August 27, 2008

Vice President, Operations
Entergy Nuclear Operations, Inc.
Pilgrim Nuclear Power Station
600 Rocky Hill Road
Plymouth, MA 02360-5508

SUBJECT: FOURTH 10-YEAR INTERVAL INSERVICE INSPECTION PROGRAM PLAN REQUEST FOR RELIEF NO. PR-03, REVISION 3 - PILGRIM NUCLEAR POWER STATION (TAC NO. MD8052)

Dear Sir or Madam:

By letter dated January 31, 2008, Entergy Nuclear Operations, Inc. (the licensee) submitted Relief Request (RR) No. PR-03, Revision 3 for the Fourth 10-Year Interval Inservice Testing (IST) Program at Pilgrim Nuclear Power Station (PNPS). The licensee requested relief from certain IST requirements of the American Society of Mechanical Engineers (ASME) Code for Operation and Maintenance of Nuclear Power Plants (OM Code), specifically, paragraph ISTB 5.2.3 (1996 Edition). In response to the Nuclear Regulatory Commission (NRC) staff's request for additional information, the licensee submitted its response to the NRC in a letter dated June 5, 2008.

The NRC staff has completed its review of the relief request and the results of the NRC staff's review are provided in the enclosed safety evaluation. The NRC staff concludes that the licensee's proposed alternative as specified in relief request PR-03, Revision 3 is authorized pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(a)(3)(ii) on the basis that compliance with the Code requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

All other ASME OM Code requirements for which relief was not specifically requested and approved remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

If you have any questions regarding this approval, please contact the Pilgrim Project Manager, James Kim, at 301-415-4125.

Sincerely,

/RA/

Mark G. Kowal, Chief
Plant Licensing Branch I-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-293

Enclosure:
As stated

cc w/encl: See next page

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cc w/encl: See next page

ADAMS ACCESSION NO.: ML082070120 *See memo dated July 14, 2008

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR RELIEF PR-03, REVISION 3

ENTERGY NUCLEAR OPERATIONS, INC.

PILGRIM NUCLEAR POWER STATION

DOCKET NO. 50-293

1.0 INTRODUCTION

By letter dated January 31, 2008 (Agencywide Documents and Management System (ADAMS) Accession No. ML080460065), Entergy Nuclear Operations, Inc. (the licensee) submitted Pump Relief Request PR-03, Revision 3 for the Fourth 10-year Interval Inservice Testing (IST) Program at Pilgrim Nuclear Power Station (PNPS). This relief request is related to high-pressure coolant injection (HPCI) main/booster pump P-205. The licensee requested relief from certain IST requirements of the American Society of Mechanical Engineers (ASME) Code for Operation and Maintenance of Nuclear Power Plants (OM Code). In response to the Nuclear Regulatory Commission (NRC) staff's request for additional information (RAI), the licensee submitted its response to the NRC in a letter dated June 5, 2008 (ML081760288).

Previously, the licensee submitted PR-03, Revision 0, along with other relief requests for the fourth 10-year interval IST program for pumps and valves at PNPS via letter dated December 6, 2002. In response to the NRC staff's RAI, the licensee submitted a letter on February 10, 2004. In a further clarification, on June 2, 2004, the licensee revised and submitted relief request PR-03, Revision 1. After a phone call, the licensee again revised and submitted relief request PR-03, Revision 2 on February 24, 2005. In a follow-up RAI, the licensee submitted a response on May 24, 2005. Based on the information provided in relief request PR-03, Revision 2 and the RAI response, interim relief was authorized for a period not to exceed two refueling cycles or 3 years.

The PNPS fourth 10-year interval IST program for pumps and valves is based on the requirements in the ASME OM Code, 1995 Edition including 1996 Addenda. The PNPS fourth 10-year IST interval began on December 7, 2002.

2.0 REGULATORY REQUIREMENTS

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(f)(4) requires that IST of ASME Code Class 1, 2, and 3 pumps and valves be performed in accordance with the ASME OM 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 the facility. Section 50.55a authorizes the Commission to approve alternatives and to grant relief from ASME OM Code requirements upon making necessary findings. NRC guidance contained in Generic Letter (GL) 89-04, "Guidance on Developing Acceptable Inservice Testing Programs," provides alternatives to Code requirements which are acceptable. Further guidance is given in GL 89-04, Supplement 1, and NUREG-1482, "Guidance for Inservice Testing at Nuclear Power Plants."

Although the licensee requested relief from certain IST requirements in accordance with 10 CFR 50.55a(a)(3)(i) based on the proposed alternative testing providing an acceptable level of quality and safety, the NRC staff has evaluated the relief request pursuant to 10 CFR 50.55a(a)(3)(ii) since compliance with the OM Code requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

3.0 TECHNICAL EVALUATION

The licensee's regulatory and technical analyses in support of its request for relief from ASME OM Code IST requirements are described in the licensee's submittal dated January 31, 2008, and RAI responses dated June 5, 2008. A description of the relief request and the NRC staff evaluation are shown below:

3.1 Pump Relief Request PR-03, Revision 3

3.1.1 Code Requirements

ASME OM Code, paragraph ISTB 5.2.3(d) requires that vibration (displacement or velocity) shall be determined and compared with corresponding reference values. Vibration measurements are to be broad band (unfiltered). If velocity measurements are used, they shall be peak. If displacement amplitudes are used, they shall be peak-to-peak.

ISTB 5.2.3(e) requires that all deviations from the reference values shall be compared with the range of Tables ISTB 5.2.1-1 and ISTB 5.2.3-1 and corrective action taken as specified in paragraph ISTB 6.2. The vibration measurements shall be compared to the relative and absolute criteria shown in the Alert and Required Action Range of Table ISTB 5.2.1-1. For example, if vibration exceeds either 6 V_r or 0.7 inch/second, the pump is in the Required Action Range.

3.1.2 Specific Relief Requested

The licensee requests relief from the Code requirements of paragraph ISTB 5.2.3 (d) and ISTB 5.2.3(e) for the HPCI main pump/booster pump P-205.

Specifically, the licensee proposed to expand the acceptable range and alert range identified in Table ISTB 5.2.1-1 during comprehensive pump testing. In addition, the resonance peaks would be evaluated and filtered during each test.

3.1.3 Component Identification

The component affected by this relief request is HPCI pump P-205. This pump is classified as an ASME Class 2, Group B pump. The HPCI pump contains a main pump and a booster pump. The HPCI pump is driven by a turbine.
The HPCI main pump P-205 has the safety function to operate in series with the booster pump to provide (1) adequate core cooling and reactor vessel depressurization following a small-break loss-of-coolant accident, and (2) reactor pressure control during reactor shutdown and isolation.

3.1.4 Licensee's Basis for Requesting Relief (as stated)

Historic testing and analysis performed on the HPCI System by PNPS (and the pump manufacturer) have consistently revealed characteristic pump vibration levels that exceed the acceptance criteria stated in [ASME OM Code] Table ISTB 5.2.1-1. High vibration appears on the Main pump bearing housings at approximately 2x RPM [(revolutions per minute)] in the horizontal direction, which is caused by the Booster pump excitation (at 4x RPM of the booster pump). Under normal circumstances at 4000 RPM, the vibration amplitude at the Main pump bearings in the horizontal direction exceeds the OM Code absolute vibration Required Action Range of >0.7 inch/sec. Additionally, under the same conditions, all of the remaining HPCI Main and Booster pump vibration monitoring points, except for two, typically exceed the OM Code absolute acceptable range upper value of 0.325 in/sec.

The vibration characteristics of the HPCI pump are predominantly a function of the pump design and should be identified as such rather than attributed to pump degradation. The high vibration has been present in the same order of magnitude since the pump was new. Although existing vibration levels of the HPCI pump are higher than the acceptance criteria provided in Table ISTB 5.2.1-1, they reflect the unique operating characteristics of the HPCI pump design configuration. There are no major vibrational concerns that would result in pump degradation or would prevent the HPCI pump from performing its design safety function for an extended period of operation.

The purpose of the Code required testing is to demonstrate the operational readiness of the HPCI pump by monitoring pump vibration for degradation and taking corrective actions when vibration levels exceed the Code specified values. The Code specifies in [the last paragraph of] ISTB 4.3(g) footnote that the reference vibration measurements should be representative of the pump and that the measured vibration will not prevent the pump from fulfilling its function. Accordingly, [the licensee] is proposing an alternative testing to demonstrate the operational readiness by taking into consideration the vibration measurements representative of the as-built configuration of the HPCI pump.

3.1.5 Proposed Alternative Testing (as stated):

3.1.5.1 Pilgrim proposes alternative testing as follows:

1. The alternative testing proposes to remove the 4x Booster pump RPM frequency component (discrete peak) from the vibration spectrum of the Main pump since its amplitude is not related to the physical condition or rotating dynamics of the Main pump rotor or bearing system. The Main pump vibration spectrum, with this single 4x Booster pump RPM frequency component removed, has been shown to be stable and more useful for monitoring actual pump condition. When this vibration frequency component at 4x Booster pump RPM is subtracted from the Main pump vibration spectrum, the remaining vibration, which is attributed to the Main pump, is below the OM Code

Required Action Range. This corrected vibration level provides a more representative measurement of the pump condition to be used for trending.

2. All other discrete vibration peaks observed at the Main pump horizontal vibration points will be evaluated during each comprehensive test, and will have an Acceptable Range upper limit of 1.05 V_r and an Alert Range upper limit of 1.3 V_r. The reviews of the frequency spectrum data ensure that any significant change in the vibration signature will be noted regardless of whether the severity causes the overall level to exceed its criteria. For example, if the overall vibration level is acceptable, but the 1x RPM component has increased to greater than 1.3 times the reference value overall level (V_r), then the pump will be placed in the vibration Required Action Range (>0.7in/sec).

3. PNPS [proposes to increase] the ASME OMa-1996, ISTB 5.2.3 required frequency for vibration monitoring (that is part of the comprehensive testing) from once/2 years to once/year. The Code required comprehensive test for flow rates [hydraulic degradation] would continue to be once/2 years. Given that the vibration will normally be within the Alert Range >0.325 in/sec, the once/year frequency will typically be doubled to twice/year. The twice/year frequency will be the commitment frequency. However, the normal PNPS practice will be to monitor vibration in the same manner during each of the Quarterly Group B Hydraulic Tests, whenever practicable. Thus, vibration monitoring will be performed up to 8 times in 2 years as part of the Group B Hydraulic Tests; instead of once/2 years as part of the comprehensive pump tests.

4. As normal practice, Pilgrim will continue to monitor vibration of HPCI pump during each of the Quarterly Group B Hydraulic Tests in the same manner as required by the OM Code. The preventive maintenance (PM) procedure will also typically be performed, which provides for vibration monitoring of specific pumps for preventing maintenance and balancing, and includes vibration monitoring and trending of the HPCI pump to detect and monitor changes in equipment conditions. As shown in the HPCI pump configuration figure, vibration monitoring is performed at locations required by the OM Code and at additional locations within the scope of the PM procedure (perpendicular to the shaft in the horizontal and vertical positions at each bearing location and at axial direction to the shaft). Vibration monitoring is thereby routinely performed for the Main pump, Booster pump, Speed Reduction Gearbox, and Steam Turbines. Using the vibration data collected at these points, an accurate diagnosis is made by analyzing the vibration spectrum and planned maintenance is determined to prevent failures. Thus, HPCI pump vibration monitoring will be performed up to 8 times in 2 years as part of Group B Hydraulic Tests and preventive or corrective maintenance will be implemented as necessary to prevent failures. […]

5. Pilgrim will continue current HPCI pump and turbine monitoring and maintenance activities, with changes as conditions warrant, as follows:

    - Quarterly pump and valve operability tests will be performed to ensure the HPCI pump and turbine function for their intended safety function.

    - Quarterly lubrication oil sampling and periodic laboratory analysis as appropriate for the pressure-fed bearings on the Turbine, Main pump, and Gear Reducer and once/cycle (2 years) sampling and analysis for the non-pressure fed Booster pump will be performed. Lubrication oil analysis currently performed includes viscosity, acidity, residue, water content, metals by A.E. spectrometry, and ferrogram readings. This type of monitoring will detect degradation of the turbine or pump bearings due to accelerated wear, fretting, surface fatigue, or oil contamination.

- HPCI pump and Turbine lube oil system will be serviced as-needed weekly. HPCI gland seal condenser hot well pump and motor bearings and HPCI auxiliary lube oil pump and motor bearings are serviced semiannually for lubrication.

- HPCI Turbine/Main pump, Main Pump/Reducer, and Reducer/Booster pump gear-type shaft couplings will be cleaned, examined, and grease-lubricated every 2 years. These examinations will detect excessive wear, fretting, heating, or fatigue due to any unusual loading conditions.

The past third IST interval testing program and all previous monitoring and maintenance activities have shown no evidence or observations of degradation in the HPCI turbine, main pump, gear reducer, or booster pump.

Thus, the continuation of the above periodic monitoring and maintenance activities will ensure that the HPCI pump remains in a high level of operational readiness and that any degradation of HPCI pump mechanical condition, reliability, or performance will be detected and corrected in a timely manner.

3.1.5.2 Technical Justification as provided by the licensee (as stated)

PNPS has conducted an evaluation of the HPCI pump vibration characteristics. An important conclusion of [the PNPS] evaluation is that the mechanical condition of the Main pump can be monitored satisfactorily by disregarding the single frequency component caused by the excitation at 4x Booster pump RPM. The four-vane impeller of the Booster pump generates the excitation force hydraulically. This small pressure pulsation force exists at the vane passing frequency (number of vanes times RPM) for all centrifugal pumps and is usually seen as a significant but not particularly troublesome component on the frequency spectrum for vibration measurements taken at the bearing housings. For the HPCI pump, this vane passing frequency is a problem because it coincides with a hydraulic standing wave resonance in the cross-over piping from the Booster pump to the Main pump when the machine is operating at the rated speed of 4000 RPM. There is an acoustic pressure standing wave pattern, at the 4x RPM frequency, whose wavelength in water is equal to an even fraction (1/4 or 1/2) of the dimensional length inside the cross-over pipe. This is the same principle on which an organ pipe generates a pure tone pneumatic pressure standing wave.

In addition, and exacerbating the vibration resonance condition, the Main pump pedestal experiences a horizontal structural rocking mode of the pump pedestal at this same frequency when the Main pump is operating at the rated speed of 4000 RPM. The vibration mode is the second fundamental rocking mode, which is a torsional or twisting mode where the two end bearings move 180 degrees out of phase horizontally. The result of these coincident acoustic and structural resonances is that the Main pump exhibits high vibration in the horizontal direction at the 4x Booster pump RPM frequency. This is solely due to the excitation from the booster pump being amplified by the coincident resonances. This level of vibration at 4x Booster pump RPM would be seen on the Main pump bearing housings even if the Main pump was not actually running (which is not possible, as both pumps are on the same drive train).

The resonant vibration condition at the 4000 RPM operating speed is not detrimental and will not prevent the HPCI pump from fulfilling its function. At the 134 Hz frequency of the resonant vibration on the Main pump, caused by the excitation at 4x Booster pump RPM, the actual displacement amplitude at 0.7 inch/second peak velocity amplitude is 0.0017 inches peak-to-peak. This displacement imposes negligible alternating stresses on the pump pedestal, housings, and connected piping. The peak-to-peak displacement is also less than the main pump fluid film journal bearing clearances and would impose negligible loading to these bearings.

The purpose of the ASME OM Code for pump testing is to monitor pumps for degradation. The concept of vibration monitoring is to establish baseline values for vibration when the pump is known to be in good working condition, such as after a maintenance overhaul. From that reference point, trending is performed to monitor for degradation based on the ratio of subsequent vibration levels relative to the reference values. The OM Code also establishes absolute vibration level criteria for Alert (>0.325 in/sec) and Required Action (>0.7 in/sec). In doing so, it was recognized that absolute vibration level limits (as opposed to relative change or ratio limits) are not always quantitatively linked directly with pump physical condition and the following remarks are stated in the ASME OMa Code 1996, [ISTB 4.3(g)]:

> Vibration measurements of pumps may be foundation, driver, and piping dependent. Therefore, if initial vibration readings are high and have no obvious relationship to the pump, then vibration measurements should be taken at the driver, at the foundation, and on the piping and analyzed to ensure that the reference vibration measurements are representative of the pump and that the measured vibration levels will not prevent the pump from fulfilling its function.

An important conclusion of the PNPS HPCI vibration evaluation is that the mechanical condition of the main pump can be monitored satisfactorily by disregarding the single frequency component caused by the excitation at 4x booster pump RPM. A single peak frequency component can be effectively deleted from a vibration spectrum using the mean-squared subtraction method, that is, the discrete component amplitude (in/sec peak) is squared and subtracted from the spectrum overall level squared, then the square root of that difference represents the overall vibration level that exists without the energy contributed by the deleted component. It has been found that when this method is used, the remaining overall vibration level is much more consistent, stable, and trendable.

This method of vibration level correction was applied to historical spectrums. The 4x booster pump RPM component was taken out of the calculation for the Main pump overall vibration level. This data shows that when the 4x Booster pump RPM component is deleted from the Main pump vibration, the level is below the Required Action Range (>0.7 in./sec) but still within the Alert Range (>0.325 in./sec). It was also shown that the potential effects from the dynamic alignment of pump shaft couplings (at 2x Main pump RPM) can still be monitored effectively.

3.1.5.3 Impact of Potential Modifications as provided by the licensee (as stated)

For the HPCI Main and Booster pumps, it has been determined that the vibration is [indeed] foundation and piping dependent. To reduce the HPCI Main and Booster pump vibration down to levels that meet acceptable OM Code vibration criteria requires modifications to the HPCI pump, mounting components, foundation and/or cross-over (interconnecting) piping.

As suggested in a Byron Jackson Tech Note, this vibration may be improved by modifying the interconnecting piping and the Main pump mounting pedestal. The alternative modification changes the Booster pump impeller from four to five vanes to alter the forcing function of the standing wave resonance.

The proposed Byron Jackson modifications, other than replacing the Booster pump impeller, are generally very difficult to implement successfully. Altering the natural frequency of a large pump installation requires either considerable additions of stiffening components or substantial additions of mass. Often the results of such design changes are unsuccessful or unfavorable due to the variable speed operation requirements.

Modification of the HPCI Booster pump would require replacing the current four-vane impeller with an upgraded five-vane impeller. The impeller modification, although yielding predictable results, requires extensive work to the HPCI pump at a time when such a major rebuild of this pump is not otherwise necessary or desired. The expected result would be a modest decrease in the vibration caused on the Main pump at 4000 RPM, although the vibration would remain above the 0.325 in/sec Alert Range criteria. A small decrease in hydraulic performance is also expected when changing from a four to five-vane impeller. The proposed major modification would cost approximately $500,000 without a compensating improvement in the pump vibration. Most HPCI pump vibration points would not achieve the underlying objective of Criteria. Accordingly, the proposed modification would not achieve the underlying objective of performing the Code required testing [for monitoring degradation or in ensuring existing pump operational readiness].

PNPS has also concluded that none of the possible modifications that could be performed on the HPCI pump, mounting pedestal, or cross-over piping are necessary. This is primarily due to the nature of the HPCI pump service profile. The Byron Jackson Tech Note describes the following consideration in the Technical Discussion:

> Pumping systems in which the vane passing pressure pulsations form standing waves in the attached piping are not unusual, especially if the pumps have a variable speed driver. Standing waves are highly dependent upon water temperature. Thus, measured vibration amplitudes often vary from test to test.

The HPCI pump service is such that the pump runs for short periods of time at highly variable speeds. The pump inservice testing at PNPS is performed with the pump operating at or close to its rated speed (4000 RPM) and flow conditions (4250 GPM) that are unique to PNPS. For this particular pump configuration, this pump speed corresponds to the point where the acoustic resonant vibration is typically most pronounced. In actual service for high pressure coolant injection to the reactor, the pump will operate at the speed that the flow controller requires to maintain reactor water level. The flow rate of 4250 GPM is the maximum makeup flow rate for which the HPCI System was intended to be capable of maintaining reactor water level. This flow rate is far in excess of the decay heat makeup water requirements for the reactor in the isolated condition in the absence of a major leak. The pump speed required is also dependent on reactor pressure with the required speed decreasing along with reactor pressure.

The same general HPCI pump configuration is used at other plants but often with different pump impellers, rated speeds and [flows such that the vibration characteristics at the inservice testing point are markedly different for that reason.] The vibration monitoring performed (including a frequency spectral review) to date under the IST

program and the PNPS Pump Vibration Monitoring Program has shown that there has not been degradation of these HPCI pump components.

Inservice Testing can be successfully performed for the PNPS HPCI pump using the methods proposed in this relief request, along with monitoring and maintenance activities currently in practice. Any significant degradation of the HPCI pump components will be readily identified using the vibration spectral analysis methods and monitoring activities described in the relief request. […]

3.1.5.4 Alternative Testing Acceptance Criteria as proposed by the licensee (as stated)

To allow for practicable monitoring of vibration levels on the HPCI pump, alternate vibration acceptance criteria are necessary. A full spectrum review will be performed for all IST vibration points during each proposed comprehensive test, utilizing the following criteria.

[Table-1 and Table-2] below provides the acceptance criteria that are applied to the overall vibration level for the Main pump. The note explains that for the horizontal Main pump points, the discrete frequency components at 4x Booster pump RPM will be extracted from the overall value using the mean-squared subtraction method. […]

Table-1, Main Pump**

Test Parameter	Vibration Point	Proposed Acceptable Range	Proposed Alert Range	Required Action Range by OM Code
V_v	Main pump** Horizontal Inboard(P3H)	≤1.5V_r but not >0.550 in./sec.	>1.5 V_r to 6 V_r or >0.550 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Main pump** Horizontal Outboard(P4H)	≤1.5V_r but not >0.600 in./sec.	>1.5 V_r to 6 V_r or >0.600 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Main pump Vertical Inboard(P3V)	≤1.5V_r but not >0.450 in./sec.	>1.5 V_r to 6 V_r or >0.450 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Main pump Vertical Outboard(P4V)	≤1.5V_r but not >0.375 in./sec.	>1.5 V_r to 6 V_r or >0.375 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Main pump Axial Inboard(P3A)	≤1.5V_r but not >0.500 in./sec.	>1.5 V_r to 6 V_r or >0.500 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.

**Note: For the main pump horizontal vibration points P3H and P4H, a frequency spectrum analysis will be performed and discrete peak at 4x booster pump RPM will be removed (using the mean-squared subtraction method) from the main pump spectrum overall value. In addition, all other discrete peaks will be evaluated during each test and will have an Acceptable Range upper limit of 1.05 V_r and an Alert Range upper limit of 1.3 V_r.

Table-2, Booster Pump

Test Parameter	Vibration Point	Proposed Acceptable Range	Proposed Alert Range	Required Action Range by OM Code
V_v	Booster pump Horizontal Inboard(P7H)	≤1.5V_r but not >0.450 in./sec.	>1.5 V_r to 6 V_r or >0.450 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Booster pump Horizontal Outboard(P8H)	≤1.5V_r but not >0.500 in./sec.	>1.5 V_r to 6 V_r or >0.500 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Booster pump Vertical Inboard(P7V)	≤1.5V_r but not >0.400 in./sec.	>1.5 V_r to 6 V_r or >0.400 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Booster pump Vertical Outboard(P8V)	≤1.5V_r but not >0.500 in./sec.	>1.5 V_r to 6 V_r or >0.500 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.
V_v	Booster pump Axial Outboard(P8A)	≤2.5V_r but not >0.325 in./sec.	>2.5 V_r to 6 V_r or >0.325 to 0.70 in./sec.	>6 V_r Or >0.70 in./sec.

3.1.6 Safety Evaluation of Pump Relief Request PR-03, Revision 3

ASME OM Code, paragraph ISTB 5.2.3(d) requires that vibration (displacement or velocity) shall be determined and compared with corresponding reference values. Vibration measurements are to be broad band (unfiltered). If velocity measurements are used, they shall be peak. If displacement amplitudes are used, they shall be peak-to-peak.

ISTB 5.2.3(e) requires that all deviations from the reference values shall be compared with the range of Tables ISTB 5.2.1-1 and ISTB 5.2.3-1 and corrective action taken as specified in paragraph ISTB 6.2. The vibration measurements shall be compared to the relative and absolute criteria shown in the Alert and Required Action Range of Table ISTB 5.2.1-1. For example, if vibration exceeds either 6 V_r or 0.7 inch/second, the pump is in the Required Action Range.

ISTB 4.7.4, “Vibration” requires that for centrifugal pumps, measurements shall be taken in a plane approximately perpendicular to the rotating shaft in two orthogonal directions on each accessible pump bearing housing. The Code further states that measurements shall be taken in the axial direction on each accessible pump thrust bearing housing. ASME OM Code, Table ISTB 5.2.1-1 requires pumps with vibration levels between 0.325 in/sec and 0.70 in/sec be classified in the “alert” range and that the testing frequency be doubled until the cause of the vibration is determined and the condition corrected (ISTB 6.2.1). ISTB 6.2.2 requires that if the measured values fall within the required action range of Table 5.2.1-1, the pump shall be declared inoperable until the cause of the vibration is determined and the condition corrected.

The HPCI pump at Pilgrim consists of a main pump and a booster pump with a speed-reducing gear driven by a common steam turbine. Because of this configuration, both pumps must be tested simultaneously. The licensee states that because of this configuration, elevated vibration levels have been recorded at the main and booster pump bearings of both pumps. The HPCI pump has exhibited high vibration that exceeds the ASME OM Code Action Required Range of 0.70 in/sec, since its installation at the PNPS. The main pump and booster pump have historically exhibited an inherently high base vibration (greater than 0.325 in/sec). Additionally, the main pump has a peak (in the horizontal direction) that exceeds 0.70 in/sec. The licensee states that this vibration level is caused by a resonant frequency in the crossover piping that is excited by the booster pump vane pass frequency. The licensee characterized this high bearing vibration level as the normal vibration level of the HPCI pump bearings. Due to costs associated with potential modifications to address this condition, and the low likelihood of their success, the licensee states that compliance with the Code requirements for the HPCI pump would result in a hardship without a compensating increase in the level of quality and safety.

The licensee measures vibrations at the following points on the HPCI main pump and booster pump:

P3H - HPCI Main Pump Turbine-End Horizontal (inboard)
P3V - HPCI Main Pump Turbine-End Vertical (inboard)
P3A - HPCI Main Pump Turbine-End Axial (inboard)
P4H - HPCI Main Pump Gear Box-End Horizontal (outboard)
P4V - HPCI Main Pump Gear-Box-End Vertical (outboard)
P7H - HPCI Booster Pump Gear Box-End Horizontal (inboard)
P7V - HPCI Booster Pump Gear Box-End Vertical (inboard)
P8H - HPCI Booster Pump -End Horizontal (outboard)
P8V - HPCI Booster Pump -End Vertical (outboard)
P8A - HPCI Booster Pump -End Axial (outboard)

The HPCI main pump and booster pump vibration measurements provided by the licensee with the relief request and RAI response are as follows:

Table-3, HPCI Main Pump and Booster Pump Vibration Velocity Inch/Second										
Date	HPCI Main Pump Location Point					HPCI Booster Pump Location Point				
	P3H	P3V	P3A	P4H	P4V	P7H	P7V	P8H	P8V	P8A
25-May-2004	0.750	0.311	N/A	0.648	N/A	0.312	0.283	N/A	N/A	N/A
24-Aug-2004	0.939	0.286	0.405	0.675	N/A	0.328	0.249	0.413	0.333	0.173
24-Nov-2004	0.798	0.309	N/A	0.626	N/A	0.298	0.302	0.354	0.357	0.178
23-Feb-2005	0.703	0.241	N/A	0.640	N/A	0.223	0.193	N/A	N/A	N/A
25-May-2005	0.969	0.354	N/A	0.611	N/A	0.347	0.253	N/A	N/A	N/A
26-Aug-2005	0.829	0.294	N/A	0.559	N/A	0.323	0.296	N/A	N/A	N/A
22-Nov-2005	0.815	0.327	0.374	0.559	0.155	0.333	0.240	0.367	0.352	0.173
24-Feb-2006	0.682	0.327	0.383	0.661	0.167	0.319	0.249	0.345	0.323	0.169
23-May-2006	0.960	0.307	0.432	0.645	0.162	0.337	0.249	0.410	0.354	0.167
21-Aug-2006	1.053	0.292	0.410	0.676	0.166	0.354	0.237	0.392	0.350	0.162
20-Nov-2006	0.850	0.312	0.368	0.593	0.143	0.345	0.273	0.376	0.352	0.165
21-Feb-2007	0.776	0.312	0.384	0.538	0.140	0.303	0.211	0.368	0.323	0.153
09-May-2007	0.795	0.314	0.357	0.592	0.153	0.307	0.275	0.401	0.305	0.152
21-Aug-2007	1.057	0.278	0.402	0.688	0.151	0.341	0.258	0.420	0.342	0.161
20-Nov-2007	0.793	0.316	0.366	0.576	0.150	0.326	0.256	0.409	0.353	0.162
21-Feb-2008	0.726	0.338	0.363	0.596	0.178	0.307	0.335	0.372	0.332	0.159
05-May-2008	0.931	0.281	0.406	0.617	0.161	0.335	0.248	0.417	0.345	0.162

Notes:

1. OM Code ISTB Table ISTB 5.2.1-1 Alert Range is 0.325 to 0.7 in/sec and Required Action Range is > 0.7 in/sec.
2. HPCI main pump points (P3V, P3A, and P4V) vibration values are below or within the Alert Range and P3H and P4H are in Required Action Range.
3. All HPCI booster pump points (P7H, P7V, P8H, P8V, and P8A) vibration amplitudes are below or within Alert Range.
4. All the historical vibration data (before 2004) are typically in the same range as in the table.
5. Booster point P8A vibration amplitude meets the Code acceptance criteria.

In its letter dated January 31, 2008, the licensee proposed to use the acceptance criteria specified in Tables 1 and 2 for the HPCI main and booster pump. The proposed acceptance criteria raise the lower alert limit for vibration velocity for the main pump bearing points P3H, P3V, P3A, P4H, and P4V (Table-1), and for the booster pump bearing points P7H, P7V, P8H, and P8V (Table-2) beyond the Code allowed value. The remaining HPCI main and booster pump vibration point (P8A) is the only point that meets the Code acceptance range of 0.325 in/sec, and would be evaluated using the ASME OM Code, ISTB, acceptance criteria. Except the main pump bearing points P3H and P4H, all the main pump and booster pump bearing points meet the Code Required Action Range requirements (see Table-4). The Required Action Range for the main pump bearing points P3H and P4H is modified with upper limits of 1.26 in/sec and 0.83 in/sec, respectively (see Table-4).

Additionally, the licensee had proposed to filter the discrete peak at 4X booster pump RPM for the main pump bearing points P3H and P4H by using mean-squared subtraction method from the main pump spectrum overall values, and to evaluate these discrete peaks with an Acceptable Range upper limit of 1.05 V_r and an Alert Range upper limit of 1.3 V_r. Since the OM Code requires that vibration measurements be broad band (unfiltered), the staff did not find the licensee's proposal to filter the peak values acceptable. Accordingly, Table-1 for the main pump was modified as shown in Table-4. The acceptance criteria for main pump bearing points P3V, P4V, and P3A are same as the licensee proposed in Table-1, however the acceptance criteria for main pump bearing points P3H and P4H are modified to account for unfiltered peak values (see Table-4, Notes 1 and 2).

Table-4, Main Pump

Test Parameter	Vibration Point	Acceptable Range	Alert Range	Required **(Note 2)*** Action Range
OM Code Table ISTB 5.2.1-1, V_v		≤ 2.5V_r	>2.5 V_r to 6 V_r or >0.325 to 0.70 in./sec	>6 V_r Or >0.70 in./sec
V_v (Proposed) **Notes 1 and 2**	Main pump **(Note 1)**** Horizontal Inboard (P3H) For Resonance peaks	≤1.05V_r but not >1.02 in./sec.	>1.05 V_r to 1.30 V_r or >1.02 to 1.26 in /sec.	>1.30 V_r or >1.26 in./sec.
V_v (Proposed) **Notes 1 and 2**	Main pump **(Note 1)**** Horizontal Outboard (P4H) For Resonance peaks	≤1.05V_r but not >0.67 in./sec.	>1.05 V_r to 1.30 V_r or >0.670 to 0.83 in /sec.	>1.30 V_r or >0.83 in./sec.
V_v (Proposed)	Main pump Vertical Inboard (P3V)	≤1.5V_r but not >0.450 in./sec.	>1.5 V_r to 6 V_r or >0.450 to 0.70 in./sec.	>6 V_r or >0.70 in./sec.
V_v	Main pump	≤1.5V_r	>1.5 V_r to 6 V_r	>6 V_r

(Proposed)	Vertical Outboard (P4V)	but not >0.375 in./sec.	or >0.375 to 0.70 in./sec.	or >0.70 in./sec.
V_v (Proposed)	Main pump Axial Inboard (P3A)	≤1.5V_r but not >0.500 in./sec.	>1.5 V_r to 6 V_r or >0.500 to 0.70 in./sec.	>6 V_r or >0.70 in./sec.
Notes: 1. **Main Pump vibration ranges are peak values without filtering the peak. Other than peak values at points P3H and P4H, all other measured values at P3H and P4H are below the Code allowable values. 2. *Required Action Range for points P3V, P4V and P3A meets the Code required vibrations values, and Required Action Range for peak vibration at points P3H and P4H is increased as proposed to 1.3 V_r (1.26 in/sec for P3H and 0.83 in/sec for P4H)				

The vibration acceptance criteria as specified in Table-4 (main pump) and Table-2 (booster pump) are acceptable as discussed below.

In response to the previously submitted relief request PR-03, Revision 2, the NRC staff approved interim use of relaxed alert and required action ranges in an SE dated August 29, 2005. In that SE, the staff stated that, "During the interim period, the licensee should reevaluate its proposed alternative to meet the OM Code vibration requirements. This may entail a more detailed analysis of the IST data, a possible design modification based on the previous vendor's recommendation, and/or consultation with the pump manufacturer, as appropriate." As discussed below, the licensee's revised Relief Request PR-03, Revision 3 is responsive to the concerns raised by the NRC staff in the letter dated August 29, 2005. In the revised PR-03 Relief Request, the licensee submitted an independent vendor report, "Independent Assessment of the Pilgrim HPCI Pump Vibration and Performance," by Mancini Consulting Services, dated January 2008. This report provides an independent assessment of the Pilgrim HPCI pump elevated vibration levels and pump performance.

The NRC staff is aware that HPCI pumps at various nuclear plants have a history of vibration issues. Byron Jackson, the HPCI pump vendor, performed a study of HPCI pump vibration at various nuclear plants, including Pilgrim, and issued their finding as Technical Note No. 9112-80-018. Byron Jackson's Technical Note states that if bearing housing vibration exceeds the Alert limits in the ASME Code, Section XI (now OM Code), the following actions are recommended: (i) verify correct dynamic alignment of all shaft couplings; (ii) verify acoustic resonant condition from measured flow, pump speed revolution per minute (RPM), water temperature, and vibration frequency; and (iii) replace four vane booster pump impeller with a staggered five vane impeller.

The licensee states that "the proposed Byron Jackson modifications, other than replacing the booster pump impeller, are generally very difficult to implement successfully. Altering the natural frequency of a large pump installation requires either considerable additions of stiffening components or substantial additions of mass. Often the results of such design changes are unsuccessful or unfavorable due to the variable speed operation requirements." Further, the licensee states that the impeller modification (from four vanes to five vanes), may yield some unpredictable results and requires extensive work to the HPCI pump at a time when such a major rebuild of this pump is not otherwise necessary or desired. Pilgrim submitted an independent assessment report of HPCI pump vibration which concludes that "(1) crossover piping modification by increasing the pipe length or diameter will reduce the acoustic frequency and a lower acoustic frequency will result in higher vibration at lower speed; and (2) the modified impeller (from four vanes to five vanes) will excite the acoustic resonance when the pumps are running at a lower speed. This scenario is much more troubling than the known condition in which the pump is now being tested."

The licensee provided past and present vibration data for the main and booster pump which shows that there has been no major change in the magnitude of vibration. The licensee states that despite the elevated vibration experienced, trended performance data has shown that the current pump design delivers satisfactory performance and reliability. Based on historical and recent vibration data and independent review by a pump consultant, the licensee concluded that these data ensure the continued operational readiness of HPCI pump to meet its safety function.

The licensee states that under normal operating conditions (4000 RPM), the vibration amplitude at the main pump bearing in the horizontal direction exceeds the OM Code absolute vibration required action range of greater than 0.7 inch/second. Also, under the same operating conditions, all the remaining HPCI main and booster pump vibration monitoring points, typically exceed the OM Code absolute alert range value of 0.325 inch/second. Based on the information provided in the above Table-3, vibration levels are summarized below:

1. Main pump bearing horizontal direction (P3H and P4H) vibration amplitudes have exceeded the action range of >0.7 in/sec. In recent tests, vibration amplitude at P4H is less than 0.7 in/sec. In 1993, however, the measured vibration values at P4H were above 0.7 in/sec.

2. Main pump bearing points vertical (P3V) and axial (P3A) vibration amplitude are typically between 0.325 in/sec and 0.5 in/sec.

3. Booster pump bearing vertical points (P7V and P8V), and horizontal points (P7H and P8H) vibration amplitudes are typically between 0.325 in/sec and 0.5 in/sec.

4. Main pump bearing vertical point (P4V) and booster pump bearing axial point (P8A) vibration amplitudes are consistently below 0.325 in/sec and meet the Code requirement.

The licensee states that historically the HPCI pump vibration level consistently exceeds the acceptance criteria of Table ISTB 5.2.1-1, and that Pilgrim has conducted an evaluation of the HPCI pump vibration data and characteristics by performing spectrum analysis. A typical spectrum analysis provides a graphic display of vibration in the frequency domain with the vibration amplitude (displacement, velocity or acceleration) on the Y-axis and frequency on the X-axis (cycles per second or Hz). The licensee provided a spectrum analysis for the HPCI main pump which shows that vibration at horizontal direction points P3H (inboard) and P4H (outboard) spikes at a frequency corresponding to 2x RPM of the main pump, which coincides with 4x RPM of the booster pump. The licensee believes that high vibration on the main pump bearing housings at approximate 2x RPM in the horizontal direction, is caused by booster pump excitation (4x RPM of the booster pump). The licensee states that the peak vibration amplitude is not related to the physical condition or rotating dynamics of the main pump rotor or bearing system. The licensee provided past and present vibration data for the main and booster pump which shows that there has been no major change in the magnitude of vibration. The licensee states that despite the elevated vibration experienced, trended performance data has shown that the current pump design delivers satisfactory performance and reliability, which is supported by the independent assessment of HPCI pump vibration by Mancini Consulting Service.

While using the alternative acceptance criteria, as reflected in Table-4 (main pump) and Table-2 (booster pump), the licensee states that they will perform HPCI pump condition monitoring, including spectrum analysis, vibration monitoring and maintenance activities, in addition to the

Code requirements, as follows:

1. Quarterly pump and valve operability tests will be performed to ensure the HPCI pump and turbine function as intended to meet the safety function.

2. Quarterly lubrication oil sampling will be performed. This includes analysis for viscosity, water content, chemical changes, and contaminants including ferrous particles.

3. Once/cycle oil sampling analysis on the non-pressure fed booster pump bearing sump will be performed.

4. Once/cycle (i. e. once/2 year) laboratory analysis of the lubrication oil for the pressure-fed bearings on the turbine, main pump, and gear reducer will be performed. The laboratory reviews include but are not limited to particle wear analysis, acid number readings, analytical ferrogram and oxidation stability. This type of monitoring will detect degradation of the turbine or pump bearings due to accelerated wear, fretting, surface fatigue, or oil contamination.

5. The HPCI pump and turbine lube oil system is serviced as-needed weekly. The HPCI gland seal condenser hot well pump and motor bearings, and the HPCI auxiliary lube oil

   pump and motor bearings are serviced semiannually for lubrication. During this service, the oil is observed for discoloration, emulsification, and foaming.

6. The HPCI turbine/main pump, main pump/reducer, and reducer/booster pump gear type shaft couplings are cleaned, examined, and grease-lubricated every 2 years. These examinations detect excessive wear, fretting, heating, or fatigue due to any unusual loading conditions.

7. Vibration monitoring shall be performed twice/year as the commitment frequency, even when the HPCI pump is below the proposed Alert Ranges.

8. As a current administrative practice, Pilgrim will continue to monitor vibration of the HPCI pump during each of the Quarterly Group B tests, whenever practicable, and preventive or corrective maintenance will be implemented as necessary to prevent failure.

9. Full spectrum analysis including vibration monitoring will be performed for all IST vibration points twice/year.

The licensee states that past monitoring and maintenance activities have shown no evidence or observations of degradation in the HPCI turbine, main pump, gear reducer, or booster pump. HPCI main and booster pump historical vibration spectrum and its evaluation by an independent vendor support this conclusion. Thus, continuation of the above periodic monitoring and maintenance activities will ensure that the HPCI pump remains in a high level of operational readiness and that degradation of HPCI pump mechanical condition, reliability, or performance will be detected and corrected in a timely manner.

Pilgrim originally proposed to filter the measured vibration values of the HPCI main pump. The OM Code, paragraph ISTB 5.2.3(d) requires that vibration measurements be broad band (unfiltered). A typical spectrum analysis is a means to reveal information as to the source of a potential vibration problem. The licensee-proposed alternative to filter the peak vibration values will not correct the elevated vibration levels at the pump. The NRC staff does not find the licensee's proposal to filter the peak values acceptable, since it is not allowed by the OM Code. However, the NRC Staff accepts the unfiltered measured vibration values at the HPCI pump with an Acceptable Range upper limit of 1.05 Vr (1.02 in/sec for P3H and 0.67 in/sec for P4H points) and an Alert Range upper limit of 1.3 Vr (1.26 in/sec for P3H and 0.83 in/sec for P4H points), as provided in Table-4 above, along with the licensee's approach to perform a frequency spectrum analysis and other commitments as discussed above, and to monitor the main pump vibration points P3H and P4H in the horizontal direction (without filtering the peak).

The NRC staff has considered the licensee's proposed enhanced monitoring and maintenance activities as described above, and the fact that vibration measurements show that vibration levels are consistent even though they exceed the Code values using the current test methodology. Therefore, the staff finds that the licensee's alternative to raise the alert range and required action range for these specific measurement points (Table-4 and Table-2) provides sufficient assurance of operational readiness of the HPCI pump.

The "Independent Assessment of Pilgrim HPCI Pump Vibration and Performance" by Mancini Consulting Service also concludes that "(a) the Pilgrim HPCI pump has not degraded during its 35 years of service due to the observed pump vibration, and (b) the proposed HPCI pump inservice testing and monitoring activities successfully monitor pump health, and ensure the continued operational readiness of this pump to meet its safety function."

The licensee's evaluation of the HPCI pump vibration issue, coupled with the historical pump vibration data, and HPCI pump vibration and performance assessment by an independent consultant show that the pump normally runs at high levels of vibration and has not experienced any failure to date. Due to costs associated with potential modification to address the elevated vibration level, and the low likelihood of their success, the compliance with the Code requirements for the HPCI pump would result in a hardship without a compensating increase in the level of quality and safety. The proposed alternative coupled with additional pump monitoring, including spectrum analysis, vibration monitoring and maintenance activities provide reasonable assurance of operational readiness because the licensee will maintain consistent (alternative) alert ranges and action ranges.

4.0 CONCLUSION

To reduce the HPCI Main and Booster pump vibration down to levels that meet acceptable OM Code vibration criteria requires modifications to the HPCI pump, mounting components, foundation and/or cross-over piping. Altering the natural frequency of a large pump installation requires either considerable additions of stiffening components or substantial additions of mass. Often the results of such design changes are unsuccessful or unfavorable due to the variable speed operation requirements.

Modification of the HPCI Booster pump would require replacing the current four-vane impeller with an upgraded five-vane impeller. The impeller modification requires extensive work to the HPCI pump at a time when such a major rebuild of this pump is not otherwise necessary or desired. The expected result would be a modest decrease in the vibration caused on the Main pump.

Therefore, the proposed alternative to the OM Code requirements regarding raising the allowable vibration level for the HPCI main and booster pump bearings is authorized pursuant to 10 CFR 50.55a(a)(3)(ii) on the basis that compliance with the specified requirements results in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

All other ASME OM Code requirements for which relief was not specifically requested and approved remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

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