July 16, 2002

Mr. J. A. Scalice
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2 - RELIEF REQUESTS RP-09 AND RP-10 ASSOCIATED WITH INSERVICE TESTING REQUIREMENTS FOR VIBRATION MONITORING OF THE TURBINE DRIVEN AUXILIARY FEEDWATER PUMPS (TAC NOS. MB4930 AND MB4931)

Dear Mr. Scalice:

By letter dated April 17, 2002, the Tennessee Valley Authority (TVA) proposed an alternative to the inservice testing (IST) program requirements for vibration monitoring of the turbine driven auxiliary feedwater pumps (TDAFW) during minimum flow conditions pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(a)(3)(i). These requirements are prescribed in Section XI of the 1989 Edition of the American Society of Mechanical Engineers (ASME) Code. For inservice testing of pumps, Section XI, Subsection IWP, references the 1987 Edition through the 1988 Addenda of the *Code for Operation and Maintenance of Nuclear Power Plants* (OM Code) Part 6 Standard. TVA proposed to use an alternative consistent with the requirements contained in the 1995 Edition through the 1996 Addenda of the OM Code, Subsection ISTB, which has been incorporated by reference into Section 50.55a. This alternative would allow the use of a comprehensive pump test to monitor vibration on a biennial basis for testing of the TDAFW pumps performed at or near full-flow conditions.

Based on our review of your submittal, we have concluded that the proposed alternatives in RP-09 and RP-10 provide an acceptable level of quality and safety and, therefore, the relief is authorized pursuant to 10 CFR 50.55a(f)(4)(iv) for the remainder of the second 10-year IST interval at Sequoyah Nuclear Plant Units 1 and 2, which began December 16, 1995.

If there are any questions regarding this issue, please feel free to contact me at (301) 415-2010.

Sincerely,
/RA by B. Mozafari Acting for/

Kahtan N. Jabbour, Acting Chief, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-327 and 50-328

Enclosure: Safety Evaluation

cc w/enclosure: See next page

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Based on our review of your submittal, we have concluded that the proposed alternatives in RP-09 and RP-10 provide an acceptable level of quality and safety and, therefore, the relief is authorized pursuant to 10 CFR 50.55a(f)(4)(iv) for the remainder of the second 10-year IST interval at Sequoyah Nuclear Plant Units 1 and 2, which began December 16, 1995.

If there are any questions regarding this issue, please feel free to contact me at (301) 415-2010.

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Docket Nos. 50-327 and 50-328

Enclosures: Safety Evaluation

cc w/enclosure: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO THE SECOND 10-YEAR INTERVAL INSERVICE TESTING PROGRAM

FOR PUMPS AND VALVES

SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2

DOCKET NOS. 50-327 AND 50-328

1.0 INTRODUCTION

In a letter dated April 17, 2002 (Ref. 1), the Tennessee Valley Authority (TVA) requested relief under the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.55a(a)(3)(i). The licensee proposes to use a comprehensive test biennially to monitor vibration of the turbine driven auxiliary feedwater (TDAFW) pumps while at near of full-flow conditions. Two relief requests were submitted, RP-09 and RP-10, which are associated with the second 10-year interval inservice testing (IST) program plan for pumps and valves at the Sequoyah Nuclear Plant (SQN). The second 10-year interval for SQN began on December 16, 1995. The plant's IST program was developed in accordance with Section XI of the 1989 Edition of the American Society of Mechanical Engineers (ASME) Code, which reference ASME/ANSI [American National Standards Institute] *Operations and Maintenance (OM) Standards* Part 6 and Part 10 (OM-6, and OM-10) for IST of pumps, and valves respectively.

2.0 REGULATORY REQUIREMENTS

Section 50.55a of 10 CFR requires that IST of certain ASME Code Class 1, 2, and 3 pumps and valves be performed at 120-month (10-year) IST program intervals in accordance with a specified ASME Code and applicable addenda, except where alternatives have been authorized or relief has been requested by the licensee and granted by the U.S. Nuclear Regulatory Commission (NRC) pursuant to paragraphs (a)(3)(i), (a)(3)(ii), or (f)(6)(i) of 10 CFR 50.55a.

In accordance with 10 CFR 50.55a(f)(4)(ii), licensees are required to comply with the requirements of the latest edition and addenda of the ASME Code incorporated by reference in the regulations 12 months prior to the start of subsequent 120-month IST program intervals. Licensees whose IST program reaches its 10-year interval after November 22, 2000, are required to implement the 1995 Edition with the 1996 Addenda of the ASME OM Code.

In proposing alternatives or requesting relief, a licensee must demonstrate that (1) the proposed alternatives provide an acceptable level of quality and safety, (2) compliance would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety, or (3) conformance is impractical for the facility. Section 50.55a authorizes the NRC to approve alternatives to and grant relief from ASME Code requirements upon making the necessary findings. NRC guidance in Generic Letter (GL) 89-04, "Guidance on Developing Acceptable Inservice Testing Programs," provides acceptable alternatives to the Code

Enclosure

requirements. Further guidance is given in GL 89-04, Supplement 1, and NUREG-1482, "Guidelines for Inservice Testing at Nuclear Power Plants."

3.0 PUMP RELIEF REQUESTS

3.1 Relief Request No. RP-09

The licensee requests relief from the test parameters associated with vibration in the 1987 Edition through the 1988 Addenda of the OM-6 for the SQN, Unit 1, TDAFW pump. The OM-6, Section 5.2(d) states "Pressure, flow rate, and vibration (displacement or velocity) shall be determined and compared with the corresponding reference values. All deviations from the reference values shall be compared with the limits given in Table 3 and corrective action taken as specified in paragraph 6.1."

As an alternative, the licensee proposes to use the 1995 Edition through the 1996 Addenda of the OM Code, Subsection ISTB, "Inservice Testing of Pumps in Light-Water Reactor Power Plants." Specifically, the licensee requests to use the comprehensive pump test (CPT), to monitor pump vibrations on a biennial basis when the pump is tested at or near full-flow conditions.

3.1.2 Licensee's Basis for Requesting Relief

The licensee states:

> The AFW [auxiliary feedwater] system serves as a backup system to the main feedwater system for supplying water to the secondary side of the steam generators (SGs), thereby maintaining the heat sink capabilities of the SG. As an Engineered Safeguards System, the AFW system is directly relied upon to remove core heat and to prevent core damage and system overpressurization in the event of transients such as a loss of normal feedwater or a secondary system pipe rupture, and to provide a means for plant cooldown following any plant transient.
>
> The AFW system is designed to start automatically in the event of a loss of offsite electrical power, a main feedwater line break, a safety injection signal, an Anticipated Transient without Scram (ATWS) mitigation system actuation circuitry (AMSAC) signal, a trip of both main feedwater pumps, or low SG water level (low level in two SGs starts the TDAFW pump). Any of these conditions may result in, may be coincident with, or may be caused by a reactor trip. As a nonsafety-related function, the AFW pumps start on a single main feedwater pump trip with a plant load greater than 80 percent. Specific details are listed in SQN FSAR [Final Safety Analysis Report] Section 10.4.7.2.2.
>
> In previous years of operation, SQN has performed modifications to refurbish the Unit 1 TDAFW pump and improve pump performance. The modifications were performed by the pump manufacturer in accordance with TVA's design change process. Refer to Attachment A of Ref. 1 for a summary of the modifications.

Hydraulic performance of the pump improved following these modifications. The pump total head was increased (approximately 3 percent) and pump brake horsepower was also increased.

While the sum effect of these changes has resulted in a stronger pump, the changes have had an effect on the vibration readings observed during ASME OM-6 pump testing. The following provides a description of the pump performance following the modifications.

A full flow test and an ASME OM-6 baseline test were performed following the replacement of the pump during the Unit 1 Cycle 11 refueling outage (November 2001). Spectral vibration analysis was performed in conjunction with these tests. The full flow pump test verified that the pump was operating acceptably and was capable of meeting its design function. The OM-6 pump test was performed with the pump running on its recirculation flow path following the performance of the full flow test. The recirculation flow path is a smaller diameter pipe than the full flow path and is provided for pump protection when the pump operates at low flow or dead-head conditions. The OM-6 pump test found the pump performed acceptably for developed differential pressure and flow. However, the vibration readings that were measured were found to be higher than during full flow test conditions. The reason for the higher vibration readings is attributed to the vane pass frequency of the pump while it is being tested on its recirculation flow path. The attached vibration report (Attachment B of Ref. 1) provides a summary report and graphical information from the vibration testing.

The vibration readings for the outboard horizontal and axial directions currently place the pump in the OM-6 alert range. However, it can be seen that the vibration readings for the same points during the full flow test are significantly lower and are below the ASME OM-6 alert range initiating value of 0.325 in/sec.

NUREG/CP-0152, pages 4-33 discusses four components that should be considered for NRC staff review. The four components are:

1. Pump vibration history,
2. Information from the pump manufacturer,
3. Discussion of owner attempts to lower vibration, and,
4. Spectral analysis of the pump-driver system.

The following addresses each of the four components:

1. Attachment B of Ref. 1 provides quarterly pump testing vibration results subsequent to the pump modification and installation. While this is not a significant amount of data, TVA believes that the situation is similar to Unit 2, for which there is additional data.

2. The pump manufacturer and the plant 's vibration staff have worked together during the pump modifications and subsequent performance testing. Both are in agreement as to the cause and effect of the vibration issue (refer to Attachments A and B of Ref. 1).

3. Modifications were made to the Unit 1 TDAFW pump as described in the Attachment A of Ref. 1, Flowserve Corporation letter. TVA considers the modifications to the Unit 1 TDAFW pump contributed to elevated vibration levels. Based on TVA analysis of pump performance, another plant modification would be required to reduce pump vibration. The modification would replace the recirculation flow path piping with larger diameter piping to allow an increase in flow through the pump. The recirculation flow path provides pump protection in the event the pump remains at a low flow or dead-head condition for a long period of time. Replacing the pump recirculation flowpath piping is considered by TVA to be cost prohibitive and results in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

4. Spectral analysis was performed by SQN plant vibration test personnel. The analysis shows that Unit 1 pump vibration frequency is seven times the pump running speed which is indicative of vane pass frequency. The elevated vibration due to vane pass frequency has not shown any evidence of pump degradation. A spectral analysis report is included as Attachment B of Ref. 1.

The TDAFW pump does not operate for extended periods of time. The AFW system is designed to start automatically from accident signals that initiate an automatic reactor trip. During normal operations or plant shutdown, the TDAFW pumps start on a manual reactor trip. The time from the reactor trip initiation to Mode 4, (when AFW is removed from service) is typically less than 12 hours. During this time, SQN's motor-driven auxiliary feedwater (MDAFW) pumps are relied upon for heat removal and are utilized during plant shutdown. The TDAFW pump is removed from service within approximately two hours following initiation of plant shutdown. Accordingly, the SQN Unit 1 TDAFW pump does not operate for extended periods of time.

During accident conditions, the MDAFW pumps supply AFW to the steam generators (SGs) for heat removal. These pumps can be throttled to match makeup needs to the SGs for heat removal from the reactor coolant system. During a station blackout event, the MDAFW pumps would not be available and the TDAFW pump would be relied upon to supply AFW to the SGs. In this scenario, the TDAFW pump will operate at full flow conditions. The elevated vane pass frequency vibration is not exhibited at full flow conditions. Consequently, based on these modes of operation for both normal plant operation and accident conditions, the TDAFW pump would only experience elevated vibration from vane pass frequencies during the quarterly OM-6 miniflow pump tests.

The pump manufacturer has been involved with the process of pump modification and subsequent testing and evaluation of the test results. The manufacturer agrees with TVA in the conclusion that vibration levels seen during OM-6 pump testing can be attributed to the vane pass frequency phenomena at low-flow conditions. The pump manufacturer further concludes that, considering the amount of time spent every quarter performing OM-6 pump tests at low-flow conditions (approximately 60 minutes every quarter), bearing life may be reduced. Bearing life, however, is sufficient to prevent any compromise in operability of the pump.

OM-6 Section 6.1 says, "If deviations fall within the alert range of Table 3, the frequency of testing specified in paragraph 5.1 shall be doubled until the cause of the deviation is determined and the condition corrected."

In the case of the SQN Unit 1 TDAFW pump, the cause of the deviation in pump vibration measurements has been analyzed and determined to be attributed to vane pass frequency. The correction for this condition is to provide additional flow through the pump by modification to the discharge piping. This change would require substantial cost to TVA. The elevated vibration condition is not indicative of pump degradation and is not predicted to result in pump failure. Doubling the frequency of pump tests, as required by OM-6, places a hardship on plant operation personnel, adds unnecessary wear to the pump bearings, and provides no additional assurance or information as to the condition of the TDAFW pump or its ability to perform its safety function.

3.1.3 Licensee's Proposed Alternative Testing

In lieu of using the requirements in the 1988 Addenda to the OM Part 6 standard, the licensee has proposed to perform IST of the Unit 1 TDAFW pump in accordance with the requirements of the ASME OM Code, 1995 Edition through 1996 Addenda, Subsection ISTB. The provisions of the 1995/96 OM code will be applied to SQN's Unit 1 TDAFW pump for testing under near full flow conditions and will be performed on a biennial basis. All the requirements of Subsection ISTB of the OM Code 1995 Edition through 1996 Addenda, will be met for SQN's Unit 1 TDAFW pump.

3.1.4 Evaluation

The AFW system serves as a backup system to the main feedwater system for supplying water to the secondary side of the SGs, thereby maintaining the heat sink capabilities of the SG. As an Engineered Safeguards System, the AFW system is directly relied upon to remove core heat and to prevent core damage and system overpressurization in the event of transients such as a loss of normal feedwater or a secondary system pipe rupture, and to provide a means for plant cooldown following any plant transient. The TDAFW pump is a standby pump during normal operation of the plant. The TDAFW pump is being tested every quarter at low-flow conditions by using a recirculation line (mini-flow) to meet the OM-6 Code requirements.

The licensee performed a modification to refurbish the Unit 1 TDAFW pump and to improve pump performance. Hydraulic performance of the pump improved following these modifications. The pump total head was increased (approximately 3 percent), and pump brake horsepower was also increased. A full flow test and an ASME OM-6 baseline test were performed following the modification during the Unit 1 Cycle 11 refueling outage. The full flow pump test verified that the pump was operating acceptably and was capable of meeting its design function. The full flow pump test also met the pump vibration requirements. However, after modification the pump was unable to meet the test parameters associated with vibration as given in Table 3 of OMa, Part 6, 1988 when the pump is running at low flow conditions using the recirculation flow path (mini-flow). The OM-6 pump test found that the pump performed acceptably for developed differential pressure and flow.

The licensee requested to perform IST of its Unit 1 TDAFW pump in accordance with the 1995 Edition through the 1996 Addenda of the OM Code, Subsection ISTB as an alternative to the requirements of the OM-6 Standard (1987 Edition through the 1988 Addenda). The major difference between the OM Code and the OM Standard is the addition of the “comprehensive pump test (CPT),” which shall be conducted with the pump operating at a specified reference point within ± 20 percent of pump design flow rate. The CPT allows less rigorous pump testing to be performed on a quarterly frequency while requiring a full-flow pump test to be performed every 2 years.

The OM Code, Subsection ISTB, 1995 Edition through 1996 requires the TDAFW pump’s vibration be measured every 2 years, while performing the CPT. The OM Code categorizes the standby pump as a group B pump (standby systems that are not operated routinely). Therefore, the TDAFW pump is a group B pump. The Code does not require vibration measurement of standby (group B) pumps during quarterly IST. However, there is increased vibration while performing this test at low-flow (10 percent of full-flow) using the recirculation flow path. The NRC staff finds that there will be insignificant degradation of the pump by having slightly increased in vibration during the quarterly IST at low-flow conditions when using the recirculation flow path (mini-flow). The details are provided as follows:

As the pump flow rate is reduced, the pumping fluid becomes unstable and interacts with the impeller at incorrect angles. This results in internal turbulence and elevated vibration at a frequency equal to the number of impeller vanes multiplied by the pump operating frequency. The magnitude of the vibration is determined by the internal clearances between the impeller vane outside diameter and diffuser vane internal diameter. The modification to the internal clearances improved pump efficiency and contributed to increased vibration levels at low-flows. A review of vibration data historical trends for this pump and the Unit 2 pump with similar conditions indicates that the vibration level at the vane passing frequency remains consistent with no increase in trends provided that the data was collected at the same pump flow rate. No pump degradation at SQN has been caused by elevated vibration levels at the pump vane passing frequency.

The Unit 1 TDAFW pump is similar to Unit 2 TDAFW pump. Additional testing was initiated for the Unit 2 pump to increase the flowrate through the pump by opening a drain valve on the pump. The resulting pump flow was increased from approximately 60 gpm to 80 gpm. The increased flowrate through the pump resulted in a decrease in pump vibration below the alert limit. This observation provided further indication that initial high vibration measurements were due to the vane pass frequency response at low flow conditions.

The cause of the vibration increase is due to the pump’s vane frequency influenced by the low pump flow rates during low-flow testing and by pump efficiency improvements. The vibration level has remained stable at this frequency with no increase in trend and no pump degradation has occurred as a result. The vibration levels are expected to remain elevated but stable and do not significantly contribute to pump degradation.

The licensee also considered and evaluated the pump's historical data, and had data evaluated by the manufacturer or vibration expert. The licensee attempted to lower vibration, and performed spectral analysis as recommended in NUREG/CP-0152, pages 4-33. Therefore, there will be insignificant degradation of the pump by having slightly increased in vibration during inservice acceptability testing for developed differential pressure and flow at low-flow conditions when using the recirculation flow path (mini-flow).

3.1.5 Conclusion

On the basis that the NRC incorporated by reference in 10 CFR 50.55a(b), the 1995 Edition through 1996 Addenda of the OM Code, the use of the OM Code, Subsection ISTB, 1995 Edition with 1996 Addenda, related to the CPT for the Sequoyah Nuclear Plant, Unit 1 TDAFW pump is acceptable. Therefore, the NRC staff concludes that the use of the OM Code, Subsection ISTB, 1995 Edition with 1996 Addenda, related to the use of a comprehensive pump test to monitor vibration on a biennial basis when the test is performed at or near full-flow conditions for the Sequoyah Nuclear Plant Unit 1 TDAFW pump is approved pursuant to 10 CFR 50.55a(f)(4)(iv).

3.2 Relief Request No. RP-10

The licensee requests relief from the IST requirements of the 1987 Edition through the 1988 Addenda of the OM-6 for the SQN, Unit 2, turbine driven auxiliary feedwater (TDAFW) pump. The OM-6, Section 5.2(d) states "Pressure, flow rate, and vibration (displacement or velocity) shall be determined and compared with the corresponding reference values. All deviations from the reference values shall be compared with the limits given in Table 3 and corrective action taken as specified in paragraph 6.1."

As an alternative, the licensee proposes to use the 1995 Edition through the 1996 Addenda of the OM Code, Subsection ISTB, "Inservice Testing of Pumps in Light-Water Reactor Power Plants," which allows the licensee to use the CPT.

3.2.2 Licensee's Basis for Requesting Relief

The licensee states:

> The AFW system serves as a backup system to the main feedwater system for supplying water to the secondary side of the steam generators (SGs), thereby maintaining the heat sink capabilities of the SG. As an Engineered Safeguards System, the AFW system is directly relied upon to remove core heat and to prevent core damage and system overpressurization in the event of transients such as a loss of normal feedwater or a secondary system pipe rupture, and to provide a means for plant cooldown following any plant transient.
>
> The AFW system is designed to start automatically in the event of a loss of offsite electrical power, a main feedwater line break, a safety injection signal, an

Anticipated Transient without Scram (ATWS) mitigation system actuation circuitry (AMSAC) signal, a trip of both main feedwater pumps, or low SG water level (low level in two SGs starts the TDAFW pump). Any of these conditions may result in, may be coincident with, or may be caused by a reactor trip. As a nonsafety-related function, the AFW pumps start on a single main feedwater pump trip with plant load greater than 80 percent. Specific details are listed in SQN FSAR Section 10.4.7.2.2.

In previous years of operation, SQN has performed modifications to refurbish the Unit 2 TDAFW pump and improve pump performance. The modifications were performed by the pump manufacturer in accordance with TVA's design change process. Refer to Attachment A of Ref. 1 for a summary of the modifications.

Hydraulic performance of the pump improved following these modifications. The pump total head was increased (approximately 3 percent) and pump brake horsepower was also increased.

While the sum effect of these changes has resulted in a stronger pump, the changes have had an effect on the vibration readings observed during ASME OM-6 pump testing. The following provides a description of the pump performance following the modifications.

The vibration readings during the first quarterly ASME OM-6 test following pump refurbishment were at or above the alert limit of 0.325 inch per second. The increase in the pump vibration level was analyzed and found to occur at pump vane pass frequency. The increase seems to be magnified by the low flow rate through the pump when testing is performed using the recirculation flowpath. Additional testing was initiated to increase the flowrate through the pump by opening a drain valve on the pump. The resulting pump flow rate was increased from approximately 60 gallons per minute (gpm) to 80 gpm. The increased flowrate through the pump resulted in a decrease in pump vibration (vibration reduced below the OM-6 alert range limit of 0.325 inch/sec.). This observation provided further indication that the initial high pump vibration measurements were due to the vane pass frequency response at low flow conditions. The vane pass frequency is a phenomenon that occurs when internal fluid within the pump recirculates causing internal turbulence. This is particularly evident while the pump operates at reduced flow rates. The increased turbulence results in elevated vibration levels at frequencies equal to the number of impeller vanes multiplied by the pump operating speed. The attached vibration report (Attachment C of Ref. 1) provides a summary description and graphical information from the vibration testing.

NUREG/CP-0152, pages 4-33 discusses four components that should be considered for NRC staff review. The four components are:

1. Pump vibration history,
2. Information from the pump manufacturer,
3. Discussion of owner attempts to lower vibration, and,
4. Spectral analysis of the pump-driver system.

The following addresses each of the four components:

1. Attachment C of Ref. 1 provides pump vibration test results recorded subsequent to the pump modifications.

2. The pump manufacturer and the plant's vibration staff have worked together during the pump modifications and subsequent performance testing. Both are in agreement as to the cause and effect of the vibration issue (refer to Attachments A and C of Ref. 1).

3. Modifications were made to the Unit 2 TDAFW pump as described in the Attachment A of Ref. 1 Flowserve Corporation letter. TVA considers the modifications to the Unit 2 TDAFW pump contributed to elevated vibration levels. Based on TVA analysis of pump performance, another plant modification would be required to reduce pump vibration. The modification would replace the recirculation flow path piping with larger diameter piping to allow an increase in flow through the pump. The recirculation flow path provides pump protection in the event the pump remains at a low flow or dead-head condition for a long period of time. Replacing the pump recirculation flowpath piping is considered by TVA to be cost prohibitive and results in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

4. Spectral analysis was performed by SQN plant vibration test personnel. The analysis shows that Unit 2 pump vibration frequency is seven times the pump running speed which is indicative of vane pass frequency. The elevated vibration due to vane pass frequency has not shown any evidence of pump degradation. A spectral analysis report is included as Attachment C of Ref. 1.

The TDAFW pump does not operate for extended periods of time. The AFW system is designed to start automatically from accident signals that initiate an automatic reactor trip. During normal operations or plant shutdown, the TDAFW pumps start on a manual reactor trip. The time from the reactor trip initiation to Mode 4, (when AFW is removed from service) is typically less than 12 hours. During this time, SQN's motor-driven auxiliary feedwater (MDAFW) pumps are relied upon for heat removal and are utilized during plant shutdown. The TDAFW pump is removed from service within approximately two hours following initiation of plant shutdown. Accordingly, the SQN Unit 2 TDAFW pump does not operate for extended periods of time.

During accident conditions, the MDAFW pumps supply AFW to the steam generators (SGs) for heat removal. These pumps can be throttled to match makeup needs to the SGs for heat removal from the reactor coolant system. During a station blackout event, the MDAFW pumps would not be available and the TDAFW pump would be relied upon to supply AFW to the SGs. In this scenario, the TDAFW pump will operate at full flow conditions. The elevated vane pass frequency vibration is not exhibited at full flow conditions. Consequently, based on these modes of operation for both normal plant operation and accident conditions, the TDAFW pump would only experience elevated vibration from vane pass frequencies during the quarterly OM-6 miniflow pump tests.

The pump manufacturer has been involved with the process of pump modification and subsequent testing and evaluation of the test results. The manufacturer agrees with TVA in the conclusion that vibration levels seen during OM-6 pump testing can be attributed to the vane pass frequency phenomena at low-flow conditions. The pump manufacturer further concludes that, considering the amount of time spent every quarter performing OM-6 pump tests at low-flow conditions (approximately 60 minutes every quarter), bearing life may be reduced. Bearing life, however, is sufficient to prevent any compromise in operability of the pump.

OM-6 Section 6.1 says, "If deviations fall within the alert range of Table 3, the frequency of testing specified in paragraph 5.1 shall be doubled until the cause of the deviation is determined and the condition corrected."

In the case of the SQN Unit 2 TDAFW pump, the cause of the deviation in pump vibration measurements has been analyzed and determined to be attributed to vane pass frequency. The correction for this condition is to provide additional flow through the pump by modification to the discharge piping. This change would require substantial cost to TVA. The elevated vibration condition is not indicative of pump degradation and is not predicted to result in pump failure. Doubling the frequency of pump tests, as required by OM-6, places a hardship on plant operation personnel, adds unnecessary wear to the pump bearings, and provides no additional assurance or information as to the condition of the TDAFW pump or its ability to perform its safety function.

3.2.3 Licensee’s Proposed Alternative Testing

In lieu of using the requirements in the 1988 Addenda to the OM Part 6 standard, the licensee has proposed to perform IST of the Unit 2 TDAFW pump in accordance with the requirements of the ASME OM Code, 1995 Edition through 1996 Addenda, Subsection ISTB. The provisions of the 1995/96 OM code will be applied to SQN’s Unit 2 TDAFW pump for testing under near full flow conditions and will be performed on a biennial basis. All the requirements of Subsection ISTB of the OM Code 1995 Edition through 1996 Addenda, will be met for SQN’s Unit 2 TDAFW pump.

3.2.4 Evaluation

The AFW system serves as a backup system to the main feedwater system for supplying water to the secondary side of the steam generators (SGs), thereby maintaining the heat sink capabilities of the steam generator. As an Engineered Safeguards System, the AFW system is directly relied upon to remove core heat and to prevent core damage and system overpressurization in the event of transients such as a loss of normal feedwater or a secondary system pipe rupture, and to provide a means for plant cooldown following any plant transient. The TDAFW pump is a standby pump during normal operation of the plant. The TDAFW pump is being tested every quarter at low-flow conditions by using a recirculation line (mini-flow) to meet the OM-6 Code requirements.

The licensee performed a modification to refurbish the Unit 2 TDAFW pump and to improve pump performance. Hydraulic performance of the pump improved following these modifications. The pump total head was increased (approximately 3 percent), and pump brake horsepower was also increased. The Unit 2 TDAFW pump is similar to the Unit 1 TDAFW pump. A full flow test has not been performed on the Unit 2 pump. However, a full flow test and an ASME OM-6 baseline test were performed following the modification during the Unit 1 Cycle 11 refueling outage. The full flow pump test verified that the Unit 1 pump was operating acceptably and was capable of meeting its design function. The full flow pump test for Unit 1 also met the pump vibration requirements. However, after modification the pump was unable to meet the test parameters associated with vibration as given in Table 3 of OMa, Part 6, 1988 when the pump is running at low flow conditions using the recirculation flow path (mini-flow). The OM-6 pump test found that the pump performed acceptably for developed differential pressure and flow.

The licensee requested to perform the IST of its Unit 2 TDAFW pump in accordance with the 1995 Edition through the 1996 Addenda of the OM Code, Subsection ISTB as an alternative to the requirements of the OM-6 Standard (1987 Edition through the 1988 Addenda). The major difference between the OM Code and the OM Standard is the addition of the “comprehensive pump test (CPT),” which shall be conducted with the pump operating at a specified reference point within ± 20 percent of pump design flow rate. The CPT allows less rigorous pump testing to be performed on a quarterly frequency while requiring a full-flow pump test to be performed every 2 years.

The OM Code, Subsection ISTB, 1995 Edition through 1996 requires the TDAFW pump’s vibration be measured every 2 years, while performing the CPT. The OM Code categorizes the standby pump as a group B pump (standby systems that are not operated routinely). Therefore, the TDAFW pump is a group B pump. The Code does not require vibration measurement of standby (group B) pumps during quarterly IST. However, there is increased vibration while performing this test at low-flow (10 percent of full-flow) using the recirculation flow path. The NRC staff finds that there will be insignificant degradation of the pump by having slightly increased in vibration during the quarterly IST at low-flow conditions when using the recirculation flow path (mini-flow). The details are provided as follows:

As the pump flow rate is reduced, the pumping fluid becomes unstable and interacts with the impeller at incorrect angles. This results in internal turbulence and elevated vibration at a frequency equal to the number of impeller vanes multiplied by the pump operating frequency.

The magnitude of the vibration is determined by the internal clearances between the impeller vane outside diameter and diffuser vane internal diameter. The modification to the internal clearances improved pump efficiency and contributed to increased vibration levels at low-flows. A review of vibration data historical trends for this pump and the Unit 1 pump with similar conditions indicates that the vibration level at the vane passing frequency remains consistent with no increase in trends provided that the data was collected at the same pump flow rate. No pump degradation at SQN has been caused by elevated vibration levels at the pump vane passing frequency.

Additional testing was initiated for the Unit 2 pump to increase the flowrate through the pump by opening a drain valve on the pump. The resulting pump flow was increased from approximately 60 gpm to 80 gpm. The increased flowrate through the pump resulted in a decrease in pump vibration below the alert limit. This observation provided further indication that initial high vibration measurements were due to the vane pass frequency response at low flow conditions.

The cause of the vibration increase is due to the pump's vane frequency influenced by the low pump flow rates during low-flow testing and by pump efficiency improvements. The vibration level has remained stable at this frequency with no increase in trend and no pump degradation has occurred as a result. The vibration levels are expected to remain elevated but stable and do not significantly contribute to pump degradation.

The licensee also considered and evaluated the pump's historical data, and had data evaluated by the manufacturer or vibration expert. The licensee attempted to lower vibration, and performed spectral analysis as recommended in NUREG/CP-0152, pages 4-33. Therefore, there will be insignificant degradation of the pump by having slightly increased in vibration during inservice acceptability testing for developed differential pressure and flow at low-flow conditions when using the recirculation flow path (mini-flow).

3.2.5 Conclusion

On the basis that the NRC incorporated by reference in 10 CFR 50.55a(b), the 1995 Edition through 1996 Addenda of the OM Code, the use of the OM Code, Subsection ISTB, 1995 Edition with 1996 Addenda, related to the CPT for the Sequoyah Nuclear Plant, Unit 2 TDAFW pump is acceptable. The NRC staff concludes that the use of the OM Code, Subsection ISTB, 1995 Edition with 1996 Addenda, related to the use of a comprehensive pump test to monitor vibration on a biennial basis when the test is performed at or near full-flow conditions for the Sequoyah Nuclear Plant Unit 2 TDAFW pump is approved pursuant to 10 CFR 50.55a(f)(4)(iv).

4.0 CONCLUSION

The NRC staff concludes that the use of the OM Code, Subsection ISTB, 1995 Edition with 1996 Addenda, related to the use of a comprehensive pump test to monitor vibration on a biennial basis when the test is performed at or near full-flow conditions for the SQN, Units 1 and 2, TDAFW pumps is approved pursuant to 10 CFR 50.55a(f)(4)(iv) for the remainder of the second 10-year IST interval which began December 16, 1995.

5.0 REFERENCE

1. Letter from Pedro Salas, TVA, to NRC, "Sequoyah Nuclear Power Plant Units 1 and 2, Request for Relief from ASME Section XI Code Requirements, Inservice Testing (IST) Program - Turbine Driven Auxiliary Feedwater Pumps" dated April 17, 2002 (including all attachments).

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