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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO EMERGENCY DIESEL GENERATOR HOT WEATHER OPERATION TEMPERATURE LIMITS

OMAHA PUBLIC POWER DISTRICT

FORT CALHOUN STATION, UNIT NO. 1

DOCKET NO. 50-285

1.0 INTRODUCTION

By letter dated October 5, 1995, Omaha Public Power District (OPPD) submitted an analysis and calculations to propose new outdoor temperature limits for the Fort Calhoun Station (FCS) diesel generators (DGs).

In September 1990, NRC imposed restrictions on the diesel generators (DGs) at the Fort Calhoun Station (FCS) as a result of concerns about the ability of the DGs to operate reliably under hot-weather conditions. Since then, the licensee has made improvements to the DGs, obtained test data and performed an engineering analysis to establish the maximum outdoor ambient air temperatures at which DG-1 and DG-2 can be expected to operate reliably.

This analysis was intended to establish the temperature limits at which the engine/generator can provide power for the worst case safety-related loads in response to a design basis accident (DBA) with a loss of offsite power. Test data was obtained to correlate DG room temperature with the outside ambient air temperature. The DG engine and cooling system performance is dependent on the DG room temperature and the ambient outside temperature. The DG room temperature however, is dependent on both the outside temperature as well as the radiant heat from the DG at various operational loads. By utilizing a methodology which combines test data acquisition and engine performance analysis, the licensee has made an assessment of the DG's ability to handle accident loads at various outside temperatures. The analysis was also intended to demonstrate that the static exciter and generator can operate at the analyzed higher temperatures.

2.0 EVALUATION

The various steps in the licensee's analysis included the following:

1. Determination of the worst case accident and peak loads on the DG.

2. Establishment of engine/generator power output and derating criteria.

3. Data acquisition and uncertainty estimates.

4. Establishment of operating temperature limits for the engine/generator.

2.1 Worst Case Load and Load Profile

FCS is required to have sufficient onsite electrical generation capacity to safely shutdown the reactor and maintain it in a safe shutdown condition under all design basis events (DBE) which could result in a loss of offsite power or require the assumption of a loss of offsite power (except station blackout). In addition, single failure criteria must also be met.

The equipment needed in response to major design basis accidents were considered to estimate load requirements for each accident scenario. These included reactor trip coincident with loss of offsite power, main steamline break and a large break LOCA. A coincident reactor trip and loss of offsite power where the reactor coolant system (RCS) and the steam generator secondary system remain intact, require a minimal amount of equipment for safe shutdown. The basic systems required are raw water, component cooling water, auxiliary feedwater, charging, containment cooling, and low pressure safety injection (shutdown cooling). In addition, the operators would be expected to have the instrument air system in operation.

A main steam line break inside the containment would require automatic initiation of the engineered safety features (ESF). In this case the raw water, component cooling water, charging, auxiliary feedwater, containment filtering and cooling, containment spray, high pressure safety injection (HPSI), and low pressure safety injection (LPSI) systems are automatically aligned and sequentially loaded on the DG. The initial loading is expected to be nearly the same as that required for a large break LOCA; however, once the RCS inventory has been restored, the HPSI and LPSI pumps will operate on minimum recirculation, resulting in a reduced load on the DGs.

The ESF response to a LOCA automatically aligns and loads the ESF and auxiliary systems on the DG. In the small break LOCA case, the LPSI pumps are expected to be on minimum recirculation load. If the small break LOCA is due to steam generator tube rupture, containment spray is not required resulting in an even smaller load on the DG. In the large break LOCA scenario, the LPSI and HPSI pumps are expected to run at full flow until the safety injection refueling water tank is empty. This represents the largest load for the longest duration for any DBE and was used to determine the worst case load profile.

The large break LOCA load profile is based on loads which reduce over time as a result of either accident mitigation or automatic trip signals actuated some time into the event. The estimated loads on DG-1 and 2 during a large break LOCA are 2251 KW and 2421 KW respectively. The staff has reviewed the calculations, #FC03382 Rev. 3, Attachment 8.1 (Reference 1), related to the load estimates and finds that these are consistent with the design basis accident loads in FCS Final Safety Analysis Report (FSAR) and, therefore, acceptable. The peak loads are expected to occur after the final loads have automatically sequenced on the diesel and the diesel has accelerated to full speed.

2.2 Engine/Generator Power Output and Derating Criteria

The DG room air temperature determines the turbocharger inlet air temperature which in turn determines the DG combustion inlet air temperature and the DG power output. The room air temperature is however dependent on the outside temperature as well as the DG jacket water temperature. Due to the room specific configuration for each engine, testing was used to establish the relation between outdoor ambient air and the room air temperature which would affect the turbocharger inlet air temperature.

Test measurements were obtained for the following critical parameters: outside ambient air temperature, combustion inlet air temperature (turbocharger intake air temperature), generator inlet temperature and jacket water temperature. Data were compiled at fifteen-minute intervals and averages were taken at each time interval where more than one thermocouple was used to measure the same temperature in a given area. Hand-held probes were used to measure indoor and outdoor ambient temperatures.

The engine capability was derated on the basis of temperature requirements to ensure the capability to support ESF loads without resulting in decreased reliability and excessive engine wear. This is interpreted as the engine 2000 Hr/Yr capability rating. To quantify the engine reliability, the manufacturer (Electro-Motive Division, General Motors Corporation or EMD) has established output ratings for its engines based on potential engine degradation over a specified period of time. The operating intervals specified are 30 minutes, 4 hours, and 2000 hours. The time ratings provide a measure of stress on the engine. Operation at the 30-minute and 4-hour ratings should be minimized; however, the engines are expected to provide reliable performance even with brief excursions into these rating ranges. EMD has developed these ratings based on considerations of engine stress caused by operation at elevated loads as well as operating experience with the engines. Following an engine run that exceeds one of the interval ratings it should be inspected for abnormal wear and refurbished, if required, to achieve an acceptable reliability for future use. The 2000-hour rating is a guide to schedule maintenance frequency. Operation at the 2000-hour rating would indicate that an inspection needs to be performed at the end of the run.

The acceptance criterion is based on the 2000-hour rating, with the goal of not exceeding this rating which is consistent with FCS Technical Specification 3.7. The published engine ratings are based on turbocharger intake temperatures of 90°F. For operation at higher intake temperatures the manufacturer has provided derating curves. When jacket water outlet temperature and turbocharger inlet temperatures are known while the engine is heating up during the initial stages of operation, a time versus engine/generator output limit can be plotted for the 2000-hour engine rating. Test data gathered during the initial stages of engine operation allows a heat-up rate to be determined. From this, jacket water temperatures versus time can be predicted for other outdoor ambient temperatures.

In the improbable event that a large break LOCA were to occur shortly after the engine has completed its monthly surveillance, the 30-minute rating curve would be applied to the initial LOCA loads in excess of the 2000-hour rating. This would assure operation to support the ESF loads based on EMD's expectations for engine performance. The limiting parameters for engine/generator power output (in kilowatts) are jacket water temperature and turbo charger air inlet temperature. The jacket water outlet temperature (JWOT) determines which turbocharger air intake temperature derating curve is applicable. These derating curves can be used to determine allowable ratings (expressed as a percent of the standard rating) for various inlet and jacket water temperatures.

Based on its review of the engine/generator power output and derating criteria as discussed above, the staff finds that these are consistent with the manufacturer's recommendations and FCS technical specifications. Therefore, the staff finds them acceptable.

2.3 Data Acquisition and Uncertainty Estimates

Test data were gathered by the licensee to correlate outside air temperatures with the indoor room temperature where the diesel generator air intake is located. The uncertainties in air temperature measurements at various locations such as the turbocharger intake, generator cooling inlet and outside weather tower were estimated. Ambient air entering the room was measured with several thermocouples mounted at the room air intake and recorded on a data logger. These thermocouples have an uncertainty of 2.2°C or 3.96°F. The data logger has a .72°F uncertainty; however, post calibration testing indicated an uncertainty of ±0 .22°F. Using the square root of the sum of the square method, the loop uncertainty for each thermocouple was calculated to be ± 3.97°F. The error analysis method for multiple inputs of equal uncertainty in Reference 2 was used in these calculations. The overall uncertainty of the average temperature is divided by the square root of the total number of channels to obtain the individual loop uncertainty. For the ambient air case, the uncertainty was calculated as ± 1.62°F. The actual outdoor ambient air temperature will conservatively be the average reading minus 1.62°F.

The turbocharger intake air (combustion air) temperature uncertainty was determined using the same method and equipment as the outside ambient air temperature. In the case of the turbocharger air intake, nine thermocouples were used. The expected uncertainty was calculated as ± 1.32°F. The temperature rise of the turbocharger intake over ambient was increased by 1.32°F to obtain a conservative derating.

Air conditioning (A/C) units were recently installed on each exciter panel. Testing was performed to determine the effects of a failed A/C unit on the ambient temperature limits of the exciters. Three resistance temperature detectors (RTDs) are proposed to be used for determining the enclosure temperature with the doors open. Since each RTD has a measurement uncertainty of ± 1°F, the uncertainty associated with this measurement was calculated as 0.58°F.

The generator cooling air inlet temperature was measured using one thermocouple and the same data logger as outside ambient air. The expected uncertainty is ± 3.97°F which would have to be subtracted from the generator operating temperature upper limits for conservatism.

Based on its review of the data acquisition methodology and uncertainty estimates as discussed above, the staff finds that these are reasonable and consistent with industry practice. The staff, therefore, finds the data acquisition techniques and uncertainty estimates acceptable.

2.4 Operating Temperature Limits for the Engine/Generator

As a result of temperature limitations imposed on the DGs in 1990, steps were taken by the licensee during the first quarter of 1991 to improve the heat removal capabilities of the DG radiators. Access doors were installed in the exhaust duct above the radiator core which allowed steam cleaning and maintenance of the radiator cooling fins. Post maintenance testing confirmed a significant improvement in air flow across the radiator cores and engine performance.

The licensee has made an assessment of the capabilities of diesel generators DG-1 and DG-2 to reliably provide power for the necessary loads during a worst-case accident scenario at outside ambient temperatures of 110°F and above. In this assessment, a large break LOCA was assumed to occur immediately after a monthly surveillance run of the DG. The test data correlating outside ambient temperatures with inlet air and jacket water temperatures was utilized to derate engine capability. Brief excursions into the 30-minute and four-hour engine ratings were considered necessary to handle peak LOCA loads. These excursions were, however, within the bounds of the manufacturer's recommendations and do not degrade engine reliability. Test results show that the jacket water temperatures are not expected to reach the recommended limit of 208°F in 20 minutes or more after a cold start with ambient temperatures of 110°F and 114°F for DG-1 and DG-2 respectively, thus allowing sufficient time to handle the worst case design basis loads.

According to the licensee's assessment which is based on input from the engine manufacturer and other industry sources, a net horsepower savings of 180 bhp (or 130 KW) can be expected if the ethylene glycol engine coolant is replaced with treated water. The licensee has utilized this additional available power to offset diesel generator derating due to operation at higher temperatures or provide additional margin in the overall assessment of diesel generator capabilities.

Based on this assessment, the licensee has determined that during hot weather, even if the outdoor temperature is 110°F, DG-1 is capable of providing power during a worst case scenario. The corresponding outdoor temperature limit for DG-2 was determined to be 114°F. The staff has reviewed the licensee's analysis and calculations provided in Reference 1 and finds that the licensee has appropriately used the worst case load profile, engine/generator output, and derating criteria in determining the maximum outside temperature limits for DG-1 and DG-2. Therefore, the staff finds the licensee's analysis acceptable.

3.0 CONCLUSION

Based on its review of the licensee's tests and evaluations as discussed above, the staff concludes that emergency diesel generators DG-1 and DG-2 will be able to carry the maximum-anticipated design basis accident load at ambient outside temperatures of up to 110 and 114°F respectively. In addition, the staff concludes that the generator and exciter cabinets will not exceed their operating temperature limits at this outdoor ambient temperature. Also, based on review of the licensee's submittal, the staff concludes that the manufacturer's rating for normal operation of the engine is not likely to be exceeded throughout the course of the worst case design basis accident.

4.0 REFERENCES

1. Omaha Public Power District (OPPD) Engineering Analysis EA-FC-90-062 Revision 3, "Diesel Generator Upper Temperature Limits," and associated Calculation #FC05916 Revision 3, for hot weather testing.

2. "Data Reduction and Error Analysis for the Physical Sciences," Phillip R. Bevington, McGraw-Hill, 1969.

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