UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO INSERVICE TESTING PROGRAM

RELIEF FROM CODE ACCEPTANCE CRITERIA REQUIREMENTS

OMA-1988, PART 6, SECTION 6.1, FOR CHARGING PUMP "A"

SOUTH CAROLINA ELECTRIC AND GAS COMPANY

VIRGIL C. SUMMER NUCLEAR STATION

DOCKET NUMBER 50-395

## 1.0 INTRODUCTION

The Code of Federal Regulations, 10 CFR 50.55a, requires that inservice testing (IST) of certain American Society of Mechanical Engineers (ASME) Code Class 1, 2, and 3 pumps and valves be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel Code (the Code) and applicable addenda, except where alternatives have been authorized or relief has been requested by the licensee and granted by the Commission pursuant to Sections (a)(3)(i), (a)(3)(ii), or (f)(6)(i) of 10 CFR 50.55a. In proposing alternatives or requesting relief, the 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 its facility. Section 50.55a authorizes the Commission to approve alternatives and to grant relief from ASME Code requirements upon making the necessary findings. NRC guidance contained in Generic Letter (GL) 89-04, "Guidance on Developing Acceptable Inservice Testing Programs," provides alternatives to the Code requirements determined acceptable to the staff. Alternatives that conform with the guidance in GL 89-04 may be implemented without additional NRC approval, but are subject to review during inspections. Further guidance was given in Generic Letter 89-04, Supplement 1, and NUREG-1482, "Guidelines for Inservice Testing at Nuclear Power Plants."

The applicable Code used in developing the Virgil C. Summer Nuclear Station (VCSNS) third 10-year interval IST program was the 1989 edition of ASME Section XI.

## 2.0 EVALUATION

The licensee has requested relief from the Code acceptance criteria requirements of OMa-1988, Part 6, Section 6.1, for the "A" charging pump. The licensee has proposed to perform a monthly vibration monitoring program of the pump until the 10th refueling outage when full-flow testing can be performed.

ENCLOSURE

2.1 Licensee's Basis for Requesting Relief

The licensee states:

> The Charging/SI Pumps are tested in accordance with NRC Generic Letter 89-04, Position 9. This position allows the use of a non-instrumented minimum flow path for quarterly testing with a test performed at substantial flow conditions during cold shutdowns or refueling outages. Quarterly testing on minimum flow in conjunction with testing at substantial flow conditions during refueling outages provides adequate assurance that these pumps are capable of performing their design safety function upon demand.
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> This position is incorporated into the VCSNS Inservice Testing (IST) Program. Through the IST Program, the acceptance criteria applied to pump performance parameters is established through ASME/ANSI OMa-1988, Part 6. Part 6 is structured to address actions to be taken when performing quarterly tests for components within systems capable of demonstrating their design function performance during power operation.
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> The actions prescribed for components with parameters in the Alert range do not accommodate components relying on cold shutdown plant mode to demonstrate design performance parameters. During the Spring 1996 refueling outage, Charging Pump A indicated one vibration point (pump vertical outboard) to be in the Alert range. It was noted that the test frequency was impacted but that the pump was still recognized as operable to the Code acceptance criteria. VCSNS initiated an evaluation to determine the cause of the deviation and establish corrective actions.
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> The evaluation included a review of Charging Pump A data collected to determine a viable cause and establish corrective actions that could be pursued at power to improve the vibration condition.
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> Efforts to determine the cause included:
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> - Analysis of the vibration data spectrum
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> - Review of past maintenance history
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> - Review of trend data (in particular, vibration and motor bearing temperatures)
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> Based on a review of available data, it was determined that the vibration deviation most likely originated from a seal replacement activity performed in November 1995. Probable cause was concluded to be misalignment during pump restoration.

At power corrective actions performed to alleviate vibration and confirm cause included:

- Measured and recorded pump parameters while on mini-flow to establish comparison parameters prior to maintenance.

- Performed alignment check; discovered that gearbox and motor were both out of alignment and that both had a "soft-foot."

- Corrected "soft-foot" problems and performed laser alignment for pump, gearbox and motor.

- Measured and recorded post-maintenance pump, parameters for evaluation.

- Monitored pump performance for two weeks following maintenance while in normal operation.

Review of testing performed (pre-maintenance and post-maintenance) and monitored data indicated that the temperature difference between motor inboard and outboard bearings had decreased significantly (~23°F $\Delta T$ down to ~10°F $\Delta T$) and that the inboard bearing temperature had dropped (~165°F down to ~145°F) while the outboard bearing temperature had risen approximately 2°F (~133°F up to ~135°F). This indicates that the two motor bearings are now more equally loaded and lessen any bearing contribution to the vibration condition.

There were no significant changes in vibration levels from pre-maintenance testing to post-maintenance testing (mini-flow). A correlation between mini-flow test results and full-flow conditions cannot be established. However, the review of monitored data did reveal that the affected parameter (pump vertical outboard vibration) was less for mini-flow than the recorded value for full-flow measured during the Spring 1996 outage. This condition was not as expected. The manufacturer was contacted and, upon considering the data and maintenance history for Charging Pump A, expressed the opinion that the high vibration during the full-flow test was most likely attributed to misalignment. They also informed SCE&G [South Carolina Electric and Gas Company] that vibration has been observed to be higher at full-flow conditions than at recirculation flow or mini-flow for pumps of this type and model.

The manufacturer concluded that the pump could perform its design function because the vibration recorded during full-flow testing was not excessive. Further discussion provided recommended actions that will be performed at the next available opportunity including:

- Torque check the pump outboard fasteners for looseness
- Recheck alignment, if necessary, after torque check
- Measure and record vibration under full-flow.

Furthermore, the data collected during the Spring 1996 outage for the full-flow test of Charging Pump A indicated that the pump outboard vertical vibration was higher than other points on the pump by several orders of amplitude. The vibration was in the direction of highest stiffness with respect to mounting; indicating a potential resonance condition.

Natural frequency testing performed during normal plant operation following the Spring 1996 outage confirmed that the pump is operating in a natural frequency region of the casing. The data indicated that a wide natural frequency band exists from 20 to 200 hertz. Additionally, it was noted that the running pump speed falls to the left side of this region and that, at the point where the pump runs relative to the natural frequency, there is a steep decreasing slope in the area of the exciting force in the region of the natural frequency. A natural frequency in the area of the exciting force of running speed makes a resonance condition possible. The fact that the running speed of the pump falls to the left side, but within the natural frequency region, allows small speed changes to affect the resulting pump casing vibration levels.

A review of Charging Pump A speed shows that the pump runs at a slower speed during full-load, full-flow conditions compared to inservice testing (IST), mini-flow testing. While operating in the natural frequency region, the result of a load changing variable, such as vibration due to misalignment, may produce a significant change as a result of resonance. Resonance is a condition affected by either mass or stiffness. Decreases in the stiffness of the machine may shift the natural frequency region to the left, increasing the possibility of a resonance condition. In this case only a small change in stiffness is required due to the left side position of the exciting force inside the natural frequency region. Stiffness changes may have occurred between full-flow testing performed in November 1994 and the full-flow testing performed in April 1996.

2.2 Proposed Alternate Testing

The licensee proposes:

> Perform monthly on-line vibration monitoring and analysis at normal plant operating conditions to verify pump performance and identify any pump degradation until the 10th Refueling Outage when full-flow testing can be performed. Full-flow testing during the next refueling outage will confirm the suspected cause and verify that maintenance actions performed during the cycle corrected the condition or will identify that further action is necessary. The test interval established by Generic Letter 89-04, Position 9, will be resumed when the cause is determined and corrected.

2.3 Evaluation

There are three single speed, horizontal centrifugal, charging pumps manufactured by Pacific Pumps (now Ingersoll-Dresser Pumps) in the VCSNS chemical volume and control system. The charging pumps are also the high-head safety injection pumps in the emergency core cooling system (ECCS). Two pumps are required to fulfill their safety function. During plant operation, one pump is normally running, one pump is a non-running pump, and the third is a spare with its associated breakers normally racked out.

Each charging pump at VCSNS is being tested in accordance with the guidance provided in GL 89-04. Position 9 of GL 89-04 states that, where flow can only be established through a non-instrumented minimum-flow path during quarterly pump testing, and a path exists at cold shutdowns or refueling outages to perform a test of the pump under full or substantial flow conditions, the increased interval is an acceptable alternative to the Code requirements provided that pump differential pressure, flow rate, and bearing vibration measurements are taken during this testing and that quarterly testing also measuring at least pump differential pressure and vibration is continued. Current considerations for Position 9, which are included in NUREG-1482, state that, if a pump parameter is measured in the alert range during refueling outage testing, it is recommended that efforts be made to take corrective actions during the outage and repeat the test post-maintenance.

The vibration acceptance criteria in inches per second (ips) for the "A" charging pump, vertical direction is as follows:

| | Minimum Flow Test | Full Flow Test |
|---|---|---|
| Reference Value | 0.123 | 0.052 |
| Alert Limit | 0.307 | 0.130 |
| Required Action Limit | 0.700 | 0.312 |

The Code requires that, if a measured pump test parameter falls within the alert range, the testing frequency shall be doubled until the cause of the deviation is determined and the condition corrected. The vibration velocity

measurement of the "A" charging pump outboard bearing, vertical direction, taken on July 16, 1996, during refueling outage 9, was 0.270 ips. This exceeded the allowable Code alert range limit of 0.130 ips (the vibration reference value of 0.052 ips multiplied by 2.5) but did not exceed the required action range limit of 0.312 ips (0.052 ips multiplied by 6). The licensee stated in their November 20, 1996, submittal that, since the pump was still operable, an evaluation would be performed to determine the cause of the deviation and appropriate corrective actions. The licensee exited the outage without correcting the problem and performing a retest.

Since the Code increased test frequency requirement applies to pumps tested at refueling outages in accordance with Position 9, the Code increased frequency test for the "A" charging pump, according to the licensee, must occur before January 15, 1997. This will occur during the current cycle while the unit is at power. The licensee is requesting relief because the pump cannot be tested at full-flow while the plant is at power.

After an evaluation of pump vibration spectral analysis and maintenance, vibration, and bearing temperature histories, the licensee has concluded that the probable cause of the alert vibration value measured during the refueling outage test was due to misalignment caused by replacement of a pump seal in November of 1995. This maintenance activity occurred while the plant was at power and prior to the full-flow inservice test during refueling outage 9. The licensee quoted the pump manufacturer as stating the high pump vibration was most likely attributed to misalignment. Corrective actions implemented by the licensee included correcting apparent "footing" problems with the pump motor and gearbox and performing a laser alignment of the pump, motor, and gearbox. Pre- and post-maintenance testing of the pump on minimum flow did not detect significant variation in measured vibration values. Motor bearing cooling temperatures indicated a decrease in the temperature differential between the inlet and outlet temperature probes. This would tend to indicate better load distribution by the motor bearings; however, this would not necessarily indicate that the pump bearing vibration was reduced.

It was noted in the January 10, 1997, letter that the vibration values for the outboard bearing, vertical direction, which were measured during pre- and post-maintenance testing on July 19, 1996, and July 23, 1996, using the minimum flow loop were 0.226 ips and 0.247 ips respectively. These values were acceptable because they were below the minimum flow alert value of 0.307 ips. They, however, indicate that the vibration value of the full-flow testing on the "A" charging pump in refueling outage 9 (0.270 ips) was greater than the vibration measured during quarterly minimum flow testing. This is contrary to general experience with centrifugal pumps where mechanical performance at the design condition is better compared with the minimum flow condition. The pump manufacturer was quoted by the licensee as stating that this model and pump has been observed to behave in this manner. The quarterly and refueling outage vibration reference values for this bearing and direction are 0.123 ips and 0.052 ips. These reference values suggest that the

condition of vibration at full-low testing being greater than vibration measured during quarterly testing was not a characteristic of the "A" charging pump prior to refueling outage 9.

The licensee stated in their submittal that one explanation of the increased vibration for this pump may be related to a combination of factors including the natural frequency of the pump casing, the reduction in pump rotational speed as a function of increasing pump flowrate, and a decrease in the stiffness of the pump/motor/gearbox system acting in combination to cause a possible resonance condition to develop. A change in the stiffness in the system, such as the corrective actions performed by the licensee after refueling outage 9, could prevent the resonance condition from occurring and reduce the measured vibration. The corrective actions performed by the licensee as described in the submittal are appropriate to reduce the magnitude of the charging pump vibration. However, the effect of these actions can only be verified definitively under full-flow test conditions.

The licensee has proposed to adopt a monthly vibration monitoring program for the "A" charging pump for an interim period until the 10th refueling outage which is currently scheduled for October of 1997. The proposed testing is in addition to the current quarterly testing performed to meet the Code requirements. The quarterly testing on minimum flow is performed at a flowrate of 60 gpm. The monthly vibration monitoring would be conducted at normal charging flowrates of 180 gpm. This testing will provide additional information on the mechanical performance of the pump at a significantly larger flowrate than the quarterly inservice test; however, this will be well below the full-flow test flowrate of 625 gpm, where vibration problems have occurred.

Because of the inability to test this pump at flow conditions similar to those where the pump was observed to be in the Code alert range, more stringent vibration acceptance criteria must be imposed to ensure that the vibration measured during the monthly and quarterly tests provides an indication of pump degradation throughout all operating regimes of the pump. For quarterly minimum flow testing, the current alert limit for the "A" charging pump outboard bearing, vertical direction of 0.307 ips will be maintained. However, for the interim period, the required action limit will be 0.325 ips (which corresponds to the Code absolute alert limit). The alert limit for the supplemental monthly test (which is at normal charging flow) will be established in accordance with the Code. The required action range for the monthly test will be 0.325 ips. The licensee committed to the more restrictive acceptance criteria in a letter dated January 10, 1997. These criteria will apply until either the interim period is concluded or the pump has been tested under full-flow conditions and either confirmed to be operating acceptably or repaired.

Compliance with the Code requirements would result in a hardship without a compensating increase in safety because the licensee would be required to bring the plant to a shutdown condition to perform the full-flow test. In addition, the vibration level in the outboard bearing may have been reduced to

a level below the alert limit by the corrective actions, although this cannot be confirmed definitively without performing a full-flow test of the pump. The proposed testing provides reasonable assurance of operational readiness in the interim period because the licensee has performed corrective actions and has committed to implement a supplemental vibration test monthly at the normal charging pump flowrate. In addition, the licensee has committed to a more stringent vibration velocity acceptance criterion of 0.325 ips for the "A" charging pump outboard bearing, vertical direction, during the quarterly Code and supplemental monthly tests, which should provide additional assurance that any degradation of the pump will be detected promptly. The licensee committed in their letter dated January 10, 1997, to test this pump under full-flow conditions if plant conditions allow for testing prior to the 10th refueling outage. The licensee also stated in their January 10, 1997, letter that, if the refueling outage full-flow test indicates bearing vibration remains in the alert range, the condition will be corrected prior to exiting the refueling outage.

## 3.0 CONCLUSION

The proposed alternative to the Code acceptance criteria requirements of OMa-1988, Part 6, Section 6.1, for the "A" charging pump is authorized pursuant to 10 CFR 50.55a(a)(3)(ii) based on the determination that compliance with the specified requirements results in a hardship without a compensating increase in the level of quality and safety. The relief is granted for an interim period from the date of this Safety Evaluation until the start of the 10th refueling outage. In a letter dated January 10, 1997, the licensee committed to the following: (1) establishing a required action range of 0.325 ips for the "A" charging pump outboard bearing, vertical direction, during the quarterly Code and supplemental monthly tests during the interim period; (2) test the "A" charging pump under full-flow conditions if plant conditions allow for testing prior to the 10th refueling outage; and (3) correct the problem with the "A" charging pump vibration prior to exiting the 10th refueling outage if the refueling outage full-flow test indicates bearing vibration remains in the alert range.

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