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SUBJECT: Submits addl info re relief request for third 10-Yr interval pump in-service test plan.Proposed alternative being submitted because code requirements for vibration cannot be met due to containment spray pumps being tested.

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September 4, 1998

AEP:NRC:0969BM
10 CFR 50.55a

Docket Nos.: 50-315
50-316

U.S. Nuclear Regulatory Commission
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Gentlemen:

Donald C. Cook Nuclear Plant Units 1 and 2
RELIEF REQUEST FOR THE THIRD TEN YEAR
INTERVAL PUMP IN-SERVICE TEST PLAN
ADDITIONAL INFORMATION

The purpose of this letter is to propose an alternative to the requirements of ASME Section XI, OMa-1988, Part 6, paragraph 5.2, Table 34 for the containment spray (CTS) pumps. This alternative is being submitted under the provisions of 10 CFR 50.55a(a)(3)(ii), "compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality or safety". The proposed alternative is being submitted because the code requirements for vibration cannot be met due to the CTS pumps being tested at low flow conditions and because of the pumps' design. Our original relief requests for the third ten year interval were submitted by letter AEP:NRC:0969AM, dated June 12, 1996. By letter dated May 27, 1997, the NRC denied the relief request for the containment spray pumps, stating that insufficient information was provided in the original request.

On January 13, 1998, and February 9, 1998, discussions were held with members of your staff regarding testing of these CTS pumps, and a request for interim relief was submitted via AEP:NRC:0969BJ, dated March 3, 1998. The interim relief was requested while a modification was made to our spare pump at the manufacturer's service center. The modification to the pump was made in an attempt to reduce the pump's vibration levels at low flows at which the vibration data are taken. The modifications, however, did not significantly reduce the vibration levels at low flow, and permanent relief is being requested. The permanent relief request is contained in the attachment to this letter. The relief request contains the additional information the NRC requested in the May 27, 1997, denial.

1/1

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Expedited review of this relief request is requested because this relief is necessary for restart of our units.

Sincerely,

R. P. Powers
Vice President

/jmc

Attachments

c: J. A. Abramson
J. L. Caldwell, w/attachments
MDEQ - DW & RPD
NRC Resident Inspector, w/attachments
J. R. Sampson, w/attachments

bc: T. P. Beilman, w/attachments
E. R. Eckstein/D. R. Hafer/K. R. Baker
J. J. Euto
FOLIO, w/attachments
E. Hines
J. B. Kingseed/M. S. Ackerman/G. P. Arent/M. J. Gumns
F. R. Pisarsky/B. B. Bradley
J. F. Stang, Jr., NRC- Washington, DC, w/attachments

ATTACHMENT TO AEP:NRC:0969BM

CONTAINMENT SPRAY PUMP RELIEF REQUEST

Summary

The Cook Nuclear Plant has four containment spray (CTS) pumps of an older vintage that met the 1983 code edition, but are unable to conform with the vibration requirements imposed by the code upgrade for the third ten-year in-service test interval. Their inability to conform is not due to degraded performance, but rather a consequence of their original design and their being tested at low flow conditions.

A modification was performed to the spare assembly in an effort to reduce low flow vibrations to within limits specified by the code. Extensive testing of the pre- and post-modification design was performed on the spare CTS pump with the assistance of the pump's manufacturer. These efforts revealed that vibrations encountered on pumps installed in the field have similar vibration signatures to the spare pump which had no previous run time and was thoroughly inspected prior to testing. The vibrations experienced were determined to be a result of impeller vane pass during low flow conditions. This vibration was inversely proportional to flow rate, with vibrations decreasing to acceptable limits at the pump's design flow rating. Although some reduction in pump vibrations was achieved, the revised acceptance limits were not met.

Based on testing performed it was concluded that full compliance with the code would require either a complete new test circuit capable of accommodating full flow, or a redesigned rotating element (e.g. five vane impeller), which would reduce the vane pass frequency vibration. Time to implement either one of these options has been estimated at six to ten months. Consequently, their installation would result in a significant hardship without a compensating increase in safety. Therefore, an alternate monitoring method is proposed to meet the intent of the code, detection of pump degradation, and to provide reasonable assurance of an acceptable level of quality and safety.

The alternate surveillance specified to monitor the safe operation of this equipment adopts an approach to analyze a vibration signature, or spectrum. Instead of an overall accumulative approach, the vibration signature will be divided into narrow bands of frequency such that specific forms of incipient degradation can be detected. Discussions with the director of the Vibration Institute, members of ASME/ANSI O&M working group for in-service testing, the pump manufacturer, and personnel from other nuclear utilities confirm that spectral analysis is an acceptable industry practice for predictive maintenance on rotating machinery.

In addition to the alternate testing specified in the attached relief request, predictive maintenance, such as infrared thermography of motor bearings and spectral monitoring on the pump casings, will be employed. Although not part of the relief request, these additional efforts will further enhance monitoring of the CTS pumps.

REQUEST NO. 1 RELIEF REQUEST
THIRD TEN-YEAR INTERVAL PUMP IN-SERVICE TEST PLAN

TITLE: Containment Spray Pump Vibration Limits
UNIT APPLICABILITY: Units 1 and 2
PUMP NAME: Containment Spray
PUMP NUMBER (S): PP-009
SYSTEM: Containment Spray (CTS)
FLOW DIAGRAM: 5144 ASME CLASS: 2
PUMP FUNCTION: Provide cooling water flow to spray the containment atmosphere in a LOCA or steamline break.
RELIEF TYPE: Proposed Alternative

ASME CODE TEST REQUIREMENTS REFERENCE:

OMa-1988, Part 6; paragraph 5.2 Test Procedure and the Ranges for Vibration Test Parameters shown in Table 3a.

CODE REQUIREMENT DESCRIPTION:

For centrifugal pumps running at ≥600 rpm, where $V_r$ is the referenced broad band unfiltered vibration measurement;
Acceptable range at ≤ 2.5 $V_r$
Alert range >2.5 $V_r$ to 6 $V_r$ or >0.325 in/sec
Required action range >6 $V_r$ or >0.70 in/sec

BASIS FOR CODE ALTERNATIVE:

The CTS pumps installed at Cook Nuclear Plant vibrate in excess of the required action level specified within Table 3a of OMa-1988. This is not due to degraded performance, but rather equipment design and the limited flow achievable during surveillance testing. Baseline testing of a spare pump assembly confirmed that the vibration decreases with increasing flow, to within acceptable limits, as shown in figure 1.

The CTS pumps are a single stage unit mounted vertically. The pumps have dual suction in a double volute casing equipped with an impeller with an even number (4) of vanes. The radial clearance "Gap B" between the impeller's vanes and each volute lip is small. The piping configuration only allows these pumps to be tested at low flow, about 25% of their best efficiency point. The resultant flow vectors, which represent fluid leaving the tip of each vane, are not in line with either volute.

Consequently, hydraulic shock waves develop at the vane pass frequency of 4 times the running speed, or 119.38 Hz (~7200 CPM), as shown in both figures 2 and 3.

In an effort to comply with the new code vibration requirements, a modification was made to our spare assembly at the pump manufacturer's service center. This consisted of maximizing the "Gap B" clearance by cutting back each casing discharge volute. The objective was to reduce the overall vibration at low flow to an acceptable level without affecting the hydraulic performance of the pump. Pre- and post-modification test results are shown in figures 4 and 5. Figure 4 illustrates that the pump hydraulic performance at the design flow was not affected. However, figure 5 illustrates less than 1/3 of the desired vibration improvement was achieved at a flow rate equivalent to the plant's test circuit. Vibration at the design flow of 3200 gpm was essentially unchanged, remaining within acceptable limits.

Based on as found testing of the spare pump assembly, modifications and subsequent testing results, it was concluded that literal compliance with the new code would require one of the following options:

1) A complete new test circuit to accommodate a much higher flow rate.

2) A different rotating element for the pump (e.g. five vane), which should reduce the vane pass frequency and overall vibration.

The first option must provide approximately 1500 gpm additional flow capacity, account for pump heat generated during the test, and meet the original design basis requirement that the CTS discharge header be maintained dry from the top of both CTS spray heat exchangers all the way into containment. There are two methods to accomplish this option:

A) To provide the flow capacity and heat removal capability without filling the CTS heat exchanger would require approximately 500 feet of large bore pipe per unit to recirculate the water from the refueling water storage tank (RWST). The routing of this pipe between the RWST located outside in the yard, and each pump located in the basement of the auxiliary building, would encounter numerous structural interferences, or

B) Use of the CTS heat exchanger would support an alternate route contained entirely within the auxiliary building. However, this route would require addition of several isolation valves, approximately 150 feet of large bore piping per unit, and additional venting capability. It would likely also require a code relief to perform the surveillance in mode 5, because of a potential for entraining the air present in the CTS discharge header.

The second option is to design and manufacture a new impeller. The manufacturer does not currently have a five vane impeller designed for this application, thus, this would require extensive development and testing. This would affect the hydraulic performance of the machines, and could require full flow testing of the installed pumps to validate the design change.

Time required to implement any of the previously described options has been estimated at six to ten months. Consequently, their installation would result in a significant hardship without a compensating increase in safety. Therefore, alternative monitoring is proposed to meet the intent of the code, and to assure an acceptable level of quality and safety.

**PROPOSED ALTERNATIVE TESTING:**

The proposed alternative testing is to perform spectral monitoring and analysis over the frequency range specified in ASME OMa-1988, Part 6. Analysis is to be performed on all frequencies contained in the frequency range, alarming to be performed on the frequencies of degradation identified below:

- Fundamental Train Frequency (FTF)
- Ball Spin Frequency (BSF)
- 2 Times Ball Spin Frequency (2XBSF)
- Bearing Pass Outer Race Frequency (BPOR)
- Bearing Pass Inner Race Frequency (BPIR)

The frequencies for establishing the alarms are contained within the following tables, including Alert[1] and Action[2] alarm levels. The alert and action alarm levels will be based on the maximum peak value of degradation frequencies contained within each band of the baseline spectral measurement. Bands which contain no distinct degradation frequency shall be alarmed using the product of 2.5 times and 6 times the maximum peak value of the baseline spectral measurement in accordance with table 3.a of ASME OMa-1988 Part 6.

| | Outboard Motor Bearing | Inboard Motor Bearing |
|---|---|---|
| Degradation Item | Frequency (Hz) | Frequency (Hz) |
| FTF | 11.513 | 12.209 |
| BSF | 62.475 | 80.146 |
| 2XBSF | 124.95 | 160.29 |
| BPOR | 92.106 | 122.09 |
| BPIR | 145.83 | 175.47 |

1 Alert levels per alarm band not to exceed 0.325 ips with a minimum alarm setting of 0.03 ips.

2 Action levels per alarm band not to exceed 0.70 ips with a minimum alarm setting of 0.06 ips.

Alarm bands are set to include those frequencies of degradation as follows:

| Band | Minimum Frequency (Hz) | Maximum Frequency (Hz) |
|---|---|---|
| 1 | 9.82 | 14.58 |
| 2 | 14.88 | 59.50 |
| 3 | 60.99 | 116.03 |
| 4 | 121 | 200 |
| 5 | 200 | 600 |
| 6 | 600 | 1000 |

It is important to note that the above alarm bands cover all but 6.76 Hz of the code required frequency range. Those 6.76 Hz not alarmed include only vane pass and line frequencies not related to mechanical degradation. Although 6.76 Hz of the frequency range is not alarmed, analysis will be performed on frequencies within each unalarmed band.

Each band is chosen to provide alarm capability for specific degradation frequencies as shown below.

| Band | Outboard Bearing | Inboard Bearing | Machine |
|---|---|---|---|
| 1 | FTF | FTF | N/A |
| 2 | N/A | N/A | RPM |
| 3 | BSF, BPOR | BSF | N/A |
| 4 | 2xBSF, BPIR | 2xBSF, BPOR, BPIR | N/A |
| 5[3] | N/A | N/A | N/A |
| 6[3] | N/A | N/A | N/A |

3 Bands 5 and 6 are set to indicate multiples of a fundamental defect frequency, and are not set to look for frequencies of degradation that only occur within those bands.

**BASIS FOR CONCLUDING ALTERNATIVE TESTING YIELDS ACCEPTABLE LEVELS OF QUALITY AND SAFETY:**

To confirm that vibration at vane pass is not an operational concern for these pumps, the plant's spare assembly was sent to the manufacturer's facility for flow loop testing. The spare pump has never been installed or tested in-situ; therefore, it served as a baseline to judge how this kind of pump performs with no elapsed run time. Cook Nuclear Plant personnel and the plant's vibration equipment were used during testing to eliminate variables when comparing test results to data collected on the installed pumps. In addition, an internal pump inspection was performed verifying all critical dimensions to be within acceptable tolerances.

Figure 2 shows the vibration spectrum for the spare machine as received by the manufacturer, before the volute lip modification was performed. This signature was taken while operating at 733 gpm, which closely approximates the test conditions at the plant. The spectrum illustrates the dominance vane pass frequency has over the entire spectrum, with no evidence of degradation at any other frequency.

Figure 3 is a recent vibration spectrum for the unit 1 east CTS pump taken during an in-service test, performed after roughly 22 years of service. This spectral plot is typical of the data obtained for the other CTS pumps installed at the plant. Figures 2 and 3 are virtually identical, confirming that the vibration component occurring at vane pass frequency is an expected consequence of pump internal design operating at the in-service test flow rate, and not an indication of pump degradation.

Full flow testing of the spare pump also verified that as flow rate is increased closer to the pump's best efficiency point, overall vibration and vane pass frequency decrease to levels well below the code alert value. Therefore, overall vibration at flow rates expected during a design basis accident satisfy code requirements (Figure 1).

The pump manufacturer has indicated that vibration occurring at vane pass frequency does not represent degradation, nor would there be any mechanical defects produced by operating at low flow conditions for short periods of time, such as periodic plant in-service tests. To confirm this assertion, the four CTS pumps installed at the plant will be disassembled and nondestructively examined for signs of degradation prior to restart. Each pump motor will also be disassembled and inspected to ensure its bearings have not degraded. These inspections will provide reasonable assurance that quarterly tests performed at low flow have not caused degradation and will establish an acceptable baseline for trending future performance using the proposed alternative methods.

Vibration monitoring is intended to detect changes in a machine's mechanical performance. The code currently requires a broad band unfiltered measurement from 1/3 minimum pump running speed up to at least 1000 Hz. This type of broad band measurement provides an overall number indicative of energy contained within frequency range. It does not indicate that a discreet frequency response has changed and, therefore, cannot precisely identify what form of degradation may be incipient. To be more effective, vibration monitoring should detect deviations at discreet frequencies. To provide a higher degree of assurance that no degradation is occurring, spectral monitoring will be performed to identify changes in discreet degradation frequencies.

Spectral monitoring is capable of determining which frequency, if any, has deviated from baseline. Analysis of spectral measurements allows for identification of discreet frequencies indicative of mechanical degradation. Identification of those discreet degradation frequencies allows more accurate mechanical performance analysis, and additional diagnostics are not typically required to identify root cause.

Based on the ability of the alternative testing to identify specific degradation types, and that unalarmed frequencies will be analyzed, it is concluded that the proposed alternative testing provides an acceptable level of quality and safety.

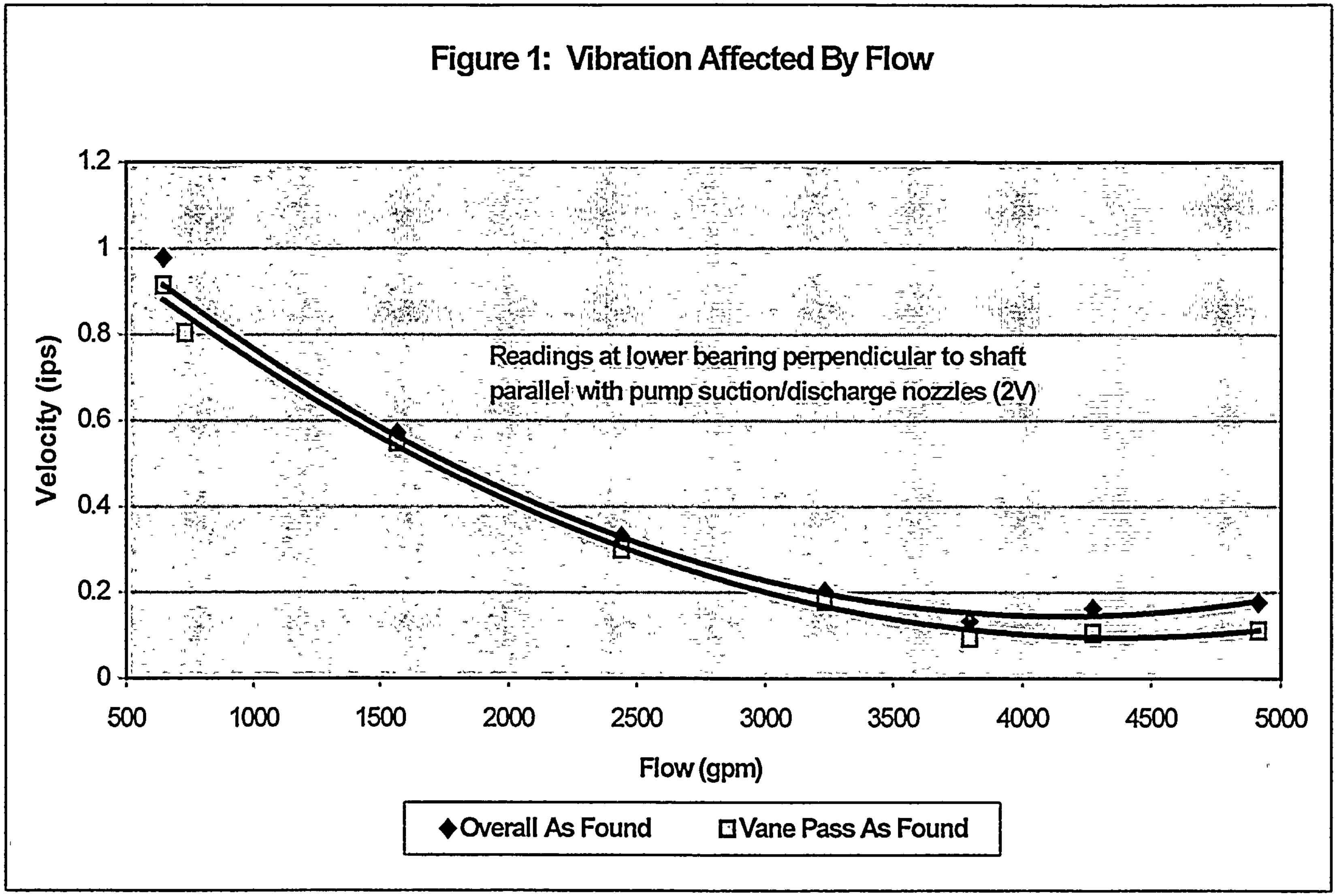


Figure 1: Vibration Affected By Flow
Readings at lower bearing perpendicular to shaft
parallel with pump suction/discharge nozzles (2V)
Velocity (ips)
1.2
1
0.8
0.6
0.4
0.2
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Flow (gpm)
Overall As Found
Vane Pass As Found

**Figure 2:** Spare pump on miniflow before lip cut at lower bearing perpendicular to shaft and parallel with suction/discharge nozzles (2V).

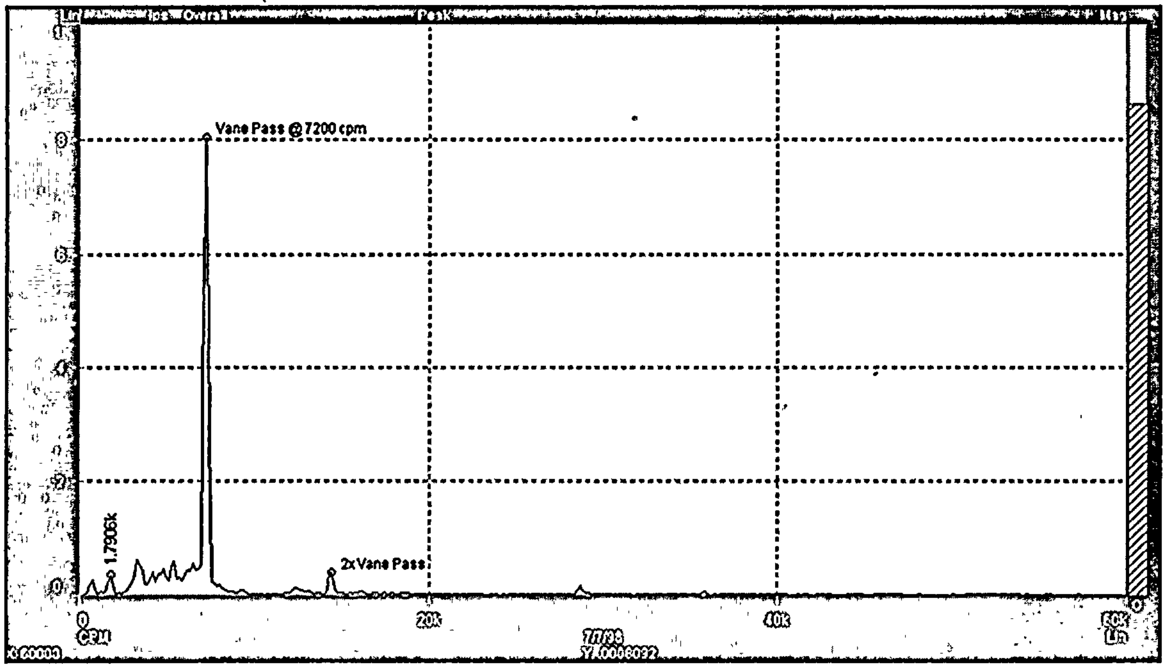
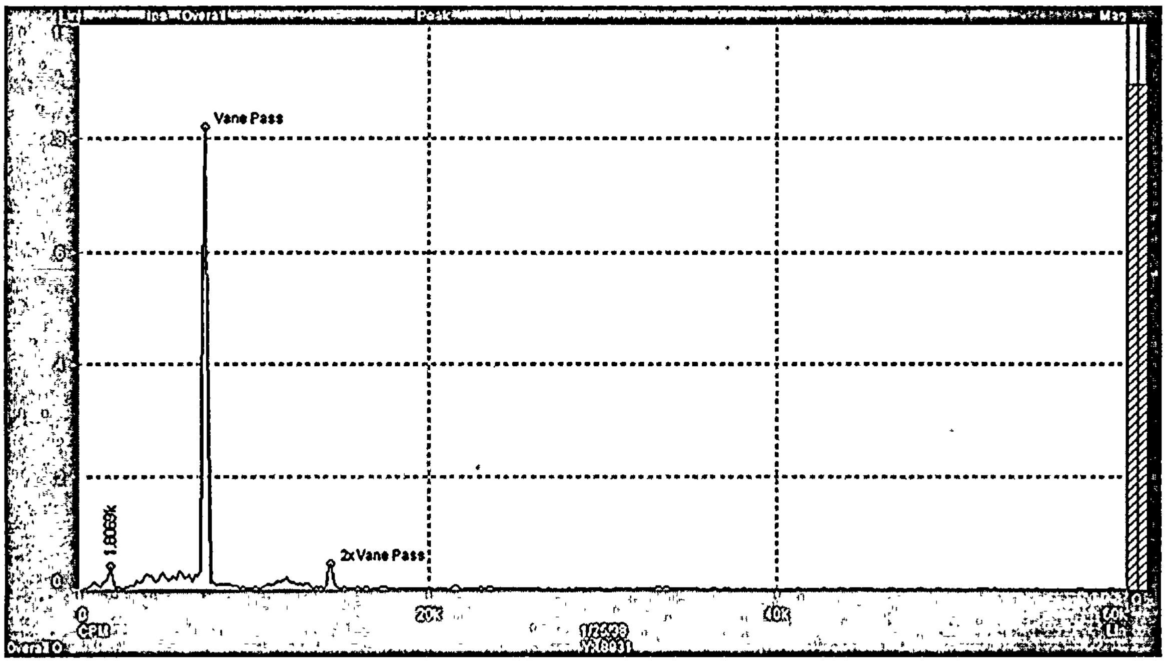



**Figure 3:** Unit 1 East CTS on miniflow at lower bearing perpendicular to shaft and parallel with suction/discharge nozzles (2V) measured on 01/25/98.



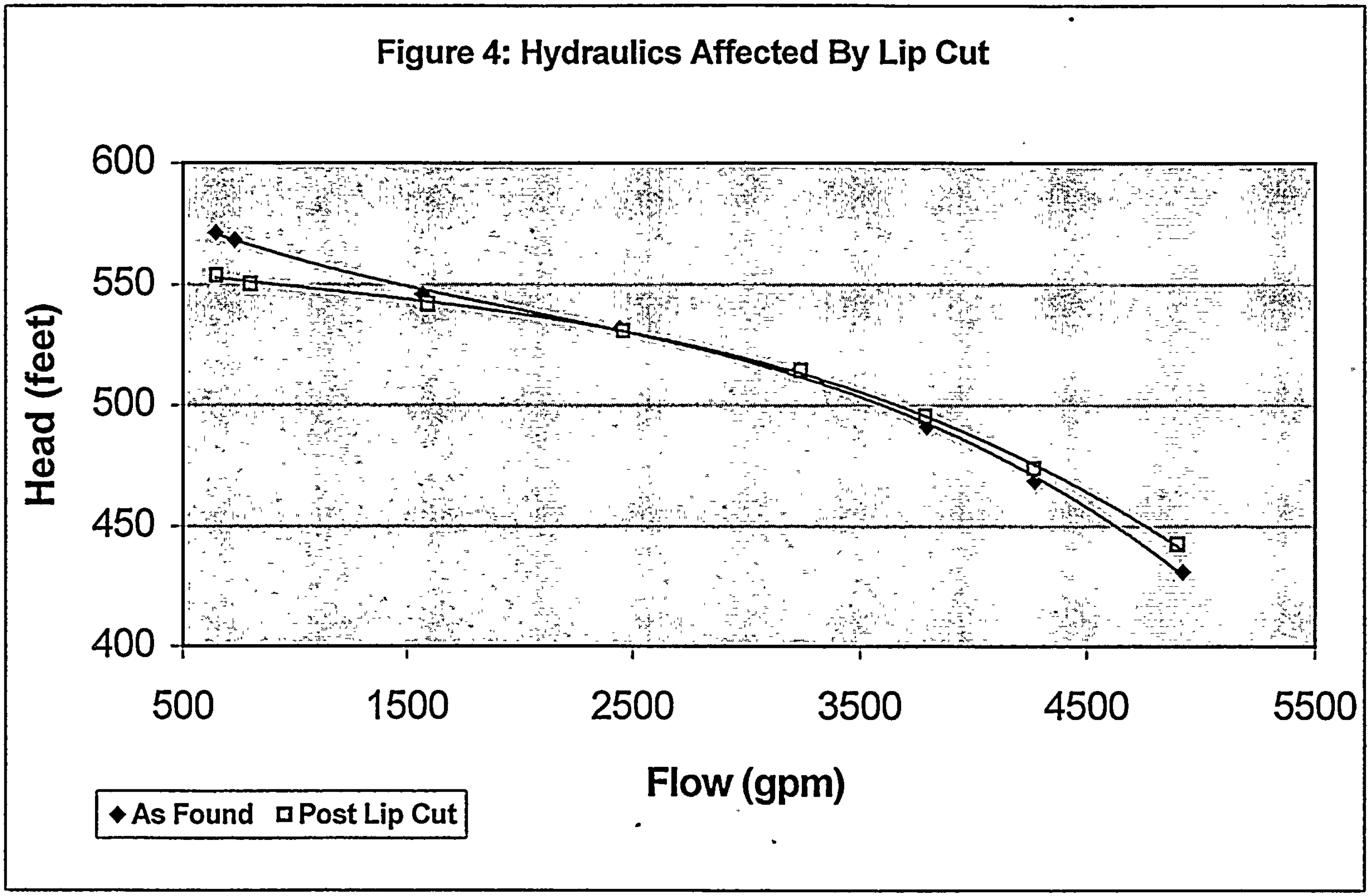


Figure 4: Hydraulics Affected By Lip Cut
600
550
500
450
400
Head (feet)
500
1500
2500
3500
4500
5500
Flow (gpm)
◆ As Found
□ Post Lip Cut

**Figure 5: Vibration Affected By Lip Cut**