Florida Power
CORPORATION

June 12, 1989
3F0689-12

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Subject: Crystal River Unit 3
Docket No. 50-302
Operating License No. DPR-72
Decay Heat Pump Test and Inspection
Supplemental Information

Dear Sir:

The purpose of this letter is to provide clarification of and additional information to Florida Power Corporation's (FPC) May 30, 1989 letter with respect to the Decay Heat Pump/Low Pressure Injection flow and operating duration required following a postulated small Break Loss of Coolant Accident (SBLOCA).

In April, 1989, FPC developed testing criteria for a low-flow operability test to be performed on DHP-1B. Calculations indicated that the "worst-case" pump minimum flow conditions would be 500 GPM for 5 hours, based on the following:

1. A postulated 0.007 sq. ft. SBLOCA occurs at time = 0. High Pressure Injection (HPI) actuates and supplies water to the Reactor Coolant System (RCS) from the Borated Water Storage Tank (BWST).

2. At a time of approximately 5 hours, the BWST is nearly depleted. The Decay Heat (DH) pump is started and operated in the "piggyback" mode with the HPI pump supplying water to the RCS from the Reactor Building (RB) sump after the BWST depletes.

3. At a time of approximately 10 hours, the RCS conditions have been reduced to 240 psig and 280 degrees F. At this point, the DH pump has operated for about 5 hours and its flow has decreased to a minimum value of 500 GPM, as governed by RCS pressure and break size. The DH drop line is then opened to the RB sump, depressurizing the RCS and allowing DH pump flow to increase to its "unrestricted" value of $\geq$ 1500 GPM.

The low-flow operability test on DHP-1B was performed on April 13-14, 1989. For conservatism, this test was conducted at 400 GPM for 10 hours.

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Subsequent to the test, evaluations by FPC Operations and Engineering indicated that, while it may be feasible to open the DH drop line to the RB sump at RCS conditions of 240 psig and 280 degrees F, this procedure would not be the preferred course of action. Instead, the DH drop line would be aligned to the DH Pump for normal decay heat removal operation, and used to further depressurize and cool the plant to Mode 5 conditions before opening the DH drop line to the RB sump. For this scenario, FPC conservatively assumed a duration of 3 days. Based on past operating experience for normal cooldowns, this evolution would be expected to be completed approximately 15 hours into the transient, at which point the DH pump will have operated for about 10 hours and its flow will have decreased to a minimum value of 400 GPM. The 3 day limit was selected based upon engineering judgement to provide the plant operators with additional margin before opening the dropline valves. FPC's evaluation shows that the DH pumps can operate for the assumed 3 days at a flowrate of 400 GPM.

Based on request from members of the NRC Staff, FPC has had additional technical justification prepared for pump operation at a flow of 400 gpm for up to 3 days. FPC's pump consultant, MPR Associates, Inc. has provided the attached letter dated June 12, 1989 which concludes the Decay Heat Pumps are adequate for the extended period. The MPR findings which FPC concurs with are based upon additional evaluations of pump vibration, impeller cavitation, pump shaft fatigue life, and the 1976 and 1978 shaft failures. Also attached to this letter is MPR Associates, Inc. May 26, 1989 letter which was previously provided to the NRC in an informal submittal.

Sincerely,

Rolf C. Widell

Rolf C. Widell, Director
Nuclear Operations Site Support

RCW:JWT:wla

Attachments

xc: Regional Administrator, Region II

Senior Resident Inspector

MPR ASSOCIATES, INC.

June 12, 1989

Mr. D. E. Porter
Florida Power Corporation
3201 34th Street, South
P.O. Box 14042
St. Petersburg, FL 33733

Attn: Mr. E. M. Morea

Subject: Crystal River Unit 3 Decay Heat Pump Low Flow Test-Justification of Pump Low-Flow Operation

Reference: MPR Letter from A. B. Russell to D. E. Porter (FPC), "Crystal River Unit 3 Decay Heat Pump Low Flow Operability Test-Extrapolation of Test Results Low Flow Operation Time Limit," dated May 26, 1989.

Dear Mr. Porter:

The purpose of this letter is to provide the requested additional technical justification for operation of the Crystal River Unit 3 (CR-3) decay heat pumps under limiting pump operating conditions during a small-break loss-of-coolant accident (SBLOCA). The referenced letter provides justification for operation based on results of a low-flow test, pump inspection, and actual operating experience at CR-3. The discussion below summarizes the main points of the referenced letter and the additional technical evaluations which have been performed to provide further confirmation that the decay heat pumps are adequate for low flow operation during a SBLOCA.

The referenced letter assumes the limiting SBLOCA pump conditions are a flow of 400 gpm for up to three days and concludes that the decay heat pumps are adequate for these conditions because:

o The April 1989 low-flow test indicated no performance degradation after 10 hours of operation at 400 gpm, and bearing vibrations and pump heatup were well within acceptable limits;

o The May 1989 inspection of the tested pump indicated no significant physical degradation of the impeller, shaft, or bearings; and

o Operating experience with the decay heat pumps at CR-3 includes operation for a period of nine days with only pump recirculation line flow (about 100 gpm, a flow at which vibrations are more intense than at 400 gpm flow, based on the April 1989 low-flow test).

The results of the additional technical evaluations, which consider vibration, impeller cavitation, pump shaft fatigue life, and the 1976 and 1978 shaft failures, are summarized below:

Vibration

The unfiltered peak vibrations at the bearing caps measured during the test at flows of 400 gpm or less ranged from 0.42 ips to 0.55 ips for the worst bearing - the thrust bearing in the vertical direction. Vibration criteria in the 1988 Addenda to ASME Section XI, Subsection IWP, "Inservice Testing of Pumps in Nuclear Power Plants" require doubling the frequency of surveillance testing when vibrations exceed 0.325 ips and require immediate corrective action when vibrations exceed 0.7 ips. Hence, the vibrations measured in the April 1989 test are within the range of values at which the ASME guidelines would permit continued pump operation.

Additionally, the results of the April 1989 test indicate no performance degradation of the pumps, and the post-test inspection results from May 1989 (including a liquid penetrant examination of the shaft) indicate no significant physical degradation after ten hours at 400 gpm. These observations indicate that these pumps can operate at the observed vibration levels for a significantly longer time than ten hours. The conclusions based on these observations and the conclusions based on the ASME Code Section XI vibration criteria are consistent.

Impeller Cavitation

After ten hours at 400 gpm (and 20 minutes at flows lower than 400 gpm), no cavitation damage was observed at the impeller discharge, or on either surface of the impeller vanes at the suction. These observations suggest that operation for times considerably longer than 10 hours can occur without significant impeller cavitation damage.

Pump Shaft Fatigue Life

Calculations have been performed which show that the life of the shaft is not limited by fatigue. Specifically,

- o The shaft material is a 17% Chromium-4% Nickel precipitation hardened alloy steel (17-4 PH). The radial load applied at the impeller that would result in a stress equal to the endurance limit is about 3000 lbs, assuming conservative corrections to the endurance limit for size, surface finish, and stress concentration effects. The limiting stress location in the shaft is at the line bearing.

- Results from the May 1989 pump inspection show evidence of a light rub at the stuffing box wear ring. A radial load of about 1000 lbs is needed to deflect the shaft so that the impeller rubs at the stuffing box ring. This radial load is a factor of three less than the radial load required to stress the shaft to the endurance limit.

- The expected radial loads that would be imposed on the shaft at low flows were calculated based on pump hydraulic experiments reported in the industry literature. At 400 gpm, these loads are in the range of 600 to 1300 lbs. Hence, the 1000 lb load required to cause the observed rubbing at the stuffing box wear ring is consistent with the expected hydraulic load.

1976 and 1978 Shaft Failures

Two pump shaft failures occurred in DHP-1A early in the life of the plant (in 1976 and 1978). In both cases, the shaft failures occurred at the impeller keyway, apparently due to bending fatigue. The 1976 failure had been attributed by Babcock and Wilcox to operation at low flows (about 80-100 gpm) for nine days. After this failure, time of operation at low flows was limited. The 1978 failure occurred after about 60 days of operation at near design conditions. After this failure, an inspection of the pump casing showed that the casing was improperly constructed and that as a result, a rub occurred between the eye-side shroud of the impeller and the casing. The pump was originally repaired by machining the casing and impeller to allow more clearance. After further problems with the pump, the casing was replaced in 1980. Since then, no further shaft failures have occurred in DHP-1A.

The 1976 and 1978 failures are not consistent with the type of pump rotor loading expected in low-flow operation (i.e., radial thrust) because the limiting stress location for the low flow case is at the line bearing, and the impeller keyway (the failure location in 1976 and 1978) is at least a factor of two less limiting. However, the casing misconstruction can induce an axial load on the impeller shroud (away from the eye) by direct interference and by altering the pressure distribution on the shroud surface. Because the axial load is offset from the shaft axis, it results in a bending moment applied to the end of the shaft. This moment can make the keyway the stress limiting location because the section modulus at the keyway is smaller than at the line bearing. Our calculations indicate that the axial load on the impeller periphery needed to make the keyway the limiting location is on the order of the radial thrust load. This suggests that the skewed casing may be the primary cause of the 1976 failure instead of the low-flow operation and that the pump could have operated longer than nine days at low-flow with the proper casing geometry.

Conclusions

The available evidence and technical evaluations performed indicate that the pump shaft is operating well below its fatigue limit when the pump is operating at 400 gpm. Accordingly, the operating time at 400 gpm is not a concern for the pump shaft. The available evidence also indicates that the bearings and the impeller should be satisfactory. Therefore, we conclude that these pumps should be able to operate for at least three days at 400 gpm.

If you have any questions regarding this letter, please do not hesitate to call me.

Sincerely,

Alan B. Russell

Alan B. Russell

cc: J. R. Maseda
E. C. Simpson
C. B. Doyel

FILE SP-88-040

MPR ASSOCIATES, INC.

May 26, 1989

Mr. D. E. Porter
Florida Power Corporation
3201 34th Street, South
P.O. Box 14042
St. Petersburg, FL 33733

Attn: Mr. E. M. Morea

Subject: Crystal River Unit 3 Decay Heat Pump Lcw Flow Operability Test - Extrapolation of Test Resultst Low Flow Operation Time Limit

References:

(1) MPR Letter from A. B. Russell to D. E. Porter (FPC), "Crystal River Unit 3 Decay Heat Pump Low Flow Operability Test - Evaluation of Test Results" Dated May 2, 1989

(2) MPR Letter from A. B. Russell to D. E. Porter (FPC), "Crystal River Unit 3 Decay Heat Pump Low Flow Operability Test - Preliminary Evaluation of Pump Inspection Results" Dated May 19, 1989

(3) Attachment to FPC Letter from B. L. Griffin to R. W. Reid (U.S. NRC) Dated July 7, 1978

Dear Mr. Porter:

The purpose of this letter is to extrapolate the results of the Crystal River Unit 3 (CR-3) decay heat pump low flow operability tests to cover the limiting pump operating conditions during a small-break loss-of-coolant accident (SBLOCA). A test performed in April 1989 at CR-3 was designed to bound expected pump operation during SBLOCA by operating at a total pump flow of about 400 gpm for 10 hours. The expected pump operation was a total flow as low as 500 gpm for five hours. These parameters were based on the time required to cool and depressurize the reactor coolant system (RCS) to the decay heat pump drop line operating conditions: RCS temperature of 280°F and RCS pressure of 255 psia. However, after further review by Florida Power Corporation (FPC) of operating procedures after the test was run, it was determined that RCS temperature and pressure should be lower (i.e., cold shutdown conditions) before opening the drop line. Because of this, the pump may be required to operate for longer than 10 hours. The limiting pump conditions are now considered to be 400 gpm for up to three days to cool the plant down to cold shutdown conditions.

DISCUSSION

In Reference 1, the results of the low flow test identified above, are discussed. Briefly, these results are reiterated below.

- A total pump flow of about 400 gpm does not result in significant pump heatup such that thermal expansion of pump components will interfere with pump function.
- Bearing vibrations were not excessive at any flow so as to warrant protective action for the pump.
- The test also included operation with only pump recirculation line flow (130 gpm indicated flow) for a short period of time (about 15 minutes). This flow is the minimum flow for the pump. Although the vibration was higher at minimum flow compared to 400 gpm, the pump performance was satisfactory.
- Pre-test and post-test runs at baseline conditions indicated no performance degradation as a result of the test.

To verify that the pump was not damaged by the test, its components were inspected for physical degradation (see Reference 2). The principal inspection results are summarized below.

- None of the parts showed excessive wear. The wear that was noted was not sufficient to result in a loss of pump function.
- A liquid penetrant examination of the shaft resulted in no crack indications.
- Bearings were in good condition.

Based on the test and inspection results, no significant physical or performance degradation occurred over the 10 hour test and thus, the pumps can operate for substantially longer periods at flows as low as 400 gpm.

To determine how much longer than the 10 hours the pumps can operate at 400 gpm, other operating experience is taken into account. This experience includes operation for nine days with only pump recirculation line flow (on the order of 100 gpm) before a shaft failure occurred (Reference 3). This indicates that the pump can operate for significantly longer than 10 hours at flows lower than 400 gpm. As discussed above, vibrations at minimum flow (i.e., on the order of 100 gpm) were more intense than at 400 gpm, thus, indicating that the pumps should be able to operate longer than nine days at 400 gpm.

CONCLUSIONS

Based on the above experience, we conclude that the pumps should be able to operate for the three days at 400 gpm (i.e, the current limiting SBLOCA conditions).

With regard to these limiting SBLOCA conditions, it is not clear to us why three days are required to cool down under these conditions. We presume that this long time is dictated by the inability of the decay heat system to cool the reactor coolant water stored in the loops. However, at TMI-2 following the accident they steamed through the turbine to cool the RCS to below 200°F in a matter of hours. If this approach is proceduralized, it could reduce time to cool the unit down and minimize the time the decay heat pump operates at low flow. FPC may wish to consider such a procedure.

If you have any questions regarding this letter, please do not hesitate to call me.

Sincerely,

Alan B. Russell

Alan B. Russell

Enclosure

cc: J. R. Maseda
E. C. Simpson
C. B. Doyel