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April 17, 2002

10 CFR 50.55a

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

Gentlemen:

In the Matter of	)	Docket Nos. 50-327
Tennessee Valley Authority	)	50-328

SEQUOYAH NUCLEAR PLANT (SQN) UNITS 1 AND 2 - REQUEST FOR RELIEF FROM AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME), SECTION XI CODE REQUIREMENTS, INSERVICE TESTING (IST) PROGRAM - TURBINE DRIVEN AUXILIARY FEEDWATER (TDAFW) PUMPS

Pursuant to 10 CFR 50.55a(a)(3)(i), TVA is requesting relief from the IST requirements in Section XI of the 1989 Edition of the ASME Boiler and Pressure Vessel Code. The SQN IST Program is currently based on the 1989 Edition of the ASME Code, Section XI, that endorses ASME OM-6, 1987 Edition with 1988 Addenda for pump testing. TVA's request for relief proposes alternative test methods for the SQN TDAFW pumps based on the 1995 Edition, 1996 Addenda of the ASME Section XI Code.

Enclosure 1 contains TVA's request for relief (RP-09) for the Unit 1 TDAFW pump. Enclosure 2 contains a similar request for relief (RP-10) for the Unit 2 TDAFW pump. These relief requests are submitted in accordance with 10 CFR 50.55a(a)(3)(i).

TVA's proposed request for relief is a cost-beneficial licensing action that reduces the burden associated with unnecessary IST activities.

While no specific scheduler milestone exists, TVA requests NRC review and approval as soon as possible to support inservice test schedules.

A047

There are no commitments contained in this letter. This letter is being sent in accordance with NRC RIS 2001-05. If you have any questions about this change, please telephone me at (423) 843-7170 or J. D. Smith at (423) 843-6672.

Sincerely,

Original signed by

Pedro Salas
Licensing and Industry Affairs Manager

Enclosures

JDS:DVG:PMB
Enclosures
cc (Enclosures):
R. J. Adney, LP 6A-C
J. L. Beasley, OPS 4A-SQN
M. J. Burzynski, BR 4X-C
C. C. Cross, LP 6A-C
M. H. Dunn, ET 10A-K
D. L. Koehl, POB 2B-SQN
NSRB Support, LP 5M-C
R. T. Purcell, OPS 4A-SQN
J. R. Rupert, LP 6A-C
J. A. Scalice, LP 6A-C
K. W. Singer, LP 6A-C
EDMS, WTC A-K

ENCLOSURE 1

SEQUOYAH NUCLEAR PLANT (SQN)
RELIEF REQUEST (RP-09)
UNIT 1
TURBINE DRIVEN AUXILIARY FEEDWATER (TDAFW) PUMP

Summary: SQN is designed with two TDAFW pumps (one for each unit). The Unit 1 TDAFW pump is tested once each quarter in accordance with American Society of Mechanical Engineers (ASME) OM Part 6. Test data for the Unit 1 pump has shown vibration measured in the alert range as defined by ASME OM Part 6 (i.e., 0.325 to 0.70 inch per second). In accordance with ASME code, the test frequency for a pump in the alert range is required to be doubled.

TVA's evaluation of the Unit 1 TDAFW pump history determined that the cause of the elevated vibration response is due to vane pass frequency while the pump is operating in recirculation (miniflow) mode. The vane pass frequency condition has also been attributed to pump modifications that were previously performed to improve pump efficiency. TVA has determined (refer to Attachment B) that the vibration levels for the Unit 1 pump remain stable at the vane pass frequency and have not contributed to pump degradation or reduced pump performance. Accordingly, doubling the pump test frequency does not serve the purpose of the code for measuring adverse trends in pump parameters.

TVA proposes to utilize alternative test requirements found in the ASME OM Code, 1995 Edition, 1996 Addenda, Subsection ISTB. The alternative test requirements from the 95/96 code provide for comprehensive pump tests that monitor pump vibration on a biennial basis. In addition, pump test alignments on a biennial basis are at full-flow (or near full-flow) test conditions (i.e., pump test alignment available during refueling outages) rather than minimum flow test conditions (alignment available for the quarterly pump test). The comprehensive pump test methods from the 95/96 code provide a more useful tool for monitoring and trending pump performance. The comprehensive test methods also eliminate unnecessary testing of the pump for the purpose of compliance with the increased frequency test requirements of the current code.

TVA requests authorization to use the alternative test methods from ASME OM Code 1995 Edition, 1996 Addenda, Subsection ISTB in accordance with 10 CFR 50.55a(a)(3)(i).

Unit: 1

System: Auxiliary Feedwater (AFW) System - (System 3)

Component: TDAFW pump

ASME Class: 3

Function: The function of AFW System is described in Section 10.4.7.2 of the SQN Final Safety Analysis Report (FSAR).

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 trip with plant load greater than 80 percent. Specific details are listed in SQN FSAR Section 10.4.7.2.2.

Code Requirement: The ASME Operation and Maintenance Code, Part 6 (OM-6), 1987 Edition with the 1988 Addenda, Section 5.2(d) states:

"Pressure, flow rate, and vibration (displacement or velocity) shall be determined and compared with 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.

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."

Table 3 provides the range for test parameters as it applies to SQN's TDAFW pump. For a centrifugal pump with a pump speed greater than 600 revolutions per minute, the alert range for vibration is from 2.5 V_r to 6 V_r or from 0.325 to 0.70 inch per second (V_r is the vibration reference value).

Code Requirements From Which Relief is Requested: Relief is requested from the test parameters associated with vibration as given in Table 3 of OMa, Part 6, 1988.

Basis for Relief: 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 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) 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 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).

3. Modifications were made to the Unit 1 TDAFW pump as described in the Attachment A 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.

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 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.

Impractical Requirement: 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.

Alternative Test: SQN will perform inservice testing of the Unit 1 TDAFW pump in accordance with the requirements of the ASME OM Code, 1995 Edition, 1996 Addenda, Subsection ISTB. The provisions of the 95/96 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.

ENCLOSURE 2

SEQUOYAH NUCLEAR PLANT (SQN)
RELIEF REQUEST (RP-10)
UNIT 2
TURBINE DRIVEN AUXILIARY FEEDWATER PUMP

Summary: SQN is designed with two TDAFW pumps (one for each unit). The Unit 2 TDAFW pump is tested once each quarter in accordance with American Society of Mechanical Engineers (ASME) Operations and Maintenance (OM), Part 6. Test data for the Unit 2 pump has shown vibration measured in the alert range as defined by ASME OM, Part 6 (i.e., 0.325 to 0.70 inches/second). In accordance with ASME code, the test frequency for a pump in the alert range is required to be doubled.

TVA evaluation of the Unit 2 TDAFW pump history determined that the cause of the elevated vibration response is due to vane pass frequency while the pump is operating in recirculation (miniflow) mode. The vane pass frequency condition has also been attributed to pump modifications that were previously performed to improve pump efficiency. TVA has determined (refer to Attachment C) that the vibration levels for the Unit 2 pump remain stable at the vane pass frequency and have not contributed to pump degradation or reduced pump performance. Accordingly, doubling the pump test frequency does not serve the purpose of the code for measuring adverse trends in pump parameters.

TVA proposes to utilize alternative test requirements found in the ASME OM Code, 1995 Edition, 1996 Addenda, Subsection ISTB. The alternative test requirements from the 95/96 code provide for comprehensive pump tests that monitor pump vibration on a biennial basis. In addition, pump test alignments on a biennial basis are at full-flow (or near full-flow) test conditions (i.e., pump test alignment available during refueling outages) rather than minimum flow test conditions (alignment available for the quarterly pump test). The comprehensive pump test methods from the 95/96 code provide a more useful tool for monitoring and trending pump performance. The comprehensive test methods also eliminate unnecessary testing of the pump due to increased frequency test requirements of the current code.

TVA requests authorization to use the alternative test methods from ASME OM Code 1995 Edition, 1996 Addenda, Subsection ISTB in accordance with 10 CFR 50.55a(a)(3)(i).

Unit: 2

System: Auxiliary Feedwater (AFW) System - (System 3)

Component: TDAFW pump

ASME Class: 3

Function: The function of the AFW System is described in Section 10.4.7.2 of the SQN Final Safety Analysis Report (FSAR).

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) at times when the feedwater system is not available, thereby maintaining the heat sink capabilities of the SG. As an Engineered Safeguards System, the AFW system is directly relied upon 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 start 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 trip with plant load greater than 80 percent. Specific details are listed in SQN FSAR Section 10.4.7.2.2.

Code Requirement: The ASME Operation and Maintenance Code, Part 6 (OM-6), 1987 Edition with the 1988 Addenda, Section 5.2(d) states:

"Pressure, flow rate, and vibration (displacement or velocity) shall be determined and compared with 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.

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."

Table 3 provides the range for test parameters as it applies to SQN's TDAFW pump. For a centrifugal pump with a pump speed greater than 600 revolutions per minute, the alert range for vibration is from 2.5 V_r to 6 V_r or from 0.325 to 0.70 inches per second (V_r is the vibration reference value).

Code Requirements From Which Relief is Requested: Relief is requested from the test parameters associated with vibration as given in Table 3 of OMa, Part 6, 1988.

Basis for Relief: 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 control process. Refer to Attachment A 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 in/sec). This observance provided further indication that the initial high pump vibration measurements were due to the vane pass frequency response at low flow conditions. 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) provides a summary description and graphical information from the vibration testing.

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

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

The following addresses each of these components:

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

2. The pump manufacturer and the plant's vibration testing 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).

3. Modifications were made to the Unit 2 TDAFW pump as described in the Attachment A Flowserve Corporation letter. TVA considers the modifications to the Unit 2 TDAFW pump contributed to the elevated vibration levels. Based on TVA analysis of current 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

increase 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 an extended 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 spectral analysis shows that the 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 in Attachment C.

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 usually less than 12 hours. During this time, SQN's motor-driven auxiliary feedwater (MDAFW) pumps are relied upon for heat removal and operate during plant shutdown. The TDAFW pump is typically removed from service within 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 SGs for heat removal. The MDAFW 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 vibrations are 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), the pump bearing life may be reduced. Bearing life, however, is sufficient to prevent any compromise in operability of the pump.

Impractical Requirement: OM-6 Section 6.1 states: "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 for deviation in pump vibration measurements has been analyzed and determined to be attributed to vane pass frequency. The correction for this condition is to allow additional flow through the pump by modification of the discharge piping. This change would involve 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 pump or its ability to perform its safety function.

Alternative Test: SQN will perform inservice testing of the Unit 2 TDAFW pump in accordance with the requirements of the ASME OM Code, 1995 Edition, 1996 Addenda, Subsection ISTB. The provisions of the 95/96 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.

FLOWSERVE

Flow Solutions Division

Pump Services Engineering

February 5, 2002

TVA – Sequoyah Nuclear Plant
Chattanooga, TN
Attn: Mr. Tim Massey

Subject:: Relief Request Evaluation - Vane Pass Vibration
Units #1 and #2 Turbine Driven Auxiliary Feedwater Pump, Model 5HMTA-5
Operational Readiness – Pump Reliability

Reference: a) Your emails and related attachments, dated 1/11/02, 1/14/02, 1/17/02
b) Flowserve letter (R.Koch to T.Massey) dated 6/18/01

Enclosure 1) Pump Industry Technical Paper, "Vane pass vibration – Source, Assessment and Correction – A practical guide for Centrifugal Pumps" – Proceedings from 16th International Pump Symposium 1999

Dear Tim,

The purpose of this letter is to reply to your Reference a) submittals and provide the technical evaluation to support the subject OM-6 IST relief request, which concludes that the high frequency (7X) vane pass vibration (at approximately .3mils displacement) – may reduce long term bearing life, but does not lead to imminent degradation and compromised operability.

The following information relates to the request:

- The vane pass energy puts the pump in "alert" only at the IST mini-flow. Full flow vibration levels are satisfactory.
- The AFW pumps are typically operated less than (60) minutes each quarter and for short periods of time during the plant start-ups every (18) months, at the low flows.
- The vibration exceeds the alert, on the outboard bearing housing – axial and horizontal positions only.
- The magnitude of the 7X vane pass has not degraded over the past several months in the Unit #2 Turbine Drive AFW pump that was installed in November 2000.
- The vane pass issue was recognized after the Unit#2 installation. As a lessons-learned path-forward process, the following further improvements were incorporated into the Unit#1 pump in 2001:
  - Further increased B-gap, to attempt to attenuate the impact energy.

Flowserve Corporation
Ingersoll-Dresser Pumps
942 Memorial Parkway
Phillipsburg, NJ 08865
Phone 908-859-7406
Facsimile 908-859-7988

- Tapered the balance sleeve face to optimize balance drum fluid stiffness.
- Increased channel ring return guide vane number to 9, to establish an optimum vane number difference of 2. (ie. 9-7=2 is preferred versus original design 8-7=1). This configuration will optimize vane pass interaction to the impeller eye back-flow.
- Slightly over-filed the impeller vanes to smooth-out the vane pass wake.

- It is understood that a postulated accident mode exists where the TDAFW pump may operate several days at miniflow, when the pump main discharge valves are secured and steam availability to the turbine continues. The pump is expected to perform during this mission scenario. The pump may experience some degradation relating to bearing loading - but will not lead to short-term failure. This position is based on the following objective evidence:
  1. The pump has been upgraded to steel diffusers, from the original iron material.
  2. The A and B-gap design upgrade to the impellers and diffusors improves pump reliability at low flows.
  3. The thrust ball bearing assembly has been upgraded to optimize operating temperature and oil quality.
  4. An HMTA model pump with similar construction, for another South East Nuclear Utility, was Endurance Tested for 300 hours at miniflow in 1994. It was performance and vibration tested. It was dismantled and inspected. No apparent degradation was observed.

As discussed in Reference b), the program upgrade workscope was as follows:

- Reduction of thrust bearing size to reduce frictional heat, spalling and ball skidding.
- Incorporation of a Schnorr spring in the thrust bearing housing to provide axial compliance and reduce axial dynamic loading of the thrust bearing during low pump flow operation (i.e. plant start-ups and IST surveillance)
- Elimination of the oil ring to assure oil contamination resulting from ring fretting was no longer an issue.
- Material improvement of the thrust bearing housing, from iron to steel. The steel provides an environment to reduce / eliminate fretting corrosion between the thrust bearing outer race and the housing bore. The steel is also an ASME code material and preferred in the water-cooled bearing housing arrangement. The steel is also substantially more stiff than the original iron housings.
- A-gap, B-gap and C-overlap (X ratio) improvement to the impellers and diffusers. Exact dimensions and geometry details have been forwarded to TVA SNP. This confirms the optimum configuration, successfully incorporated in several industry pumps of same, similar and much larger sizes.
- Clocking of the channel rings (diffusers) to minimize vane-pass energy interaction with the impeller.

- Diffuser material upgrade from iron to steel. This has been an NRC / Industry initiative to improve diffuser material reliability relative to low flow pressure pulsations and corrosion. Cracked and corroded iron diffusers have been experienced in the Nuclear Industry due to the high (low flow) vane pass pressure pulsations and high (>.04ppm) oxygenated storage tank water. The MDFW pumps (except for one) have been upgraded to the steel diffusers.

The program upgrade goals were to increase pump flow performance, and reduce/eliminate low flow surging that was identified as a source that was causing abnormal bearing fretting and oil contamination. That scope was successfully achieved.

Underfiling of the impellers to increase the delivered flow may have become a contributor to the elevated vane pass (7X) vibration. Please note that the MD pumps are operating at 22% BEP and are 55HP/stage; the TD pumps are operating at 5% BEP and are approximately 140HP/stage. Also, the MD impellers are not underfiled. Vane pass energy in the past, with the iron diffusers and channel rings was not an issue.

One other hypothesis is that the high vane pass wake energy in the past was in fact damped by the iron channel rings and diffusers ($10X10^6$ iron modulus of elasticity vs $29X10^6$ steel modulus; iron also has 10-times the "specific damping capacity" factor than steel). The more-stiff stainless steel channel rings and diffusers could be transmitting the energy to the pump casing and bearing housings. Note that the MD channel rings remain iron – only the attached diffusers were upgraded to steel. This hypothesis is further supported by the fact that the shaft, casing and bearing housing vibration, acquired by the writer in June 2001 indicates that all the vibration to be "in phase" – indicating "solid body motion". It is noted that this solid body motion implies that there is very little relative motion and forces relating to the vane pass energy. This condition would indicate less stress and fatigue loading (bearing loading) versus vibration that was out-of-phase with the pump rotor.

Another factor is how damaging is the higher frequency vane pass energy, versus 1X vibration (ie. unbalance, misalignment or bent shaft). Many Pump Industry experts assert that the higher frequency vane pass energy is not as deleterious to the pump as would be a "1X" or sub-synchronous vibration. Papers have been written on this issue. The Enclosure 1) Pump Symposium Technical Paper, Table I indicates "proposed allowables", over .45ips for pump flows less than 45% BEP. Again – the 4000rpm TD AFW pump is OM6 Surveillance Tested at 5% BEP. Note that the mils-displacement relating to a .45ips 7X (463Hz) is only .3mils. The displacement amplitude is an indicator of "stress" on the machine.

In conclusion, the above discussion supports the recommendation of the Relief Request to change the "Alert" at an FFT measured 7X (analysis allowed by the ASME Code) to (up to) .45ips. This is consistent with what Diablo Canyon has done on the Flowserve pump (4DVMX-6) 4000rpm TD-AFW pump.

If there are any questions or comments, please advise.

Yours truly,

R.P.Koch
Engineering Manager
Pump Services Group
Flowserve Corporation

ATTACHMENT B

TVA- Sequoyah Nuclear Plant
Predictive Maintenance Group
Vibration Report for the
Unit 1 Turbine Driven Auxiliary Feed Water Pump

01/09/02

The SQNP Unit 1 Turbine Driven Auxiliary Feed Water Pump (AFWP 1A-S) has elevated vibration levels on the pump outboard bearing occurring during pump low flow rate conditions. This report provides an evaluation of the vibration levels in effort to determine the cause. Vibration spectra plots are attached.

The pump was recently rebuilt which included material up-grade and design change to improve pump performance.

All surveillance testing is conducted at a reduced pump flow rate of approximately 10% of rated flow.

The full flow rate for this pump is 630 GPM at approximately 3937 RPM. Vibration data is collected in the vertical, horizontal and axial direction using a frequency maximum of 6000 Hz (approximately 91X the pump operating speed).

The overall direct vibration levels on the pump inboard and outboard bearing housings during reduced and full flow rates are:

Direction	Baseline Reduced Flow Vibration	Jan'28,2002 Reduced Flow Vibration Data	Full Flow Vibration Test Data
Inboard Vertical	0.248	0.232	0.079
Inboard Horizontal	0.243	0.256	0.08
Inboard Axial	0.273	0.243	0.08
Outboard Vertical	0.206	0.194	0.079
Outboard Horizontal	0.422	0.424	0.182
Outboard Axial	0.359	0.334	0.1

A significant decrease in vibration levels is observed during pump full flow conditions.

The alert vibration level for this pump is 0.325 ipsp. The turbine vibration levels have remained well below the alert specifications and consistent with previous trends and are not related to the pump vibration.

Tachometer synchronized phase data was taken during reduced flow testing. This data indicates that the mode shape of the pump is in phase from the inboard bearing to the outboard bearing. The data is available for review but is not provided in this report.

Spectra analysis of the vibration data on the pump outboard bearing indicates that the predominant vibration is occurring at 463 Hz which coincides with 7X the pump operating speed. The 7X represents the pump's impeller vane passing frequency and is predominant in the vibration spectrum at both reduced and full flow. See the attached spectra plots.

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 times 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 recent modifications to the internal clearances improved pump efficiency and contributed to the increased vibration levels.

A review of vibration data historical trends for this pump, the SQNP Unit 2 AFWP 2A-S and other pumps with similar conditions indicates that the vibration level at the vane passing frequency remains consistent with no increase in trend provided that the data was collected at the same pump flow rate. No equipment degradation at SQNP has been caused by elevated vibration levels at the pump vane passing frequency.

A review of industry high vibration data due to vane passing frequency revealed similar conditions experienced at SQNP. Elevated vibration levels at the vane passing frequency were present and remained consistent with no increase in trend and no equipment degradation.

In summary, the cause of the vibration increase is due to the pump's vane passing frequency influenced by the low pump flow rates during surveillance testing and by pump efficiency improvements. The vibration level has remained stable at this frequency with no increase in trend and no equipment degradation has occurred as a result. The mode shape of the pump is in-phase between the pump bearings. Having elevated vibration levels out-of-phase would be a concern for equipment condition. Based on this, the vibration levels are expected to remain elevated but stable and not contribute to equipment degradation.

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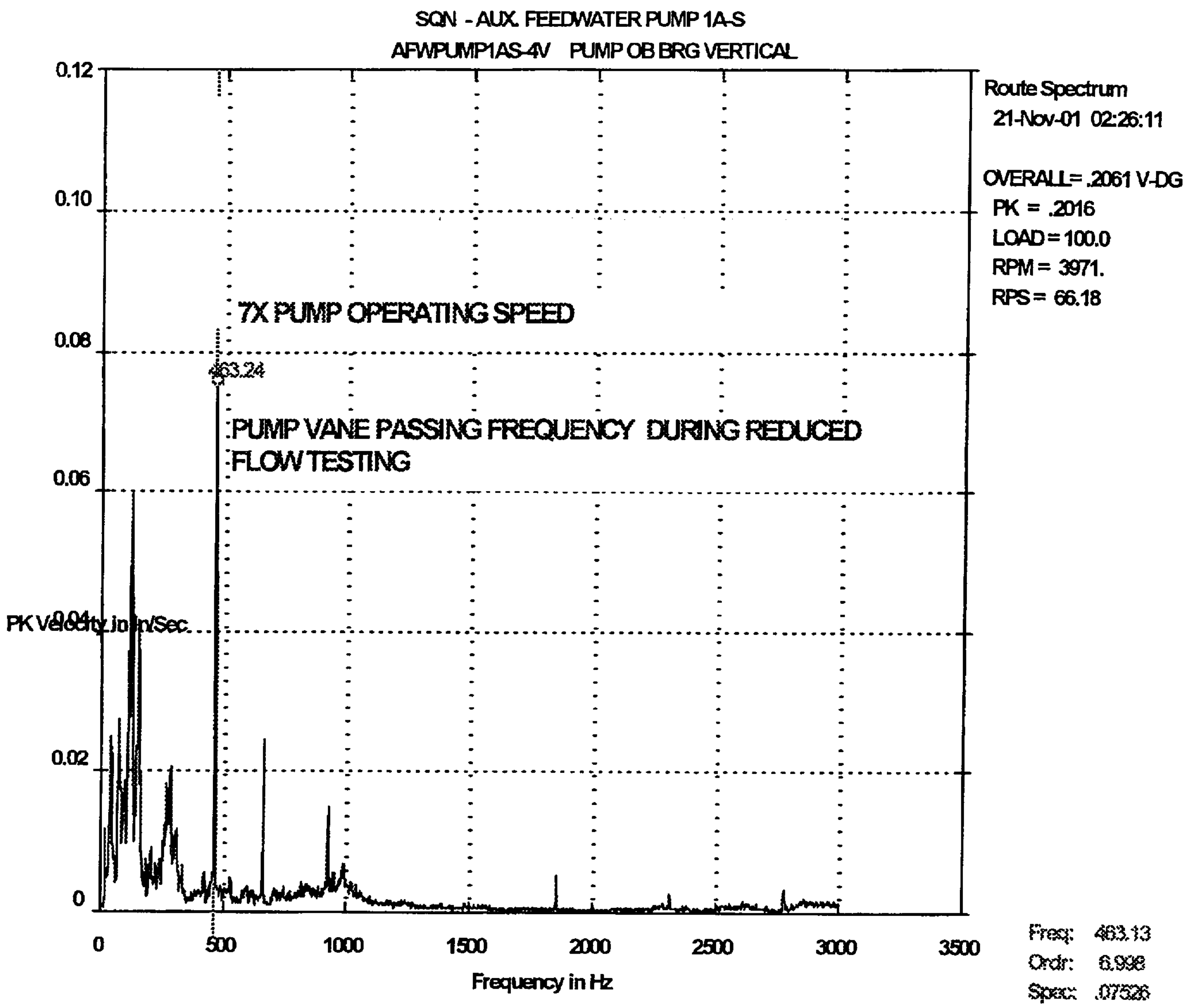
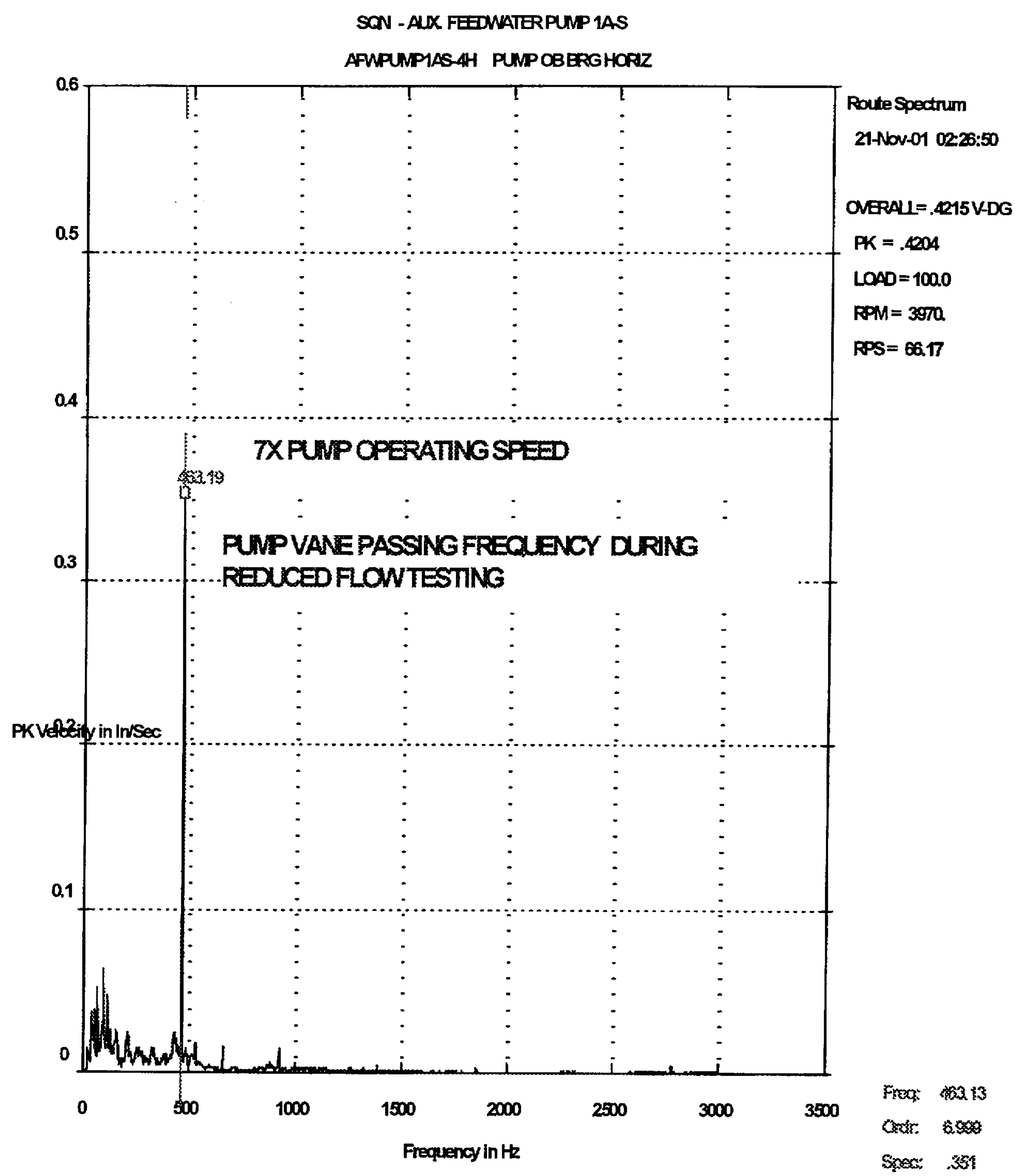
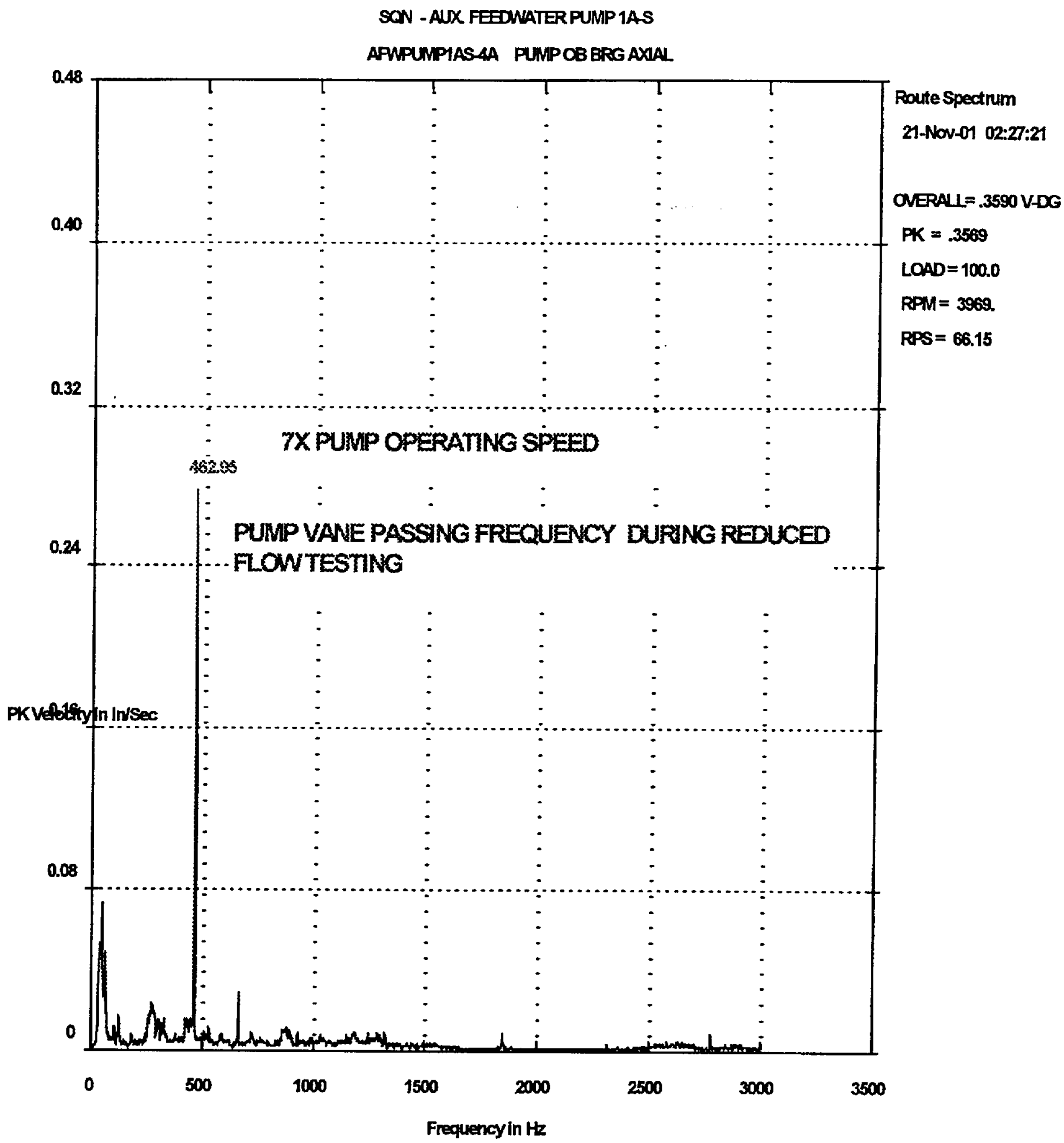

SQN - AUX. FEEDWATER PUMP 1A-S
AFWPUMP1AS-4V PUMP OB BRG VERTICAL
Route Spectrum
21-Nov-01 02:26:11
OVERALL= .2061 V-DG
PK = .2016
LOAD = 100.0
RPM = 3971.
RPS = 66.18
7X PUMP OPERATING SPEED
463.24
PUMP VANE PASSING FREQUENCY DURING REDUCED FLOW TESTING
PK Velocity in In/Sec
0.12
0.10
0.08
0.06
0.04
0.02
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Freq: 463.13
Ordr: 6.998
Spec: .07526



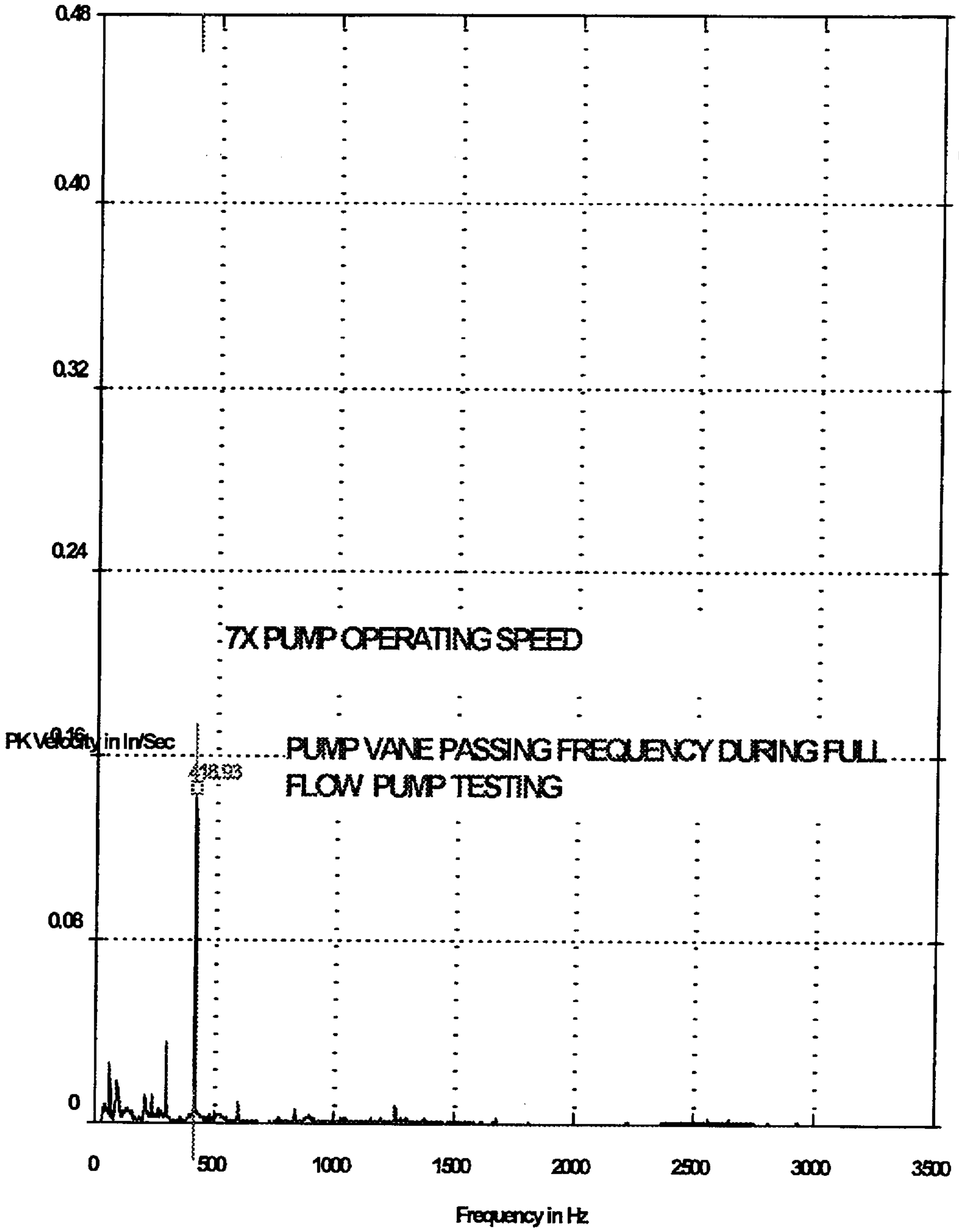
SQN - AUX. FEEDWATER PUMP 1A-S
AFWPUMP1AS-4H PUMP OB BRG HORIZ
Route Spectrum
21-Nov-01 02:26:50
OVERALL= .4215 V-DG
PK = .4204
LOAD = 100.0
RPM = 3970.
RPS = 66.17
7X PUMP OPERATING SPEED
463.19
PUMP VANE PASSING FREQUENCY DURING
REDUCED FLOW TESTING
PK Velocity in In/Sec
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Freq: 463.13
Ordr: 6.999
Spec: .351



SQN - AUX. FEEDWATER PUMP 1A-S
AFWPUMP1AS-4A PUMP OB BRG AXIAL
Route Spectrum
21-Nov-01 02:27:21
OVERALL= .3590 V-DG
PK = .3569
LOAD = 100.0
RPM = 3969.
RPS = 66.15
7X PUMP OPERATING SPEED
462.95
PUMP VANE PASSING FREQUENCY DURING REDUCED FLOW TESTING
PK Velocity in In/Sec
0.48
0.40
0.32
0.24
0.16
0.08
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz

SQN - AUX. FEEDWATER PUMP 1A-S

AFWPUMP1AS-4H PUMP OB BRG HORIZ



Route Spectrum
21-Nov-01 08:34:16

OVERALL= .1822 V-DG
PK = .1817
LOAD= 100.0
RPM= 3589.
RPS= 59.81

Freq: 418.13
Ordr: 6.991
Spec: .144

ATTACHMENT C

TVA- Sequoyah Nuclear Plant
Predictive Maintenance Group
Vibration Report for the
Unit 2 Turbine Driven Auxiliary Feed Water Pump

01/14/02

The SQNP Unit 2 Turbine Driven Auxiliary Feed Water Pump (AFWP 2A-S) has elevated vibration levels on the pump outboard bearing occurring during low flow conditions. The pump was rebuilt approximately 18 months ago which included material up-grade and design changes similar to the SQNP Unit 1 AFWP 1A-S. This report provides an evaluation of the vibration levels in effort to determine the cause. Vibration data and spectra plots are provided.

All surveillance testing is conducted at a reduced pump flow rate of approximately 10% of rated flow. Vibration is monitored in the vertical, horizontal and axial direction on both pump bearings using a frequency maximum of 6000 Hz (approximately 91X the pump speed).

The following tabulation provides a history of the direct vibration levels on the pump during surveillance testing. The alert vibration level for this pump is 0.325 ipsp

	Pump Inboard Bearing			**Pump Outboard Bearing**		
Date	**Vertical**	**Horizontal**	**Axial**	**Vertical**	**Horizontal**	**Axial**
19-Apr-00	0.24	0.265	0.135	0.282	0.263	0.305
13-Jul-00	0.208	0.218	0.154	0.261	0.231	0.264
12-Nov-00	0.229	0.253	0.203	0.229	0.325	0.217
17-Nov-00	0.178	0.244	0.219	0.205	0.283	0.295
11-Jan-01	0.198	0.266	0.118	0.232	0.278	0.225
21-Feb-01	0.208	0.262	0.17	0.218	0.328	0.244
21-Feb-01	0.209	0.251	0.167	0.240	0.321	0.237
05-Apr-01	0.21	0.265	0.166	0.294	0.324	0.313
12-Jun-01	0.164	0.213	0.194	0.205	0.305	0.251
09-Jul-01	0.2	0.23	0.177	0.220	0.308	0.298
05-Sep-01	0.212	0.249	0.176	0.211	0.318	0.251
29-Nov-01	0.205	0.239	0.198	0.240	0.310	0.271

The baseline testing performed on 12-Nov-00 indicate that the vibration levels on the pump outboard bearing in the horizontal direction were at alert. Some reduction in pump vibration was achieved by Plant efforts to increase flow rates during subsequent testing. Since baseline, the vibration levels on both pump bearings have remained consistent with no indication of increase in trend.

The turbine vibration levels have remained well below the alert specifications and consistent with previous trends and are not related to the pump vibration.

Tachometer synchronized phase data was taken during pump low flow baseline testing. This data indicates that the mode shape of the pump is in phase from the inboard bearing to the outboard bearing. The data is available for review but is not provided in this report.

Spectra analysis of the vibration data on the pump outboard bearing in the horizontal direction indicates that the predominant vibration is occurring at 464 Hz which coincides with 7X the pump operating speed. The 7X represents the pump's impeller vane passing frequency. The attached spectra plots provide signature comparison between baseline and current readings and confirm that the vibration has not degraded.

As the pump flow rate is reduced, the pumping fluid becomes unstable and interacts with the impeller at incorrect angles creating internal turbulence. This results in elevated vibration at a frequency equal to the number of impeller vanes multiplied times 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 previous modification to the internal clearances improved pump efficiency and contributed to the increased vibration levels.

Vibration monitoring has not been performed on this pump during full flow testing. The vibration levels on the SQNP Unit 1 AFWP 1A-S were confirmed to decrease as the flow rate was increased. Since the elevated vibration levels are a function of the vane passing frequency, it is suspected that AFWP 2A-S vibration levels will decrease.

A review of vibration data historical trends for this pump, the SQNP Unit 1 AFWP 1A-S and other pumps with similar conditions indicates that the vibration levels at the vane passing frequency remains consistent with no increase in trend provided that the data was collected at the same pump flow rate. No equipment degradation at SQNP has been caused by elevated vibration levels at the pump vane passing frequency.

A review of industry high vibration data due to vane passing frequency revealed similar conditions experienced at SQNP. Elevated vibration levels at the vane passing frequency were present and remained consistent with no increase in trend and no equipment degradation.

In summary, the elevated vibration is due to the pump's vane passing frequency influenced by the low pump flow rates during surveillance testing and by pump efficiency improvements. The vibration level has remained stable since baseline testing and no equipment degradation has occurred as a result. The mode shape of the pump is in-phase between the pump bearings. Having elevated vibration levels out-of-phase would be a concern for equipment condition. Based on this, the vibration levels are expected to remain elevated but stable and not contribute to equipment degradation.

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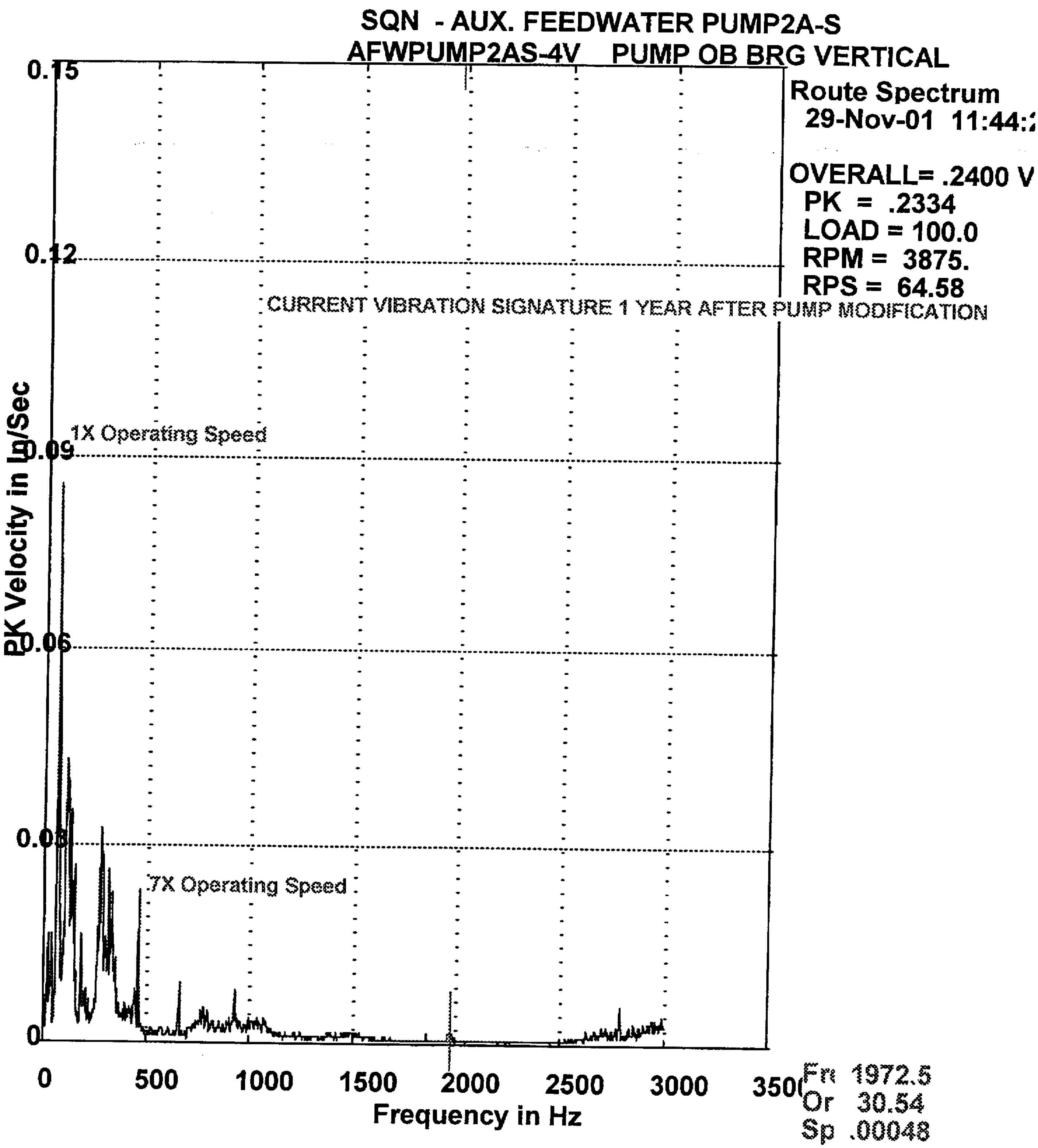
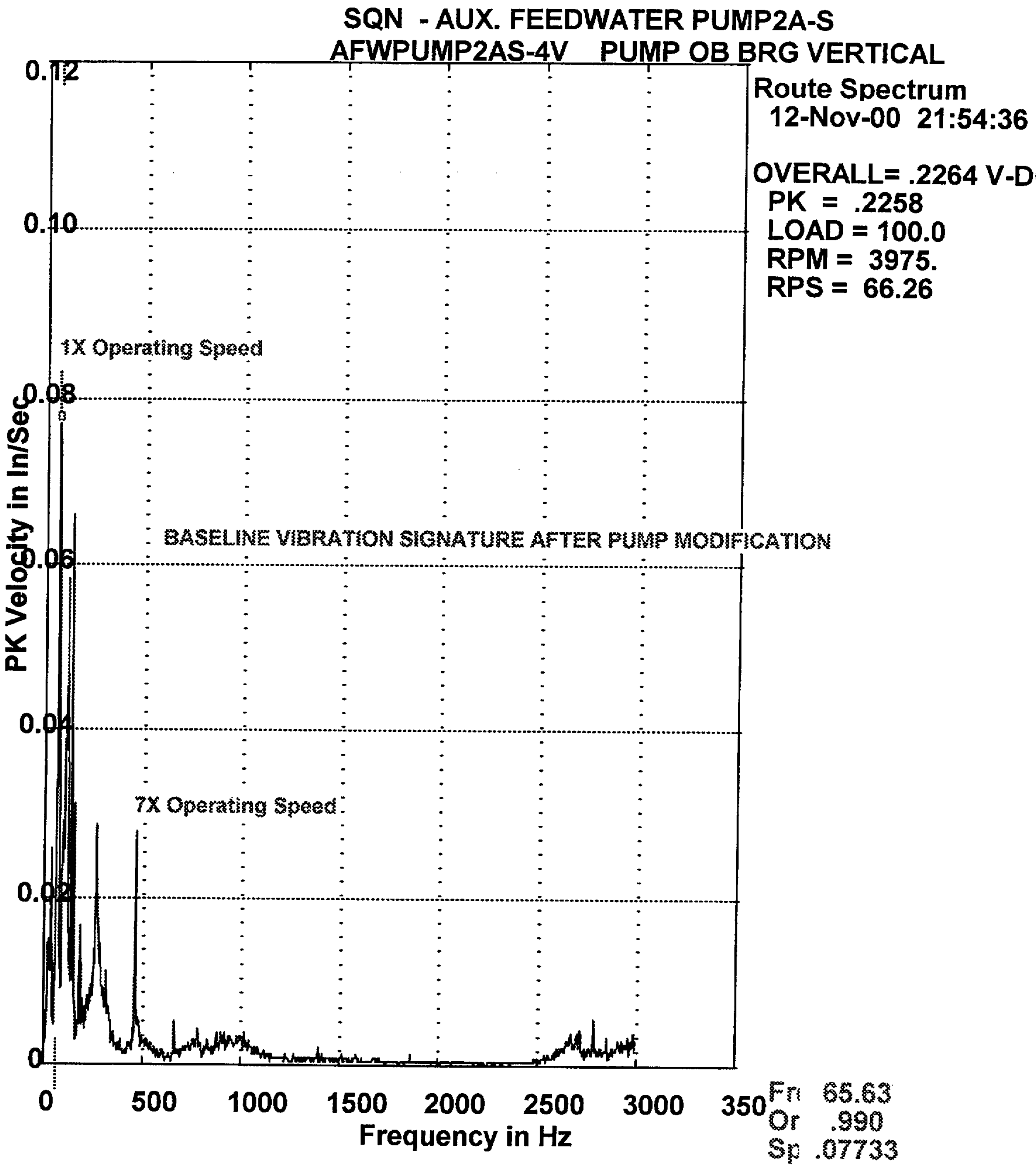
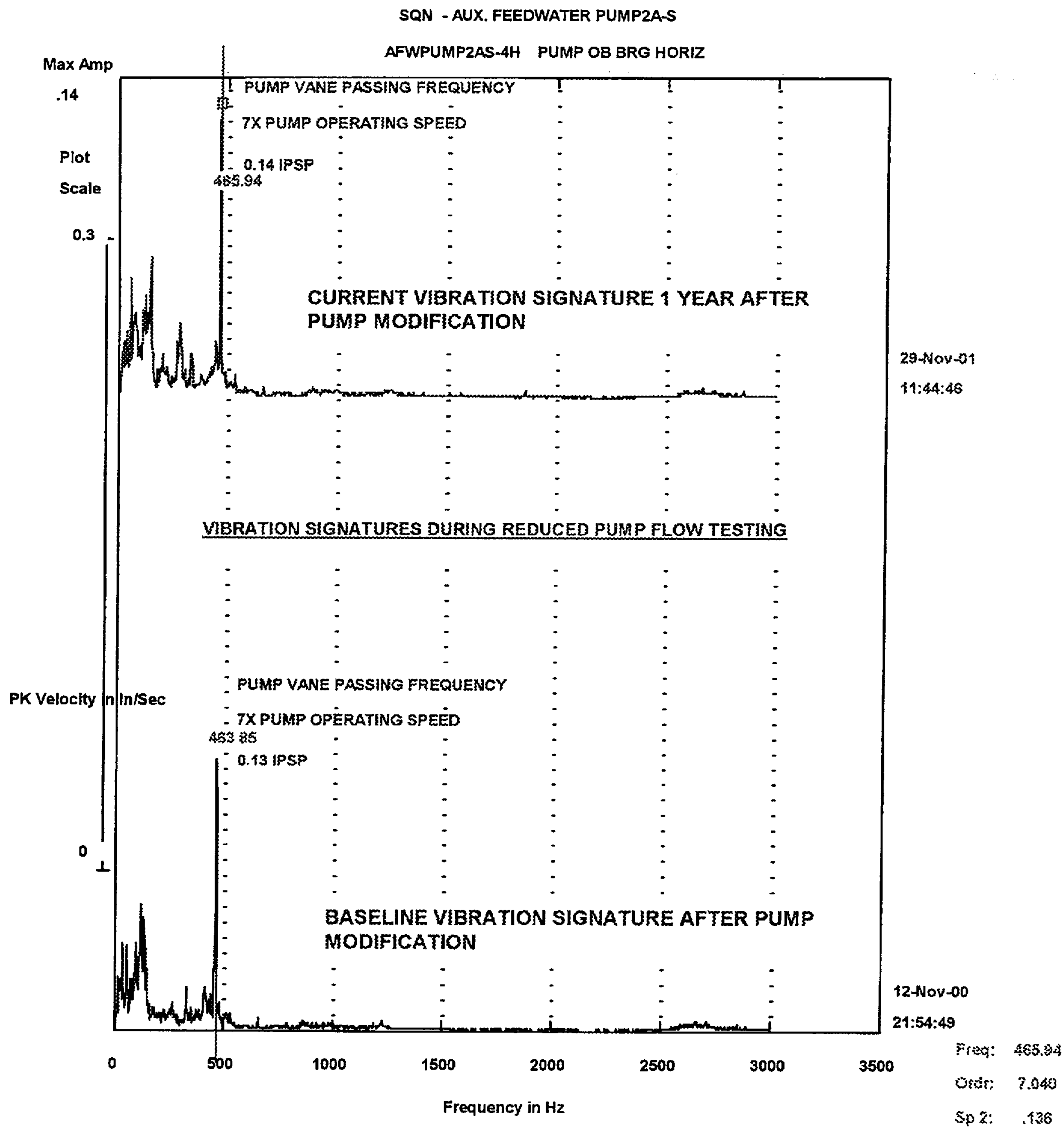
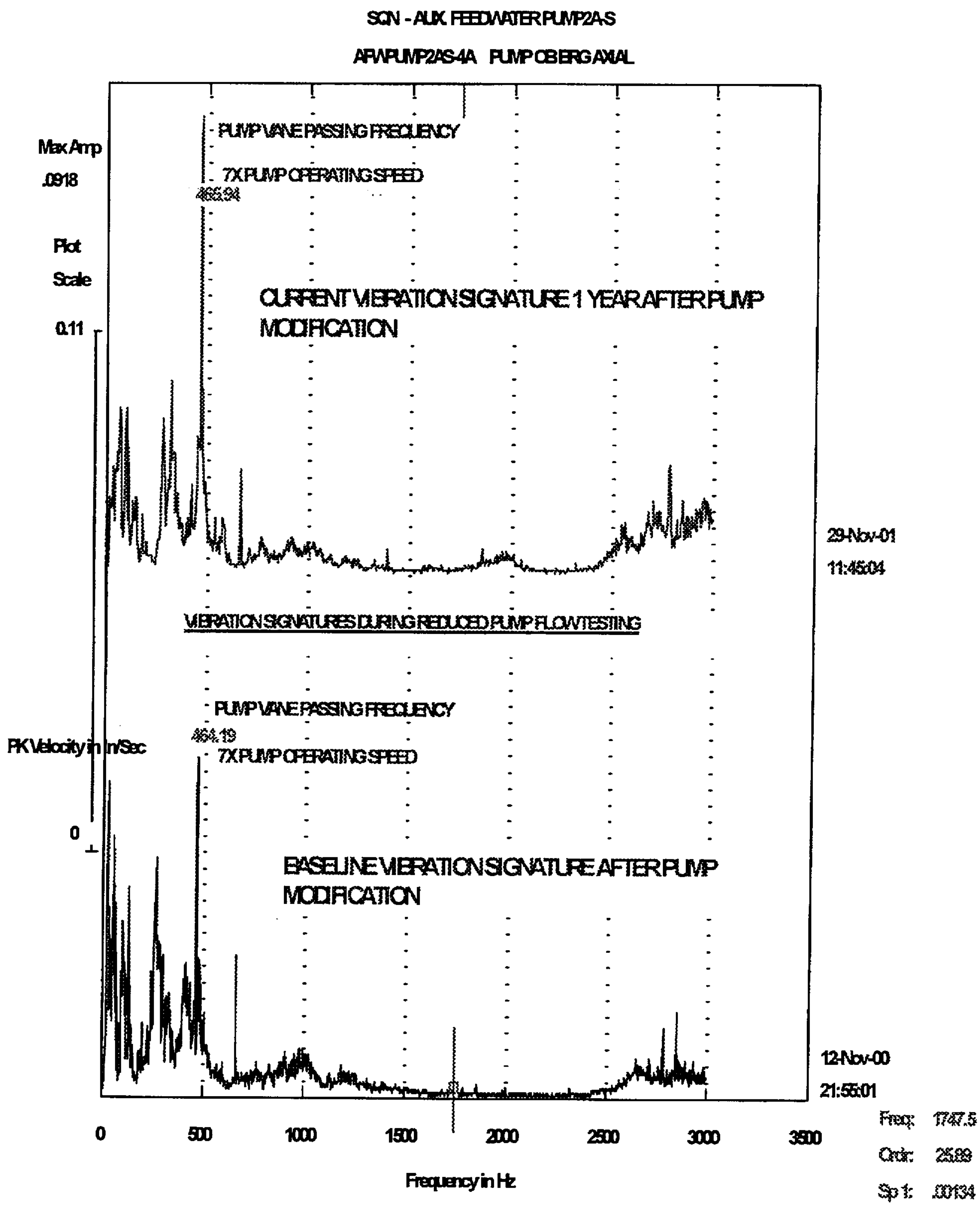


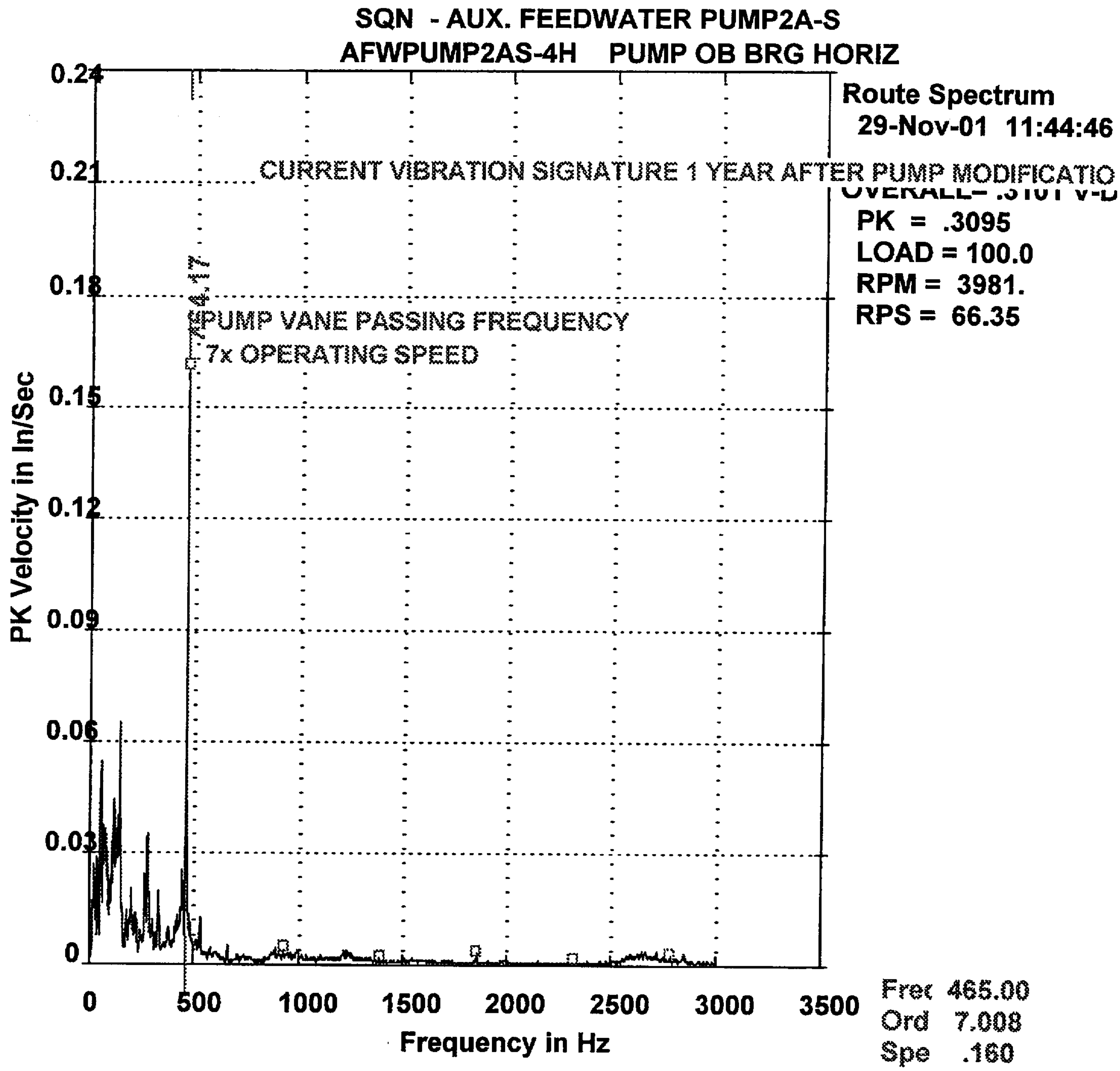
SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4V PUMP OB BRG VERTICAL
Route Spectrum
29-Nov-01 11:44:
OVERALL= .2400 V
PK = .2334
LOAD = 100.0
RPM = 3875.
RPS = 64.58
CURRENT VIBRATION SIGNATURE 1 YEAR AFTER PUMP MODIFICATION
1X Operating Speed
7X Operating Speed
PK Velocity in In/Sec
0.15
0.12
0.09
0.06
0.03
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Fre 1972.5
Or 30.54
Sp .00048

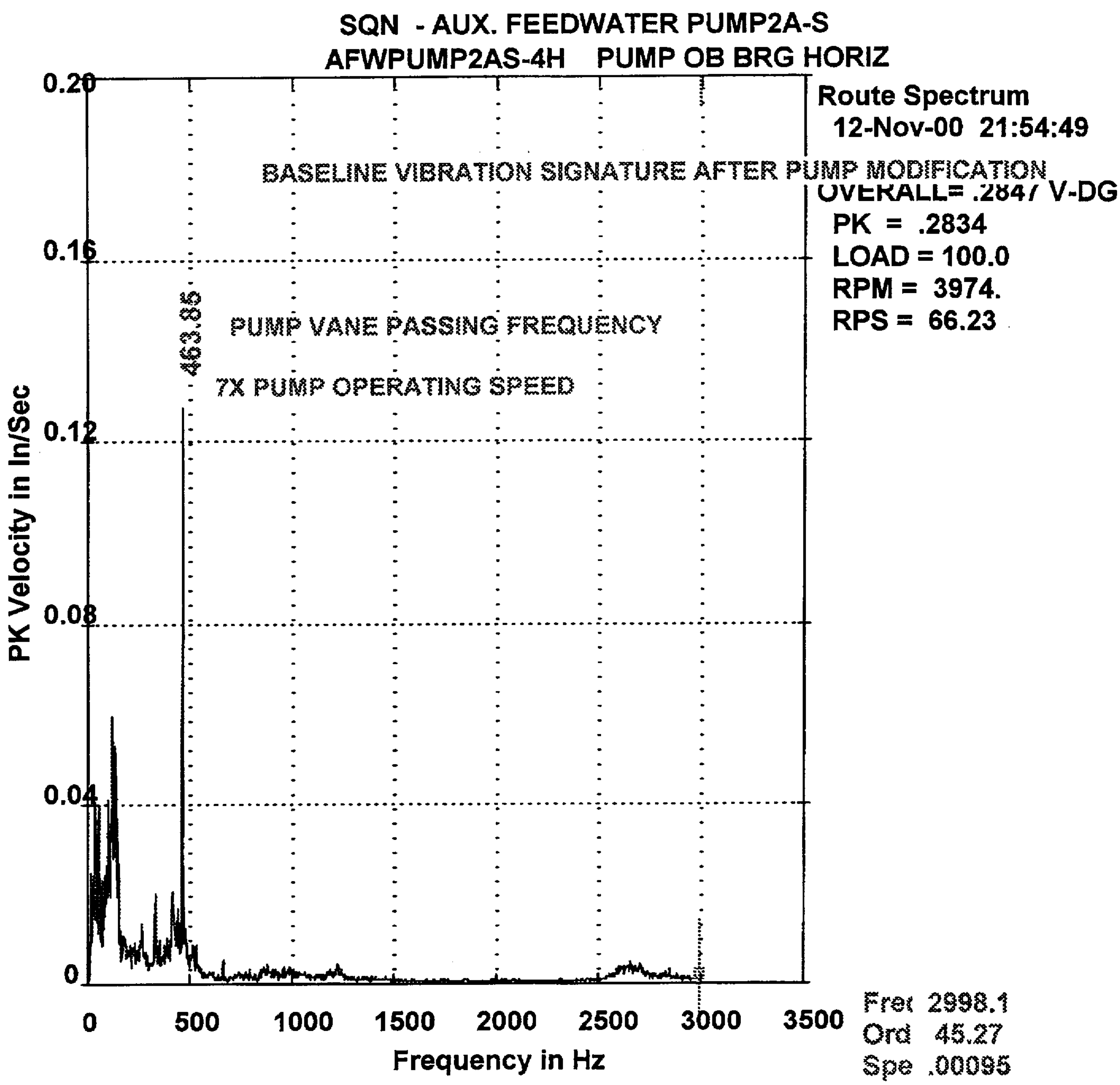

SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4V PUMP OB BRG VERTICAL
Route Spectrum
12-Nov-00 21:54:36
OVERALL= .2264 V-D(
PK = .2258
LOAD = 100.0
RPM = 3975.
RPS = 66.26
1X Operating Speed
7X Operating Speed
BASELINE VIBRATION SIGNATURE AFTER PUMP MODIFICATION
PK Velocity in In/Sec
0.12
0.10
0.08
0.06
0.04
0.02
0
500
1000
1500
2000
2500
3000
350
Frequency in Hz
Fr 65.63
Or .990
Sp .07733

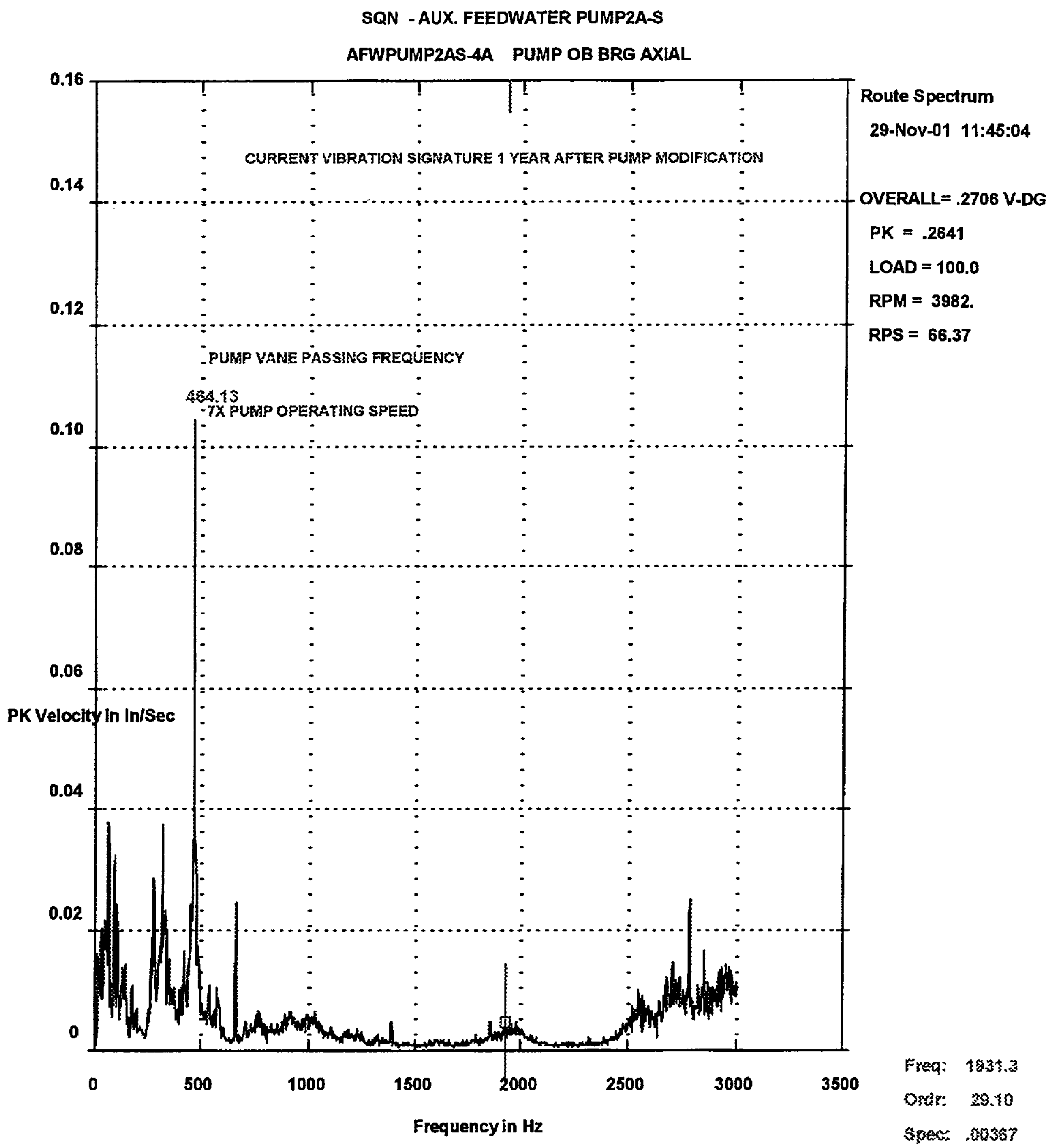
THIS PLOT PROVIDES A SPECTRA COMPARISON BETWEEN THE CURRENT AND BASELINE VIBRATION SIGNATURES OF THE VIBRATION ON THE PUMP OUTBOARD BEARING IN THE HORIZONTAL DIRECTION

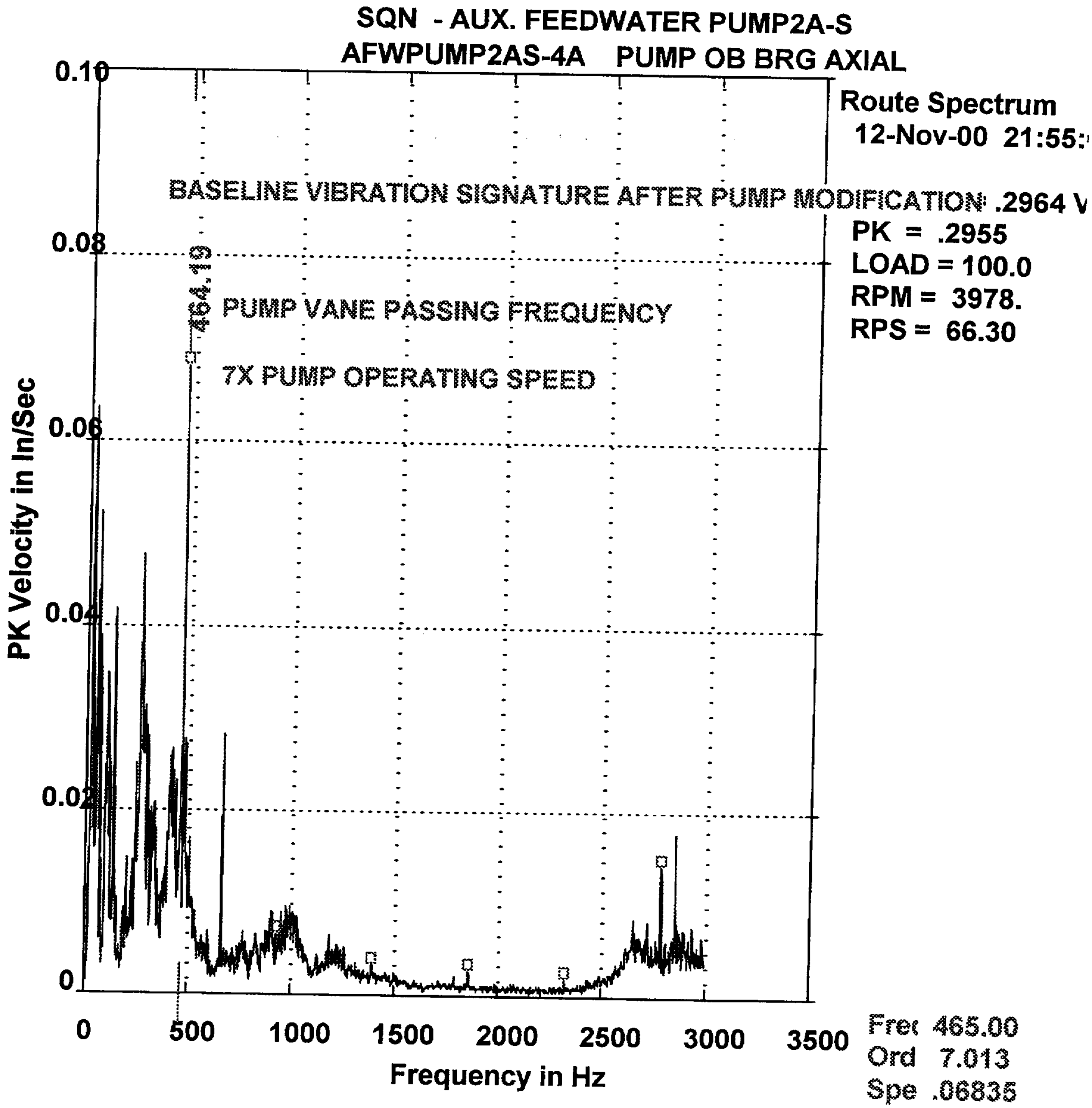



SQN - AUX FEEDWATER PUMP 2A-S
AFWPUMP2AS-4A PUMP OBERG AXIAL
PUMP VANE PASSING FREQUENCY
7X PUMP OPERATING SPEED
465.94
Max Amp
.0918
Plot
Scale
0.11
CURRENT VIBRATION SIGNATURE 1 YEAR AFTER PUMP MODIFICATION
29-Nov-01
11:45:04
VIBRATION SIGNATURES DURING REDUCED PUMP FLOW TESTING
PUMP VANE PASSING FREQUENCY
464.19
7X PUMP OPERATING SPEED
PK Velocity in In/Sec
0
BASELINE VIBRATION SIGNATURE AFTER PUMP MODIFICATION
12-Nov-00
21:55:01
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Freq: 1747.5
Ordr: 25.89
Sp 1: .00134


SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4H PUMP OB BRG HORIZ
Route Spectrum
29-Nov-01 11:44:46
CURRENT VIBRATION SIGNATURE 1 YEAR AFTER PUMP MODIFICATIO
PK = .3095
LOAD = 100.0
RPM = 3981.
RPS = 66.35
PUMP VANE PASSING FREQUENCY
7x OPERATING SPEED
PK Velocity in In/Sec
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Frec 465.00
Ord 7.008
Spe .160


SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4H PUMP OB BRG HORIZ
Route Spectrum
12-Nov-00 21:54:49
BASELINE VIBRATION SIGNATURE AFTER PUMP MODIFICATION
OVERALL= .2847 V-DG
PK = .2834
LOAD = 100.0
RPM = 3974.
RPS = 66.23
463.85
PUMP VANE PASSING FREQUENCY
7X PUMP OPERATING SPEED
PK Velocity in In/Sec
0.20
0.16
0.12
0.08
0.04
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Freq 2998.1
Ord 45.27
Spe .00095


SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4A PUMP OB BRG AXIAL
CURRENT VIBRATION SIGNATURE 1 YEAR AFTER PUMP MODIFICATION
PUMP VANE PASSING FREQUENCY
464.13
7X PUMP OPERATING SPEED
Route Spectrum
29-Nov-01 11:45:04
OVERALL= .2706 V-DG
PK = .2641
LOAD = 100.0
RPM = 3982.
RPS = 66.37
PK Velocity in In/Sec
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Freq: 1931.3
Ordr: 29.10
Spec: .00367



SQN - AUX. FEEDWATER PUMP2A-S
AFWPUMP2AS-4A PUMP OB BRG AXIAL
Route Spectrum
12-Nov-00 21:55:
BASELINE VIBRATION SIGNATURE AFTER PUMP MODIFICATION
.2964 V
PK = .2955
LOAD = 100.0
RPM = 3978.
RPS = 66.30
464.19
PUMP VANE PASSING FREQUENCY
7X PUMP OPERATING SPEED
PK Velocity in In/Sec
0.10
0.08
0.06
0.04
0.02
0
0
500
1000
1500
2000
2500
3000
3500
Frequency in Hz
Fre 465.00
Ord 7.013
Spe .06835