ATTACHMENT 2

PROPOSED LICENSE CONDITIONS AND TECHNICAL SPECIFICATIONS

30

L. Diesel Generators

(The license conditions have been deleted and their requirements incorporated into the Technical Specifications.)

3.7 AUXILIARY ELECTRICAL SUPPLY

APPLICABILITY: Applies to the availability of electrical power for the operation of the plant auxiliaries.

OBJECTIVE: To define those conditions of electrical power availability necessary (1) to provide for safe reactor operation, (2) to provide for the continuing availability of engineered safeguards, and (3) to ensure that the station can be maintained in the shutdown or refueling condition for extended time periods.

SPECIFICATION: I. In MODES 1, 2, 3 and 4 the following specifications shall apply:

A. As a minimum the following shall be OPERABLE:

1. One Southern California Edison Company and one San Diego Gas & Electric Company high voltage transmission line to the switchyard and two transmission circuits from the switchyard, one immediate and one delayed access, to the onsite safety-related distribution system. This configuration constitutes the two required offsite circuits.

2. Two separate and independent diesel generators each with total connected design load not to exceed 6,000 kW and with:

   a. A separate day tank containing a minimum of 290 gallons of fuel,

   b. A separate fuel storage system containing a minimum of 37,500 gallons of fuel, and

   c. A separate fuel transfer pump.

3. AC Distribution

   a. 4160 Volt Bus 1C and 2C,

   b. 480 Volt Bus No. 1, Bus No. 2 and Bus No. 3, and

   c. Vital Bus 1, 2, 3, 3A, 4, 5 and 6.

4. DC Bus No. 1 and DC Bus No. 2 (including at least one full capacity charger and battery supply per bus).

5. The two Safety Injection System Load Sequencers.*

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* The automatic load function may be blocked in Mode 3 at a pressure ≤ 1900 psig.

B. ACTION:

1. With one of the required offsite circuits inoperable, demonstrate the OPERABILITY of the remaining AC sources by performing Surveillance Requirement A of Technical Specification 4.4 within one hour and at least once per eight (8) hours thereafter and SURVEILLANCE REQUIREMENT B.1.a within 24 hours; restore an additional offsite circuit to OPERABLE status within 72 hours or be in COLD SHUTDOWN within the next 36 hours.

2. If one diesel generator in declared inoperable, demonstrate the OPERABILITY of the two offsite transmission circuits and the remaining diesel generator by performing Surveillance Requirement A of Technical Specification 4.4 within one hour and at least once per eight (8) hours thereafter and SURVEILLANCE REQUIREMENT B.1.a within 24 hours; restore the inoperable diesel generator to service within 72 hours or be in COLD SHUTDOWN within the next 36 hours.

3. With one offsite circuit and one diesel generator of the above required AC electrical power sources inoperable, demonstrate the OPERABILITY of the remaining AC sources by performing Surveillance Requirement A of Technical Specification 4.4 within one hour and at least once per eight (8) hours thereafter and SURVEILLANCE REQUIREMENT B.1.a within 8 hours; restore at least one of the inoperable sources to OPERABLE status within 12 hours or be in COLD SHUTDOWN within the next 36 hours. Have at least two offsite circuits and two diesel generators OPERABLE within 72 hours from, the time of initial loss or be in COLD SHUTDOWN within the next 36 hours.

4. With two required offsite circuits inoperable, demonstrate the OPERABILITY of two diesel generators by performing Surveillance Requirement B.1.a of Technical Specification 4.4 within 8 hours, unless the diesel generators are already operating; restore at least one of the inoperable sources to OPERABLE status within 24 hours or be in at least HOT STANDBY within the next 4 hours. With only one of the required offsite circuits restored, restore the remaining offsite circuit to OPERABLE status within 72 hours from the time of initial loss or be in COLD SHUTDOWN within the next 36 hours.

5. With two of the above required diesel generators inoperable, demonstrate the OPERABILITY of two offsite circuits by performing Periodic Testing Requirement A of Technical Specification 4.4 within one hour and at least once per two (2) hours thereafter; restore at least one of the inoperable diesel generators to OPERABLE status within 2 hours or be in COLD SHUTDOWN within the next 36 hours. Restore both diesel generators to OPERABLE status within 72 hours from time of initial loss or be in COLD SHUTDOWN within the next 36 hours.

6. With less than the above complement of AC buses OPERABLE, restore the inoperable bus within 8 hours or be in COLD SHUTDOWN within the next 36 hours.

7. With one required DC bus inoperable, restore the inoperable bus to OPERABLE status within 2 hours or be in COLD SHUTDOWN within the next 36 hours.

8. With a required DC bus battery and both of its chargers inoperable, restore the inoperable battery and one of its chargers to operable status within 2 hours or be in cold shutdown within the next 36 hours.

9. With one Safety Injection Load Sequencer inoperable, restore the inoperable sequencer to OPERABLE status within 72 hours or be in COLD SHUTDOWN within the next 36 hours.

II. Additionally, in MODES 1, 2 and 3 the following specifications shall apply:

A. As a minimum, the following shall be OPERABLE:

1. The MOV850C Uninterruptable Power Supply (UPS).

B. ACTION:

1. With the MOV850C UPS inoperable, restore the UPS to OPERABLE status within 72 hours or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 6 hours.

III. In MODES 5 and 6 the following specifications shall apply:

A. As a minimum, the following shall be OPERABLE:

1. One Southern California Edison Company or San Diego Gas and Electric Company high voltage transmission line to the switchyard and one transmission circuit from the switchyard, immediate or delayed access, to the onsite safety-related distribution system.

2. One diesel generator (capable of automatic start) with total connected design load not to exceed 6,000 kW and with:

a. A day tank containing a minimum 290 gallons of fuel,

b. A fuel storage system containing a minimum of 37,500 gallons of fuel, and

c. A fuel transfer pump.

3. The electrical Buses associated with the operable power sources as follows:

a. One 4,160 Volt AC Bus

b. One 480 Volt AC Bus

c. AC Vital Buses 1, 2 and 4, and

d. One DC Bus (including at least one full capacity charger and battery supply per Bus).

B. ACTION:

1. With less than the minimum required AC and DC electrical sources specified in III.A above, suspend all operations involving core alterations or positive reactivity changes.

BASIS: The station is connected electrically to the Southern California Edison Company and San Diego Gas & Electric Company system via either of two physically independent high voltage transmission routes composed of four Southern California Edison Company high voltage lines and four San Diego Gas & Electric Company high voltage lines.

Of the four Southern California Edison Company lines, any one can serve as a source of power to the station auxiliaries at any time. Similarly, any of the four San Diego Gas & Electric Company lines can serve as a source of power to the station auxiliaries at any time. By specifying one transmission line from each of the two physically independent high voltage transmission routes, redundancy of sources of auxiliary power for an orderly shutdown is provided.

Similarly, either transformer A or B, along with transformer C, provide redundancy of 4160 volt power to the auxiliary equipment, and in particular to the safety injection trains. Correct operation of the safety injection system is assured by the operability of the load sequencers and the UPS for MOV 850C. Correct operation of the recirculation system is assured by the operability of the UPS for MOV 850C which also supplies MOV 358. In addition, each 4160 volt bus has an onsite diesel generator as backup.

In MODES 1, 2, 3 and 4, two diesel generators provide the necessary redundancy to protect against a failure of one of the diesel generator systems or in case one diesel generator system is taken out for maintenance, without requiring a reactor shutdown. This also eliminates the necessity for depending on one diesel generator to operate for extended periods without shutdown if it were required for post-accident conditions.

In MODES 5 and 6, the requirement for one source of offsite power and one diesel generator to be OPERABLE will provide diverse and redundant electrical power sources in order that the station can be maintained in the COLD SHUTDOWN or REFUELING condition for extended time periods. Additionally, this requirement will assure that operations involving core alterations or positive reactivity changes can be conducted safely.

In all operating Modes, the total connected design load on each diesel generator is restricted to 6,000 kW or less. This requirement was the result of a crankshaft crack propagation analysis (See Reference 1). The analysis postulated that the crankshaft initially has stress-induced surface cracks. The analysis then considered the effect of four types of diesel load histories on the growth of these cracks. Each load history consisted of repeated start-stop cycles with some steady state operation at full load (6,000 kW) between each start and its stop. The analysis concluded that for a crankshaft with a detectable size crack (10 mils deep), the number of start-stop cycles required to enlarge the crack until it becomes self-propagating (18 mils deep) under the full load steady state stresses represents the effective life of the crankshaft.

REFERENCES: (1) Report No FaAA-84-12-14 (Revision 1.0), Evaluation of Transient Conditions on Emergency Diesel Generator Crankshafts at San Onofre Nuclear Generating Station, Unit 1.

4.4 EMERGENCY POWER SYSTEM PERIODIC TESTING

APPLICABILITY: Applies to testing of the Emergency Power System.

OBJECTIVE: To verify that the Emergency Power System will respond promptly and properly when required.

SPECIFICATION:

A. The required offsite circuits shall be determined OPERABLE at least once per 7 days by verifying correct breaker alignments and power availability.

B. The required diesel generators shall be demonstrated OPERABLE:

1. At least once per 31 days on a STAGGERED TEST BASIS by:

   a. Verifying the diesel performs a DG SLOW START[1] from standby conditions,

   b. Verifying a fuel transfer pump can be started and transfers fuel from the storage system to the day tank,

   c. Verifying the diesel generator is synchronized and running at 6,000 kW (+100 kW, -500 kW) for $\geq$ 60 minutes,

   d. Verifying the diesel generator is aligned to provide standby power to the associated emergency buses,

   e. Verifying the day tank contains a minimum of 290 gallons of fuel, and

   f. Verifying the fuel storage tank contains a minimum of 37,500 gallons of fuel.

2. At least once per 3 months by verifying that a sample of diesel fuel from the required fuel storage tanks is within the acceptable limits as specified by the supplier when checked for viscosity, water and sediment.

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1 All diesel starts for testing and surveillance will be slow starts (greater than 24 seconds duration) except for the fast start required by Technical Specification 4.4.G conducted once per 18 months during shutdown and any other fast start required following specific maintenance involving the fast start capability.

C. Periodic maintenance, surveillance, overhaul and inspection of the required diesel generator shall comply with the following:

1. A diesel engine maintenance and surveillance program as described in the Safety Evaluation related to Amendment No. 123 to this Operating License will be implemented. Changes to this program will be subject to the provisions of 10 CFR 50.59.

2. The frequency of major diesel engine overhaul that is a part of the diesel engine maintenance and surveillance program shall be at least once every ten years. For this overhaul, one engine may be inspected during the refueling outage immediately prior to the ten years and the other engine inspected during the refueling outage immediately following the ten years. Alternatively, both inspections may be performed coincident with the 10-year reactor vessel inservice inspection. The 10-year overhaul interval shall be determined on a calendar basis from the date of completion of the last overhaul.

3. Oil hole locations in journals 8 through 12 on each crankshaft shall be inspected with liquid penetrant. This inspection shall be performed at each refueling outage or at the end of fifty[2] start-stop cycles on the engine since the previous inspection, whichever comes first. Indications found shall be evaluated with eddy current testing as appropriate.

   During each major engine overhaul, the fillets of main journal Nos. 4 through 12 should be inspected together with the oil holes, using liquid penetrant. Indications found shall be evaluated with eddy current testing as appropriate. In addition, these inspections should be performed for the oil holes and fillets in at least three of the crankpin journals at each major engine overhaul.

   If during the oil hole and fillet inspections described above, cracks are found in the oil holes or in other crankshaft surfaces, these findings are to be reported to the NRC within 24 hours. The affected engine is to be considered inoperable and is not to be restored to OPERABLE status until the disposition and/or corrective actions have been approved by the NRC staff.

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2 Start-stop cycles associated with idle (no load) engine operation at 200 rpm or less need not be counted toward the limit of fifty.

4. Cylinder blocks shall be inspected for "ligament" cracks, "stud-to-stud" cracks and "stud-to-end" cracks as defined in the report[3] by Failure Analysis Associates, Inc. (FaAA) entitled "Design Review of TDI R-4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks" (FaAA Report No. FaAA-84-9-11.1) and dated December 1984. (Note that the FaAA report specifies additional inspections to be performed for blocks with "known" or "assumed" ligament cracks.) The inspection intervals (i.e., frequency) shall not exceed the intervals calculated using the cumulative damage index model in the subject FaAA report. In addition, inspection methods shall be consistent with or equivalent to those identified in the subject FaAA report

   Blocks determined in the future to have "ligament" cracks as the result of the above inspections should be inspected at each refueling outage to determine whether or not cracks have initiated on the top surface, which was exposed because of the removal of two or more cylinder heads. This process should be repeated over several refueling outages until the entire block has been inspected. If after this process has been completed new "ligament" cracks are found, this process should again be repeated. Liquid penetrant testing or a similarly sensitive nondestructive testing technique should be used as appropriate to determine the depth of any cracks discovered.

   Whenever diesel generator No. 1 is operated in excess of 4,375 kW for one hour or more, a visual inspection of the right bank cylinder block is to be performed under intense light within 48 hours after engine shutdown to verify the absence of "stud-to-stud" and "stud-to-end" cracks.

   If "stud-to-stud" or "stud-to-end" cracks are found, these findings are to be reported to the NRC within 24 hours. The affected engine is to be considered inoperable and is not to be restored to OPERABLE status until the disposition and/or corrective actions have been approved by the NRC staff.

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3 This report was transmitted to H.R. Denton, (NRC), from C.L. Ray, Jr., (TDI Owners Group), by letter dated December 11, 1984.

D. AC Distribution

1. The required buses specified in Technical Specification 3.7, Auxiliary Electrical Supply, shall be determined OPERABLE and energized from AC sources other than the diesel generators with tie breakers without automatic SIS/SISLOP tripping circuitry open between redundant buses at least once per 7 days by verifying correct breaker alignment and power availability.

E. The required DC power sources specified in Technical Specification 3.7 shall meet the following:

1. Each DC Bus train shall be determined OPERABLE and energized at least once per 7 days by verifying correct breaker alignment and power availability.
2. Each 125 volt battery bank and charger shall be demonstrated OPERABLE:

   a. At least once per 7 days by verifying that:

      (1) The parameters in Table 4.4-1 meet the Category A limits, and

      (2) The total battery terminal voltage is greater than or equal to 129 volts on float charge.

   b. At least once per 92 days and within 7 days after a battery discharge with battery terminal voltage below 110 volts, or battery overcharge with battery terminal voltage above 150 volts, by verifying that:

      (1) The parameters in Table 4.4-1 meet the Category B limits,

      (2) There is no visible corrosion at either terminals or connectors, or the connection resistance of these items is less than 150×10^{-6} ohms, and

      (3) The average electrolyte temperature of ten connected cells is above 61°F for battery banks associated with DC Bus No. 1 and DC Bus No. 2 and above 48°F for the UPS battery bank.

   c. At least once per 18 months by verifying that:

      (1) The cells, cell plates and battery racks show no visual indication of physical damage or abnormal deterioration,

(2) The cell-to-cell and terminal connections are clean, tight and coated with anticorrosion material,

(3) The resistance of each cell-to-cell and terminal connection is less than or equal to 150×10^{-6} ohms,

(4) The battery charger for 125 volt DC Bus No. 1 will supply at least 800 amps DC at 130 volts DC for at least 8 hours,

(5) The battery charger for 125 volt DC Bus No. 2 will supply at least 45 amps DC at 130 volts DC for at least 8 hours, and

(6) The battery charger for the UPS will supply at least 10 amps AC at 480 volts AC for at least 8 hours as measured at the output of the UPS invertor.

d. At least once per 18 months, during shutdown, by verifying that the battery capacity is adequate to supply and maintain in OPERABLE status all of the actual or simulated emergency loads for the design duty cycle when the battery is subjected to a battery service test.

e. At least once per 60 months, during shutdown, by verifying that the battery capacity is at least 80%, 85% for Battery Bank No. 1, of the manufacturer's rating when subjected to a performance discharge test. Once per 60 month interval, this performance discharge test may be performed in lieu of the battery service test required by Surveillance Requirement 4.4.D.2.d.

f. Annual performance discharge tests of battery capacity shall be given to any battery that shows signs of degradation or has reached 85% of the service life expected for the application. Degradation is indicated when the battery capacity drops more than 10% of rated capacity from its average on previous performance tests, or is below 90% of the manufacturer's rating.

F. The required Safety Injection System Load Sequencer shall be demonstrated OPERABLE at least once per 31 days on a STAGGERED TEST BASIS, by simulating SISLOP* conditions and verifying that the resulting interval between each load group is within $\pm$ 10% of its design interval.

G. The required diesel generators and the Safety Injection System Load Sequencer shall be demonstrated OPERABLE at least once per 18 months during shutdown by:

1. Simulating SISLOP*, and:

   a. Verifying operation of circuitry which locks out non-critical equipment,

   b. Verifying the diesel performs a DG FAST START from standby condition on the auto-start signal, energizes the emergency buses with permanently connected loads and the auto connected emergency loads** through the load sequencer (with the exception of the feedwater, safety injection, charging and refueling water pumps whose respective breakers may be racked-out to the test position) and operates for ≥ 5 minutes while its generator is loaded with the emergency loads,

   c. Verifying that on the safety injection actuation signal, all diesel generator trips, except engine overspeed and generator differential, are automatically bypassed.

2. Verifying the generator capability to reject a load of 4,000 kW without tripping. The generator voltage shall not exceed 4,800 volts and the generator speed shall not exceed 500 rpm (nominal speed plus 75% of the difference between nominal speed and the overspeed trip setpoint) during and following the load rejection.

* SISLOP is the signal generated by coincident loss of offsite power (loss of voltage on Buses 1C and 2C) and demand for safety injection.

** The sum of all loads on the engine shall not exceed 6,000 kW.

TABLE 4.4-1

BATTERY SURVEILLANCE REQUIREMENTS

	CATEGORY A[1]	CATEGORY B[2]	
Parameter	Limits for each designated pilot cell	Limits for each connected cell	Allowable[3] value for each connected cell
Electrolyte Level	>Minimum level indication mark, and ≤1/4″ above maximum level indication mark	>Minimum level indication mark, and ≤1/4″ above maximum level indication mark	Above top of plates, and not overflowing
Float Voltage	≥2.13 volts	≥2.13 volts[c]	>2.07 volts
Specific[a] Gravity	≥1.200[b]	≥1.195	Not more than .020 below the average of all connected cells
		Average of all connected cells >1.205	Average of all connected cells ≥1.195[b]

(a) Corrected for electrolyte temperature and level.

(b) Or battery charging current is less than 2 amps when on charge.

(c) Corrected for average electrolyte temperature in accordance with IEEE STD 450-1980.

(1) For any Category A parameter(s) outside the limit(s) shown, the battery may be considered OPERABLE provided that within 24 hours all the Category B measurements are taken and found to be within their allowable values, and provided all Category A and B parameter(s) are restored to within limits within the next 6 days.

(2) For any Category B parameter(s) outside the limit(s) shown, the battery may be considered OPERABLE provided that the Category B parameter(s) are within their allowable values and provided the Category B parameter(s) are restored to within limits within 7 days.

(3) Any Category B parameter not within its allowable value indicates an inoperable battery.

BASIS: The normal plant Emergency Power System is normally in continuous operation, and periodically tested.[1]

The tests specified above will be completed without any preliminary preparation or repairs which might influence the results of the test except as required to perform the DG SLOW START test set forth in T.S. 4.4.B.1.a. The tests will demonstrate that components which are not normally required will respond properly when required.

DG maintenance, surveillance, overhaul and inspection requirements are intended to ensure the reliability and operational readiness of the diesels for emergency service. The basis for these requirements is discussed in NUREG-1216.[2] The maintenance and surveillance program is primarily based on the TDI diesel generator owners group recommendations, as modified by NUREG-1216. The frequency of major engine overhaul conforms to the frequency specified in those recommendations.

The DG design basis load restriction of 6,000 kW and the start-stop restriction of fifty between successive crankshaft inspections were the result of assumptions and recommendations found in the owners group crack propagation analysis.[3] The analysis postulated that the crankshaft initially has stress-induced surface cracks. The analysis then considered the effect of four types of diesel load histories on the growth of these cracks. Each load history consisted of repeated start-stop cycles with some steady state operation at full load (6,000 kW) between each start and its stop. The analysis concluded that for a crankshaft with a detectable size crack (10 mils deep), the number of start-stop cycles required to enlarge the crack until it becomes self-propagating (18 mils deep) under the full load steady state stresses represents the effective life of the crankshaft. Based on this conclusion, the analysis recommended that each crankshaft should be inspected at intervals of approximately fifty start-stop cycles.

Crankshaft stresses associated with idle (no load) DG speeds of 200 rpm or less have been found to be less than steady state stresses and so need not be counted toward the limit of fifty start-stop cycles.[4]

DG SLOW STARTS are specified for the monthly surveillances in order to reduce the cumulative fatigue damage to the engine crankshafts to levels below the threshold of detection under a program of augmented inservice inspection. In the event that the DG SLOW START inadvertently achieves steady state voltage and frequency in less than 24 seconds, the surveillance will not be considered a failure and require restart of the diesel generator.

For the monthly surveillances, each DG is loaded to between 5,500 kW and 6,100 kW. The lower of these limits meets or exceeds the total connected design load on either diesel engine. The upper limit is to accommodate load variations above 6,000 kW.

Main journals numbered 8 through 12 of the DG crankshafts are the most highly stressed journals during engine operation and are therefore the most susceptible to fatigue-induced cracking. For this reason, the oil hole locations at these main journals are inspected for cracks at least once at every refueling outage. At each 10-year major engine overhaul, this inspection is expanded to include additional oil hole locations and selected journal fillets.

The purpose of inspecting the four cylinder blocks is to assure that these blocks, particularly the block that has degraded Widmanstaetten microstructure, remain free of cracks in the area surrounding the cylinder head stud holes.

The DG requirements and restrictions were initially imposed by the NRC as license conditions.[5]

The surveillance requirements for demonstrating the OPERABILITY of the station 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 on float charge, connection resistance values and the performance of battery service and discharge tests ensure 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 4.4-1 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 .020 below normal full charge specific gravity or a battery charger current that has 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 .020 below normal full charge specific gravity with an average specific gravity of all the connected cells not more than .010 below normal full charge specific gravity, ensures the OPERABILITY and capability of the battery.

Operating with a battery cell's parameter outside the normal limit but within the allowable value specified in Table 4.4-1 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 .020 below normal 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 will not be more than .040 below normal full charge specific gravity and that the overall capability of the battery will be maintained within an acceptable limit; and (4) the allowable value for an individual cell's float voltage, greater than 2.07 volts, ensures the battery's capability to perform its design function.

REFERENCE:

(1) Supplement No. 1 to Final Engineering Report and Safety Analysis, Section 3, Questions 6 and 8.

(2) NUREG-1216, Safety Evaluation Report Related to the Operability and Reliability of Emergency Diesel Generators Manufactured by Transamerica Delaval, Inc. (August 1986)

(3) Report No. FaAA-84-12-14 (Revision 1.0), Evaluation of Transient Conditions on Emergency Diesel Generator Crankshafts at San Onofre Nuclear Generating Station, Unit 1.

(4) Letter dated May 2, 1990, from SCE to NRC, Emergency Diesel Generators.

(5) Amendment No. 123 to San Onofre Unit 1 Provisional Operating License, Issued on April 14, 1989.

PCN-220.IAA2

ATTACHMENT 3

(REPORT NO. FaAA-SF-90-02-03, REVISION 1.0
DATED APRIL 19, 1990)

Failure Analysis Associates®

Engineering and Scientific Services
149 Commonwealth Drive, P.O. Box 3015
Menlo Park, California 94025
(415) 326-9400 Telex 704216 Fax (415) 326-8072

FaAA-SF-90-02-03
Revision 1.0

April 19, 1990

Mr. David Pilmer
Southern California Edison Company
Nuclear Engineering and Construction
23 Parker Street
Irvine, California 92718

Re: Response to NRC Safety Evaluation Report Issues

Dear Mr. Pilmer:

This letter provides responses to the issues raised by the NRC in their Safety Evaluation Report dated November 21, 1989, regarding the crankshafts in the TDI DSRV20-4 diesel engines at San Onofre Nuclear Generating Station (SONGS), Unit 1. Specifically two issues were identified by the NRC: 1) reliability and sensitivity of the eddy current inspection method, and 2) evaluation of the crankshaft stresses during an engine start up to 200 rpm.

ISSUE: Demonstrate that SONGS Unit 1 eddy current inspection technique is capable of detecting 10 mil deep flaws with a high degree of accuracy

RESPONSE: The ability of the eddy current inspection technique to detect 10 mil deep flaws in the crankshaft oil holes was demonstrated by development and evaluation of a reference standard for the SONGS Unit 1 crankshaft oil holes. The reference standard was created from material similar to the crankshafts at SONGS Unit 1. A standard size oil hole (as specified by TDI drawings) was bored through the center of the reference block, and oil hole fillet radii were machined on each end of the block.

Artificial flaws of known dimensions were machined into the oil hole fillets utilizing electro-discharge machining (EDM). Artificial flaws with depths of 5, 10, and 20 mils with a length to depth ratio of 6:1 and 2:1 were machined into the simulated oil hole. The higher aspect ratio was evaluated, since the cracks discovered in the main journal oil holes at SONGS Unit 1 in 1984 had high aspect ratios. Although the method of crack removal did not allow exact determination of crack depth and thus aspect ratio, based on the observed lengths and estimated depths, an aspect ratio of 14 is representative of the cracking observed at SONGS Unit 1. The width of the EDM notches was between 4 and 5 mils. The flaws were placed 70 degrees into the fillet radius (0 degrees being on the journal surface) to correspond with the location of initial cracking observed in 1984.

Eddy current response of each flaw was evaluated in order to demonstrate the sensitivity of the eddy current test method for the inspection of crankshaft oil holes. The eddy current probe used for this work was an FaAA 100R type, radius tip, shielded probe with a sensing spot size of 0.1 inch in diameter. with an operating frequency of 2MHz. The test instrument was a smartEDDY 3.0 computer-based, portable eddy current instrument. The probe was manipulated over the cracks by means of a standard test fixture specifically designed for inspection of oil hole fillet radii. Eddy current inspection of the reference standard clearly detected all six artificial flaws with a high signal-to-noise ratio.

The literature surveyed is inconclusive with respect to the ability of EDM notches to represent actual fatigue cracks which may form under service conditions. The main geometric feature of an EDM notch which differs from an actual fatigue crack is the degree of opening that exists between the faces of the crack. Support is found in the literature to demonstrate that the crack opening does not have a significant effect on the magnitude of the eddy current signal. It is also found that in certain instances the signal from a natural crack is smaller than that from an EDM notch. EDM notch widths are typically between 3 and 5 mils, whereas a natural fatigue crack is expected to be significantly tighter. The crack response is reduced when two fracture surfaces touch and an electrically conductive path results. Conductivity of this path is dependent on whether or not a sufficient insulating layer exists between the crack faces to produce a high resistive path to the current in comparison to the path within the metal. For the case where a sufficient insulating layer is present, an EDM notch will act as a good simulator for actual fatigue cracks. If a crack is tight and if some amount of shorting of the crack occurs, then the eddy-current response will not be as large as from an EDM notch of the same size.

If a crack were to initiate in the crankshaft oil hole environment, some combination of oil, oxide, and air must exist in the crack in order to provide the insulating layer necessary for detection. FaAA believes that an oxide layer would form to provide a sufficient insulating layer for purposes of eddy current testing.

The calibration response used in the past eddy-current inspection of oil holes are quite conservative. They are based on the response from flaws with a 2:1 length to depth ratio compared with the much larger aspect ratio characteristic of cracks in the oil-hole. The study reported here demonstrated that the eddy-current response from flaws with a 6:1 aspect ratio is three times larger than the response from the calibration flaws.

The analysis method used to predict the inspection interval assumes high aspect ratio cracks by utilizing a 1DOF crack model [16]. If a 10 mil deep crack with a 2 to 1 aspect ratio did occur, a 3DOF crack model would be appropriate resulting in a much greater inspection interval.

FaAA has found the eddy current inspection technique to be the most sensitive technique for detection of crack-like indications in crankshaft oil holes. This technique has been used extensively for the inspection of crankshaft oil holes in work performed for the TDI Diesel Generator Owner's Group.

Details of the eddy current evaluation are provided in Attachment A. *

ISSUE: Engine start-stop cycles with engine speed less than 200 rpm need not be counted towards the 50 start-stop limit provided it is demonstrated that the induced crankshaft stress levels remain below full load steady state values

RESPONSE: The purpose of this study was to evaluate the stress levels during a 200 rpm idle speed test and verify that they remain below 6000kW load steady-state operating stress levels. Steady-state analyses were performed to ascertain the effect of dwelling at an engine speed during the test. Transient analyses and test data were used to evaluate stress levels during the test startup and coastdown. The lumped inertia and torsional spring model, used for previous steady-state and transient analyses of the SONGS Unit 1 crankshafts, was used for the current work.

A 150 to 200 rpm idle speed test is sometimes performed after maintenance and rework of the engine. During this test, the engine is started and the engine speed is manually increased by the operator until an engine speed of 150 to 200 rpm is reached. The engine is run with no load between 150 and 200 rpm for approximately 20 minutes and then shut down. During the transient portions of this test, the engine passes through the first mode 10th order resonant speed of 119 rpm. The engine speed versus time data for the startup varies and is not necessarily repeatable since the speed of the engine is controlled by the operator. The engine speed is not controlled during a coastdown. Throughout the duration of the test, the engine speed does not exceed 200 rpm (SONGS, Special Engineering Procedure SO1-SPE-712).

Steady-state harmonic analyses at engine speeds between 120 and 200 rpm (in 10 rpm increments) were performed to determine the effect of dwelling at a particular speed. This condition could occur either during the manual startup procedure or while running at constant speed with no load. No-load pressure harmonics calculated from a cold compression curve with a peak pressure of 450 psi (developed previously for the coastdown analysis) were used to simulate no-load operation at a particular speed. For all engine speeds

*For Attachment A, see SCE to NRC letter dated May 2, 1990, "Emergency Diesel Generators."

evaluated, the amplitude of torsional stress was below the maximum full-load steady-state stress level of 3185 psi at 6000kW load.

Transient analyses were performed to evaluate stress levels developed during the startup portion of the 200 rpm idle speed test. Four different startup conditions were evaluated, starts with a 20 second duration up to 150 and 200 rpm and starts with a 30 second duration up to 150 and 200 rpm. For all starts a linear increase in speed was assumed. The cylinder pressure loading on the crankshaft was estimated from the same technique used for a previous study of the impact of slow starts on the SONGS Unit 1 crankshafts. An initial crankshaft start angle of 0 degree was assumed for all startup conditions.

Results of the analyses indicated that the linear startup to 150 rpm in 20 seconds produced the highest stress amplitudes. Stress levels during this start were below the peak stress amplitude during 6000kW load normal operation. During recent torsiograph testing at SONGS Unit 1, data were collected during a 200 rpm start. Preliminary data reduction indicate that the test data are consistent with the input used for and the results obtained from the analytical model.

The effect of initial start position on the crankshaft response amplitudes was quantified by performing analyses with different initial start positions for the startup condition that produced the highest stress levels (150 rpm in 20 seconds). The following initial startup positions were evaluated: 0, 45, 90, 180, 360, and 540 degrees. A 22% variation in response was observed as the initial crankshaft position changed. For all initial start positions evaluated, the maximum stress amplitude was below the 6000kW load steady-state stress levels.

Coastdown response levels during a 200 rpm idle speed test were obtained from previous test data and analyses on the SONGS Unit 1 crankshaft. Stress amplitudes as the engine passed through the 10th order resonant speed were below the 6000kW load steady-state stress levels.

Evaluation of the stress levels during the 200 rpm idle speed test indicates that the crankshaft stresses remain below the 6000kW load steady-state stress levels throughout the duration of the test. Details of the 200 rpm idle speed analysis are provided in Attachment B.*

*For Attachment B, see SCE to NRC letter dated May 2, 1990, "Emergency Diesel Generators."

This work was performed in accordance with FaAA's Quality Assurance Operating Procedures for nuclear safety-related equipment. If you have any questions, please feel free to call me at (415) 688-7210.

Sincerely,

Paul R. Johnston, Ph.D.
Principal Engineer

Lisa M. Shusto, P.E.
Senior Engineer

ATTACHMENT 4

(REPORT NO. FaAA-SF-90-02-18,
DATED MARCH 9, 1990)

Failure Analysis Associates®

Engineering and Scientific Services
149 Commonwealth Drive P.O. Box 3015
Menlo Park, California 94025
(415) 326-9400 Telex 704216 Fax (415) 326-8072

FaAA-SF-90-02-18

March 9, 1990

Mr. David Pilmer
Southern California Edison Company
Nuclear Engineering and Construction
23 Parker Street
Irvine, California 92718

Re: Response to NRC Safety Evaluation Report Oil Impurity Issue

Dear Mr. Pilmer:

This letter provides a response to the NRC Safety Evaluation Report dated November 21, 1989, concerning potential oil impurities in the TDI DSRV20-4 diesel generator crankshaft lubricating oil used at San Onofre Nuclear Generating Station (SONGS), Unit 1. Specifically, the NRC requested that SONGS Unit 1 review their current diesel generator oil maintenance procedures to assure that oil quality is properly maintained Their concern was that no impurities exist in the oil which could contribute to crack initiation and propagation.

Diesel generator oil maintenance procedures were reviewed to assure that oil quality is properly maintained and impurities in the oil do not significantly contribute to crack initiation and propagation. The following documents and information were available for this review: 1) the current SONGS Unit 1 crankcase oil maintenance procedures [1], 2) crankcase oil analyses for DG1 and DG2 for the period of March 1988 to November 1989 [2], 3) information obtained from the manufacturer of the oil [3, 9], 4) literature on the fatigue properties of steel in an oil environment [4-8], 5) American Petroleum Institute and Society of Automotive Engineer specifications for class CD oil [10, 11, 12, 14], and 6) Transamerica Delaval Inc. Instruction and Operating Manual for San Onofre Nuclear Generating Station [13]. No specific crankcase oil recommendations were identified by reviewing the TDI Diesel Generator Owner's Group documents available for SONGS Unit 1.

LITERATURE REVIEW

Mechanical behavior technical literature was reviewed to identify the effect of oil environments on the fatigue properties of carbon steel. Elements in the oil that could increase the susceptibility of steel to crack initiation and the effect of the oil environment on the crack growth rate of steel were specific items addressed.

The literature indicates that water, acids, and sulfide-bearing environments are known to have a negative effect on the fatigue and fracture properties of steel [4-6]. However, low-strength steels, such as that used for the SONGS Unit 1 crankshafts, are less susceptible to stress corrosion cracking (SCC) than higher strength steels. The National Association of Corrosion Engineers suggests that steels with hardness values of less than 20 HRC can be used in sulfide/hydrogen bearing environments when stress levels are less than 75% of the yield strength [4]. Stress corrosion cracking of low strength structural steels is not expected to be a problem in sulfuric acid environments if the hardness level is below 93 HRB [4]. The hardness level of the crankshafts at SONGS Unit 1 are estimated to be 93 HRB which is equivalent to 13 HRC based on the known tensile strength of the crankshaft. While stresses would exceed 75% of yield for a short period of time during start-up and coastdown, the normal operating stresses are below 25% of yield.

Based upon stress corrosion cracking literature, crankshafts at SONGS Unit 1 should not be susceptible to SCC in the crankshaft oil environment. If the total base number of the oil is greater than 4, then the oil can neutralize the sulfuric acid, and if the water content is kept within the specified limits, aqueous corrosion and cracking are unlikely. The hardness and strength of the crankshafts are below the recommended limits suggested in the literature and should not be susceptible to hydrogen embrittlement. The crankcase oil used by SONGS Unit 1 does not appear to accelerate stress corrosion cracking or bulk corrosion processes.

Under some conditions, oil environments have been shown to extend life by shifting the fatigue curve or by decreasing the fatigue crack growth rate, while certain additives or test configurations have resulted in fatigue lives that were comparable to "air" data [7,8]. Unless oils are heavily contaminated or depleted, crack growth rates in oil environments are expected to either extend or produce comparable lives to those observed in air environments. Based upon the level of impurities that exist in the crankcase oil, and discussions with Chevron [3, 9], the crack growth rate behavior of the SONGS Unit 1 crankshaft in the Chevron Delo 6170 oil would not be expected to be higher than fatigue crack growth rates in air.

Research personnel at Chevron were contacted to see if any industry experience which indicated degradation of mechanical properties of steel components in the diesel oil environment existed [3, 9]. They could not identify any such experience. When asked about the potential for sulfide induced cracking in the oil environment, they indicated they had not heard of customer experience with sulfide induced degradation as a result of exposure to the oil. Chevron indicated they were unaware of any standard tests for monitoring the sulfide content of the diesel oil.

SONGS Unit 1 Maintenance Procedure and Oil Analyses

The diesels at SONGS Unit 1 currently use Chevron Delo 6170 oil for crankcase lubrication. This is a standard diesel engine lubricating oil. Current maintenance procedures for crankcase lubricating oil at SONGS Unit 1 address the condition of the base oil, wear debris, additives, and water content as well as other details regarding the oil and operating service of the engine. Ferrography and spectrochemical analysis of the oil are also performed. Procedures regarding sampling, frequency, and "Trendline Analysis" for monitoring oil analysis test results and responding to changes in trend of test results are implemented [1].

The Total Base Number (TBN) and water content are two important test results regarding the assessment of the corrosive nature of the oil [3]. The TBN is a measure of the neutralizing capability of the oil. If the TBN drops too low, this indicates that acids generated during operation (nitric and sulfuric) have exhausted a substantial amount of the neutralizing capability of the oil and that corrosion may be likely to occur. The current SONGS Unit 1 procedures require the oil to have a TBN between 4 and 13. Data from diesel engines DG1 and DG2 between March 1988 and November 1989 was available when Delo 6000 oil was in use. These data indicate that the TBN ranged between 8.02 and 13.4 [2].

Chevron does not have a specific policy regarding oil change outs based on TBN values. However, they stated their customer experience base indicates that if the TBN falls below 6, the oil should be changed out [9]. This TBN number is based upon ASTM procedure ASTM D2896, which is the standard procedure used to report TBN to SCE. Therefore, increasing the minimum allowable TBN value from 4 to 6 would place SONGS Unit 1 into the typical range of operating parameters. This increase in TBN is conservative and would result in a less corrosive environment. Recent past operating conditions reported in the oil analyses reports [2] indicated that the lowest TBN value observed on the SONGS Unit 1 engines was approximately 8 which is above the typical TBN value where other operators would change out oil.

The TDI operating manual states that lubricating oils for diesel engines must meet API class CD performance requirements and must be specifically compounded for use in four cycle, medium speed, highly turbocharged diesel engines. Desirable physical and performance characteristics of an oil, based on engine design parameters and service experience, are provided. TBN values between 10 and 12 are specified for diesels with a fuel sulfur content less than 0.5% by weight (current fuel sulfur content at SONGS Unit 1 is limited to 0.25% maximum). They state that it is not recommended to specify a TBN significantly greater than the values they suggest. However, they indicate that it is the responsibility of the owner to consult with the lubricating oil supplier concerning the proper selection of a lubricant that will perform best under service conditions. Conversations with personnel at API indicate they did not know of any standards specifically describing the allowable levels of impurities for the oil classifications CC and CD. They indicated that with the various viscosities and additive packages available specific guidelines would be difficult to determine [14].

Oil analyses reviewed for the period of March 1988 to November 1989 indicated that the diesels at SONGS Unit 1 used Chevron Delo 6000 oil. Recently, the oil was changed to Chevron 6170 oil. Chevron is recommending to all their customers that they change from Delo 6000 to 6170 as it has additional calcium compound contents to increase its dispersal capability. In addition, the TBN has been increased from 13 in Delo 6000 to 17 in 6170. Both of these changes will result in an oil which will provide better corrosion resistance.

Water bearing environments have been shown to provide a medium for corrosive attack. The water content of the diesel generator oils during the period identified above indicated water contents less than 0.05%, which is well below the maximum allowable level of 0.15% in the SONGS Unit 1 specifications and below the maximum allowable of 0.25% recommended by Chevron [3].

The TDI operating manual suggests that representative oil samples be evaluated on a monthly basis or more often if operating conditions indicate the necessity [3]. Currently, the SONGS Unit 1 procedure does not specify a frequency interval for sampling the crankcase lubricating oil. The procedure indicates the sampling frequency is based on the critical nature, type of the equipment, and the number of service hours. Oil sample test reports were available on a monthly basis for the time period reviewed. Thus, the current monthly sampling period is consistent with the manufacturer's recommendations.

The current maintenance procedures implemented at SONGS Unit 1 include a "Trendline Analysis" to allow detection of significant changes in the key components so that any deficiencies in the oil may be corrected prior to a significant corrosion problem occurring. In addition to the TBN and water content discussed above, the ferrography and spectrochemical analyses of the oil are indicators of corrosion. If significant corrosion were occurring, results of these analyses would indicate an increase in the number and type of particulates and iron content of the oil.

Summary

No evidence was found to indicate the crankcase oil used by SONGS Unit 1 accelerates stress corrosion cracking or bulk corrosion processes. SONGS Unit 1 sampling and analysis procedures have maintained oil parameters such as total base number and water content levels within acceptable limits so that corrosion should not be a problem. Current crankcase oil maintenance procedures implemented at SONGS Unit 1 allow detection of significant changes in key oil properties so that any deficiencies that may lead to corrosion may be corrected prior to development of a significant problem.

This work was performed in accordance with FaAA's Quality Assurance Operating Procedures for nuclear safety-related equipment. If you have any questions, please feel free to call me at (415) 688-7210.

Sincerely,

Paul R. Johnston, Ph.D.
Principal Engineer

Lisa M. Shusto, P.E.
Senior Engineer

REFERENCES:

1) SONGS Engineering Procedure SO123-V-5.18, Lubricant Sampling, Testing and Analysis.

2) Oil analyses from S1-DLN-D-10 [1-006] DG2 LO RSVR TK VLV DLN-314, S1-DLS-D-9 [1-003] DG-1 LO CLR VLV DLS-314, and S1-DLN-10 [1-005] DG2 LO RSVR TK VLV DLN-317 for various periods and times ranging from March, 1988 to November 1989.

3) Telephone conversation between Mr. Ray Ryason, Research Scientist in Chevron Oil Research Department, Richmond, CA (Expertise - Diesel Engine Oils) and Harry Wachob, FaAA, on January 26, 1990.

4) C.S. Carter and M.V. Hyatt, *Review of Stress Corrosion Cracking in Low Alloy Steels with Yield Strengths Below 150 Ksi*, Proceedings of Stress Corrosion Cracking and Hydrogen Embrittlement of Iron Base Alloys, NACE, 1977, pp524-600.

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9) Telephone conversation with Mario Bellavia, Chevron Oil, Senior Product Engineer, Richmond, CA, and Harry Wachob, FaAA, on February 23, 1990.

10) API, "Engine Service Classification System and Guide to Crankcase Oil Selection, Publication No. 1509, Eleventh Edition, July, 1988.

11) SAE Handbook, Engines, Fuels, Lubricants, Emissions, and Noise, Volume 3, 1989.

12) "Lubricating Oil, Internal Combustion Engine (Heavy Duty)," Military Specification MIL-L-2104B, Amendment 3, December 1968.

13) TDI Instruction and Operating Manual for San Onofre Nuclear Generating Station, Part K-Lubricating Oil System and Appendix VI, Lubricating Oil Recommendations.

14) Telephone conversation between Mr. Hap Thompson, API Refining Department, and Marianna Keane, FaAA, regarding Standards on Allowable Levels of Impurity for Oil Classifications CC and CD.