is applies to the current, five-diesel configuration. By letter dated July 3, 1989, PG&E proposed that, prior to the installation of the sixth diesel, only the swing diesel be allowed to be taken out of service for 7 days, only once per year, and only to perform preplanned maintenance. Except for this once a year, 7 day outage for the swing diesel, the five diesels will be restricted to the current 72 hour AOT. When the swing diesel is inoperable as a result of preplanned maintenance, several compensatory measures were proposed by PG&E to verify the operability and availability of certain safety-related equipment.

The various changes proposed by PG&E have been categorized into three cases, which have been evaluated separately. These are:

- Case 1. The current 5 diesel generator configuration with the allowed outage time increased from 3 to 7 days for unplanned maintenance on all diesel generators. This was proposed in the May 12, 1989 PG&E letter. After discussion with the NRC staff, PG&E withdrew this proposal in its July 3, 1989 letter.
- Case 2. The current 5 diesel generator configuration with the allowed outage time increased from 3 to 7 days for periodic, preplanned preventive maintenance on the swing diesel generator. This case was proposed by the July 3, 1989 PG&E letter.
- Case 3. The future 6 diesel generator configuration with the allowed outage time increased from 3 to 7 days for unplanned maintenance on all diesel generators. This case was proposed by PG&E's May 12, 1989 letter and was not changed by the July 3, 1989 letter.

The NRC staff has reviewed the proposed changes, as revised by PG&E's letter of July 3, 1989 (i.e., Cases 2 and 3, above), and the supporting information submitted by PG&E letters dated May 11, July 18, and September 5, 1989, and has found the proposed changes to be acceptable. The bases for the staff's findings, including the staff's negative finding for Case 1, are given below. The information contained in the PG&E letters dated July 12, and September 5, 1989 did not change the staff's proposed determination of no significant hazards consideration published in the Federal Register on July 26, 1989 at 54 FR 31109.

The staff evaluation presented below quotes the results of the PG&E probabilistic risk analyses (PRA). Information on the PRA was submitted by PG&E letters dated May 11, July 18, and September 5, 1989. In order to verify PG&E's PRA results, the NRC staff hired a contractor, Brookhaven National Laboratories (BNL), to perform an independent review and analysis. The BNL report evaluating PG&E's diesel generator allowed outage time study is enclosed. The BNL findings and conclusions support those reported by PG&E, and may be summarized as follows:

- A. The risk reduction (core damage frequency) effect of adding the sixth DG is greater than the effect of changing to a seven day AOT.
- B. The effect on risk of changing from a three day to a seven day AOT is insignificant, on the order of two to three percent.
- C. The increase of the risk associated with a seven day AOT over a three day AOT for performing scheduled maintenance on the swing diesel is also insignificant; less than three percent.



## 2.0 EVALUATION:

Case 1: The current 5 diesel generator configuration with the allowed outage time increased from 3 to 7 days for unplanned maintenance on all diesel generators.

The results of the licensee's Probabilistic Risk Analysis (PRA), presented in Table 4-4 of PG&E's May 11, 1989 Diesel Generator Allowed Outage Time Study, shows a of  $2.078\text{E-}04/\text{yr}$  core damage frequency (CDF) risk level for the 3 day and a  $2.120\text{E-}04/\text{yr}$  CDF for the 7 day allowed outage time. These PRA results translate to a  $4.2\text{E-}06/\text{yr}$  CDF increase.

In the calculations used to establish the above PRA results, the licensee used a mean diesel generator outage time of 10 hours for the 3 day allowed outage time and 16 hours for the 7 day allowed outage time. Thus, the above  $4.2\text{E-}06/\text{yr}$  CDF increase in the level of risk reflects a change of mean diesel generator outage time from 10 to 16 hours. The licensee by letter dated July 3, 1989, withdrew the proposed Case 1 request for the reasons described below in Case 2.

Case 2: The current 5 diesel generator configuration with the allowed outage time increased from 3 to 7 days for preplanned maintenance on the diesel generator that is shared between units 1 and 2.

The results of the licensees Probabilistic Risk Analysis (PRA), presented in Table 4-4 of the May 11, 1989 Diesel Generator Allowed Time Study, shows (1) a  $2.078\text{E-}04/\text{yr}$  CDF risk level for the 3 day allowed outage time for unplanned maintenance with zero allowed outage time for preplanned preventive maintenance on the diesel generator that is shared and (2) a  $2.152\text{E-}04/\text{yr}$  CDF for the 7 day allowed outage time for unplanned maintenance with a 7 day allowed outage time for preplanned preventive maintenance on the shared diesel generator. These results translate into a  $7.4\text{E-}06/\text{yr}$  CDF increase.

The staff informed the licensee by telecon that this  $7.4\text{E-}06/\text{yr}$  increase in core damage frequency was not acceptable and that further measures were needed to compensate for the increased risk. In response, the licensee, by letter dated July 3, 1989, withdrew the Case 1 request for a 3 to 7 day increase in allowable outage time for unplanned maintenance on all diesel generators. With Case 1 withdrawn, the risk numbers for Case 2 improved from the  $7.4\text{E-}06/\text{yr}$  CDF to a  $3.2\text{E-}06/\text{yr}$  CDF increase. As further compensatory measures, the licensee committed to take the following actions prior to taking the shared diesel generator out for preplanned preventive maintenance.

- a. Verify that the shut down unit is in Mode 5 or 6.
- b. Verify that the motor operated disconnect for the delayed access offsite circuit for the shut down unit is disconnected.

- c. Verify operability of the offsite circuits required by TS 3.8.1.1 by checking correct breaker alignments and indicated power availability.
- d. Verify operability of the auxiliary feedwater pumps for the operating unit.
- e. Perform surveillance requirements 4.8.1.1.1a and 4.8.1.1.2a.4 within 48 hours prior to removing the shared diesel generator from service.

Further, PG&E committed to assure the that following conditions are met during the time that the shared diesel generator is out of service:

- a. No preventive maintenance will be performed on the other four diesel generators.
- b. The other diesel generators will be verified operable once per 24 hours, by examining logs or other information to verify that no components are out of service for maintenance or other reasons.
- c. Verify that the capability exists for cross-tie between units of the other diesels in accordance with the provisions of Emergency Operating Procedure EP ECA-0.3, "Restore Vital Bus."

Based on the above compensatory measures, the staff finds PG&E's request for a 7 day allowed outage time for the shared diesel generator during the Unit 1 third and fourth refueling outages to be acceptable.

Case 3: The future 6 diesel generator configuration with the allowed outage time increased from 3 to 7 days for unplanned maintenance on all diesel generators.

The results of PG&E's Probabilistic Risk Analysis (PRA), presented in Table 4-4 of the May 11, 1989 Diesel Generator Allowed Outage Time Study, shows a  $2.078\text{E-}04/\text{yr}$  CDF risk level for the 3 day allowed outage time with the current 5 diesel generator configuration and a  $2.017\text{E-}04/\text{yr}$  CDF for the 7 day allowed outage time with the future 6 diesel generator configuration. These results translate to a  $6.1\text{E-}06/\text{yr}$  CDF reduction in risk.

In the calculations used to establish the above PRA results, the licensee used a mean diesel generator outage time of 10 hours for the 3 day allowed outage time and 16 hours for the 7 day allowable outage time. Thus, the above  $6.1\text{E-}06/\text{yr}$  CDF reduction in risk primarily reflects an increase in the number of diesel generators from 5 to 6 and a change of the mean outage time from 10 to 16 hours.

Due to operational and technical specification constraints when a diesel generator is inoperable, PG&E indicated that changing from a 3 to 7 day allowed outage time should not cause a significant increase in the mean diesel generator outage time. In addition, operating experience at other utilities with the same type of diesel generator and 7 day allowed outage time have demonstrated that the mean outage time is in the range of 10 to 18 hours. Based on these considerations, one can expect the mean outage time at Diablo Canyon to remain at about 10 hours when the allowed outage time is increased from 3 to 7 days.

Based on the above considerations, the staff concludes that there is reasonable assurance that the risk associated with plant operation with a 7 day allowed outage time and 6 diesel generator configuration will be the same as or better than the risk associated with plant operation with a 3 day allowed outage time and 5 diesel generator configuration. The staff therefore finds the proposed change to be acceptable.

The licensee indicated at a March 31, 1989 meeting that with the addition of the sixth diesel generator, preplanned preventive maintenance which requires the incapacitation of a diesel generator during power operation will no longer be required and will thus only be scheduled for performance during cold shutdown and/or refueling outages. The performance of preplanned maintenance only during plant shutdown and/or refueling meets the guidelines of Regulatory Guide 1.93 and is acceptable.

### 3.0 ENVIRONMENTAL CONSIDERATION

These amendments involve changes in the installation or use of facility components located within the restricted area as defined in 10 CFR Part 20, and changes in surveillance requirements. At Diablo Canyon, the restricted area is coincident with the site boundary. We have determined that the amendments involve no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendments involve no significant hazards consideration and there has been no public comment on such finding. Accordingly, these amendments meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of these amendments.

#### 4.0 CONCLUSION

We have concluded, based on the considerations discussed above, that:  
(1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and  
(2) such activities will be conducted in compliance with the Commission's regulations and (3) the issuance of these amendments will not be inimical to the common defense and security or the health and safety of the public.

Principal Contributors: John Knox  
Nilesh Chokshi  
Glen Kelly  
Harry Rood

Dated: October 4, 1989

**A REVIEW OF THE DIABLO CANYON POWER PLANT  
DIESEL GENERATOR ALLOWED OUTAGE TIME STUDY**

**G. Bozoki  
R. Fitzpatrick  
M. Sabek**

**September 1989**

**Risk Evaluation Group  
Department of Nuclear Energy  
Brookhaven National Laboratory  
Upton, NY 11973**

**Prepared for  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555  
Contract No. DE-AC02-76CH00016  
FIN A-3958**

8910180122 891004  
PDR ADOCK 05000275  
P PDC

## I. INTRODUCTION

### I.1 Scope and Objectives

The scope of the present study is to support the NRC's effort to respond to a request by the Pacific Gas and Electric Co. (PG&E) to modify the Technical Specifications for Allowed Outage Time (AOT) for the Diesel Generators (DGs) presently operating and an additional one to be installed at its Diablo Canyon Nuclear Power Plant.

The direct objectives of this report are:

- To review the approaches applied in a supporting study, attached to the request, which analyzes the impact of the system and AOT modifications to the core damage frequency (CDF).
- To provide and to compare the results of auditing or validating calculations performed at BNL with those obtained in the PG&E study and to comment on them.

### I.2 Background

The PG&E request is supported by detailed analysis of the unavailabilities of system configurations consisting of five and six DGs under various redundancy and AOT conditions as well as an evaluation of the impacts of the modified system and AOT conditions to the CDF.

The document entitled, "Diablo Canyon Power Plant, Diesel Generator Allowed Outage Time Study,"<sup>1</sup> contains the description of the approaches used and the results of the calculations. The study extensively uses, "The Diablo Canyon Probabilistic Risk Assessment (DCPRA)"<sup>2</sup> presently under review at BNL. Additional information on the AOT study was provided by PG&E in a presentation at the NRC (June 1989) and in two letters<sup>3,4</sup> sent to BNL in regard to various review questions.

### I.3 Organization of the Report

The first part (Part 1) of the present report summarizes the results obtained by BNL in reviewing the methodology and calculations described in the AOT study.<sup>1</sup> The second part (Part 2) contains the detailed descriptions of the Diablo Canyon diesel generator, the diesel fuel transfer systems, and their PRA unavailability models.<sup>2</sup> This latter part also contains the results of a comprehensive review of the models performed recently at BNL and targeted to AOT-related aspects of the system's analysis.

Part 1 is organized as follows: Section 1 presents the proposed relaxation of Technical Specifications and briefly discusses PG&E's methodology and the results of the justification analyses. Section 2 comments on PG&E's approaches and maintenance data used. It compares the results of BNL's calculations on diesel unavailabilities (top event split fractions) obtained under various AOT conditions for both seismic and nonseismic accident sequences with those given in the AOT study. Section 3 describes the results of BNL's audit and sensitivity calculations performed by scrutinizing the CDF impact and risk ratio analyses of the AOT study. Section 4 summarizes the findings and the main conclusions of the BNL review. - Appendix I contains the prior maintenance duration distribution used in the AOT study and maintenance duration and failure rate data for various diesel generator subsystems and components.

Part 2 is essentially represented by "Letter Report-07" on the DCPRA review which is entitled, "A Review of System Analysis in the DCPRA: Diesel Generator and Diesel Fuel Transfer Systems." The description of its organization can be found in its introductory Section I.2. We note that some of the review findings include open issues at this time, however, we do not believe the resolution of these items will have an appreciable effect upon the overall PRA results and conclusions.

---

**PART 1**  
**REVIEW RESULTS OF THE DG AOT STUDY**

---



## 1. JUSTIFICATION ANALYSES FOR RELAXED TECHNICAL SPECIFICATIONS FOR DIESEL GENERATORS

For the sake of clear understanding and reader convenience, this section reiterates the Technical Specification relaxation issues requested by PG&E and provides a brief summary of the methodology and results of their justification analyses.

### 1.1 Proposed Relaxation of Technical Specifications for Diesel Generators

Currently, five DGs constitute the emergency DG system at the DCPD Units 1 and 2: two DGs dedicated to Unit 1, two DGs dedicated to Unit 2, and one, a "swing diesel" is shared between the two units. The swing diesel is physically located in Unit 1.

In order to increase the flexibility of plant operation and diesel maintenance scheduling efficiency, PG&E committed itself to install a sixth DG by the fourth refueling outage of Unit 2 (scheduled for October 1991). The sixth DG will also be an ALCO type DG like the five existing ones. With the sixth diesel installed and operable, each Diablo Canyon unit will have three dedicated DGs which will simplify the operation of the plant.

The present DCPD Technical Specifications provide a 72-hour AOT when a given unit DG is inoperable with that unit in Modes 1 through 4. When a DG becomes inoperable, the operability of the ac offsite sources must be demonstrated by performing surveillance tests within one hour and at least once per eight hours thereafter. If the DG became inoperable due to causes other than preventive maintenance or testing, the operability of the remaining DGs must be demonstrated within 24 hours (regardless of when the inoperable DG is restored to operable status). The inoperable DG must be restored to operable status within the 72-hour AOT or action must be initiated to place the unit to cold shutdown (Mode 5), where the subject limiting condition for operation (LCO) is no longer applicable.

The relaxation of the Technical Specifications (No.3.8.1.1 Action Statement b) proposed by PG&E is the following: Increase the AOT from the current three days (72-hours) to seven days (168 hours), so that corrective (non-scheduled) maintenance, inspection and post-maintenance operability testing appropriately and conveniently could be performed.

The proposal relates to both diesel configurations, the current five, as well as the planned six diesel configuration. Preventive (scheduled) maintenance (overhauls) of the dedicated DGs would be performed, as in the past, during the unit's refueling periods.

## 1.2 Methodology of the Justification Analyses

PG&E claims that the above proposed AOT relaxation is fully supported by plant experience, training of personnel on advanced diesel maintenance, recent improvements of the DGs and by the results of justification analyses described in Reference 1.

The justification analyses were directed to the assessments of two main issues:

- a. the appropriateness of a seven-day AOT for the purposes of unscheduled maintenance of the present and planned DG configurations and
- b. the safety impact of performing required scheduled maintenance of the swing diesel given a seven-day AOT.

Two approaches were used for these assessments. The first was based on the DCPRA,<sup>2</sup> thus Reference 1 and consequently the present report refer to it as the "risk analysis approach." The second was based on stand-alone fault-tree models of the current and planned DG configurations. Reference 1 as well as the present report refer to this as the "reliability analysis" approach.

The annual and relative risks were evaluated by both of the approaches. Relative risk was defined<sup>5</sup> by the ratio of the risk during the AOT to the risk

during the time interval when no DG is in maintenance or test. This "risk ratio" (RR) constrains the duration of the AOT by requiring that the ratio should be less than unity. In general, "risk" may refer to system unavailability, core damage frequency or health risks, depending on the "level" where the effect of the AOT is evaluated. The PG&E AOT study evaluated "risk" at the core damage frequency level.

The application of the reliability analysis approach by PG&E was intended to complement the risk analysis approach. A PRA usually calculates time averaged risk values; time-dependent effects (like testing) on the availability of the remaining diesels when one DG is in maintenance or staggered testing are not taken into account. In addition, the unavailability modelling of the DGs in a PRA does not usually go "deep" enough, so that failure modes of the diesel subsystems or support systems are not explicitly indicated in the model.

The time-dependent unavailability analysis was performed by PG&E on the fault tree models of the diesel systems by using the FRANTIC-ABC PC computer code.

### 1.3 Results of the Justification Analyses

Both of the approaches, risk and reliability analyses, were used to calculate the following cases:

- Base Case -- SDG configuration, three-day AOT on all DGs to perform unscheduled maintenance. The risk analysis approach addressed also performing scheduled maintenance on the swing diesel during power operation of one unit with the other unit in refueling. Total scheduled outage was assumed to be ten days (i.e., several three-day AOT periods) during a refueling period of 1.5 years. Table 2.1 contains the definitions of the calculations performed by the risk analysis approach, these calculations are denoted by 1A and 2.

- Second Case -- 5DG configuration, seven-day AOT on all DGs to perform unscheduled maintenance. The risk analysis approach also addressed performing scheduled maintenance on the swing diesel. Total scheduled outage was seven days (no multiple outages) during a refueling period of 1.5 years. In Table 2.1, these calculations are denoted by 1B and 3.
- Third Case -- 6DG configuration, seven-day AOT on all DGs to perform unscheduled maintenance. Since there is no swing diesel, scheduled maintenance can now be performed without affecting the other unit. In Table 2.1 this calculation is denoted by 4.

In order to determine the relative risk, several support calculations were carried out. Those associated with the risk analysis approach are denoted by 5 and 6 in Table 2.1. Calculation 5 analyzed the condition when no maintenance (scheduled or unscheduled) is allowed on any of the 5DGs. Calculation 6 provided the risk (5DG configuration) if the swing diesel were unavailable for the entire year (i.e., calculated the conditional core damage frequency). This calculation assumed seven-day AOT for unscheduled maintenance on other DGs.

For completeness, the results of both of the analyses, risk and reliability, are reproduced in Table 1.1 from Table 6.1 of Reference 1. Based on the data presented, PG&E concluded that:

- The risk ratio criterion is satisfied for all cases by both methods of analysis.
- The effect on risk of changing from a three-day to a seven-day AOT is insignificant; on the order of 1 to 3 percent of the CDF.
- The effect on risk of adding the sixth DG is greater than the effect of changing to a seven-day AOT with an overall decrease of the order of 5 to 15 percent in CDF. Both of the analysis approaches confirmed the appropriateness of a seven-day AOT for the purpose of performing unscheduled maintenance for both the five and six DG configurations.

- According to the results of the risk analysis approach, 1) there is a negligible increase in risk associated with a seven-day AOT over a three-day AOT with regard to performing scheduled maintenance on the swing diesel and 2) the resulting quantitative benefits of a single seven-day AOT far outweighs the risk associated with multiple three-day AOTs.

Table 1.1  
Analytical Results<sup>1</sup> for Unplanned and Planned Maintenance Activities

	<u>PRA Analysis</u>			<u>Reliability Analysis</u>	
	<u>Unplanned &amp; Planned<sup>2</sup></u>	<u>Unplanned</u>		<u>(Unplanned)</u>	
	Frequency	Frequency	Relative Ratio <sup>3</sup>	Frequency	Relative Ratio <sup>3</sup>
<u>Base Case</u>					
3-Day AOT/5 DGs (10 day Outage) <sup>2</sup>	2.12E-04	2.08E-04	0.05	LOOP 2.29E-04	0.06
				LOCA/	
				LOOP 1.10E-09	0.08
<u>Case 2</u>					
7-Day AOT/5 DGs (7 day Outage) <sup>2</sup>	2.15E-04	2.12E-04	0.08	LOOP 2.35E-04	0.08
				LOCA/	
				LOOP 1.10E-09	0.10
<u>Case 3</u>					
7-Day AOT/6 DGs (0 day) <sup>2</sup>	2.02E-04	2.02E-04	0.08	LOOP 2.00E-04	0.05
				LOCA/	
				LOOP 7.43E-10	0.13

<sup>1</sup>PRA reflects frequency for Unit 1 only, whereas reliability considers frequency for both units

<sup>2</sup>Duration of outage for planned maintenance.

<sup>3</sup>AOT Risk Level/Non-AOT Risk Level.

## 2. REVIEW OF THE RISK ANALYSIS RESULTS

### 2.1 General

After having invested some preliminary efforts to review the AOT study, BNL selected the risk analysis approach and its associated calculations and results to be the focus of our review efforts.

There were several reasons to choose this particular focused approach. These are as follows:

1. As was mentioned in the introduction, the unavailability modelling of the DG and diesel fuel transfer systems of the DCPRA were already under review by BNL (see Part 2) and therefore relevant computer software was already available for further calculations to be carried out in a timely fashion. A substantial in-depth review of the results obtained by the reliability analysis would have required audit calculations of the diesel fault trees practically starting from scratch.
2. The reliability analysis assumes four-hour mission times for the 5DG configuration (the PRA model assumes six hours for nonseismic and 24 hours for seismic events) and two hour mission times for the 6DG configuration. The use of different mission times prevents the direct comparison of the results obtained for 5DG and 6DG configurations.
3. The reliability analysis did not address seismic effects.
4. The reliability analysis approach did not address or evaluate the risk impact of the scheduled maintenance on the swing diesel.
5. The results of the reliability analysis, although numerically different from the risk analysis, supports the same conclusions as the risk analysis.

## 2.2 The Review Approach

As a first phase, the adequacy of the unavailability modelling of the DGs and diesel fuel transfer system in the DCPRA was reviewed. This was done partly in the framework of the general review of the DCPRA. The detailed results are described in Part 2 of this report. Two main observations which have to be kept in mind, however are reiterated here:

1. The diesel system analysis in the DCPRA seems to be weak in adequately representing the potential failure contributions of diesel subsystems. (The reliability analysis used a much more detailed diesel model.)
2. The unavailability contributions due to the overhauls of the other unit diesels and the swing diesel when one unit is at power were not taken into account. (In the case of the swing diesel, that is precisely the cause that additional risk calculations had to be performed in the AOT study.)

As a second phase (Part 1 of this report), the adequacy of the risk (core damage frequency) impact calculations due to changes in AOT and system redundancy were scrutinized taking into account comments 1 and 2 above.

This phase consisted of the following steps:

- a. A review of the quantities which determine the total unavailability of DGs (average total unavailability of DGs due to maintenance duration and maintenance frequency).
- b. Review and sensitivity calculations on non-seismic and seismic top event split fractions characterizing the unavailabilities of DGs under various boundary and AOT conditions. These top events appear in the support system event tree of the plant core damage frequency model.
- c. Audit and sensitivity calculations on the core damage frequencies. These were performed by propagating the audited or newly generated top



events through the dominant sequence PRA model. Table 2.1 lists the definitions of various core damage frequency calculations. New calculations made to study sensitivity or consistency are denoted by "BNL's sensitivity calculation." They will be explained later.

d. Audit of the risk ratio results.

The subsequent subsections and Section 3 describe these steps in detail.

### 2.3 Maintenance Unavailability of the DGs

In the DCPRA the AOT dependency of the diesel top events appears through a quantity called total diesel maintenance unavailability,  $P_T$ . The quantity reflects the conditions that due to Technical Specification limitations only one diesel or one Level Control Valve (LCV) of the Fuel Oil Day Tank may be in maintenance at a time (see also Part II).

Thus,  $P_T = P_{DC} + P_{LCV} - P_{DC} * P_{LCV}$ , where  $P_{DC}$  is the maintenance unavailability of the diesel itself and  $P_{LCV}$  is the maintenance unavailability of the LCV. Furthermore,  $P_{DC}$  is defined as:  $P_{DC} = ZMDGSD * ZMDGSF$ , where  $ZMDGSD = 10.1$  hours is the mean duration of the diesel maintenance; and  $ZMDGSF = 7.74 \cdot 10^{-4} \text{ hr}^{-1}$  is the mean frequency of diesel maintenance.

Similarly,  $P_{LCV} = ZMDGN3D * ZMGNDF$ , where  $ZMGN3D = 18.9$  hours is the mean duration of the LCV maintenance; and  $ZMGNDF = 2.03 \cdot 10^{-5} \text{ hr}^{-1}$  is the mean frequency of LCV maintenance. With these values  $P_{DC} = 7.817 \cdot 10^{-3}$  and  $P_{LCV} = 3.837 \cdot 10^{-4}$ , and  $P_T = 8.201 \cdot 10^{-3}$ .

The above mean maintenance duration and frequency data are AOT-dependent values. They were obtained by updating generic maintenance duration and frequency values using plant-specific data. These data were used in the "Base Case" calculations in the AOT study.

If one compares this data with those used in the reliability approach, one can observe some inconsistencies. From Table 5.7 of the AOT study<sup>1</sup> one

can easily obtain, by assuming a lognormal distribution, the following data (without updating any priors):

ZMDGSD' Median = 11.63 hours, Mean = 11.90 hours

ZMDGSF' Median =  $1.04 \cdot 10^{-3} \text{ hr}^{-1}$ , Mean =  $1.06 \cdot 10^{-3} \text{ hr}^{-1}$

P<sub>DC</sub>' Median =  $1.21 \cdot 10^{-2}$ , Mean =  $1.26 \cdot 10^{-2}$

By using the previous value for P<sub>LCV</sub>, one obtains a new value for the mean total maintenance unavailability:

$$P'_T = P_{LCV} + P'_{DG} = 1.198 \cdot 10^{-2}$$

The main cause of the inconsistency is the diesel maintenance frequency and in a lesser measure the mean maintenance duration.

Consider now the generic mean priors:

ZMDGSD<sup>P</sup> = 17 hours

ZMDGSF<sup>P</sup> =  $1.03 \cdot 10^{-3} \text{ hr}^{-1}$

ZMGN3D<sup>P</sup> = 13 hours

ZMGND<sup>P</sup> =  $2.7 \cdot 10^{-5} \text{ hr}^{-1}$

One can observe that the generic mean prior maintenance frequency almost exactly coincides with the plant-specific value (w/o update). Its not clear how the DCPRA arrived at the updated value: ZMDGSF =  $7.74 \cdot 10^{-4} \text{ hr}^{-1}$ . However, the essential problem here is that P<sub>T</sub>' seems to be the correct total unavailability and this should have been used in the "Base Case" calculations.

BNL requested additional information from PG&E about the generic prior diesel maintenance duration distribution (ZMDGSD). The distribution and its characteristic parameters are reproduced in Table I.1 of Appendix I from PG&E's answer.<sup>3</sup> The mean value of that prior is: ZMDGSD<sup>P</sup> = 10.5 hours, in apparent variance with the value given in the DCPRA (see above).

In the "Second" and "Third Case" calculations, i.e., when a 7-day AOT is considered, PG&E increased only the mean maintenance duration of the diesels. The mean maintenance frequency of the diesel was taken to be the same, as for

the 3-day AOT. For the increased value of the mean maintenance duration, PG&E took ZMDGSD = 16 hours. The selection of this value was supported by several qualitative arguments. Among others the expert opinions of the maintenance personnel. The arguments were also repeated in Reference 3. The Palisades diesel outage data were quoted as experience values. There was no reference to any other experience data source.

Also from Table 5.7 of the AOT study, one can easily obtain the Palisades values (AOT is 7-days):

$ZMDGSD_{Pal}$  Mean = 11.55 hours, Mean = 11.90 hours

$ZMDGSF_{Pal}$  Median =  $1.33 \cdot 3 \text{ hr}^{-1}$ , Mean  $1.36 \cdot 3 \text{ hr}^{-1}$

$P_{DG}^{Pal}$  Median =  $1.54 \cdot 2$ , Mean  $1.62 \cdot 2$

Thus, the mean total maintenance unavailability:

$$P_T^{Pal} = P_{LCV} + P_{DG}^{Pal} = 1.66 \cdot 2$$

The AOT study uses for the 7-day AOT (ZMDGSD = 16 hours):  $P_T = 1.277 \cdot 2$ , an underestimation of about 30% relative to the value determined based on the Palisades data. In order to obtain an independent assessment for a generic mean diesel maintenance duration, BNL used the diesel subsystem downtimes and failure rates collected in a recent EPRI study.<sup>7</sup> These downtimes are given in Table I.2 of Appendix I ranked in decreasing order. Based on these data and by assuming a lognormal maintenance duration distribution, an overall mean maintenance duration value was determined (see Appendix I). The value obtained by BNL is:

$$\overline{ZMDGSG} = 20.6 \text{ hours.}$$

Since it is considerably higher than 16 hours, one can infer that the above value of  $P_T$ ,  $P_T = 1.277 \cdot 2$  indeed may underestimate the expected mean maintenance unavailability for a 7-day AOT.

Because of the above ambiguities in the correct values of the mean maintenance duration and frequencies, it was decided that besides auditing the

risk calculations of the AOT study, additional sensitivity calculations would be performed with a bounding mean diesel maintenance duration of 24 hours and the original mean maintenance frequency of  $7.74 \times 10^{-4} \text{ hr}^{-1}$ . The corresponding range of total maintenance unavailability,  $P_T$ , extends from quite low values up to  $2.10^{-2}$ . The exact values are given in Table 2.2. The table also shows that this  $P_T$  range covers a mean maintenance duration range from 0 hours to 17.5 hours, if for the mean maintenance frequency, the reliability analysis value,  $ZMDGSF' = 1.06 \times 10^{-3} \text{ hr}^{-1}$  is taken. In Table 2.1 these calculations are denoted by 1C, 3A, 4C, and 6B.

The sensitivity calculations allowed BNL to determine an unambiguous functional relationship between the total maintenance unavailability and the diesel top event split fractions, i.e., through them the core damage frequency.

#### 2.4 Review of Top Event Split Fractions

The DCPRA defines six top events in the electric part of the support system event tree associated with the unavailability of the diesel generators. The top event definitions, boundary conditions, success criteria, their quantified values for seismic and non-seismic accident sequences, the top event split fractions, and the main contributors to the top event split fractions are thoroughly described and discussed in Part 2. For better understanding and convenience, however, the designators of the top events and their relationships with the diesels are also given here:

- Top Event GF - Diesel Generator 13 ("Swing diesel")
- Top Event GG - Diesel Generator 12
- Top Event GH - Diesel Generator 11
- Top Event 2G - Diesel Generator 21
- Top Event 2H - Diesel Generator 22
- Top Event SW - Units alignment of swing diesel, 13.

For the audit calculations of the AOT modified top events and for BNL's own sensitivity calculations, the same SETS-code<sup>8</sup> models and locally generated PC software were used which had been developed for auditing the DCPRA results. Tables 2.5 and 2.7 of Part 2 show the detailed comparison of the results of the audit calculations with those of the DCPRA and the AOT study in the "Base Case" for (3-day AOT, 10.1 hours mean maintenance duration) non-seismic and seismic split fractions.

The final results of these calculations are also listed in Tables 2.3.A and 2.3.B of this section for non-seismic and seismic split fractions, respectively. These tables also contain the results of the audit calculations for the "Second Case" (7-day AOT, 16 hour mean maintenance duration) and of the BNL's sensitivity calculation (7-day AOT, 24 hour mean maintenance duration). For comparison, the tables conveniently also list the values given by PG&E in Table 4.3 of the AOT study.<sup>1</sup>

In order to check the internal consistency of the results obtained, the various split fractions can be plotted against the Total Maintenance Unavailability,  $P_T$ . This functional representation is convenient because it allows us to interpret the results when one considers a mean diesel maintenance frequency other than the  $7.74 \cdot 4 \text{ hr}^{-1}$  offered by PG&E.

Figure 2.1 shows such a functional representation for the non-seismic top event split fractions GF1, GG3, GH6, 2GA, 2HG. The graph of these split fractions appears to be a straight line. Its extrapolation to  $P_T = 0$  provides a quite accurate graphical checking of the corresponding PG&E value given for "Zero Diesel Maintenance" calculations in Table 4.3 of the AOT study.<sup>1</sup> (Similar "graphical" spot checking "validated" other "zero maintenance" split fractions as well.)

The split fractions shown in Figure 2.1 essentially represent the unavailability of the individual diesel units in the DCPRA, when all the support systems are available (see Part II).

For comparison, the unavailabilities of DG11 and DG13 determined by the "more detailed" reliability analysis calculations are also plotted as a function of the maintenance duration. Its not clear why the PRA unavailabilities are larger (about a factor of 2) than those obtained with the reliability model, where the support system unavailabilities were not taken to be zero.<sup>2</sup>

The results of BNL's audit calculation on those top event split fractions (non-seismic and seismic) which had to be completely requantified to account for the condition when the swing diesel is unavailable, are shown in Table 2.4. (More specifically, the unscheduled maintenance duration of the other diesels given the swing diesel is inoperable is set equal to eight hours. This is based on Technical Specification 3.8.1.1 Action Statement f.) For comparison, Table 2.4 also indicates the original PG&E values. One can observe that there is a general agreement between the two calculations.

Summarizing, (disregarding the discrepancies previously identified between the results of the risk and reliability approaches in Section 2.1 and the factor of two from just above) one can say that there is an overall agreement between the BNL audit results and PG&E split fraction data. The small inconsistencies appearing here or there are presumably the consequences of the fact that BNL used point estimates, while PG&E used a Monte-Carlo approach in the split fraction quantification.



Table 2.1  
Definition of Calculations - Risk Analysis Approach

Number of Calculation	Number of DGs	Allowed Outage Time, AOT (Days)	Mean DG Maintenance Duration, MMD (Hrs)	With One Unit at Power		Notes
				Overhaul Period of Swing Diesel (Days)	Overhaul Period of DGs of the Other Unit (Days)	
5	5	**	0	0	0	Audited by BNL.
1A*	5	3	10.1	0	0	Audited by BNL.
1B	5	7	16	0	0	Audited by BNL.
1C	5	7	24	0	0	BNL's sensitivity calculation.
2	5	3	10.1	10	0	Audited by BNL.
3	5	7	16	7	0	Audited by BNL.
3A	5	7	24	7	0	BNL's sensitivity calculation.
4A	6	**	0	0	0	BNL's sensitivity calculation.
4B	6	3	10.1	0	0	BNL's sensitivity calculation.
4	6	7	16	0	0	Audited by BNL.
4C	6	7	24	0	0	BNL's sensitivity calculation.
6A	5	3	10.1	1 year	0	BNL's sensitivity calculation.
6	5	7	16	1 year	0	Audited by BNL.
6B	5	7	24	1 year	0	BNL's sensitivity calculation.

\*DCPRA assumptions.

\*\*No DG maintenance.



Table 2.2  
Total Maintenance Unavailability,  $P_T$

Mean DG Maintenance Duration, ZMDGSD, hr	$P_T$ , With DG Main- tenance Frequency, ZMDGSF = $7.74 \cdot 10^{-4} \text{ hr}^{-1}$	Mean DG Maintenance Duration, ZMDGSD' hr	$P'_T$ , With DG Main- tenance Frequency, ZMDGSF' = $1.06 \cdot 10^{-3} \text{ hr}^{-1}$
0	$3.837 \cdot 10^{-4}$	0	$3.837 \cdot 10^{-4}$
10.1	$8.201 \cdot 10^{-3}$	-	-
16	$1.277 \cdot 10^{-2}$	11.9	$1.298 \cdot 10^{-2}$
24	$1.896 \cdot 10^{-2}$	17.5	$1.896 \cdot 10^{-2}$

Table 2.3.A  
Nonseismic Conditional Split Fractions for the Diesel Generators

Top Event	Split Fraction	10.1 Hours MMD for all Diesels		16 Hours MMD for all Diesels		24 Hours MMD for all Diesels	
		PG&E	BNL	PG&E	BNL	PG&E	BNL
GF	GF1	4.523-2	4.571-2	4.946-2	5.010-2	---	5.606-2
GG	GG1	4.477-2	4.527-2	4.909-2	4.976-2	---	5.592-2
	GG2	5.561-2	5.474-2	5.682-2	5.649-2	---	5.843-2
	GG3	4.523-2	4.571-2	4.946-2	5.010-2	---	5.606-2
GH	GH1	4.436-2	4.490-2	4.878-2	4.948-2	---	5.583-2
	GH2	5.408-2	5.322-2	5.545-2	5.516-2	---	5.732-2
	GH3	8.265-2	8.097-2	8.063-2	7.873-2	---	7.641-2
	GH4	4.477-2	4.527-2	4.909-2	4.976-2	---	5.592-2
	GH5	5.561-2	5.474-2	5.682-2	5.649-2	---	5.843-2
	GH6	4.523-2	4.571-2	4.946-2	5.010-2	---	5.606-2
2G	2G1	4.396-2	4.453-2	4.847-2	4.921-2	---	5.576-2
	2G2	5.364-2	5.271-2	5.507-2	5.475-2	---	5.702-2
	2G3	6.250-2	6.246-2	6.254-2	6.229-2	---	6.211-2
	2G4	2.898-1	2.910-1	2.726-1	2.711-1	---	2.493-1
	2G5	4.436-2	4.490-2	4.878-2	4.948-2	---	5.583-2
	2G6	5.408-2	5.322-2	5.545-2	5.516-2	---	5.732-2
	2G7	8.265-2	8.097-2	8.063-2	7.873-2	---	7.641-2
	2G8	4.477-2	4.527-2	4.909-2	4.976-2	---	5.592-2
	2G9	5.561-2	5.474-2	5.682-2	5.649-2	---	5.843-2
	2GA	4.523-2	4.571-2	4.946-2	5.010-2	---	5.606-2
2H	2H1	4.356-2	4.417-2	4.817-2	4.894-2	---	5.571-2
	2H2	5.320-2	5.219-2	5.470-2	5.434-2	---	5.675-2
	2H3	6.206-2	6.196-2	6.205-2	6.177-2	---	6.157-2
	2H4	6.922-2	7.003-2	6.996-2	7.017-2	---	7.031-2
	2H5	7.729-1	8.294-1	7.521-1	8.114-1	---	7.883-1
	2H6	4.396-2	4.453-2	4.847-2	4.921-2	---	5.576-2
	2H7	5.364-2	5.271-2	5.507-2	5.475-2	---	5.702-2
	2H8	6.250-2	6.246-2	6.254-2	6.229-2	---	6.211-2
	2H9	2.898-1	2.910-1	2.726-1	2.711-1	---	2.493-1
	2HA	4.436-2	4.490-2	4.878-2	4.948-2	---	5.583-2
	2HB	5.408-2	5.322-2	5.545-2	5.516-2	---	5.732-2
	2HC	8.265-2	8.097-2	8.063-2	7.873-2	---	7.641-2
	2HD	4.477-2	4.527-2	4.909-2	4.976-2	---	5.592-2
	2HE	5.561-2	5.474-2	5.682-2	5.649-2	---	5.843-2
	2HG	4.523-2	4.571-2	4.946-2	5.010-2	---	5.606-2

Table 2.3.B  
Seismic Conditional Split Fractions for the Diesel Generators

Top Event	Split Fraction	10.1 Hours MMD for all Diesels		16 Hours MMD for all Diesels		24 Hours MMD for all Diesels	
		PG&E	BNL	PG&E	BNL	PG&E	BNL
GF	GF1	8.510-2	8.389-2	8.721-2	8.810-2	---	9.382-2
GG	GG1	8.417-2	8.325-2	8.654-2	8.756-2	---	9.347-2
	GG2	9.502-2	9.085-2	9.428-2	9.375-2	---	9.726-2
	GG3	8.510-2	8.389-2	8.721-2	8.810-2	---	9.382-2
GH	GH1	8.334-2	8.272-2	8.595-2	8.712-2	---	9.322-2
	GH2	9.329-2	8.913-2	9.275-2	9.219-2	---	9.591-2
	GH3	1.115-1	1.080-1	1.090-1	1.088-1	---	1.098-1
	GH4	8.417-2	8.325-2	8.654-2	8.756-2	---	9.347-2
	GH5	9.502-2	9.085-2	9.428-2	9.375-2	---	9.726-2
	GH6	8.510-2	8.389-2	8.721-2	8.810-2	---	9.382-2
2G	2G1	8.251-2	8.221-2	8.537-2	8.670-2	---	9.300-2
	2G2	9.244-2	8.827-2	9.205-2	9.144-2	---	9.532-2
	2G3	1.016-1	1.794-2	9.964-2	9.956-2	---	1.014-1
	2G4	1.903-1	1.908-1	1.851-1	1.846-1	---	1.777-1
	2G5	8.334-2	8.272-2	8.595-2	8.712-2	---	9.322-2
	2G6	9.329-2	8.913-2	9.275-2	9.219-2	---	9.591-2
	2G7	1.115-1	1.080-1	1.090-1	1.088-1	---	1.098-1
	2G8	8.417-2	8.325-2	8.654-2	8.756-2	---	9.347-2
	2G9	9.502-2	9.085-2	9.428-2	9.375-2	---	9.726-2
	2GA	8.510-2	8.389-2	8.721-2	8.810-2	---	9.382-2
2H	2H1	8.169-2	8.175-2	8.481-2	8.632-2	---	9.282-2
	2H2	9.162-2	8.744-2	9.138-2	9.072-2	---	9.478-2
	2H3	1.005-1	9.688-2	9.863-2	9.857-2	---	1.005-1
	2H4	1.112-1	1.077-1	1.087-1	1.085-1	---	1.094-1
	2H5	5.269-1	5.433-1	5.214-1	5.207-1	---	4.937-1
	2H6	8.251-2	8.221-2	8.537-2	8.670-2	---	9.300-2
	2H7	9.244-2	8.827-2	9.205-2	9.144-2	---	9.532-2
	2H8	1.016-1	1.794-2	9.964-2	9.956-2	---	1.014-1
	2H9	1.903-1	1.908-1	1.851-1	1.846-1	---	1.777-1
	2HA	8.334-2	8.272-2	8.595-2	8.712-2	---	9.322-2
	2HB	9.329-2	8.913-2	9.275-2	9.219-2	---	9.591-2
	2HC	1.115-1	1.080-1	1.090-1	1.088-1	---	1.098-1
	2HD	8.417-2	8.325-2	8.654-2	8.756-2	---	9.347-2
	2HE	9.502-2	9.085-2	9.428-2	9.375-2	---	9.726-2
	2HG	8.510-2	8.389-2	8.721-2	8.810-2	---	9.382-2

Table 2.4  
Nonseismic and Seismic Conditional Split Fractions  
Scheduled Maintenance on Diesel 13\*

Top Event	Split Fraction	Renamed Split Fraction	Nonseismic		Renamed Split Fraction	Seismic	
			PG&E	BNL		PG&E	BNL
GF	GF1	GFF	1.0	1.0	GFF	1.0	1.0
GG	GG1 GG2 GG3	GG4	4.344-2	4.393-2	GG5	8.114-2	8.218-2
GH	GH1 GH2 GH3 GH4 GH5 GH6	GH7 GH8 GH9	4.324-2 4.784-2 4.344-2	4.377-2 4.751-2 4.393-2	GHA GHB	8.064-2 8.685-2	8.181-2 8.629-2
2G	2G1 2G2 2G3 2G4 2G5 2G6 2G7 2G8 2G9 2GA	2GC  2GE	4.631-2  4.324-2	4.599-2  4.377-2	2GI	8.531-2	8.471-2
2H	2H1 2H2 2H3 2H4 2H5 2H6 2H7 2H8 2H9 2HA 2HB 2HC 2HD 2HE 2HG	2HI 2HJ	4.585-2 5.573-2	4.552-2 5.560-2			

\*Renamed split fractions were used to evaluate conditional core damage sequences that involved maintenance of the swing DG. The DG split fractions not listed for this case were not needed to quantify these sequences.

### 3. CORE DAMAGE FREQUENCY AND RISK RATIO CALCULATIONS

#### 3.1 General

Fifty initiating event categories, including six seismic levels are quantified in the DCPRA. For the AOT study, however, only the leading sequences (contributing approximately 82% of the total core damage frequency) were selected to be potential subjects of modification due to changes in the diesel-related top event split fractions. This subset of sequences is called the "Dominant Sequence PRA Model" in the AOT study. The omitted sequences are taken into account by appropriate correction factors. The model consists of two parts: 1) non-seismic sequences and 2) seismic sequences. 420 leading non-seismic sequences constitute "the non-seismic part" and 791 leading seismic sequences constitute "the seismic part." The non-seismic and seismic contributions to the total core damage frequency are 83.2% and 16.8%, respectively. The 420 non-seismic and the top 200 seismic sequences are listed in the AOT study. Each leading sequence is represented as the algebraic product of the frequency of a single initiating event and the unavailabilities of the plant safety systems under specific boundary conditions, or "top event split fractions." Where appropriate, sequence-specific recovery actions are also included in the sequence. Normally, the system success probabilities (availabilities) are very close to unity and therefore can be conservatively omitted. For sequences in which this is not the case, the system success probabilities were included to avoid over-conservatism. The DG success probabilities are included in the non-seismic part. In the seismic part, all the success probabilities are considered.

#### 3.2 Core Damage Frequencies Without Contribution Due to Swing Diesel Overhaul

For core damage frequency calculations in which there is no scheduled maintenance performed on the swing DG while a unit is at power, both non-seismic and seismic sequences (420 and 791 sequences, respectively) were used. The BNL audit focussed on the non-seismic sequences because for the seismic failures the DCPRA treated the DGs as completely correlated and because the

seismic sequences show a practically negligible (order of  $\sim 10^{-7}$ ) dependency on the change of the total maintenance unavailability of the diesels, i.e., AOT.

The core damage frequency (according to the terminology of the AOT study, the absolute risk) was evaluated by propagating the top event split fractions determined with various mean diesel maintenance times through the dominant sequence PRA model. This was done for both diesel configurations; for 5DG and 6DG systems. To represent the 6DG configuration, the swing diesel was modelled as always being aligned to Unit 1. This was accomplished by setting the swing diesel alignment top event split fraction SW always to 0. This is an acceptable modelling approach.

In order for BNL to check the internal consistency of the calculations and to express the core damage frequency as a function of the total diesel maintenance unavailability (i.e., AOT), sensitivity and consistency runs were done, in addition to the audit computations.

The results obtained are shown in Table 3.1 along with those obtained by PG&E. The logically connected calculations are grouped together for the 5DG and 6DG configurations. (These are: 5DGs-Calculations No.5, 1A, 1B, and 1C, and 6DGs-Calculations No.4A, 4B, 4, and 4C).

Figure 3.1 shows the core damage frequency as a function of the total maintenance unavailability,  $P_T$  for the 5DG and 6DG configurations. One can observe that the functional correlation between the CDF and the total maintenance unavailability can be fairly approximated by straight lines. The lines for 5DG and 6DG configurations run (almost) parallel, showing that under any reasonable AOT condition the 6DG configuration always provides smaller risk than the 5DG configuration.

### 3.3 Core Damage Frequencies With Contribution Due to Swing Diesel Overhaul

For the calculations where maintenance of the swing diesel is considered (Calculations 2, 3, and 3A) the quantification process is different. The calculations are based on the conditional core damage frequency calculations when the swing diesel is considered to be down for one year; i.e., when top event GF is set to 1.0 (GFF), and the modified and renamed top events of Table 2.4 are used. (The ID numbers of these calculations are: 6A, 6, and 6B.) These latter calculations are rather intricate and complex, especially the seismic parts. Some numerical values and interpretation of the variables were not provided in the AOT study; BNL received them more recently as supplemental information.<sup>4</sup>

Calculations 2, 3, and 3A essentially contain the sum of two terms; the first one is the CDF without scheduled maintenance and the second is the conditional CDF multiplied by the fraction of time the swing diesel is in scheduled maintenance.

The results obtained from the above calculations are also listed in Table 3.1 along with the original PG&E data. The conditional core damage frequency if the swing diesel is down for a year (5DG configuration) is also plotted as a function of the total maintenance unavailability,  $P_T$ , at the bottom part of Figure 3.1. The curve reflects a strong linear dependency.

Comparing the results obtained by PG&E and BNL associated with the swing diesel overhaul (Calculations 2, 3, and 3A) one observes that:

- a. By changing the AOT from three to seven days (from Calculations 2 and 3) PG&E calculated a risk increase of about 1.3%, while BNL obtained a risk increase of 1.4%. These correspond to a mean diesel maintenance frequency of  $7.74 \cdot 10^{-4} \text{ hr}^{-1}$ .
- b. If one takes for the diesel maintenance frequency the value used for the reliability calculation, i.e.,  $1.06 \cdot 10^{-3} \text{ hr}^{-1}$ , and considers the

results of BNL's Calculations 3 and 3A which characterize the AOT change, the risk increase would be less than 2.8%.

### 3.4 Risk Ratio Calculations

This section compares the results of the risk ratios obtained by BNL with those calculated by PG&E. Since the risk ratios are defined differently for unscheduled and scheduled maintenances, they are discussed in the following two subsections.

#### 3.4.1 Risk Ratios for Unscheduled Maintenance

The risk ratio for unscheduled maintenances is defined by the formula:

$$RR_{u.m.} = \frac{MMD}{BP} * \frac{CCDF_{13}}{CDFOM},$$

where, MMD is the mean maintenance duration of a DG,

BP is the base period with no DG maintenance (i.e., average interval between DG outages,

$CCDF_{13}$  is the conditional core damage frequency when the swing diesel is assumed to be down for a year (in Table 3.1, Calculations 6A, 6, and 6B), and

$CDFOM$  is the core damage frequency when there is no maintenance of any of the DGs (in Table 3.1, Calculation 5).

The RR values obtained by PG&E for the 5DG and 6DG configurations are listed in the column PG&E of Table 3.2.A. These values were obtained by using the same base period for both the 5DG and the 6DG configurations. The base period was determined by the DG maintenance frequency,  $7.74 \cdot 4 \text{ hr}^{-1}$ . Per unit basis, it was assumed that the frequency of one of three DGs being out for maintenance is three times the individual DG maintenance frequency. The interval between DG maintenance outages is then the inverse of this value. The ratio  $CCDF_{13}/CDFOM$  was also treated to be the same for 5DG and 6DG configurations.



By comparing the PG&E RR values with each other, one notices that while there is an increase in the relative risk when the AOT changes from three days to seven days for the 5DG configuration; the relative risk does not decrease if one keeps the AOT the same but increases the system redundancy from 5DGs to 6DGs. In other words, the PG&E calculation does not indicate any advantage of installing the 6th DG.

According to BNL, the cause of this discrepancy is that PG&E used an incorrect base period for the 5DG configuration. BNL presumed that whenever a dedicated diesel is put into unscheduled maintenance at Unit 2, the swing diesel will be assigned to that unit, thus from the point of view of Unit 1 the swing diesel has an outage. (Both units are assumed to be operating.) Thus, on a per unit basis, the frequency of one of three DGs being out for maintenance is five times the individual DG maintenance frequency (the swing diesel counts three). Of course, in the case of 6DGs (three dedicated DGs per unit) the PG&E reasoning is correct.

BNL performed two relative risk calculations. In the first one, the DG maintenance frequency was assumed to be  $7.74 \cdot 4 \text{ hr}^{-1}$  corrected by the maintenance frequencies of the LCVs. In the second one, the DG maintenance frequency was calculated by using the Diablo Canyon outage data (Table 5-7 of the AOT study<sup>1</sup>). This roughly corresponds to a DG maintenance frequency of  $1.06 \cdot 3 \text{ hr}^{-1}$ .

The length of base periods used and the obtained RR results are listed in the columns "BNL" of Table 3.2.A. The results show a risk ratio increase of about a factor of two higher than the increase obtained by PG&E when the AOT changes from three days to seven days. For the same time periods, the BNL results correctly reflect the expected decrease of the risk ratio when the redundancy of the system increases (5DGs to 6).

In other words, the BNL calculations definitely indicate the advantage of the installation of the 6th DG.

### 3.4.2 Risk Ratios for Scheduled Maintenances

The risk ratio for scheduled maintenance is defined by the formula:

$$RR_{s.m.} = \frac{SCHD}{RP} * \frac{CCDF_{13}}{CDF},$$

where, SCHD is the scheduled outage duration (10 days for 3-day AOT and 7 days for 7-day AOT),

RP is the period between scheduled maintenances of the swing diesel (i.e., the refueling period, 1.5 years),

CCDF<sub>13</sub> is the conditional core damage frequency when the swing diesel is assumed to be down for a year (in Table 3.1, Calculations 6A, 6, and 6B), and

CDF is the core damage frequency calculated with various mean maintenance durations (in Table 3.1, Calculations 1A, 1B, and 1C).

The results of the BNL calculations are shown in Table 3.2.B along with those of PG&E. There is an overall agreement between the two sets of data. Notice that the risk ratio for the 6DG configuration is zero. There is no scheduled maintenance during operation, hence, by definition  $RR_{s.m.} = 0$ .

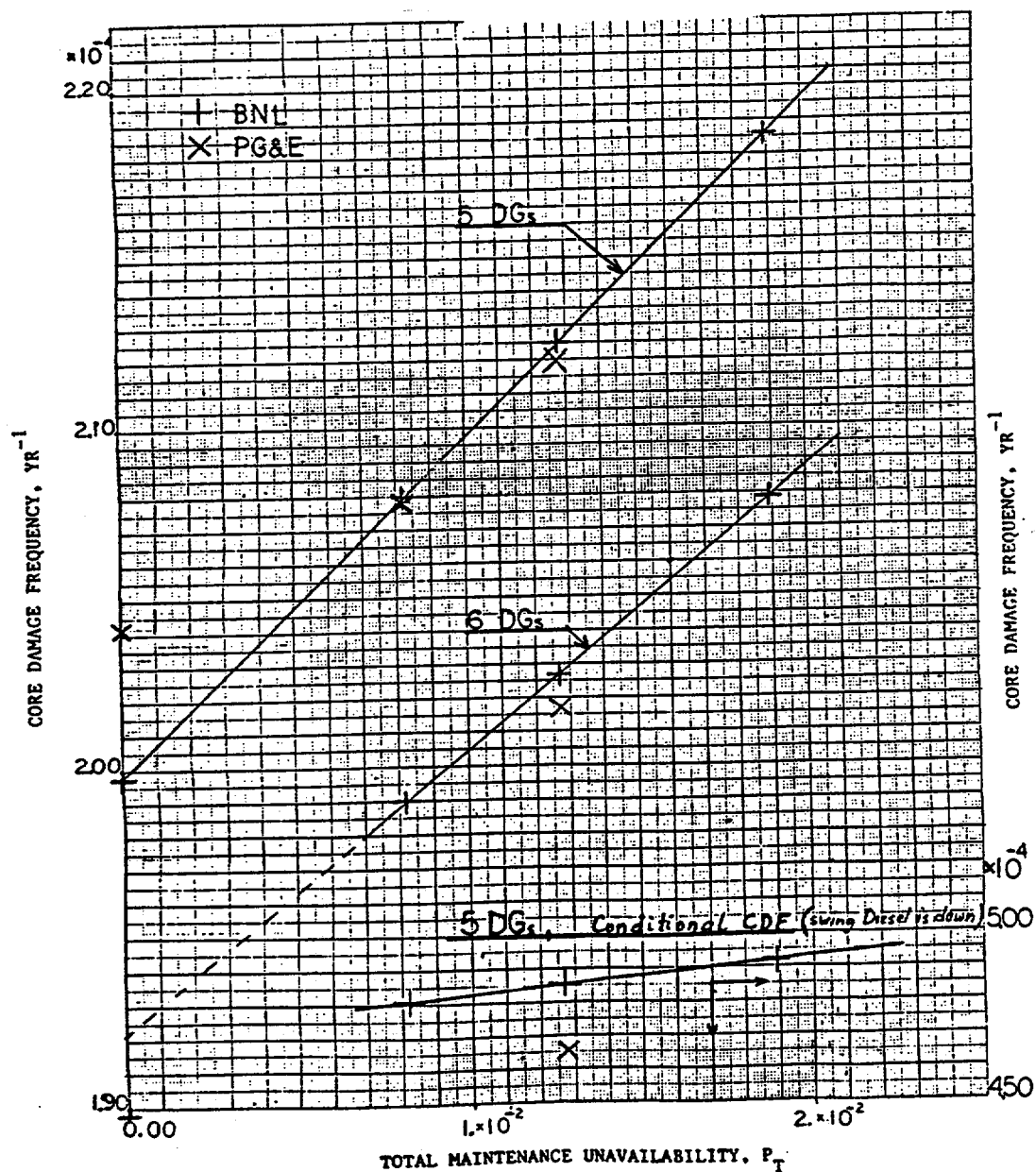


Figure 3.1 Core damage frequency as a function of total maintenance (diesel plus level control valve) unavailability for the present (5 DGs) and the planned (6 DGs) diesel configurations. Bottom curve: conditional core damage frequency for the present configuration, if the swing diesel is down for a year.

Table 3.1  
Core Damage Frequencies  
(Based on the Risk Analysis Approach)

Number of Calculation	Number of DGs	Allowed Outage Time, AOT (Days)	Mean DG Maintenance Duration, MMD (Hrs)	With One Unit at Power		CDF (Yr <sup>-1</sup> )	
				Overhaul Period of Swing Diesel (Days)	Overhaul Period of DGs of the Other Unit (Days)		
				PG&E	BNL		
5	5	*	0	0	0	2.042-4	1.971-4
1A	5	3	10.1	0	0	2.078-4	2.080-4
1B	5	7	16	0	0	2.120-4	2.125-4
1C	5	7	24	0	0	---	2.186-4
2	5	3	10.1	10	0	2.124-4	2.130-4
3	5	7	16	7	0	2.152-4	2.160-4
3A	5	7	24	7	0	---	2.221-4
4A	6	*	0	0	0	---	1.898-4
4B	6	3	10.1	0	0	---	1.990-4
4	6	7	16	0	0	2.017-4	2.027-4
4C	6	7	24	0	0	---	2.078-4
6A	5	3	10.1	1 year	0	---	4.812-4
6	5	7	16	1 year	0	4.650-4	4.857-4
6B	5	7	24	1 year	0	---	4.919-4

a DG maintenance.

Table 3.2.A  
Risk Ratio Results  
Unscheduled DG Maintenance

Definition: RR = Risk of Core Damage During Mean Maintenance Duration/Risk of Core Damage During Base Period With No Maintenance

DG Configuration	AOT, Days	Mean Maintenance Duration, Hrs	PG&E		BNL			
			Length of Base Period, Hrs	RR <sub>s.m.</sub>	Length of Base Period*, Hrs	RR <sub>s.m.</sub>	Length of Base Period, Hrs	RR <sub>s.m.</sub>
5 DGs	3	10.1	448.0	.05	245.5	.10	---	---
		11.9	---	---	---	---	188	.15
	7	16.0	448.0	.08	245.5	.16	---	---
		17.5	---	---	---	---	184.9	.24
	7	24.0	---	---	245.5	.25	---	---
6 DGs	3	10.1	---	---	409.2	.06	---	---
		11.9	---	---	---	---	312	.09
	7	16.0	448.0	.08	409.2	.09	---	---
		17.5	---	---	---	---	369.9	.12
	7	24.0	---	---	409.2	.15	---	---

\*Maintenance frequencies of LCVs are included.

Table 3.2.B  
Risk Ratio Results  
Scheduled DG Maintenance

Definition: RR - Risk of Core Damage During Scheduled Outages/Risk of Core Damage  
Between Refuelings (1.5 Years)

DG Configuration	DG Maintenance Policy Between Refuelings		Scheduled Outage Duration, Days	PG&E RR <sub>s.m.</sub>	BNL RR <sub>s.m.</sub>	Remarks
	AOT, Days	Mean Maintenance Duration, Hrs				
5 DGs	3	10.1	10	.041	.042	
	7	16.0	7	.028	.029	
	7	24.0	7	--	.029	
6 DGs	7	16.0	--	0.0	0.0	No scheduled DG outage is planned during unit operation.

#### 4. CONCLUSIONS

BNL performed a thorough review of the PG&E AOT study. The review focused on the risk analysis approach.

The review identified some problematic spots in the analysis:

- The diesel top event split fractions 2G and 2H do not include the unavailability contribution of the overhauls of Unit 2 diesels performed with Unit 1 at power. PG&E performed conditional core damage calculations when the swing diesel is considered to be down and also (as sensitivity calculations) when the dedicated Unit 1 diesels are down. There are no calculations as to what is the conditional core damage frequency if Unit 2 diesels are down (i.e., when top events 2G or 2H are set to 1).
- The AOT analysis as well as the DCPRA are tacit about the coupling of the swing diesel when a dedicated diesel undergoes unscheduled maintenance with both units at power. For Unit 1, the swing diesel is unavailable if it is coupled to Unit 2 while a dedicated Unit 2 diesel is in maintenance.
- The risk analysis uses a low value for the maintenance frequency of the diesels. This means that the absolute risks are underestimated at a given AOT. With more realistic maintenance frequencies, the correct risk values for the present and suggested AOTs lie around the risk values obtained with the low maintenance frequency and mean maintenance times of 16 hours and 24 hours, respectively.

The BNL review found an overall agreement between the top event split fraction values obtained by BNL and PG&E. The small inconsistencies appearing sporadically are presumably due to the fact that BNL used point estimates, while PG&E used a Monte Carlo approach in the split fraction quantification. There is also an overall agreement between the BNL and PG&E core damage frequency values (disregarding the "no maintenance" base). There is a slight tendency that the BNL CDF values lie somewhat higher than those of PG&E.

BNL concurs with PG&E's findings that:

- The risk reduction effect of adding the sixth DG is greater than the effect of changing to a seven day AOT. This is demonstrated by Figure 3.1, which shows that the CDF curve for the 6DG configuration always runs below and almost parallel with the CDF curve for 5 DG configuration.
- The effect on risk of changing from a three day to a seven day AOT is insignificant, on the order of 2 to 3%. (The curves in Figure 3.1 provide practical tools to evaluate risk changes for any combinations of diesel maintenance duration and frequency values.)
- The increase of the risk associated with a seven day AOT over a three day AOT performing scheduled maintenance on the swing diesel is also insignificant; less than 2.8%. The risk ratios determined by PG&E for this case are in agreement with those obtained by BNL for both 5DG and 6DG configurations.

BNL found that the risk ratios associated with unscheduled diesel maintenance are higher by a factor of 2 or 3 in absolute value than the values determined by PG&E for the 5DG configuration for any AOTs. The risk ratio increase associated with changing the AOT from three days to seven days was also found to be a factor of two higher than that of PG&E.

In contrast with the finding of the AOT study,<sup>1</sup> BNL's risk ratio calculations definitely indicate the advantage of the installation of the sixth DG.



## REFERENCES

1. Diesel Generator Allowed Outage Time Study, Pacific Gas & Electric Company, May 1989.
2. Final report on the Diablo Canyon Long-Term Seismic Program, Pacific Gas and Electric Co., Diablo Canyon Power Plant, Docket Nos. 50-275 and 50-323, July 1988.
3. Diesel Generator Allowed Outage Time Study, Supplemental Information on DG Maintenance Duration, PG&E Letter to NRC, July 18, 1989.
4. Diesel Generator Allowed Outage Time Study, Supplemental Information Regarding the Equations Presented in Appendix B, p.B-15, September 5, 1989.
5. Lofgren, E.F. and F. Varcolik, "Probabilistic Approaches to LCO's and Surveillance Requirements for Standby Safety Systems," NUREG/CR-3082, November 1983.
6. Cho, N.Z., et al., "Analysis of Allowed Outage Times at the Byron Generating Station," NUREG/CR-4404, June 1986.
7. Driscoli, G.D., et al., "Surveillance Monitoring and Diagnostic Techniques to Improve Diesel Generator Reliability," EPRI NP-5924, July 1988.
8. Worrel, R.B. and D.W. Stack, "A SETS User's Manual for the Fault Tree Analyst," Sandia National Laboratories, NUREG/CR-0475, November 1978.

---

**APPENDIX I**

**DATA ON MAINTENANCE DURATION OF DGs AND DG SUBSYSTEMS**

---

Table I.1  
Discretized Prior For Generic Maintenance Duration  
Distribution of DGs Having 72 Hour AOT\*

Maintenance Duration (Hours)	Probability	Cumulative Probability
2.15+0	2.12-1	2.12-1
4.24+0	2.20-1	4.31-1
6.48+0	5.63-2	4.88-1
7.25+0	2.54-2	5.13-1
7.75+0	2.37-2	5.37-1
8.25+0	2.22-2	5.59-1
8.75+0	2.07-2	5.80-1
9.15+0	1.18-2	5.92-1
9.45+0	1.13-2	6.03-1
9.80+0	1.44-2	6.17-1
1.01+1	1.04-2	6.28-1
1.04+1	9.97-3	6.38-1
1.08+1	1.27-2	6.50-1
1.12+1	1.50-2	6.65-1
1.17+1	1.41-2	6.80-1
1.22+1	1.33-2	6.93-1
1.27+1	1.25-2	7.05-1
1.40+1	4.34-2	7.49-1
1.64+1	4.97-2	7.98-1
2.61+1	2.02-1	1.00+0

	Percentiles		
<u>Mean</u>	<u>5th</u>	<u>50th</u>	<u>95th</u>
10.5 hours	.507	6.85	23.7

\*From "Supplemental Information to Diesel Generator AOT Study," PG&E Letter.<sup>3</sup>  
Data provided to PG&E by PL&G. Mosleh, A., et al., "A Data Base for  
Probabilistic Risk Assessment of LWRs," Pickard, Lowe and Garrick, Inc. PLG-  
0500, 1987.

Table I.2  
Diesel Subsystem Downtimes Ranked in  
Decreasing Order and Subsystem Failure Rates\*

Rank, i	Major Sub- system Failure	Mean Failure Rate $\times 10^{-3}$ $F_i$ (Failures/ Diesel-Mth)	Mean Downtime Per Failure $D_i$ (Hours)	Expected Downtime
				$F_i \times D_i \times 10^{-3}$ Hrs/Diesel-Mth
1	Engine, Mechanical	1.7	308	530
2	Turbocharger	2.3	82.6	190
3	Coolant Pumps, Motors & Associated Electrical	1.3	58.4	75.9
4	Lubricating Oil Contamin- ation, Clogged Filters	1.0	50.3	50.3
5	Generator, Mechanical & Electrical	3.3	43.5	142
6	Air Motor Mechanical	1.4	26.9	37.7
7	Coolant Leakage	3.1	26.8	83.0
8	Exhaust System	1.1	22.0	24.2
9	Oil Leakage	1.9	20.0	38.0
10	Start Air Leakage	1.6	18.6	29.8
11	Electric Start	.54	17.8	9.6
12	Control & Instrumenta- tion-Switches, Relays and Wiring	3.2	15.1	48.3
13	Start Air Signal	1.9	13.5	25.7
14	Governor Setpoint & Synchronizing Errors	1.9	12.4	23.6
15	Fuel Leakage	1.8	12.0	21.6
16	Voltage Regulator	3.0	10.8	32.4
17	Lubricating Oil Miscel- laneous	1.4	10.8	15.1
18	Protective Trips	2.4	9.5	22.8
19	Start Air - Moisture, Rust & Contamination	2.1	9.4	19.7
20	Governor Oil	1.8	9.3	16.7
21	Injectors, Engine Fuel	1.4	9.3	13.0
22	Governor Sensing & Control	3.7	9.2	34.0
23	Oil Pumps, Prelube & Associated Electrical	.63	9.0	5.7
24	Fuel-Water, Air & Contamination	1.9	8.5	16.2
25	Tachometer	1.5	8.4	12.6
26	Governor-Hydraulic/Air Booster, Servomechanism & Linkage	2.5	7.5	18.8
27	Coolant-Heat Exchanger, Radiator	1.0	7.4	7.4
28	Load Sequencing Timers	3.8	6.5	23.4

Table I.2 (Continued)

Rank, i	Major Sub- system Failure	Mean Failure Rate x 10 <sup>-3</sup>	Mean Downtime	Expected Downtime
		F <sub>i</sub> (Failures/ Diesel-Mth)	Per Failure D <sub>i</sub> (Hours)	F <sub>i</sub> x D <sub>i</sub> x 10 <sup>-3</sup> Hrs/Diesel-Mth
29	Start-Air Valve Electri- cal & Mechanical	2.2	6.5	13.7
30	Start-Air Compressor & Miscellaneous	.63	6.0	3.8
31	Fuel Transfer Pumps & Associated Instrumenta- tion & Electrical	1.3	5.1	6.6
32	Control Electric Power	1.1	4.8	5.3
33	Cooling-Miscellaneous	1.1	4.3	4.7
34	Output Breaker-Associated Circuitry & Control	1.9	3.1	5.9

Sums  $\sum_i F_i = 63.4$   $\sum_i F_i D_i = 1607.5$

Overall Mean Downtime,  
Per Failure  $\bar{D} = \sum_i F_i D_i / \sum_i F_i = 25.35$

Assuming Lognormal  
Downtime Distribution

Maximum Likelihood  $\mu = 2.6203$   
Maximum Likelihood  $\sigma^2 = .8137$   
Overall Median Downtime Per Failure 13.74  
Overall Mean Downtime Per Failure 20.64  
5th Percentile 3.12  
95th Percentile 60.59

\*From Driscoli, G.D., et al., "Surveillance, Monitoring, and Diagnostic Techniques to Improve Diesel Generator Reliability," EPRI-NP-5924, July 1988.

---

**PART 2**

**REVIEW RESULTS OF THE SYSTEM ANALYSIS IN THE DCPRA:  
DIESEL GENERATOR AND DIESEL FUEL TRANSFER SYSTEMS**

---

## 1. INTRODUCTION

### 1.1 Objectives

The main objective of this letter report is to summarize the results, to date, of reviewing the unavailability analysis of the Diesel Generator and Diesel Fuel Transfer Systems described in the DCPRA.<sup>1</sup> The review was carried out with special attention to the details of the unavailability modelling of the maintenance activities on the DGs. (This particular emphasis was prompted by a request of the Pacific Gas and Electric Co to change the Allowed Outage Time (AOT) of the DGs from the present outage of three days to seven days, and the fact that the study<sup>2</sup> supporting this request derived data on expected core damage frequency changes based mainly on the DCPRA.) This report reflects BNL's current understanding of the subject systems and as such must be considered interim results. Final results will be provided in the NUREG/CR to be issued at the end of the project. That will reflect, at that time, any additional supporting input submitted by PG&E as well as any direct feedback on these preliminary findings.

### 1.2 Organization of the Report

Section 2 provides condensed descriptions about the configurations and functions of the Diesel Generator and the Diesel Fuel Oil Transfer Systems. It also describes the dependency of these systems on support equipment, the surveillance and maintenance conditions, the unavailability modelling in the DCPRA, and the original PRA results. The purpose of this approach is to present the reader stand alone documentation to which the review's findings can be directly compared. Section 3 contains the results of the BNL review and presents the current preliminary findings.

For completeness, the ranked cut sets of hardware unavailabilities (both independent and total) obtained by BNL for various diesel configurations are given in Appendix A.

## 2. UNAVAILABILITY MODELLING OF THE DIESEL GENERATOR AND DIESEL FUEL OIL TRANSFER SYSTEMS

### 2.1 Diesel Generator System Description, Configurations and Functions

The Diesel Generator System at the Diablo Canyon plant consists of five diesel generators: two dedicated to Unit 1, two dedicated to Unit 2, and one (a "swing diesel") shared between the two units. According to the DCFSAR,<sup>3</sup> the individual diesel generator units are isolated from each other and from other equipment. The swing diesel is physically located in Unit 1. Each diesel generator supplies power to its associated 4.16kV vital bus (H, G, and F - Units 1 and 2). In the event of a loss of electrical power from the main generator (due to a unit trip, a safeguard signal or a loss of voltage on a vital bus) the vital 4.16kV buses are automatically disconnected from the main generator and transferred to the offsite standby source. (The Unit 1 main generator provides power through auxiliary transformer 12. The standby power is provided through startup transformers 11 and 12.) If this transfer is unsuccessful or the standby power is unavailable, the diesel generators must start and provide power to the affected buses. The diesel generators start on undervoltage signals from their respective buses, load onto those buses (the output breakers are normally open), initiate reloading of the vital loads and continue delivering power at normal frequency to the buses. A safety injection actuation signal (SIS) from either Train A or B of the SSP System will also start the diesels (Train A will start 11 and 13, Train B will start 11 and 12).

The swing diesel (13) may supply power to either Unit 1 or Unit 2 vital Bus F. It will start with an undervoltage or an SI signal from either unit (SSPS Train A). Because the output is not shared simultaneously by the units, only one of its two circuit breakers is closed at a time. The breakers have individual sets of control and protection circuits. If one of the units receives an SI signal (earlier than the other), it is given priority of using the swing diesel.



The DGs are 2750 kW, 18 cylinder, vee configuration, ALCO made units. Each unit consists of a self-contained diesel engine directly connected to an alternating current generator. Each diesel has dual train electrical starting circuits and air system with turbocharger, ventilation, fuel oil system, self-contained radiator cooled jacket cooling water system, lube oil system, and speed control governor system.

- Each independent starting circuit has its own dc power source (DG11; dc panels 13, 12. DG12; dc panels 12, 11. DG13; dc panels 11, 13. DG21; dc panels 22, 21. DG22; dc panels 23, 22). The operating control circuit is common. Without control power a unit keeps running. A mechanical trip handle, located in the diesel compartment serves to shut the unit down.
- The air start system consists of two trains. Each train includes a compressor, a dryer, an air receiver and two air-driven motors. Air from receivers is fed through regulator valves and up to the starting air system solenoid valves. Only one motor is needed to start a diesel. Power supply to the compressor trains are provided by 480V ac buses: [DG11; Trains A and B; 1H, 1G. DG12; Trains A and B; 1G, 1F. DG13; Trains A and B; 1F (backup 2F), 1H (backup 2F). DG21; Trains A and B; 2G, 2F. DG22; Trains A and B; 2H, 2G.] One solenoid control valve of an air driven motor in each compressor train gets its "open" signal from the normal control, the other solenoid valve receives signal from the backup control. Upon initiation of a start, the solenoid valves open supplying air to the motors. After initiation, pressure switches located on the discharge of the jacket water pump shuts off the air supply. The air start system supplies air to the Level Control Valves (LCVs) of the diesel fuel oil day tanks. There is one air supply line per LCV.
- The air start system also includes an air operated turbocharger for quick starting and load pickup. The associated air subsystem consists of one turbo air compressor, one starting air receiver tank, and an air dryer. Two solenoid operated shutoff valves, one on each of the two supply lines, control the air supply to the turbocharger. A solid state speed-loss sensor

controls the turbo-assist air supply to prevent a critical loss of speed when a sudden large load increase occurs.

- Each diesel has also another air system: the combustion air and exhaust system (ventilation), containing the intake and exhaust silencers and the two motor-driven crankcase exhauster fans.
- The engine fuel oil system involves the fuel oil day tank. Fuel oil is supplied by the Diesel Fuel Oil Transfer System (see its description in Section 2.2). The fuel oil level in the day tank is controlled by two redundant level control valves (LCVs). Each LCV has two 480V ac control power sources; a normal supply and a backup supply. The power sources for LCVs associated with the primary fuel oil transfer pump (Train 02) are: 480V ac buses 1G and 2G. Power sources for LCVs associated with the secondary fuel oil transfer pumps (Train 01) are: 480V ac buses, 2H and 1H. The valves may be actuated also manually.
- The cooling of a diesel unit is provided by a closed loop jacket cooling water system. The jacket water pump takes water from the lube oil cooler and the turbocharger aftercooler. There is a 50-gallon expansion tank connected to the suction side of the pump. The pump discharges water through the engine block and turbocharger to a common return line. Engine water temperature is maintained at 170°F by a thermostatically controlled three-way valve set. Overheated water is sent to a water radiator, where it is cooled by forced air (engine driven fan) taken from outside the building.
- The lubricating oil system consists of an oil reservoir, an engine driven pump and a heat exchanger. The heat exchanger is cooled by the engine jacket cooling water system. Lubricating oil temperature is thermostatically controlled. The oil is kept in the range of 90°-110°F circulated by a small pre-circulation pump even if the generator is idle, to reduce wear during the engine start period. The diesel automatically stops if the oil pressure drops below 40 psig.

- To control the fuel delivery and therefore the engine's speed and generator output frequency to a predetermined value, an engine governor speed control unit is used. The governor has electrical and mechanical controls; both of which act through a hydraulic actuator to control the fuel supply.

The diesels cannot respond to a start signal under the following conditions:

1. Shutdown relay tripped.
2. Manual test condition.
3. Low fuel level in the day tank.
4. Low pressure in both starting air receivers.
5. Loss of dc control power.
6. Voltage regulator on manual.

The eventual problems of the diesels are annunciated by various alarms (14 groups of signals) in the control room.

The loads of the diesels are listed in Table 2.1. Each diesel has enough capacity to handle some extra startup load. The loading of the diesels during the recirculation phase of a LOCA is under the control of the operator.

Each generator compartment is provided with an automatic flooding CO<sub>2</sub> gas system for fire protection.

## 2.2 Diesel Fuel Oil Transfer System, Configuration and Function

The diesel fuel oil transfer system maintains a supply of fuel oil to each DG day tank from two large underground storage tanks (capacity: 40,000 gallons per tank). It contains two trains (01 and 02), each having a rotary screw type positive displacement pump. These pumps are self priming. A single pump has enough capacity (55 gpm at 50 psig) to supply all the five diesels. (The fuel consumption rate is about 3.2 gpm per DG). Each pump train has a fuel oil distribution header supplying all five of the DGs.

Manual crosstie valving between headers allow either transfer pump to deliver to either header. Also, it is possible to pump from either of the storage tanks.

Local controls for the system are located at each DG. There are two sets of controls; one for pump train 01 and another for pump train 02. These are the LCV switches: a total of 10 (5x2). Each switch starts the transfer pumps and opens the LCV of its respective train. The pump start levels are different: 252 gallons for train 01 and 271 gallons for train 02. Once a pump is started it will remain running until shut down by the operator. If all the LCVs are closed (the day tanks are full) the fuel oil will recirculate back to the main storage tank.

The motors that drive the pumps are powered by 480V vital ac buses (pump train 01 by either bus 1H or 2H, from Units 1 and 2 respectively, and pump train 02 by either bus 1G or 2G). A manual transfer switch determines the alignment, the only criterion for alignment is that the pumps should be powered by different units.

The operation of the oil fuel transfer system is made on a demand basis: when one of the day tanks reaches a low level set point, the fuel transfer pumps start and remain running until all diesels have been shut down. For the six hour mission time (24 hours for seismic events) of the diesels, the fuel transfer system must remain functioning to replenish the fuel supply to each running diesel. The minimum total storage in the storage tanks is sufficient for seven days of power generation.

The importance of the operability of the fuel oil transfer system for the plant safety is obvious: if the fuel transfer system is unavailable, it results in failure of all the DGs of both units, Unit 1 and Unit 2. For events when both ac powered fuel transfer pumps might become unavailable, a dedicated portable fuel oil driven pump is kept at hand. This pump takes suction directly from the main storage tank and connects to one of the fuel

delivery headers. Flexible hoses are used to make the appropriate connections.

### 2.3 Top Event Definitions, Success Criteria

Associated with the unavailability of the diesel generators, the DCPRA defines six top events in the electric part of the support system event tree. The designators of these top events and their relationships with the diesels are:

- Top Event GF - Diesel Generator 13 ("swing diesel")
- Top Event GG - Diesel Generator 12
- Top Event GH - Diesel Generator 11
- Top Event 2G - Diesel Generator 21
- Top Event 2H - Diesel Generator 22
- Top Event SW - Units alignment of the swing diesel, 13

If the offsite grid is available (top event OG in the support system event tree is successful) only the "G" events (GF, GG, GH) are questioned in the support systems event tree. If the offsite grid fails, all the five top events are questioned. The boundary conditions of these top events depend on the status of the preceding diesel generators in the event tree. Thus, top event GF has only one boundary condition (GF1) corresponding to the case when all support is available. GG has three boundary conditions (GG1, when GF succeeded; GG2, when GF failed; and GG3, when GF was bypassed, i.e., not demanded). Similarly GH has 6, 2G has 10, and 2H has 15 boundary conditions. Top event SW has four boundary conditions: one for LOCAs; one for LOOPs, when an equal number of diesels are operating at Unit 1 and Unit 2; and two for LOOPs, when an unequal number of diesels are operating at the two units.

Only one top event is defined in the DCPRA for the support system event tree associated with the diesel fuel oil transfer system. The designator of this top event is: LO. It is evaluated for six boundary conditions, depending

on the availability of 480V ac buses at both of the units (i.e., 1G, 2H, 2G, and 1H).

The success criteria of the above top events are described in Table 2.1. The Technical Specification requirements with respect to the operability of the associated systems are also indicated.

#### 2.4 Logic Model of the Diesels and Diesel Fuel Oil Transfer System Dependency on Other Support Systems

The generic reliability block diagram for the diesel generators is shown in Figure 2.1. The diagram is constructed from blocks (supercomponents) of the DG system. The boundaries of the supercomponents (for instance: GH-1, GH-2A, GH-2B) are indicated in Figures 2.2 through 2.9. Notice, that the equipment boundaries for each of the diesels start with the diesel generator and include the output breaker, the fuel oil day tank, the day tank level control valves, and the undervoltage and transfer control relays. The diesel starting air system was not modelled separately because it was included as part of the diesel start failure data.

The reliability block diagram shows the dependencies on the super-components of the plant (ac and dc) electrical systems.

The reliability block diagram for the diesel fuel oil transfer system (Top Event, FO) is presented in Figure 2.10. The boundaries of the pump train blocks are indicated in Figure 2.11. The reliability block diagram shows also the system dependencies on other supercomponents of the plant (ac and dc) electrical systems.

#### 2.5 Quantification of Top Event Split Fractions

The definitions of the boundary conditions and the associated split fractions for top events associated with the DG system are listed in Table

2.3. Table 2.4 presents a similar list for the diesel fuel oil transfer system (Top Event, LO).

Table 2.5 presents the values of diesel generator related top event split fraction values quantified by PG&E. Notice, that to provide better train-wise dependency tracking in the event tree model, the split fractions are expressed in terms of unavailabilities of various diesel state combinations (conditional split fractions, CSF). The arithmetic is explained in the DCPRA, Chapter D.2.1.5. The table presents also the total unavailability value (TTL) used in the calculation of each CSF, along with the main contributors to the total unavailabilities, such as hardware (HW), maintenance (MN), test (TS), and human error (HE). At a given boundary condition the hardware contribution relates to the normal alignment, when no test or maintenance activities are being performed. To provide complete information, the table also indicates the two constituent parts of the hardware contribution to the unavailability: the independent (HWI) and the dependent (HWD) (i.e., common cause) failures of the supercomponents of the diesels.

The maintenance contribution is a significant contributor to the total unavailability. The DCPRA assumes that, due to Technical Specification limitations, only one diesel or level control valve may be in maintenance at a time. The following relevant quantities are used in the maintenance unavailability quantification:

Diesel maintenance frequency, ZMDGSF: 7.74-4/hr (Mean Value). Variance = 2.33-8, 5th Percentile = 5.25-4, Median = 7.52-4, 95th Percentile = 9.66-4.

Diesel maintenance duration, ZMGSD: 1.01+1 hr (Mean Value). Variance = 3.99, 5th Percentile = 6.65, Median = 9.74, 95th Percentile = 13.3.

Level control valve maintenance frequency, ZMGNDF: 2.03-5/hr (Mean Value). Variance = 3.52-11, 5th Percentile = 1.14-5, Median = 1.91-5, 95th Percentile = 2.97-5.

Level control valve maintenance duration, ZMGN3D: 1.89+1 hr (Mean Value). Variance = 597.0, 5th Percentile = 1.54, Median = 10.1, 95th Percentile = 51.3.

Notice that the total maintenance unavailability of a diesel unit is determined by the diesel (as defined in DCPRA) maintenance unavailability plus the LCV maintenance unavailability. When a diesel is unavailable (not for reason of preventive maintenance) the other diesels must be surveillance tested once within 24 hours to verify operability. The DCPRA includes the unavailability contribution due to this type of test in the maintenance unavailability (MN).

The test contribution to the total unavailability is modelled in the DCPRA as to be due to the scheduled monthly surveillance tests, which include the manual test of the fuel transfer system to the diesels and the quarterly stroke test of the LCVs.

There is no explicit human error contribution to the total unavailability, because human errors occurring after maintenances and tests due to leaving diesel components in misalignment are included in the maintenance and test contributions.

Table 2.6 lists the split fraction values for the various boundary conditions of the FO top event. The table, as the previous one, details the hardware (independent and dependent components), maintenance test and human error contributions to the total unavailability values. Notice there are no explicit test or human error contributions. All the tests on fuel oil transfer system can be performed without making the system inoperable, human errors occurring leaving a fuel oil transfer train in misalignment after maintenance are included in unavailability values due to maintenance.



## 2.6 Quantification of Seismic Split Fractions for DG Top Events

The basis for detailing the seismic split fraction quantification for the DG top events is to provide insight into how the maintenance unavailability (and through it, the AOT) affects the seismic top events and consequently the seismic contribution to the core damage frequency. (This particular investigation was done as part of the parallel BNL DG AOT review as discussed in Section 1.)

All diesel generator components susceptible to failures by seismic events contribute to the diesel unavailability. The components considered to be the most vulnerable to seismic effects are the following:

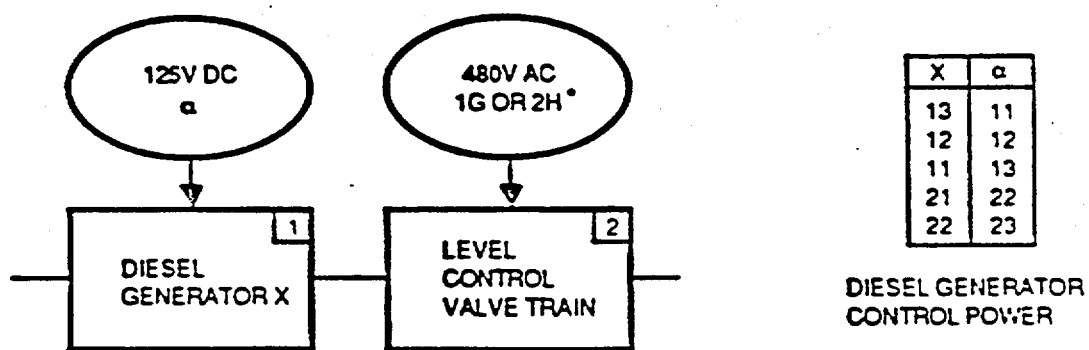
<u>Component</u>	<u>Fragility Designator</u>
DG Control Panel	ZDGCPN
DG Excitation Panel	ZDGEXC
DG Radiator/Water Pump	ZDGRWP
Diesel Generator Itself	ZDGSLGN

By using the conditional seismic failure probabilities ("fragilities"), the DCPRA combines them into a "seismic term" denoted by SEIST. SEIST has seven values corresponding to the seven seismic levels (i.e., spectral acceleration ranges) defined in the DCPRA. The seven SEIST values were determined by the mean fragilities of the diesel components listed in Table 6-44 on p.6-175 of Reference 1.

In order to calculate seismic split fractions, the DCPRA combines the SEIST values with the total unavailability values (TTL) coming from the conventional hardware, maintenance, test and human failures. In the case of seismic events, however, the DCPRA (correctly and innovatively) treats many human failures as seismic level-dependent; that is, the human factor probabilities are also dependent upon the seismic level.

To be more specific, the human failure which affects the TTL unavailabilities is the "failure to reestablish fuel oil transfer to day tanks by aligning a portable fuel oil transfer pump (see also Figure 2.10) and by controlling the day tank LCVs manually;" its designator is ZHEF06. For numerical values as a function of seismic level, see Appendix G of the DCPRA Table G.1-2, transmitted recently to BNL by PG&E.<sup>4</sup>

By using the resultant unavailabilities (SEIST + seismic level dependent TTL) the conditional seismic split fractions were determined for each diesel top events according to the rules of the sequential diesel failure model. These split fractions are listed as a function of the seismic level in Table 2.7. Each value of the table has a slight AOT dependence through the maintenance contribution to the TTL component of the unavailability.

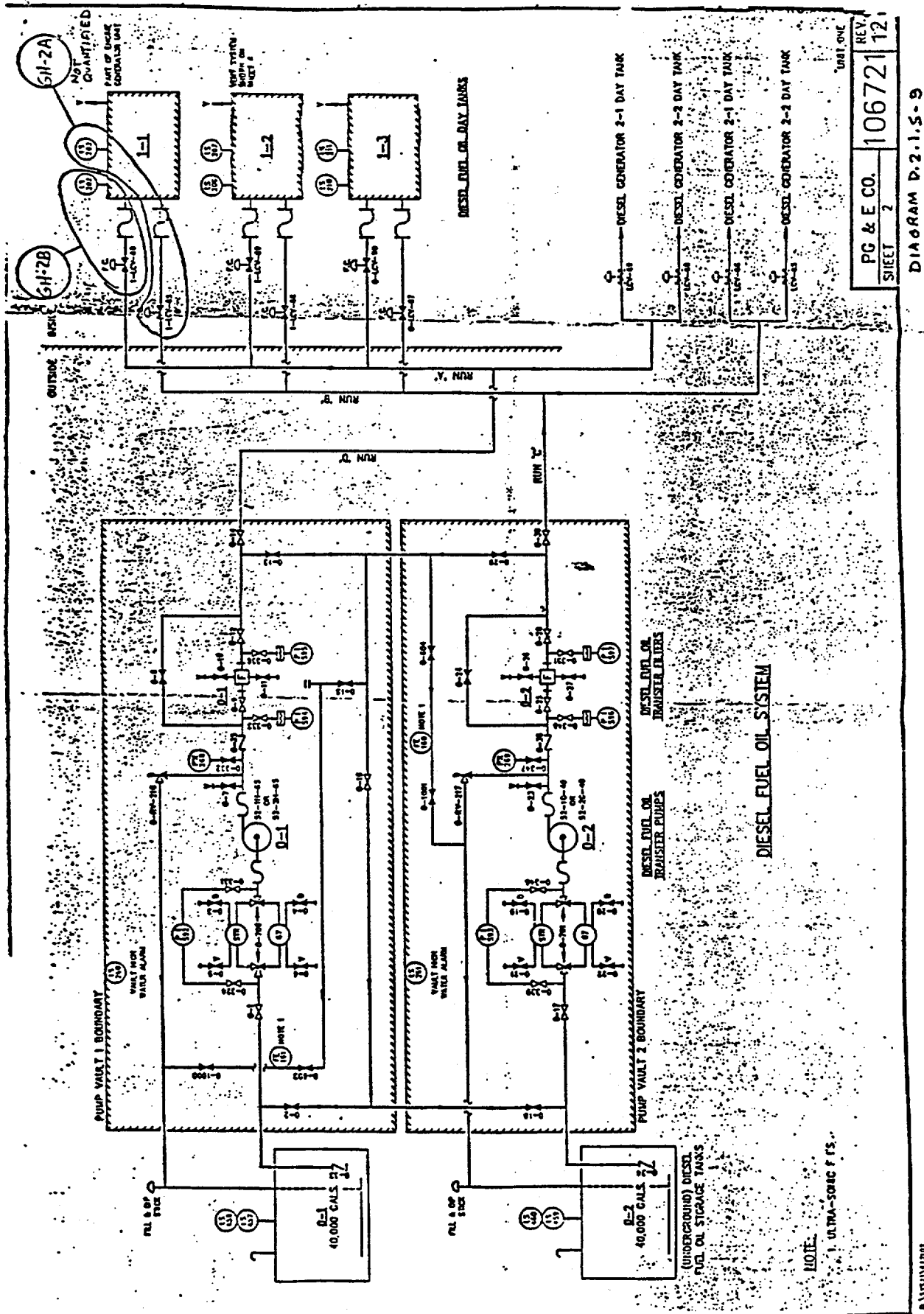


\* THESE ARE THE NORMAL POWER SUPPLIES FOR THE TWO LCV TRAINS;  
THE BACKUPS ARE 2G AND 1H RESPECTIVELY

Figure 2.1. Reliability block diagram for the diesel generators.









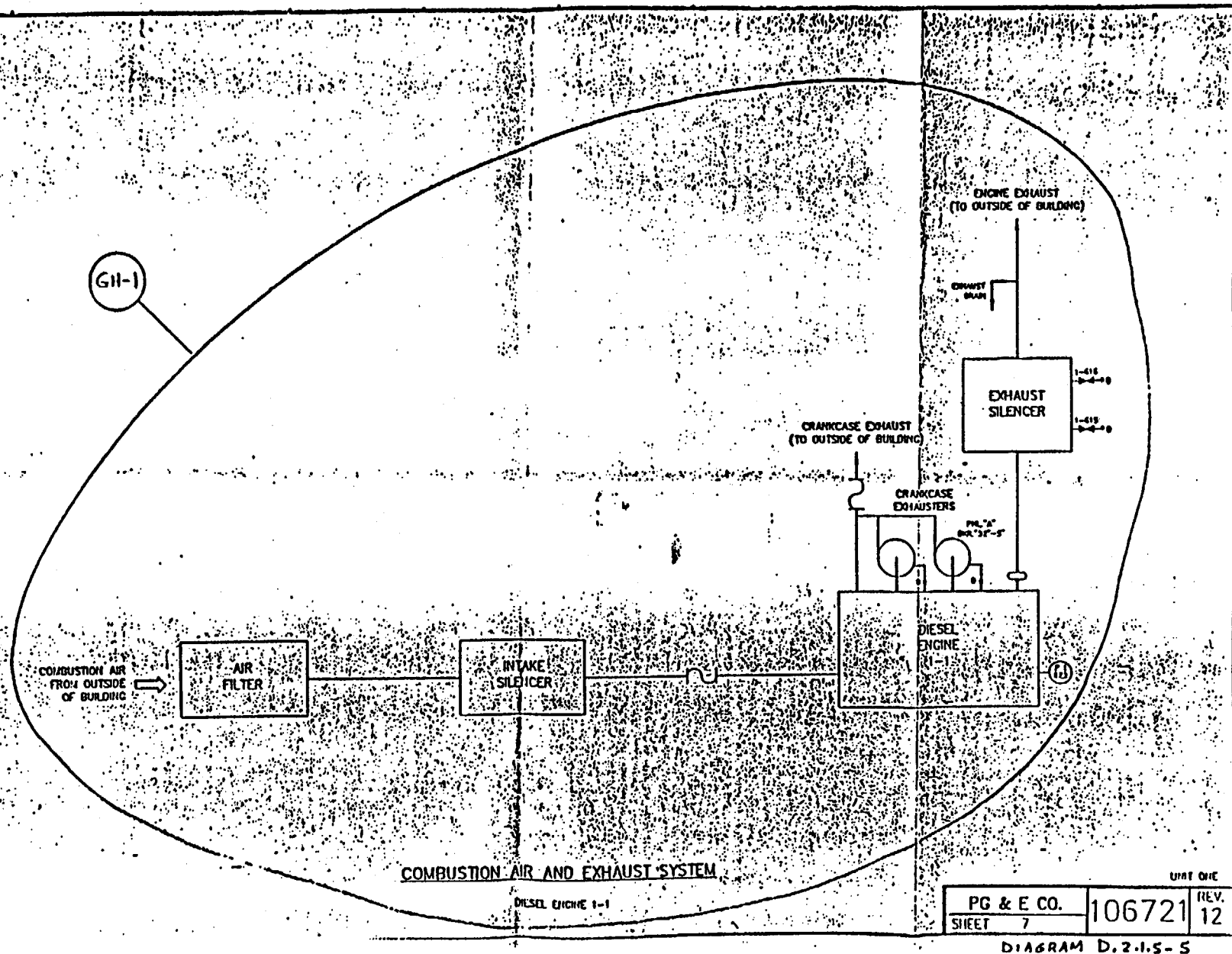
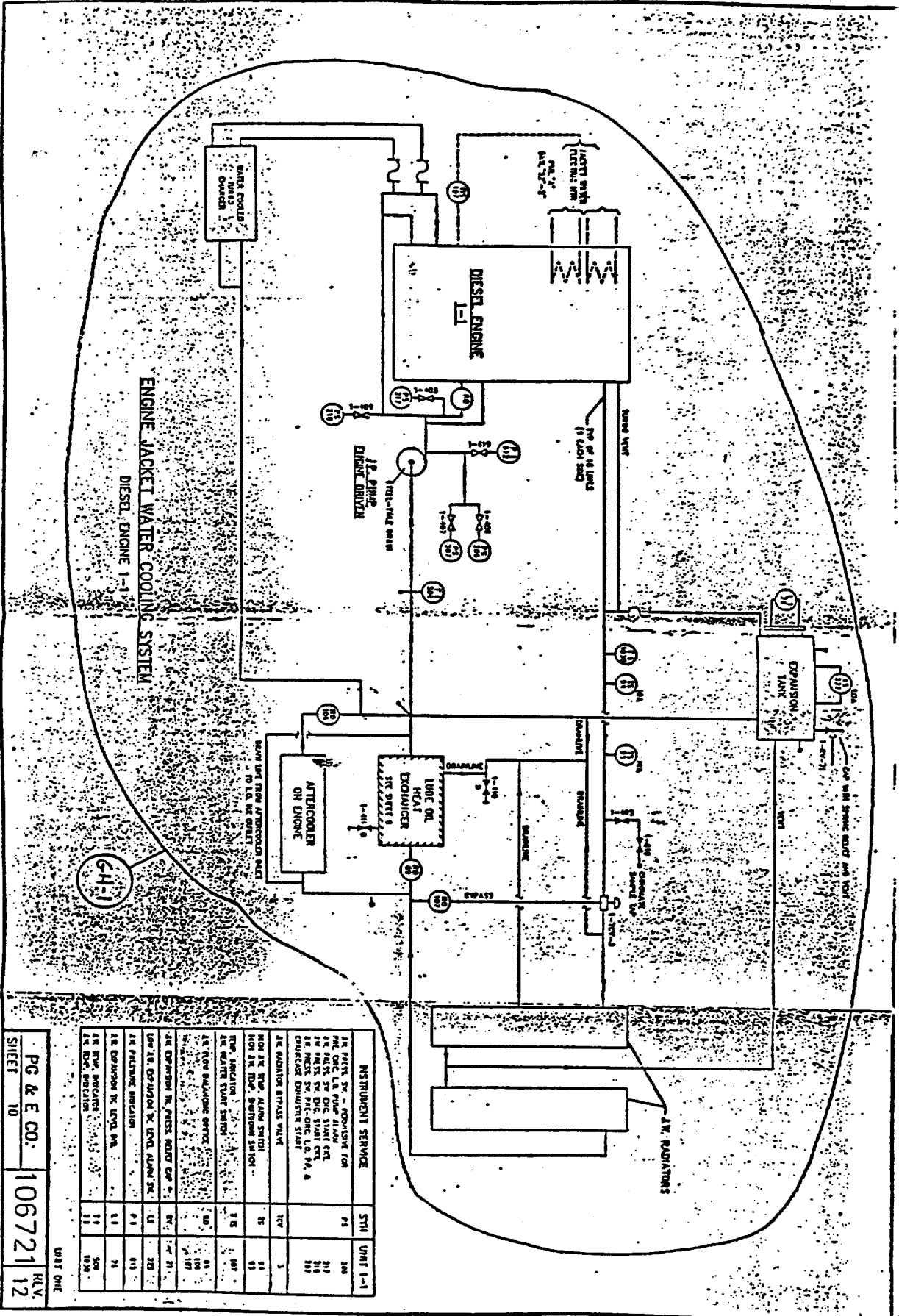


Figure 2.6. Diesel Generators; Supercomponents.



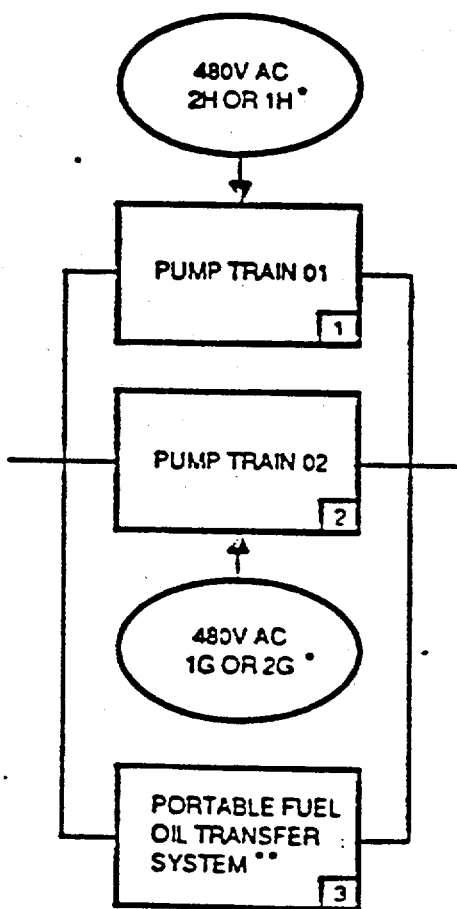






INSTRUMENT SERVICE		SYM	UNIT 1-1
1-1 PRESS. SW. - PRODUCTION FOR		P1	200
1-1 PRESS. SW. - PRODUCTION FOR		P2	210
1-1 PRESS. SW. - PRODUCTION FOR		P3	220
1-1 PRESS. SW. - PRODUCTION FOR		P4	230
1-1 PRESS. SW. - PRODUCTION FOR		P5	240
1-1 PRESS. SW. - PRODUCTION FOR		P6	250
1-1 PRESS. SW. - PRODUCTION FOR		P7	260
1-1 PRESS. SW. - PRODUCTION FOR		P8	270
1-1 PRESS. SW. - PRODUCTION FOR		P9	280
1-1 PRESS. SW. - PRODUCTION FOR		P10	290
1-1 PRESS. SW. - PRODUCTION FOR		P11	300
1-1 PRESS. SW. - PRODUCTION FOR		P12	310
1-1 PRESS. SW. - PRODUCTION FOR		P13	320
1-1 PRESS. SW. - PRODUCTION FOR		P14	330
1-1 PRESS. SW. - PRODUCTION FOR		P15	340
1-1 PRESS. SW. - PRODUCTION FOR		P16	350
1-1 PRESS. SW. - PRODUCTION FOR		P17	360
1-1 PRESS. SW. - PRODUCTION FOR		P18	370
1-1 PRESS. SW. - PRODUCTION FOR		P19	380
1-1 PRESS. SW. - PRODUCTION FOR		P20	390
1-1 PRESS. SW. - PRODUCTION FOR		P21	400
1-1 PRESS. SW. - PRODUCTION FOR		P22	410
1-1 PRESS. SW. - PRODUCTION FOR		P23	420
1-1 PRESS. SW. - PRODUCTION FOR		P24	430
1-1 PRESS. SW. - PRODUCTION FOR		P25	440
1-1 PRESS. SW. - PRODUCTION FOR		P26	450
1-1 PRESS. SW. - PRODUCTION FOR		P27	460
1-1 PRESS. SW. - PRODUCTION FOR		P28	470
1-1 PRESS. SW. - PRODUCTION FOR		P29	480
1-1 PRESS. SW. - PRODUCTION FOR		P30	490
1-1 PRESS. SW. - PRODUCTION FOR		P31	500
1-1 PRESS. SW. - PRODUCTION FOR		P32	510
1-1 PRESS. SW. - PRODUCTION FOR		P33	520
1-1 PRESS. SW. - PRODUCTION FOR		P34	530
1-1 PRESS. SW. - PRODUCTION FOR		P35	540
1-1 PRESS. SW. - PRODUCTION FOR		P36	550
1-1 PRESS. SW. - PRODUCTION FOR		P37	560
1-1 PRESS. SW. - PRODUCTION FOR		P38	570
1-1 PRESS. SW. - PRODUCTION FOR		P39	580
1-1 PRESS. SW. - PRODUCTION FOR		P40	590
1-1 PRESS. SW. - PRODUCTION FOR		P41	600
1-1 PRESS. SW. - PRODUCTION FOR		P42	610
1-1 PRESS. SW. - PRODUCTION FOR		P43	620
1-1 PRESS. SW. - PRODUCTION FOR		P44	630
1-1 PRESS. SW. - PRODUCTION FOR		P45	640
1-1 PRESS. SW. - PRODUCTION FOR		P46	650
1-1 PRESS. SW. - PRODUCTION FOR		P47	660
1-1 PRESS. SW. - PRODUCTION FOR		P48	670
1-1 PRESS. SW. - PRODUCTION FOR		P49	680
1-1 PRESS. SW. - PRODUCTION FOR		P50	690
1-1 PRESS. SW. - PRODUCTION FOR		P51	700
1-1 PRESS. SW. - PRODUCTION FOR		P52	710
1-1 PRESS. SW. - PRODUCTION FOR		P53	720
1-1 PRESS. SW. - PRODUCTION FOR		P54	730
1-1 PRESS. SW. - PRODUCTION FOR		P55	740
1-1 PRESS. SW. - PRODUCTION FOR		P56	750
1-1 PRESS. SW. - PRODUCTION FOR		P57	760
1-1 PRESS. SW. - PRODUCTION FOR		P58	770
1-1 PRESS. SW. - PRODUCTION FOR		P59	780
1-1 PRESS. SW. - PRODUCTION FOR		P60	790
1-1 PRESS. SW. - PRODUCTION FOR		P61	800
1-1 PRESS. SW. - PRODUCTION FOR		P62	810
1-1 PRESS. SW. - PRODUCTION FOR		P63	820
1-1 PRESS. SW. - PRODUCTION FOR		P64	830
1-1 PRESS. SW. - PRODUCTION FOR		P65	840
1-1 PRESS. SW. - PRODUCTION FOR		P66	850
1-1 PRESS. SW. - PRODUCTION FOR		P67	860
1-1 PRESS. SW. - PRODUCTION FOR		P68	870
1-1 PRESS. SW. - PRODUCTION FOR		P69	880
1-1 PRESS. SW. - PRODUCTION FOR		P70	890
1-1 PRESS. SW. - PRODUCTION FOR		P71	900
1-1 PRESS. SW. - PRODUCTION FOR		P72	910
1-1 PRESS. SW. - PRODUCTION FOR		P73	920
1-1 PRESS. SW. - PRODUCTION FOR		P74	930
1-1 PRESS. SW. - PRODUCTION FOR		P75	940
1-1 PRESS. SW. - PRODUCTION FOR		P76	950
1-1 PRESS. SW. - PRODUCTION FOR		P77	960
1-1 PRESS. SW. - PRODUCTION FOR		P78	970
1-1 PRESS. SW. - PRODUCTION FOR		P79	980
1-1 PRESS. SW. - PRODUCTION FOR		P80	990
1-1 PRESS. SW. - PRODUCTION FOR		P81	1000

Figure 2.9. Diesel Generators; Supercomponents.



- \* BACKUP POWER SOURCE
- \*\* THE PORTABLE FUEL OIL TRANSFER SYSTEM IS EVALUATED IN THE ELECTRIC POWER RECOVERY MODEL

Figure 2.10. Reliability block diagram for the diesel fuel oil transfer system (Top Event, FO).

July 12, 1989

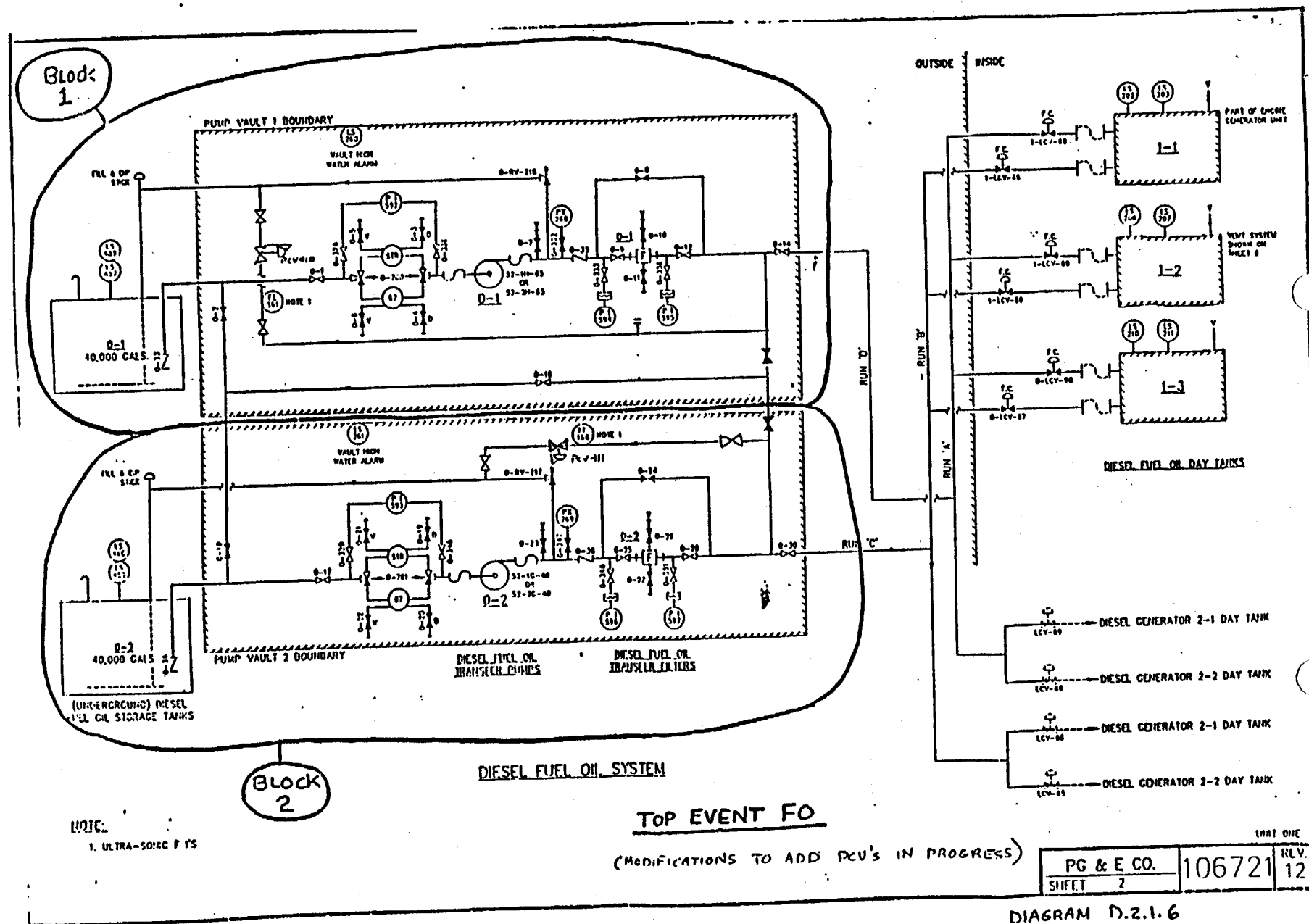


Figure 2.11. Top Event, FO - Supercomponents. Diesel fuel oil transfer system.

Table 2.1

Bus	DG	Vital Safety-Related Loads
F	1-3 (Swing)	Centrifugal Charging Pump No.1 Safety Injection Pump No.1 Containment Fan Cooler Unit No.2 Containment Fan Cooler Unit No.1 Component Cooling Water Pump No.1 Auxiliary Saltwater Pump No.1 Auxiliary Feedwater Pump No.3
G	1-2 (2-1)	Centrifugal Charging Pump No.2 Residual Heat Removal Pump No.1 Containment Fan Cooler Unit No.3 Containment Fan Cooler Unit No.5 Component Cooling Water Pump No.2 Auxiliary Saltwater Pump No.2 Containment Spray Pump No.1
H	1-1 (2-2)	Safety Injection Pump No.2 Residual Heat Removal Pump No.2 Containment Fan Cooler Unit No.4 Component Cooling Water Pump No.3 Auxiliary Feedwater Pump No.2 Containment Spray Pump No.2

Table 2.2  
Top Event Definition and Success Criteria  
Diesel Generator and Diesel Fuel Transfer Systems

Top Event Designator	Top Event Definition	Top Event Success Criteria
GF	DG13 provides power for	Each top event is successful if the corresponding DG starts on undervoltage signal from its bus, takes bus loads and continues powering loads for the appropriate mission times. (6 hours or 24 hours).
GG	DG12 6 hours (24 hours	
GH	DG11 for seismic events)	
2G	DG21 to 4.16kV ac buses	
2H	DG22	
	(Bus index numbers indicate plant Unit No.)	
SW	Swing diesel alignment. DG13 is normally aligned to Unit 1.	The value of SW determines whether DG13 goes to Unit 2. A value of 0 indicates it does not, a value between 0 and 1 represents the probability that it does.
FO	Diesel fuel oil transfer system provides fuel oil for each of the DGs for six hours (24 hours for seismic events).	One of two pumps starts on low day tank level and refills each day tank for the period that each diesel operates.

FSAR Success Criteria:

Any two of three DGs and their associated buses are adequate to serve the vital loads necessary for safe shutdown of a single unit (although one DG may supply power to two vital buses at the same time, no credit is currently given this mode of operation).

The diesel fuel oil transfer system must remain operable and deliver fuel to each of the DGs for the time the DGs are required to operate. There must be enough fuel in storage tanks for seven days of power generation.

Technical Specifications:

With a single DG inoperable, demonstrate the operability of the remaining ac sources within 24 hours. Restore the diesel within 72 hours.

With two DGs inoperable, demonstrate the operability of the two offsite ac circuits (one 230kV and one 500kV line) within one hour and at least once every eight hours. Restore at least two of the inoperable diesels within two hours.

Table 2.3  
Boundary Condition and Split Fraction Identifications  
for Top Events GF, GG, GH, 2G, 2H, and SW

Top Event	Case	Diesel Conditions					Comments
		13	12	11	21	22	
GF - Unavailability of DG13 under the following conditions:							
	GF1						All support available.
GG - Unavailability of DG12 under the following conditions:							
	GG1	0					Offsite grid succeeded, GF succeeded.
	GG2	1					Offsite grid succeeded, GF failed.
	GG3	-					Offsite grid succeeded, GF bypassed (not demanded)
GH - Unavailability of DG11 under the following conditions:							
	GH1	0	0				Offsite grid succeeded, both GF, GG succeeded.
	GH2	0	1				Offsite grid succeeded, GF-S/F, GG-F/S (two possible combinations).
	GH3	1	1				Offsite grid succeeded, both GF, GG failed.
	GH4	0	-				Offsite grid succeeded, GF-S/B, GG-B/S (two possible combinations).
	GH5	1	-				Offsite grid succeeded, GF-F/B, GG-B/F (two possible combinations).
	GH6	-	-				Offsite grid succeeded, both GF, GG bypassed.
2G - Unavailability of DG21 under the following conditions:							
	2G1	0	0	0			Offsite grid failed, all GF, GG, and GH succeeded.
	2G2	0	0	1			Offsite grid failed, two of GF, GG, and GH succeeded, the third failed (three possible combinations).
	2G3	0	1	1			Offsite grid failed, two of GF, GG, GH failed, the third succeeded (three possible combinations).
	2G4	1	1	1			Offsite grid failed, all GF, GG, GH failed.
	2G5	0	0	-			Offsite grid failed, two of GF, GG, GH succeeded, the third bypassed (three possible combinations).



Table 2.3 (Continued)

Top Event	Case	Diesel Conditions					Comments
		13	12	11	21	22	
	2G6	0	1	-			Offsite grid failed, one of GF, GG, GH succeeded, one failed, the third bypassed (six possible combinations).
	2G7	1	1	-			Offsite grid failed, two of GF, GG, GH failed, the third bypassed (three possible combinations).
	2G8	0	-	-			Offsite grid failed, one of GF, GG, GH succeeded, the other two bypassed (three possible combinations).
	2G9	1	-	-			Offsite grid failed, one of GF, GG, GH failed, the other two bypassed (three possible combinations). 2GA-- -Offsite grid failed, all of GF, GG, GH bypassed.

## 2H - Unavailability of DG22 under the following conditions:

2H1	0	0	0	0			Offsite grid failed, all of GF, GG, GH, 2G succeeded.
2H2	1	0	0	0			Offsite grid failed, one of GF, GG, GH, 2G failed, the other three succeeded (four possible combinations).
2H3	1	1	0	0			Offsite grid failed, two of GF, GG, GH, 2G failed, the other two succeeded (six possible combinations).
2H4	1	1	1	0			Offsite grid failed, three of GF, GG, GH, 2G failed, the fourth succeeded (four possible combinations).
2H5	1	1	1	1			Offsite grid failed, all of GF, GG, GH, 2G failed.
2H6	0	0	0	-			Offsite grid failed, three of GF, GG, GH, 2G succeeded, the fourth bypassed (four possible combinations).
2H7	0	0	1	-			Offsite grid failed, two of GF, GG, GH, 2G succeeded, one failed, the fourth bypassed (12 possible combinations).
2H8	0	1	1	-			Offsite grid failed, two of GF, GG, GH, 2G failed, one succeeded, the

Table 2.3 (Continued)

Top Event	Case	Diesel Conditions					Comments
		13	12	11	21	22	
	2H9	1	1	1	-		fourth bypassed (12 possible combinations). Offsite grid failed, three of GF, GG, GH, 2G failed, the fourth bypassed (four possible combinations).
	2HA	0	0	-	-		Offsite grid failed, two of GF, GG, GH, 2G succeeded, the other two bypassed (six possible combinations).
	2HB	-	-	1	0		Offsite grid failed, two of GF, GG, GH, 2G bypassed, one failed, the fourth succeeded (12 possible combinations).
	2HC	-	-	1	1		Offsite grid failed, two of GF, GG, GH, 2G bypassed, the other two failed (six possible combinations).
	2HD	-	-	-	0		Offsite grid failed, three of GF, GG, GH, 2G bypassed, the fourth succeeded (four possible combinations).
	2HE	-	-	-	1		Offsite grid failed, three of GF, GG, GH, 2G bypassed, the fourth failed (four possible combinations).
	2HG	-	-	-	-		Offsite grid failed, all of GF, GG, GH, 2G bypassed.
SW	SW0						LOCA, the swing diesel locked to the Unit 1.
	SW1						LOSP, with equal chance for swing diesel to operate on each unit.
	SW2						LOSP, with more DGs aligned to Unit 2 than Unit 1.
	SW3						LOSP, with more DGs aligned to Unit 1 than Unit 2.

Notes: 0 - Succeeded  
 1 - Failed  
 - - Bypassed

Table 2.4  
 Diesel Fuel Oil Transfer System Boundary  
 Conditions for Top Event, LO

Split Fraction ID	
F01	All support available.
F02	Support available to one train only.
F03	1/2 normal support available; recover support to the other train by realignment to backup support.
F04	2/2 normal support unavailable; recover supports by realignment to backups.
F05	2/2 normal supports unavailable; recover only 1/2 backup support by realignment.
F06	All support unavailable (guaranteed failure).

Table 2.5  
Unavailability Values (Conditional Split Fractions) for the  
Diesel Generator System

Top Event	Case	Calc.	CSF	TTL	HW	HWI	HWD	TS	MN	HE	Comment #
GF	GF1	PG&E	4.523-2	4.554-2	3.703-2	3.689-2	1.393-4	2.950-4	8.217-3	--	
		BNL	4.571-2	4.603-2	3.754-2	3.695-2	5.860-4	2.934-4	8.198-3	--	
GG	GG1	PG&E	4.477-2	4.554-2	as GF1						
		BNL	4.527-2	4.603-2							
	GG2	PG&E	5.561-2	2.702-3	1.749-3	1.536-3	2.129-4	4.989-5	9.025-4	--	
		BNL	5.474-2	2.540-3	1.581-3	1.366-3	2.149-4	4.980-5	9.089-4	--	
	GG3	PG&E	4.523-2	4.554-2	as GF1						
		BNL	4.571-2	4.603-2							
GH	GH1	PG&E	4.436-2	4.554-2	as GF1						
		BNL	4.490-2	4.603-2							
	GH2	PG&E	5.408-2	2.702-3	as GG2						
		BNL	5.322-2	2.540-3							
	GH3	PG&E	8.265-2	2.339-4	1.264-4	7.438-5	5.204-5	3.173-5	7.566-5	--	
		BNL	8.097-2	2.066-4	1.034-4	5.057-5	5.284-5	3.128-5	7.194-5	--	
	GH4	PG&E	4.477-2	4.554-2	as GF1						
		BNL	4.527-2	4.603-2							
	GH5	PG&E	5.561-2	2.702-3	as GG2						
		BNL	5.474-2	2.540-3							
	GH6	PG&E	4.523-2	4.554-2	as GF1						
		BNL	4.571-2	4.603-2							
2G	2G1	PG&E	4.396-2	4.554-2	as GF1						
		BNL	4.453-2	4.603-2							
	2G2	PG&E	5.364-2	2.702-3	as GG2						
		BNL	5.271-2	2.540-3							
	2G3	PG&E	6.250-2	2.339-4	as GH3						
		BNL	6.246-2	2.066-4							
	2G4	PG&E	2.898-1	6.369-5	2.597-5	4.314-6	2.166-5	3.049-5	7.221-6	--	
		BNL	2.910-1	5.995-5	2.363-5	1.874-6	2.176-5	3.017-5	6.176-6	--	

Table 2.5 (Continued)

Top Event	Case	Calc.	CSF	TTL	HW	HWI	HWD	TS	MN	HE	Comment #
	2G5	PG&E BNL	4.436-2 4.490-2	4.554-2 4.603-2	as GF1						
	2G6	PG&E BNL	5.408-2 5.322-2	2.702-3 2.540-3	as GG2						
	2G7	PG&E BNL	8.265-2 8.097-2	2.339-4 2.066-4	as GH3						
	2G8	PG&E BNL	4.477-2 4.527-2	4.554-2 4.603-2	as GF1						
	2G9	PG&E BNL	5.561-2 5.474-2	2.702-3 2.540-3	as GG2						
	2GA	PG&E BNL	4.523-2 4.571-2	4.554-2 4.603-2	as GF1						
	2H1	PG&E BNL	4.356-2 4.417-2	4.554-2 4.603-2	as GF1						
	2H2	PG&E BNL	5.320-2 5.219-2	2.702-3 2.540-3	as GG2						
	2H3	PG&E BNL	6.206-2 6.196-2	2.339-4 2.066-4	as GH3						
	2H4	PG&E BNL	6.922-2 7.003-2	6.369-5 5.995-5	as 2G4						
	2H5	PG&E BNL	7.729-1 8.294-1	5.034-5 4.975-5	1.851-5 1.842-5	3.020-7 6.950-8	1.820-5 1.836-5	3.039-5 3.006-5	1.436-6 1.272-6		
	2H6	PG&E BNL	4.396-2 4.453-2	4.554-2 4.603-2	as GF1						
	2H7	PG&E BNL	5.364-2 5.271-2	2.702-3 2.540-3	as GG2						
	2H8	PG&E BNL	6.250-2 6.246-2	2.339-4 2.066-4	as GH3						
	2H9	PG&E BNL	2.898-1 2.910-1	6.369-5 5.995-5	as 2G4						

Table 2.5 (Continued)

Exp Event	Case	Calc.	CSF	TTL	HW	HWI	HWD	TS	MN	HE	Comment #
	2HA	PG&E	4.436-2	4.554-2	} as GF1						
		BNL	4.490-2	4.603-2							
	2HB	PG&E	5.408-2	2.702-3	} as GG2						
		BNL	5.322-2	2.540-3							
	2HC	PG&E	8.265-2	2.339-4	} as GH3						
		BNL	8.098-2	2.066-4							
	2HD	PG&E	4.477-2	4.554-2	} as GF1						
		BNL	4.527-2	4.603-2							
	2HE	PG&E	5.561-2	2.702-3	} as GG2						
		BNL	5.474-2	2.540-3							
	2HG	PG&E	4.523-2	4.554-2	} as GF1						
		BNL	4.571-2	4.603-2							
	SW0	PG&E		0.000							
		BNL		0.000							
	SW1	PG&E		5.000-1							
		BNL		5.000-1							
	SW2	PG&E		1.767-3							
		BNL		1.770-3							
	SW3	PG&E		9.981-1							
		BNL		9.982-1							

Table 2.6  
Unavailability Values (Split Fractions) for the  
Diesel Fuel Transfer System

Top Event	Case	Calc.	TTL	HW	HWI	HWD	TS	MN	HE
FO	FO1	PG&E	2.164-4	1.919-4	1.176-5	1.802-4	0.0	2.445-5	0.0
		BNL	2.092-4	1.848-4	8.533-6	1.763-4	0.0	2.447-5	0.0
	FO2	PG&E	7.040-3	3.113-3	2.933-3	1.802-4	0.0	3.930-3	0.0
		BNL	7.048-3	3.097-3	2.921-3	1.763-4	0.0	3.951-3	0.0
	FO3	PG&E	3.509-4	1.919-4	1.176-5	1.802-4	0.0	2.445-5	0.0
		BNL	3.460-4	1.848-4	8.533-6	1.763-4	0.0	2.447-5	0.0
	FO4	PG&E	2.263-2	1.919-4	1.176-5	1.802-4	0.0	2.445-5	0.0224
		BNL	2.250-2	1.848-4	8.533-6	1.763-4	0.0	2.447-5	0.0223
	FO5	PG&E	5.079-2	3.113-3	2.933-3	1.802-4	0.0	3.930-3	0.0224
		BNL	2.292-2	3.097-3	2.921-3	1.763-4	0.0	3.951-3	0.0223
	FOF	PG&E	1.0						
		BNL	1.0						

Table 2.7a  
Conditional Split Fractions for DG Top Events  
as a Function of Seismic Level

PC&E

Split Fraction SD	Seismic Level (spectral acceleration, g )						
	0.0-0.2	0.2-1.25	1.25-1.75	1.75-2.0	2.0-2.5	2.5-3.0	3.0-4.0
CC1	8.5100E-02	8.5100E-02	8.5660E-02	9.3020E-02	1.0550E-01	1.7000E-01	2.8270E-01
CC2	8.4170E-02	8.4170E-02	8.4170E-02	8.7670E-02	8.7670E-02	1.0560E-01	1.0560E-01
CC3	9.5020E-02	9.5020E-02	1.0150E-01	1.4510E-01	2.5700E-01	4.8460E-01	7.3210E-01
CC4	8.5100E-02	8.5100E-02	8.5660E-02	9.3020E-02	1.0550E-01	1.7000E-01	2.8270E-01
CB1	8.3340E-02	8.3340E-02	8.3340E-02	8.6700E-02	8.6700E-02	1.0430E-01	1.0430E-01
CB2	9.3290E-02	9.3290E-02	9.3290E-02	9.7810E-02	9.7810E-02	1.1630E-01	1.1630E-01
CB3	1.1150E-01	1.1150E-01	1.7450E-01	4.2380E-01	7.1720E-01	8.7630E-01	9.5750E-01
CB4	8.4170E-02	8.4170E-02	8.4170E-02	8.7670E-02	8.7670E-02	1.0560E-01	1.0560E-01
CB5	9.5020E-02	9.5020E-02	1.0150E-01	1.4510E-01	2.5700E-01	4.8460E-01	7.3210E-01
CB6	8.5100E-02	8.5100E-02	8.5660E-02	9.3020E-02	1.0550E-01	1.7000E-01	2.8270E-01
CC1	8.2510E-02	8.2510E-02	8.2510E-02	8.5740E-02	8.5740E-02	1.0310E-01	1.0310E-01
CC2	9.2440E-02	9.2440E-02	9.2440E-02	9.6770E-02	9.6770E-02	1.1490E-01	1.1490E-01
CC3	1.0160E-01	1.0160E-01	1.0160E-01	1.0740E-01	1.0740E-01	1.2650E-01	1.2650E-01
CC4	1.9030E-01	1.9030E-01	5.1950E-01	8.5400E-01	9.5770E-01	9.8210E-01	9.9440E-01
CC5	8.3340E-02	8.3340E-02	8.3340E-02	8.6700E-02	8.6700E-02	1.0430E-01	1.0430E-01
CC6	9.3290E-02	9.3290E-02	9.3290E-02	9.7810E-02	9.7810E-02	1.1630E-01	1.1630E-01
CC7	1.1150E-01	1.1150E-01	1.7450E-01	4.2380E-01	7.1720E-01	8.7630E-01	9.5750E-01
CC8	8.4170E-02	8.4170E-02	8.4170E-02	8.7670E-02	8.7670E-02	1.0560E-01	1.0560E-01
CC9	9.5020E-02	9.5020E-02	1.0150E-01	1.4510E-01	2.5700E-01	4.8460E-01	7.3210E-01
CC10	8.5100E-02	8.5100E-02	8.5660E-02	9.3020E-02	1.0550E-01	1.7000E-01	2.8270E-01
CB1	8.1690E-02	8.1690E-02	8.1690E-02	8.4800E-02	8.4800E-02	1.0190E-01	1.0190E-01
CB2	9.1620E-02	9.1620E-02	9.1620E-02	9.5780E-02	9.5780E-02	1.1360E-01	1.1360E-01
CB3	1.0050E-01	1.0050E-01	1.0050E-01	1.0600E-01	1.0600E-01	1.2470E-01	1.2470E-01
CB4	1.1120E-01	1.1120E-01	1.1120E-01	1.1890E-01	1.1890E-01	1.3930E-01	1.3930E-01
CB5	5.2690E-01	5.2690E-01	8.9720E-01	9.7970E-01	9.9470E-01	9.9750E-01	9.9920E-01
CB6	8.2510E-02	8.2510E-02	8.2510E-02	8.5740E-02	8.5740E-02	1.0310E-01	1.0310E-01
CB7	9.2440E-02	9.2440E-02	9.2440E-02	9.6770E-02	9.6770E-02	1.1490E-01	1.1490E-01
CB8	1.0160E-01	1.0160E-01	1.0160E-01	1.0740E-01	1.0740E-01	1.2650E-01	1.2650E-01
CB9	1.9030E-01	1.9030E-01	5.1950E-01	8.5400E-01	9.5770E-01	9.8210E-01	9.9440E-01
CB10	8.3340E-02	8.3340E-02	8.3340E-02	8.6700E-02	8.6700E-02	1.0430E-01	1.0430E-01
CB11	9.3290E-02	9.3290E-02	9.3290E-02	9.7810E-02	9.7810E-02	1.1630E-01	1.1630E-01
CB12	1.1150E-01	1.1150E-01	1.7450E-01	4.2380E-01	7.1720E-01	8.7630E-01	9.5750E-01
CB13	8.4170E-02	8.4170E-02	8.4170E-02	8.7670E-02	8.7670E-02	1.0560E-01	1.0560E-01
CB14	9.5020E-02	9.5020E-02	1.0150E-01	1.4510E-01	2.5700E-01	4.8460E-01	7.3210E-01
CB15	8.5100E-02	8.5100E-02	8.5660E-02	9.3020E-02	1.0550E-01	1.7000E-01	2.8270E-01
SW0	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01
SW1	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01	5.0000E-01
SW2	1.7500E-03	1.7500E-03	1.7500E-03	1.0000E-02	1.0000E-02	5.0000E-02	5.0000E-02
SW3	9.9820E-01	9.9820E-01	9.9820E-01	9.9000E-01	9.9000E-01	9.5000E-01	9.5000E-01

July 25, 1989



Table 2.7b  
Conditional Split Fractions for DG Top Events  
as a Function Seismic Level

BNL

Split Fraction ID	Seismic Level (spectral acceleration, g )						
	0.0-0.2	0.2-1.25	1.25-1.75	1.75-2.0	2.0-2.5	2.5-3.0	3.0-4.0
GF1=	3.339E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GG1=	8.325E-02	8.325E-02	8.325E-02	8.687E-02	8.687E-02	1.054E-01	1.054E-01
GG2=	9.085E-02	9.087E-02	9.748E-02	1.419E-01	2.551E-01	4.831E-01	7.309E-01
GG3=	8.389E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GH1=	8.272E-02	8.272E-02	8.272E-02	8.618E-02	8.618E-02	1.044E-01	1.044E-01
GH2=	8.913E-02	8.913E-02	8.913E-02	9.417E-02	9.417E-02	1.145E-01	1.145E-01
GH3=	1.080E-01	1.082E-01	1.747E-01	4.306E-01	7.250E-01	8.774E-01	9.578E-01
GH4=	8.325E-02	8.325E-02	8.325E-02	8.687E-02	8.687E-02	1.054E-01	1.054E-01
GH5=	9.085E-02	9.087E-02	9.748E-02	1.419E-01	2.551E-01	4.831E-01	7.309E-01
GH6=	8.389E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GG1=	3.339E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GG2=	8.325E-02	8.325E-02	8.325E-02	8.687E-02	8.687E-02	1.054E-01	1.054E-01
GG3=	9.085E-02	9.087E-02	9.748E-02	1.419E-01	2.551E-01	4.831E-01	7.309E-01
GG4=	1.905E-01	1.929E-01	5.374E-01	8.614E-01	9.603E-01	9.823E-01	9.944E-01
GG5=	8.272E-02	8.272E-02	8.272E-02	8.618E-02	8.618E-02	1.044E-01	1.044E-01
GG6=	8.913E-02	8.913E-02	8.913E-02	9.417E-02	9.417E-02	1.145E-01	1.145E-01
GG7=	1.080E-01	1.082E-01	1.747E-01	4.306E-01	7.250E-01	8.774E-01	9.578E-01
GG8=	8.325E-02	8.325E-02	8.325E-02	8.687E-02	8.687E-02	1.054E-01	1.054E-01
GG9=	9.085E-02	9.087E-02	9.748E-02	1.419E-01	2.551E-01	4.831E-01	7.309E-01
GG10=	8.389E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GG11=	3.175E-02	8.175E-02	8.175E-02	8.492E-02	8.492E-02	1.024E-01	1.024E-01
GG12=	8.744E-02	8.744E-02	8.744E-02	9.200E-02	9.200E-02	1.115E-01	1.115E-01
GG13=	9.638E-02	9.689E-02	9.689E-02	1.034E-01	1.034E-01	1.246E-01	1.246E-01
GG14=	1.077E-01	1.077E-01	1.077E-01	1.166E-01	1.166E-01	1.382E-01	1.382E-01
GG15=	5.433E-01	5.495E-01	9.073E-01	9.812E-01	9.952E-01	9.975E-01	9.992E-01
GG16=	8.221E-02	8.221E-02	8.221E-02	8.553E-02	8.553E-02	1.034E-01	1.034E-01
GG17=	8.827E-02	8.827E-02	8.827E-02	9.306E-02	9.306E-02	1.130E-01	1.130E-01
GG18=	9.794E-02	9.794E-02	9.794E-02	1.048E-01	1.048E-01	1.264E-01	1.264E-01
GG19=	1.905E-01	1.929E-01	5.374E-01	8.614E-01	9.603E-01	9.823E-01	9.944E-01
GG20=	8.272E-02	8.272E-02	8.272E-02	8.618E-02	8.618E-02	1.044E-01	1.044E-01
GG21=	8.913E-02	8.913E-02	8.913E-02	9.417E-02	9.417E-02	1.145E-01	1.145E-01
GG22=	1.080E-01	1.082E-01	1.747E-01	4.306E-01	7.250E-01	8.774E-01	9.578E-01
GG23=	8.325E-02	8.325E-02	8.325E-02	8.687E-02	8.687E-02	1.054E-01	1.054E-01
GG24=	9.085E-02	9.087E-02	9.748E-02	1.419E-01	2.551E-01	4.831E-01	7.309E-01
GG25=	8.389E-02	8.389E-02	8.445E-02	9.193E-02	1.044E-01	1.694E-01	2.815E-01
GG26=	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
GG27=	5.000E-01	5.000E-01	5.000E-01	5.000E-01	5.000E-01	5.000E-01	5.000E-01
GG28=	1.770E-03	1.770E-03	1.770E-03	1.000E-02	1.000E-02	5.000E-02	5.000E-02
GG29=	9.982E-01	9.982E-01	9.982E-01	9.900E-01	9.900E-01	9.500E-01	9.500E-01

July 25, 1989

### 3. RESULTS OF THE BNL REVIEW

#### 3.1 General

The unavailability modelling of the Diesel Generators and the Diesel Fuel Transfer System in the DCPRA were reviewed by BNL with special emphasis because of the following:

- a. The DGs are the most important support systems; impacting the safety of the majority of plant operations, including cold shutdown.
- b. As discussed in Section 1, a request for changing the Allowed Outage Time (AOT) of the Diesel Generators was submitted to the NRC by PG&E and the study<sup>2</sup> supporting the request is based mainly on the DCPRA. BNL is reviewing this study in a parallel effort to this review.

Therefore, to check the adequacy of the DCPRA modelling for "system-specific" effects which may also influence granting permission for AOT changes, BNL used the following approach: BNL compared the vendor-specific (ALCO) diesel failure events with those obtained from generic diesel data. This was done to see how well the DCPRA model reflects the vendor-specific "experience" and to estimate the expected downtime distribution of the diesels. The evaluation was carried out by reviewing the failure modes and maintenance unavailabilities involved in the diesel model. In order to check for calculational inconsistencies, all of the split fractions were recalculated (seismic inclusive).

#### 3.2 Comparison of ALCO Type DG Failures With All Types of DG Failures

In order to see whether the ALCO-type DGs used at the Diablo Canyon power plant have some subsystem- or component-specific failure modes (and thus, some subsystem or component specific expected downtimes) BNL compared the leading failure contributions of subsystems and components of ALCO diesels with those of all other types of DGs. The data were taken from a recent study performed at Battelle on aging of diesel components.<sup>5</sup> Table 3.1 presents the results.

One can see that the Instruments and Control System's (and within it the governor's) failures are the main contributors to the generic failures of ALCO diesels. Also with ALCO diesels, the Cooling System and to a lesser extent the Lubrication System seem to be more prone to failures than in the total generic DG population. A positive feature of the ALCO diesels is that the starting system appears to be less vulnerable to failure than the generic DG population. Finally, the ALCO fuel system does not seem to be any more prone to failures than the generic one.

### 3.3 Remarks on the Unavailability Modelling of the Diesels and Fuel Oil Transfer System in the DCPRA

- a. The system modelling of the DGs in the DCPRA represents an elaborate sequential unavailability analysis of a "five train" system, where one train (the swing diesel) is playing a special role. There is no question that the approach used is mathematically appealing because it uses the symmetry aspects of the diesel configuration and renders the results of the analysis very suitable for integration into the DCPRA. The complexity of the calculation, however, for casual readers is difficult and for eventual uses (e.g., change of AOT) is rather cumbersome. .
- b. In contrast with the systems modelling, the unavailability modelling of the individual diesels (the fault tree modelling) was kept simplistic by using the standard "diesel fails to start and run" failure modes. The diesel starting air system (i.e., air compressors, receivers, etc.) were not modelled separately because they were considered to be included as part of the diesel start failure data. An attempt was made to display some components of the diesel subsystems in the model. This effort, however, tended to be inconsistent in that only some support failures were modelled and inconsequential in that the modelled failures were of such low probability. For example, each supercomponent "2A" and "2B" contains the failure rates: "DG Air Receiver - Rupture During Operation: ZTTK1B - 2.66-8/hr," "Air Check Valve - Transfer Closed During Operation: ZTVCOB - 1.04-

8/hr," etc. The failure contribution of the turbocharger, however, with an estimated<sup>2</sup> failure probability of 2.73-4/d was neglected.

Another example: while the diesel supercomponent boundaries indicate several subsystems as part of the supercomponents (see Figures 2.6, 2.8, and 2.9), one cannot find any representative component failure rate contributing to the combined unavailability of those supercomponents. Such subsystems are: the cooling, the lubrication and the combustion air systems. Table 3.1 shows that the cooling system is the second largest contributor to the failure of the ALCO type diesels.

- c. The following remark also has relevance in connection with the AOT study<sup>2</sup> and concerns the expected downtime distribution of the diesel systems. The DCPRA models the maintenance frequency and duration of the LCVs as separate quantities from those of the diesels. If the day tank and other fuel system components are included in the maintenance data of the diesel, it is not clear why the LCV is treated separately. Given that it is treated separately, the mean and 95th percentile of the "effective" downtime distribution of the diesel system would be determined by the combination of the diesel and the LCV maintenance duration distributions (the 95th percentile value of the LCV maintenance durations is 51.3 hours).
- d. The DCPRA considers only unscheduled maintenances performed on Unit 2 diesels as contributing to the unavailabilities of the associated top events, "2G" and "2H." Unavailabilities due to large overhauls lasting over a protracted period of time performed when Unit 1 is operating and Unit 2 is in refueling (or cold shutdown) (say two times 10 to 16 days each) were not included in the model.
- e. In Table 2.6 the PG&E total split fraction value, F05 seems to be in variance with that obtained by BNL. The probable cause of the discrepancy is that the human error contribution was double counted in the DCPRA. The PG&E value is seemingly also in contradiction with the PG&E seismic values

given at the lowest three seismic levels in Table 6-46 (p.6-182) of Reference 1.

- f. The detailed analysis of the Fuel Oil Transfer System (see Figure D.2.1-3 Sheet 3 of 4) contains the following item (Item No.12): "In an emergency where it is necessary to get into the fuel oil pump vault to manipulate valves, it may take several hours to get security to open the vault." This item renders questionable the estimates of the human factors (among others the value of ZHEF06 used in the diesel analysis) considered for recovery of the Fuel Oil Transfer System and through it, the recovery of electrical power.
- g. Among the DG failure related LERs filed by the Diablo Canyon power plant,<sup>6</sup> there was one failure in the Fuel Oil Transfer System which would affect all the DGs. This common cause failure involved the degradation of the diesel oil in the underground reserve tanks caused by fungi. According to PG&E, the problem does not exist any more. However because of its peculiarity and importance it is quoted here:

LER 88-14. This report is being voluntarily submitted for information purposes only as described in Item 19 of Supplement No.1 to NUREG-1022. On May 4, 1988, during performance of surveillance test procedure (SRP) M-96, "diesel generator 24 hour load test," the diesel generator (DG) 1-1 load decreased below the value specified in the SRP acceptance criteria. An investigation showed that a high differential pressure existed across the primary fuel oil filter. After switching to the standby primary fuel oil filter, the load returned to the required value. An investigation determined that the DG day tank contained a fungus and that the first primary filter was clogged by fungus. The other DG day tanks also contained a fungus and fungus spores were found in the main storage tanks. The fuel oil in the day tanks was biocided and filtered until the fuel oil met the criteria of STP M-108, "diesel fuel oil analysis," for particulate contamination, flash point, API gravity and viscosity. The day tanks were drained, inspected and cleaned. The bottom of main storage tanks 0-1 and 0-2 were suctioned out and a biocide was added. A biocide program will be developed and implemented to inhibit the growth of fungus in the DG fuel oil storage system. Also, a sampling and inspection program for the DG day tanks will be developed. Both will be incorporated into plant procedures.

- h. It is not clear how the fire suppression (CO<sub>2</sub>) system in the DG rooms responds to various levels of seismic event. The safety concern is that if an earthquake fails the diesel units without causing fire, one or more DG rooms might be flooded with CO<sub>2</sub>, and therefore rescue personnel may not be able to recover the DGs within proper time intervals.

### 3.4 Audit Calculations

In order to scrutinize the quantified split fractions themselves, BNL performed audit calculations for each of the split fractions associated with each of the boundary conditions. The calculations were extended for both non-seismic (mission time: 6 hours) and seismic (mission time: 24 hours) cases. Seismic calculations were not performed for the Fuel Oil Transfer System. In these audit calculations the same assumptions, input data, maintenance and test frequency and duration, as well as mean fragility and human factor values were used as in the DCPRA. The SETS code<sup>7</sup> and locally generated PC software were used for the computations. The use of the SETS code allowed the identification of the most important cut sets contributing to the hardware unavailabilities. These cut sets are not readily accessible for direct review in the DCPRA. Appendix A lists the ranked cut sets for single, double, triple, quadruple and quintuple diesel failures. The definition of the basic events appearing in the cut sets are identical to those given in Chapter D.2.1.5 of the DCPRA.

The results obtained by the audit calculations are presented in Tables 2.6 and 2.7.b for the DGs and for the Fuel Oil Transfer System, respectively. They are denoted by "BNL" to be compared with the values given in the DCPRA (denoted by "PG&E"). It has to be emphasized, that if the review of the fragilities would identify incorrect values characterizing diesel components or the use of incorrect human failure rates would be detected during the review of the human factors, complete requantification of the Table 2.7.b split fractions would be necessary.

By comparing the PG&E and BNL results one can see that there is an overall agreement between the data. The agreement is even better, if one takes into account that BNL used point estimates, while PG&E mainly used a Monte-Carlo approach in the split fraction quantification.

### 3.5 Conclusions

The BNL review identified several inconsistencies and neglect of failures of diesel subsystems in the unavailability modelling of diesel generators in the DCPRA and the omission of the unavailability contribution from Unit 2 (and swing) diesels overhauls. The combined effect of these neglects may result in underestimation of the associated top event split fractions and through them the expected core damage frequency value of Unit 1.

The above remarks made in connection with the DCPRA simultaneously represent preliminary results concerning the verification of the Diesel Generator AOT study. In fact, the results of the audit calculations can also be considered as verification of the "base case" (i.e., present AOT conditions) in the PG&E diesel AOT study.<sup>2</sup>

Table 3.1  
Systems and Components Contributing Most to Failures  
at All Types of DGs and at ALCO Type DGs

Systems and Components	Percent of All Failures	Percent of Failures at ALCO DGs
Instrument and Controls System	25	26
Governor	10	15
Sensors	3	3
Relays	2	1
Startup Components	2	1
Fuel System	11	10
Piping on Engine	3	1
Injector Pumps	2	1
Fuel Oil Pumps		5
Starting System	10	6
Controls	3	3
Starting Air Valve	2	
Starting Motors	2	2
Air Compressor	1	1
Switchgear System	10	10
Breakers	3	4
Relays	5	4
Instrument and Controls	1	1
Cooling System	9	14
Pumps	2	1
Heat Exchangers	2	1
Piping	2	6
Lubrication System	7	8
Heat Exchangers	2	3
Pumps	2	3
Lube Oil	1	
Other Systems	28	26

Date Base: 1984 failure event recorded between 1974 and 1984 in Reference 5.  
Nuclear plants where ALCO Diesel Generators have been used in 1984:

    Indian Point 1 and 2, Power Authority of the State of NY  
    Salem 1 and 2, Public Service Electric and Gas Company  
    Palisades, Consumers' Power Company  
    Pilgrim 1, Boston Edison  
    Ginna, Rochester Gas and Electric



## REFERENCES

1. Final report on the Diablo Canyon Long-Term Seismic Program, Pacific Gas and Electric Co., Diablo Canyon Power Plant, Docket Nos. 50-275 and 50-323, July 1988.
2. Diesel Generator Allowed Outage Time Study, Pacific Gas & Electric Company, May 1989.
3. Units 1 and 2 Diablo Canyon Power Plant, "Final Safety Analysis Report Update," Pacific Gas and Electric Co., December 1988.
4. PG&E letters to NRC signed by J.D. Shiffer, No. DCL-88-238, October 10, 1988, No. DCL-88-260, October 28, 1988, No. DCL-88-285, November 29, 1988, No. DCL-88-297, December 9, 1988, No. DCL-89-010, January 16, 1989, and No. DCL-89-152, June 2, 1989.
5. Hoopingarner, K.R., Vause, J.W., Dingee, D.A., Nesbitt, J.F., "Aging of Nuclear Station Diesel Generators: Evaluation of Operating and Expert Experience," NUREG/CR-4590, August 1987.
6. DOE/RECON, Nuclear Safety Information Center (NSIC), 1963 to present.
7. Worrel, R.B. and Stack, D.W., "A SETS User's Manual for the Fault Tree Analyst," Sandia National Laboratories, NUREG/CR-0475, SAND77-2051, November 1978.

---

**APPENDIX A**

**HARDWARE UNAVAILABILITY CUT SETS FOR THE  
DIESEL GENERATORS**

---

# Hardware Unavailability Cutsets in Case of One DG

## Total Hardware, HW -

1	3.6736E-02	FID1F *
2	2.1339E-04	HEV * FIV1F *
3	1.1373E-04	DTC *
4	1.1073E-04	DDA *
5	1.1073E-04	DDD *
6	1.1073E-04	DDB *
7	1.7783E-05	GGG *
8	1.6417E-05	TDA *
9	1.6417E-05	TDC *
10	1.6417E-05	TDE *
11	1.6417E-05	TDB *
12	1.6417E-05	TDF *
13	1.6417E-05	TDD *
14	5.8176E-05	HEV * DVC *
15	5.8176E-05	HEV * DYA *
16	5.8176E-05	HEV * DVB *
17	5.8176E-05	HEV * DVS *
18	4.1268E-07	HEV * TVA *
19	4.1268E-07	HEV * TVC *
20	4.1268E-07	HEV * TVE *

## Independent Hardware, HWI -

1	3.6736E-02	FID1F *
2	2.1339E-04	HEV * FIV1F *

July 25, 1989

# Hardware Unavailability Outsets in Case of Two Dcs

Total Hardware, HW -

1	1.3-95E-01	FID1F + FID1G +
2	1.157E-04	DCA +
3	1.770E-05	CGG +
4	1.6-17E-05	TDE +
5	1.6-17E-05	TOA +
6	1.6-17E-05	TDC +
7	7.8392E-05	FID1F + MEV + FIV1G +
8	7.8392E-05	MEV + FIV1F + FID1G +
9	5.9175E-05	MEV + QVA +
10	4.357E-05	FID1F + DCF +
11	4.357E-05	FID1S + DDC +
12	4.357E-05	FID1F + DCG +
13	4.357E-05	FID1F + DCE +
14	4.067E-05	FID1G + DCC +
15	4.067E-05	FID1G + DDB +
16	1.1304E-05	MEV + FIV1F + FIV1G +
17	6.3309E-07	FID1F + FDI +

Independent Hardware, HWI -

1	1.3-95E-01	FID1F + FID1G +
2	7.8392E-05	FID1F + MEV + FIV1G +
3	7.8392E-05	MEV + FIV1F + FIV1G +
4	1.1304E-05	MEV + FIV1F + FIV1G +

July 25, 1989

# Hardware Unavailability Cutssets in Case of Three DGs

Total Hardware, HW =

Independent Hardware, HWI =

1	4.976E-05	FID1E + FID1G + FID1H +
2	1.770E-05	GOG +
3	1.647E-05	TDA +
4	4.067E-05	FID1H + DDA +
5	4.067E-05	FID1E + DDE +
6	4.067E-05	FID1G + DDE +
7	6.023E-07	FID1H + ICC +
8	6.020E-07	FID1E + TDA +
9	6.020E-07	FID1E + TDC +
10	6.020E-07	FID1G + TDD +
11	6.020E-07	FID1H + TDE +
12	6.020E-07	FID1G + TDE +
13	4.126E-07	MEV + TAA +
14	3.109E-07	MEV + GCG +
15	2.479E-07	MEV + FIV1E + FID1G + FID1H +
16	2.479E-07	FID1E + MEV + FIV1G + FID1H +
17	2.479E-07	FID1E + MEV + FIV1G + FIV1H +
18	2.137E-07	MEV + FID1H + DVA +

1	4.976E-05	FID1E + FID1G + FID1H +
2	2.479E-07	FID1E + MEV + FIV1G + FID1H +
3	2.479E-07	MEV + FIV1E + FID1G + FID1H +
4	2.479E-07	FID1E + MEV + FIV1G + FIV1H +
5	4.142E-06	FID1E + MEV + FIV1G + FIV1H +
6	4.142E-06	MEV + FIV1E + FIV1G + FID1H +
7	4.142E-06	MEV + FIV1E + FIV1G + FIV1H +
8	6.071E-09	MEV + FIV1E + FIV1G + FIV1H +

July 25, 1989

# Hardware Unavailability Cuts in Case of Four DCS

Total Hardware, HW -

1	1.7703E-05	GDG	+
2	1.9212E-06	FID1F	• FID1G • FID1H • FID2G
3	6.0309E-07	FID2G	• FID1G • FID1H • FID2G
4	6.0309E-07	FID1H	• FID1G • FID2G
5	6.0309E-07	FID1G	• FID1H • FID2G
6	6.0309E-07	FID1F	• FID1G • FID2G
7	3.1996E-07	MEV	• GCG
8	1.4943E-07	FID1H	• FID2G • FID2H
9	1.4943E-07	FID1F	• FID2G • FID2H
10	1.4943E-07	FID1G	• FID2G • FID2H
11	1.4943E-07	FID1G	• FID1H • FID2G
12	1.4943E-07	FID1F	• FID1G • FID2G
13	1.4943E-07	FID1H	• FID1G • FID2G
14	2.2155E-08	FID1F	• FID2G • FID2H
15	2.2155E-08	FID1G	• FID2G • FID2H
16	2.2155E-08	FID1H	• FID2G • FID2H
17	2.2155E-08	FID1H	• FID2G • FID2H
18	2.2155E-08	FID1F	• FID1G • FID2G
19	2.2155E-08	FID1H	• FID1G • FID2G
20	1.5160E-08	MEV	• FID1G • FID2G

Independent Hardware, HWI -

1	1.9212E-06	FID1F	• FID1G • FID1H • FID2G
2	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
3	1.0579E-06	MEV	• FID1G • FID1H • FID2G
4	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
5	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
6	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
7	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
8	1.0579E-06	MEV	• FID1G • FID1H • FID2G
9	1.0579E-06	MEV	• FID1G • FID1H • FID2G
10	1.0579E-06	MEV	• FID1G • FID1H • FID2G
11	1.0579E-06	FID1F	• MEV • FID1G • FID1H • FID2G
12	2.2311E-10	MEV	• FID1G • FID1H • FID2G
13	2.2311E-10	FID1F	• MEV • FID1G • FID1H • FID2G
14	2.2311E-10	MEV	• FID1G • FID1H • FID2G
15	2.2311E-10	MEV	• FID1G • FID1H • FID2G
16	2.2311E-10	MEV	• FID1G • FID1H • FID2G
17	3.2403E-11	MEV	• FID1G • FID1H • FID2G

July 25, 1989

July 25, 1989

1	5.6935E-09	FID1E • FID1G • FID1H • FID2G • FID2H •
2	3.9967E-10	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
3	3.9967E-10	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
4	3.9967E-10	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
5	3.9967E-10	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
6	3.9967E-10	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
7	5.6730E-11	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •
8	5.6730E-11	FID1E • MEV • FID1G • FID1H • FID2G • FID2H •

Independent Hardware, HWI =

1	1.7702E-05	60G •
2	3.1994E-07	MEV • 60G •
3	6.6935E-09	FID1E • FID1G • FID1H • FID2G • FID2H •
4	2.2155E-09	FID1E • FID2G • FID2H •
5	2.2155E-09	FID1E • FID2G • FID2H •
6	2.2155E-09	FID1E • FID2G • FID2H •
7	2.2155E-09	FID1E • FID2G • FID2H •
8	2.2155E-09	FID1E • FID2G • FID2H •
9	2.2155E-09	FID1E • FID2G • FID2H •
10	2.2155E-09	FID1E • FID2G • FID2H •
11	2.2155E-09	FID1E • FID2G • FID2H •
12	2.2155E-09	FID1E • FID2G • FID2H •
13	2.2155E-09	FID1E • FID2G • FID2H •
14	5.6796E-09	FID1E • FID2G • FID2H •
15	5.6796E-09	FID1E • FID2G • FID2H •

Total Hardware, HW =

Hardware Unavailability Cutssets in Case of Five DGs