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IES UTILITIES

John F. Franz, Jr.
Vice President, Nuclear

October 13, 1995
NG-95-2961

Mr. William T. Russell, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Mail Station P1-37
Washington, DC 20555-0001

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
Inservice Testing (IST) Relief Request PR-07

References: 1) Letter from J. Franz (IES) to W. Russell (NRC) dated December 16, 1994, NG-94-4202
2) Letter from G. Marcus (NRC) to L. Liu (IES) dated April 13, 1995, Duane Arnold Energy Center Inservice Testing of the HPCI Pump

File: A-107a, A-286e

Dear Mr. Russell:

In Reference 1, IES Utilities Inc. submitted Duane Arnold Energy Center (DAEC) Inservice Testing (IST) relief request PR-07 for NRC review and approval. This relief request proposed the use of vibrational spectrum data assessment in place of ASME/ANSI OM Part 6 vibrational alert criteria for the determination of increased frequency testing of the High Pressure Coolant Injection (HPCI) pump.

210046

A047/1

In their Safety Evaluation (Reference 2), your Staff granted a modified version of this relief for an interim period of one year. Additional information was requested about the DAEC's vibration program in order to evaluate the acceptability of using spectral analysis to determine "alert" status. This additional information, along with a revised version of relief request PR-07, is included in the attachment.

Should you have any questions regarding this matter, please contact this office.

Sincerely,

John F. Franz
Vice President, Nuclear

JFF/CJR/cjr
n\lic\ng-95\95-pr07.doc

Attachment

cc: C. Rushworth
L. Liu
B. Fisher
G. Kelly (NRC-NRR)
H. Miller (Region III)
NRC Resident Office
DOCU

IES UTILITIES INC RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON DAEC IST RELIEF REQUEST PR-07

NRC Request a:

A detailed baseline spectral data summary of the HPCI pump. This summary should explain all significant frequency peaks (e.g., running speed and harmonics; gear mesh; natural frequencies; rolling element bearing frequencies; blade pass frequencies; imbalance, misalignment, etc.). Trend plots of any potential machine fault frequencies should also be included. The HPCI pump IST reference values (speed, differential pressure, flow, vibration velocities) for which these data were obtained should also be included.

IES Utilities Response:

The typical High Pressure Coolant Injection (HPCI) pump installation consists of a driver (turbine), and a main and booster pump coupled through a gearbox. During operation, the main and booster pumps rotate at different speeds. The typical HPCI installation utilizes a 2:1 gear reducer. The DAEC HPCI combination utilizes a 1.2575:1 reducer.

The DAEC HPCI main pump consists of three stages: a first stage 5 vane impeller and 6 vane second and third stage impellers. The pump case is a double-volute casing. The rotating element is supported by sleeved bearings. The DAEC HPCI booster pump has a double suction four vane impeller and operates at a speed 1.2575 times less than the main pump. The pump has a double-volute casing and the discharge is routed to the main pump through a 10" diameter cross tie pipe. The booster pump rotating element is supported by angular contact ball bearings.

Since it is impractical to perform inservice testing of the DAEC HPCI pump at a single reference flow rate, the pump performance is trended against a reference curve from 3000 to 3400 gpm to detect hydraulic degradation. A reference speed of 3800 rpm (as read at the main pump) has been established for inservice testing. At this main pump speed, the booster pump is rotating at 3022 rpm. Differential pressure inservice test data for the DAEC HPCI pump combination establish operation on the vendor total developed head (TDH) curve.

The vane pass pressure pulsations in the booster pump generate high vibration amplitudes at the bearing housings of the booster and main pumps at 201.65 Hz, or four times booster pump running speed. The booster pump discharges in a horizontal direction; therefore, the vibration levels in the horizontal direction are approximately 0.1 in/sec higher than in the vertical direction. The impeller vane to double volute combination results in increased pressure pulsations because the impeller vanes, which are 180 degrees apart, pass the two discharge volutes simultaneously. The magnitude of vane pass vibration present is influenced by the clearance between the impeller vanes and volute tongue. The booster pump has a 9/16 inch impeller vane-to-volute tongue gap (as measured in 1992). This is less than the gap recommended in current literature, but typical of a pump built twenty years ago. Also present in the spectrum are harmonics of vane pass occurring at two and three times booster pump vane pass frequency.

The running speed vibrations are low at all monitoring points on the booster pump with twice running speed vibrations also at low levels. Axial vibration likewise is low. These low levels and absence of trends are indicative of a high degree of accuracy for balance and alignment.

Vane pass vibration from the main pump six vane impeller is present in the booster pump spectrum at 380.32 Hz (3800 rpm main pump reference speed) and a harmonic at 760.66 Hz. Vane pass vibration from the main pump's five vane impeller is present at 316.94 Hz and 634.01 Hz. This vibration is transmitted through the cross-tie pipe. Impact testing on the pump base indicated adequate rigidity. Main pump running speed vibration is present at low levels at 63.39 Hz.

Critical bearing defect frequencies for the booster pump guide and thrust bearings are listed in the appendix (pages 34, 35) to this attachment. A diagram of the HPCI pump combination showing the vibration locations is also included in the appendix (page 12). The overall vibrational reference value at position A10 is currently 0.184 in/sec. The peaks across the vibration spectrum at this location are low, nominally 0.06 in/sec or less. Vibration levels in the Y09 and Y10 location are likewise low across the spectrum. In the horizontal direction, X09 and X10 show vane pass vibration at 201.65 Hz. The remaining peaks are overall low levels. The overall high vibration levels are not imposing a bearing concern for the booster pump. Analysis of subsynchronous vibration and running speed harmonics indicate good sleeve bearing stability and no rubs in the main pump.

The HPCI pump gearbox has been monitored periodically under the DAEC Vibration Monitoring Program; no abnormalities currently exist. The DAEC HPCI pump peak reference values and current OM Part 6 vibration "required action" limits are tabulated below.

DAEC HPCI PUMP VIBRATION INSERVICE TEST PARAMETERS

LOCATION	REF. VALUE (PEAK)	REQUIRED ACTION (PEAK)
A04	.144	.700
X03	.444	.700
X04	.460	.700
Y03	.151	.700
Y04	.095	.570
A10	.184	.700
X09	.288	.700
X10	.303	.700
Y09	.171	.700
Y10	.188	.700

ASME/ANSI OM Part 6 allows measurement of vibration parameters in units of mils or in/sec. Table 3 of Part 6 (OMa-1988) refers to a figure to use to establish displacement limits for pumps with speeds greater than or equal to 600 rpm. This figure is missing from Part 6, OMa-1988, but was added under OMb-1989. This "roughness chart" allows establishing mils limits for alert and action vibration levels as a function of machine speed. At 3800 rpm, an alert limit of 1.6 mils is established for the main pump; at 3022 rpm, an alert limit of 2 mils is established for the booster pump. Current test data in the horizontal direction for both pumps is well under these alert limits:

X03	(main pump)	0.86 mils
X04	(main pump)	0.81 mils
X09	(booster pump)	0.51 mils
X10	(booster pump)	0.66 mils

NRC Request (b):

A discussion of the method used to analyze the spectral data in monitoring the HPCI pump. The discussion should include such considerations as how machine potential faults are identified; how unexplained spectral peaks are handled; how trending bands involving specific frequencies of interest are chosen; how the alarms are set for trending frequencies (alert, warning and fault); what action will be taken when each alarm level is reached; and how a non-trended frequency would be identified if it were changing from its baseline value.

IES Utilities Response:

Overall peak reference values for the HPCI pump have been established at OM Part 6 locations. Operability is established by comparison of measured peak test values to OM Part 6, Table 3a action limits (0.700 in/sec maximum). The Table 3a action limits constitute the "fault" limits for the DAEC HPCI pump combination. In addition, these pumps are also monitored under the DAEC Vibration Monitoring Program for critical plant rotating machinery. The need for increased frequency testing will be assessed under this program.

Inservice test data is stored on a portable equipment analyzer and down-loaded to a computer for vibration engineer analysis. The analyzer and computer software perform a fast fourier transform of the data for detailed analysis of vibration amplitude versus frequency at each OM Part 6 monitored location. The vibration software is capable of trending individual frequency bands which are established to monitor specific machine condition frequencies. Six bands have been used for HPCI pump monitoring over several years. Alert levels are established in the first five frequency bands on the HPCI main and booster pump OM Part 6 locations. The sixth band is above the OM Part 6 frequency limit of 1000 Hz. If the alert level was exceeded, the pump would be placed on increased frequency testing.

Technical literature does not specifically address the establishment of spectral band alarm levels for the unique HPCI pump/gearbox configuration. Therefore, spectral alert levels are based on an average of historical reference vibration readings in the specified frequency bands. Spectral alert criteria for the DAEC HPCI pump combination are tabulated on the following page.

The DAEC HPCI pump specific alert levels represent 2.5 times the reference value in the frequency band but are no less than 0.05 in/sec and do not exceed 0.65 in/sec. The 2.5 times reference parallels the OM Part 6 specified overall alert multiplier. A minimum value of 0.05 in/sec was established due to the very low levels of vibration in several frequency bands. A change of greater than 2.5 times reference will still result in a low vibration level which may not indicate pump degradation. Vibrations at low levels can be influenced by various operating conditions which do not indicate degradation.

The maximum alert level of 0.65 in/sec was established in the vane pass frequency band for three horizontal monitoring points. The alert value of 0.65 in/sec was established to prevent exceeding the OM Part 6 "action required" value of 0.700 in/sec while allowing margin for normal fluctuations in vane pass vibration.

The five monitored frequency bands cover the OM Part 6 requirement of one-third running speed to 1000 Hz. The first frequency band monitors sub-harmonic vibration (less than pump running speed) to trend pump hydraulic characteristics, looseness and bearing rubs. The second band targets running speed vibration to trend rotating element balance, pump alignment and rotor bow. The third frequency band includes 1.5 and 2 times running speed to allow further trending and to identify misalignment and rotor bow and looseness. The fourth frequency band trends pump vane pass energy and contains most of the pump vibration energy. The fifth band measures harmonics of vane pass and booster pump roller bearing frequencies.

In addition to the aforementioned alert levels for the five frequency bands, warning levels have been established to identify developing or abnormal trends prior to exceeding an alert level. The warning levels are established in each frequency band for all OM Part 6 monitoring points and are based on 1.5 times the reference value or one-half of the alert level, whichever is greater. The establishment of warning levels will identify "unexplained spectral peaks" or changes from baseline levels and at a minimum will be subject to vibration engineer assessment.

HPCI MAIN PUMP SPECTRAL ALERT LEVELS (in/sec)*					
PARAMETER BAND (Hz)	Pos. X03	Pos. Y03	Pos. X04	Pos.Y04	Pos. A04
1 (21-55 Hz)	.05 (.012)	.05 (.006)	.05 (.010)	.05 (.005)	.05 (.011)
2 (55-70 Hz)	.219 (.088)	.051 (.020)	.199 (.080)	.05 (.014)	.062 (.025)
3 (70-135 Hz)	.253 (.101)	.052 (.021)	.308 (.123)	.055 (.022)	.102 (.041)
4 (135-570 Hz)	.65 (.431)	.412 (.165)	.65 (.425)	.234 (.094)	.356 (.142)
5 (570-1000 Hz)	.118 (.047)	.071 (.028)	.05 (.013)	.058 (.023)	.050 (.019)

* Reference values are listed under their respective alert level in parenthesis.

HPCI BOOSTER PUMP SPECTRAL ALERT LEVELS (in/sec)*					
PARAMETER BAND (Hz)	Pos. X09	Pos. Y09	Pos. X10	Pos.Y10	Pos. A10
1 (16-45 Hz)	.05 (.014)	.05 (.012)	.05 (.015)	.05 (.007)	.05 (.011)
2 (45-55 Hz)	.05 (.017)	.05 (.009)	.05 (.013)	.05 (.013)	.10 (.04)
3 (55-135 Hz)	.141 (.056)	.087 (.035)	.156 (.063)	.101 (.04)	.184 (.074)
4 (135-570 Hz)	.546 (.218)	.379 (.152)	.650 (.3)	.392 (.157)	.367 (.147)
5 (570-1000 Hz)	.278 (.111)	.106 (.043)	. 166 (.066)	.085 (.034)	.162 (.065)

* Reference values are listed under their respective alert level in parenthesis.

NRC Request (c):

A discussion of any resonance or critical frequency conditions that have been identified for these pumps over the entire authorized speed range of HPCI turbine and how these resonances could affect pump operability if the critical speeds were encountered while HPCI was performing its design safety function.

IES Utilities Response:

To analyze the vibrational characteristics of the HPCI pump, data was collected for the pump at various speeds. The main pump shows the highest level of vibration at a speed of 3600 rpm. A structural resonance is present in coastdown data, but was not present in static impact testing. The conclusion to be drawn is that a dynamic condition is causing the resonance condition. The pump bearing response is significantly changed during operation due to the oil film build-up in the sleeve bearings. Film thickness varies as speed changes. This results in varied response dependent on speed.

Main pump location X03 shows the highest vibration level at 3600 rpm. Constant operation at 3600 rpm is not expected during injection, pump speed is "slaved" to reactor pressure and maintaining a fixed injection rate. A spectrum plot for position X03 at 3600 rpm is included in the appendix (page 33). The major energy contributor is vane pass energy. Vane pass energy from the 4 vane booster pump is present at 190.9 Hz, or four times 2864 rpm. The main peak is at 6X running speed. Vane pass vibration from the main pump six vane impellers is amplified by the bearing housing resonance. Operation at 3600 rpm is not a concern from an operability standpoint. The pump vibration spectrum at location X03 shows low running speed and subsynchronous vibration levels and an absence of running speed harmonics. No internal degradation is occurring in the pump and good sleeve bearing stability and an absence of rubs in the main pump is indicated.

NRC Request (d):

An explanation of why a complete spectral analysis should not include data from all points and directions. The current relief request proposes to only measure vibration data and perform spectrum analyses "at selected points that typically exceed levels of 0.325 ips." Code requirements specify that vibration velocity measurements be made in two orthogonal directions perpendicular to each accessible pump bearing housing, and axially on each accessible pump thrust bearing housing. Tailoring the measurement points and directions to problems experienced in the past may result in having an incomplete picture when a new problem is encountered.

IES Utilities Response:

Relief Request PR-07 has been modified to note that all ASME/ANSI OM Part 6 points monitored during inservice testing will be subject to spectral analysis. The HPCI pump will be subject to increased frequency testing or other corrective actions if spectral peak alert levels are exceeded at these locations. The revised relief request is included in the appendix (pages 10, 11).

NRC Request (e):

A discussion of all methods that DAEC has explored to reduce HPCI pump vibration levels and the basis for rejecting or implementing these methods.

IES Utilities Response:

In preparation for adoption of ASME/ANSI OM Part 6, coincident with the start of the DAEC's Third Ten-Year IST Interval on February 1, 1995, an internal analysis of HPCI pump vibration was undertaken. This analysis was initiated well in advance of Refueling Outage (RFO) 13, which occurred early in the new interval, to identify any reasonable measure that could be implemented during the outage to reduce vibration levels. Misalignment was diagnosed as not problematic at axial and radial locations due to acceptable vibration at the frequencies of interest for alignment condition. Impact testing of the pump structure and adjacent piping was also conducted. The recorded frequencies were not in a range that would be excited by pump operation.

The HPCI pump's higher-than-Part 6-alert vibration levels are inherent with the initial design. The pump vendor issued a service letter to licensees with booster pumps larger than the DAEC's which recommended replacement of the four vane booster pump impeller with a five vane impeller. Similar to the technical bulletin, the 4X vibration at the booster pump is caused by interaction of the four vane impeller in conjunction with the 2 volute pump casing producing pressure pulsations at vane pass frequency compounded by a smaller impeller to volute gap. Booster vibration is amplified and transferred to the main pump, increasing overall vibration levels.

The typical HPCI installation utilizes a 2:1 gear reducer, while the DAEC HPCI combination utilizes a 1.2575:1 reducer. The expected vibration reduction from a 4 to 5 vane impeller replacement for a 2:1 reduction unit is greater than for a 1.2575:1. Therefore, the DAEC would be faced with modifications to the pump beyond booster impeller replacement to reduce vibration levels below the OM Part 6 alert limits. Both main and booster pump impellers would need to be replaced, along with impeller to volute clearance modifications on both pumps, in order to reduce the main pump horizontal vibration to an estimated 0.301 in/sec, marginally below the 0.325 in/sec OM Part 6 alert value. The total cost of this work was estimated at $300,000. Such modifications are not prudent since the vibration levels of the pump have been relatively constant, indicating an absence of degradation. Applying a generic vibration roughness chart to different combinations of equipment without considering historical vibration levels and performance is not a sound basis for equipment modification.

Analysis of pump installations similar to DAEC's have concluded the HPCI pump combination capable of reliable operation with vibration levels of 0.7 in/sec overall without undue concern for the onset of vibration induced failure.

NRC Request (f):

A discussion of any extended periods (greater than 2 hours) of HPCI pump operation at DAEC during which pump vibration was monitored.

IES Utilities Response:

Technical Specification limitations on suppression pool temperatures during testing which adds heat to the suppression pool limits HPCI run time. The nominal run time per quarterly surveillance is 45 minutes; the cumulative run time since rebuild in 1992 on the current HPCI pump is sixteen hours for quarterly testing.

APPENDIX

RELIEF REQUEST NO. PR-07

PUMPS:

1P-216 - High Pressure Coolant Injection (HPCI)

TEST REQUIREMENT

The acceptance criteria for pump vibration shall be determined from OM Part 6, Table 3a. Specifically, should measured vibration velocity equal or exceed 0.325 in/sec, the corrective action of Paragraph 6.1, doubling the test frequency, must be imposed until the cause of the deviation has been determined and the condition corrected.

BASIS FOR RELIEF:

The HPCI pump combination consists of two separate centrifugal pumps in series driven on a common shaft, through gear reduction, by a non-condensing steam turbine. Due to the arrangement and design of the various components (which is generally a General Electric standard), several of the operating vibration levels at various locations are typically in the range of 0.3 to 0.5 in/sec. This is considered to be a generic industry condition.

At several facilities, the utility has attempted to reduce vibration levels by modification of the booster pump impeller and other approaches such as opening clearances within the pump casing. To date, these approaches at many utilities have not been successful in reducing vibration velocity levels to a level below 0.325 in/sec.

The operational vibration characteristics of the Duane Arnold Energy Center (DAEC) HPCI pump combination have been analyzed and evaluated by IES Utilities Inc. As a result, it has been determined that pump vibration levels are related to the combination of interaction of the impeller vanes, casing, volute design amplified by bearing resonance and fluid reaction (pulsing) in the short connecting piping between the two pumps. Alignment and foundation were evaluated and it was determined that they were not contributing to the elevated vibration levels. It was determined that the vibration being experienced in the HPCI pumps is not indicative of pump degradation or conditions that would suggest that the pumps are unreliable or incapable of reliably fulfilling their safety function.

Analyses of pump installations similar to the one at DAEC have been evaluated and it was determined that reliable operation of these pumps can be expected with vibration levels of 0.7 in/sec without undue concern for the onset of vibration induced failure.

RELIEF REQUEST NO. PR-07 (cont.)

BASIS FOR RELIEF (Cont'd):

The HPCI pump combination has undergone testing and vibration monitoring in conjunction with the previous editions of the ASME Code over the past 15 years. During that time, there has been no evidence of degradation or pump failure to suggest that the existing vibration levels are functionally significant. The application of spectrum analyses in addition to the existing Code requirement (broad band) will enhance the monitoring capability further ensuring that the pumps are operating properly.

The HPCI pumps are standby emergency pumps that are operated infrequently, normally for testing purposes. Thus, during periods between testing, it is reasonable to assume that no pump degradation is taking place that would manifest itself in changes of vibration levels. Therefore, testing these pumps at increased frequency serves no useful purpose and increases equipment wear.

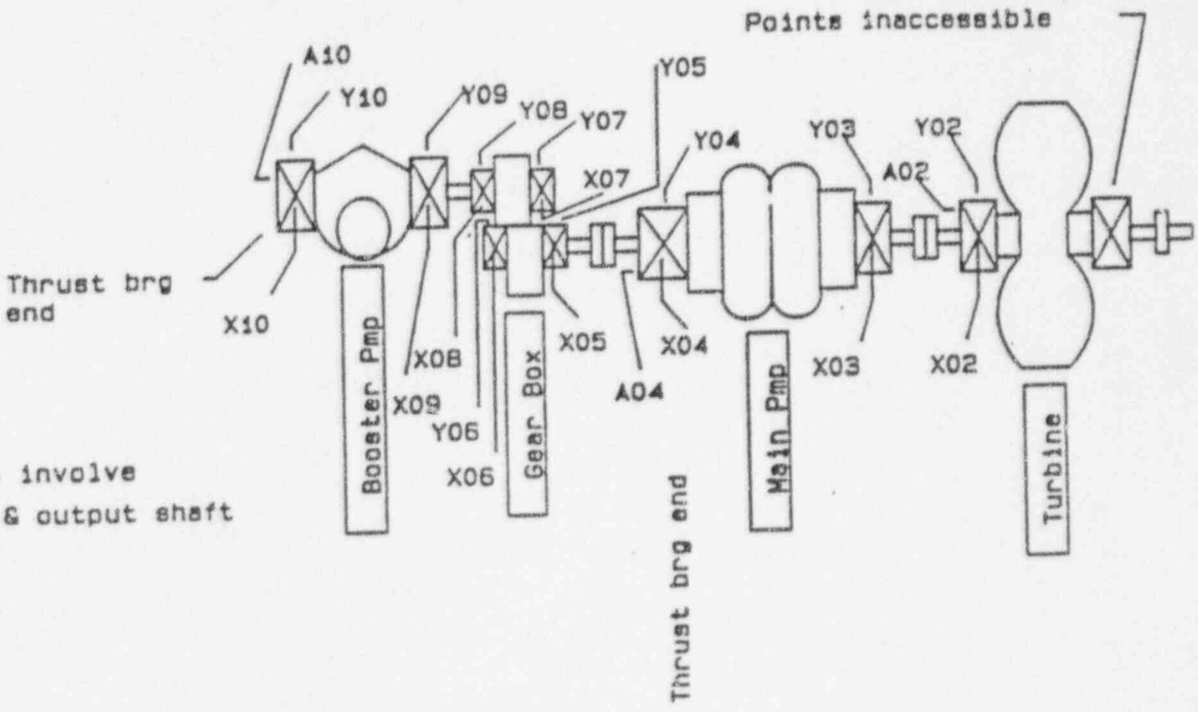
In consideration of the foregoing, subjecting the HPCI pumps to a doubling of the normal test frequency (quarterly) provides no useful information and adds no measure of additional level of pump reliability. Continued testing of these pumps on a quarterly frequency is proposed.

ALTERNATE TESTING:

The vibration data measured during inservice testing of the HPCI pumps will be evaluated in accordance with the operability limits imposed by Table 3a except that the test frequency will not be doubled when vibration levels equal or exceed 0.325 in/sec. Consistent with Table 3a, vibration levels greater than .70 in/sec will result in the pump being declared inoperable.

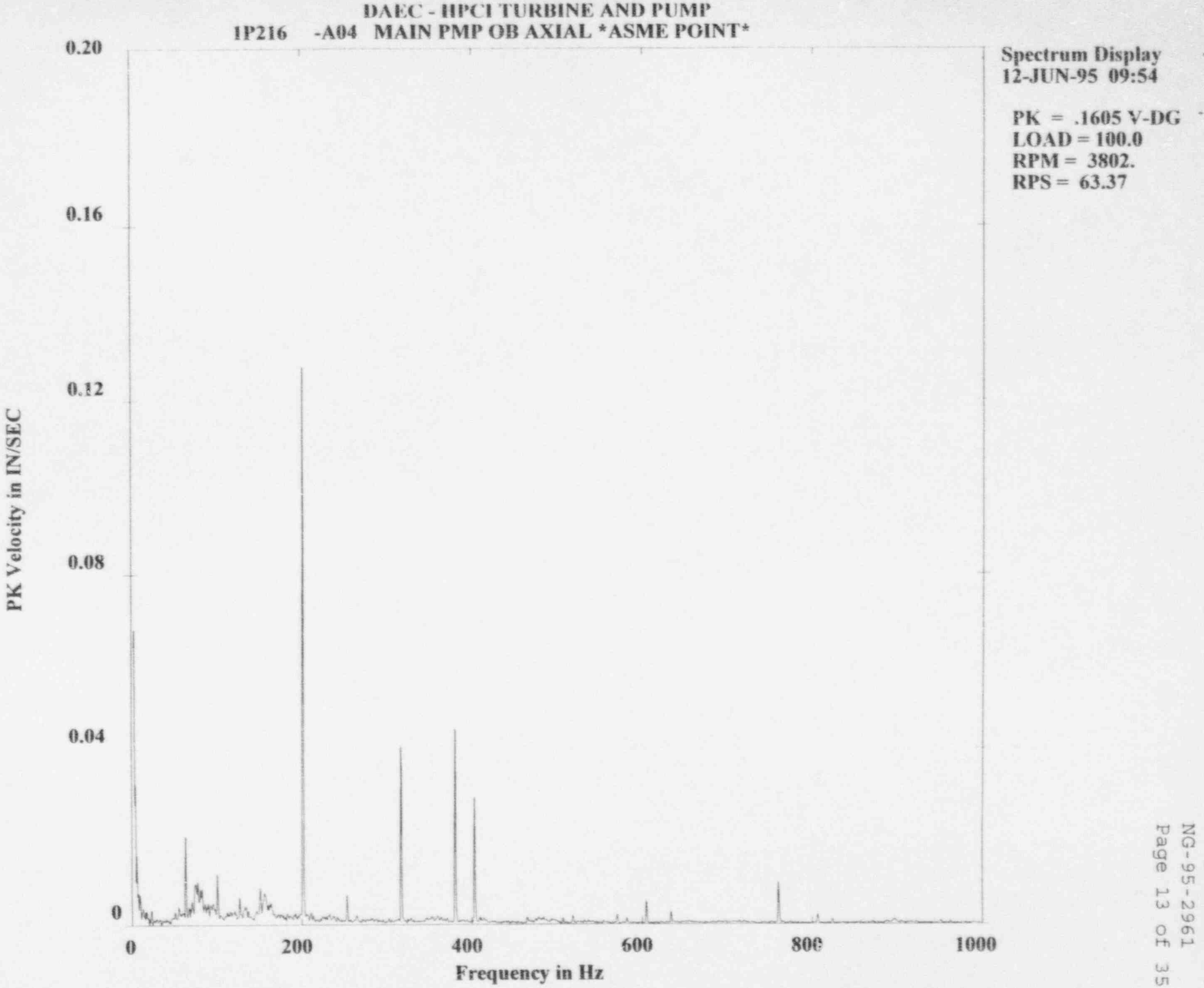
During inservice testing (quarterly and post-maintenance) of the HPCI pumps, IES Utilities Inc. will record vibration data and perform spectrum analyses. These analyses will be completed and subjected to a formal evaluation within one (1) week of test performance. A spectrum analysis measures a narrow vibration band width over a wide frequency range and indicates the frequency and magnitude of vibration peaks, which permits identification of problems with bearings and other pump mechanical components. The spectrum analysis allows a more comprehensive evaluation of pump condition than the Code required wide range vibration measurements. Five Spectral frequency bands at each OM-6 location will be monitored. Alert and warning levels are established for each frequency band, based on deviation from spectral reference levels. Alert levels are established at 2.5 times reference, not to exceed .65 in/sec or be less than .05 in/sec. When warning levels are exceeded, an assessment of machine condition by the DAEC vibration engineer is made. Should an alert level be exceeded, the pumps will be tested at an increased frequency - consistent with the Code requirement.

POINT LOCATIONS



Gear box points involve both the input & output shaft bearings.

HPCI TURBINE & MAIN/BOOSTER PUMPS



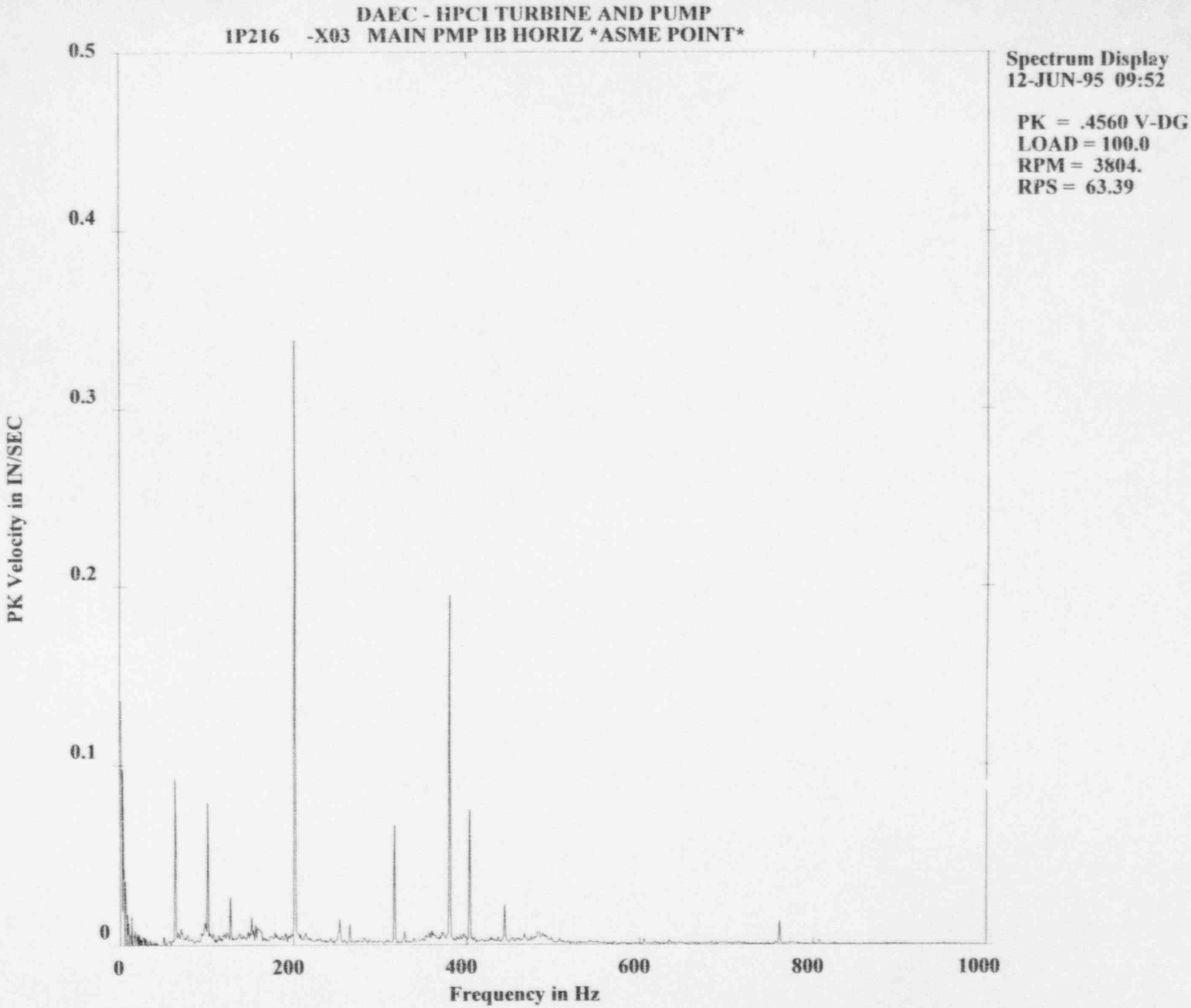
DAEC - HPCI TURBINE AND PUMP
1P216 -A04 MAIN PMP OB AXIAL *ASME POINT*
Spectrum Display
12-JUN-95 09:54
PK = .1605 V-DG
LOAD = 100.0
RPM = 3802.
RPS = 63.37
PK Velocity in IN/SEC
0.20
0.16
0.12
0.08
0.04
0
0
200
400
600
800
1000
Frequency in Hz

LIST OF SPECTRAL PEAKS
****

Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -A04 --> MAIN PMP OB AXIAL *ASME POINT*
Date/Time: 12-JUN-95 09:54:51 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	2.93	.0770	.05	13	100.66	.0116	1.59
2	4.20	.0352	.07	14	126.76	.0069	2.00
3	5.83	.0163	.09	15	151.18	.0092	2.39
4	7.28	.0081	.11	16	156.08	.0084	2.46
5	9.58	.0072	.15	17	163.58	.0058	2.58
6	63.36	.0210	1.00	18	201.58	.1306	3.18
7	70.45	.0060	1.11	19	253.49	.0068	4.00
8	74.77	.0110	1.18	20	316.86	.0453	5.00
9	77.78	.0105	1.23	21	380.22	.0474	6.00
10	80.90	.0085	1.28	22	403.14	.0309	6.36
11	82.38	.0089	1.30	23	604.69	.0059	9.54
12	95.41	.0057	1.51	24	760.44	.0104	12.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.1969	.1137 / 33%	.0708 / 13%	.1444 / 54%



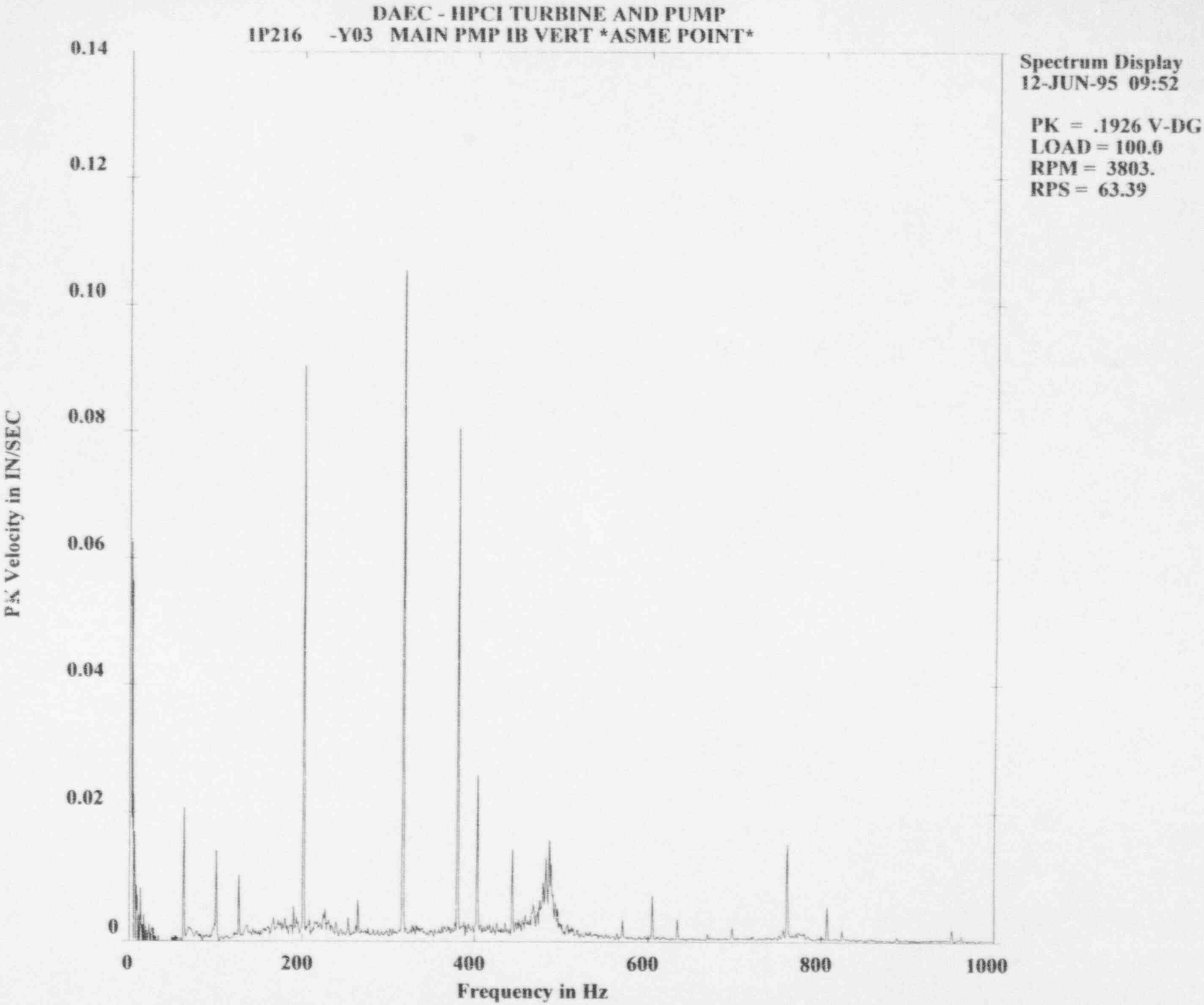
DAEC - HPCI TURBINE AND PUMP
1P216 -X03 MAIN PMP IB HORIZ *ASME POINT*
Spectrum Display
12-JUN-95 09:52
PK = .4560 V-DG
LOAD = 100.0
RPM = 3804.
RPS = 63.39
PK Velocity in IN/SEC
0
0.1
0.2
0.3
0.4
0.5
Frequency in Hz
0
200
400
600
800
1000

LIST OF SPECTRAL PEAKS
****

Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -X03 --> MAIN PMP IB HORIZ *ASME POINT*
Date/Time: 12-JUN-95 09:52:05 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	3.13	.0975	.05	13	153.49	.0090	2.42
2	4.20	.0468	.07	14	155.92	.0117	2.46
3	5.86	.0376	.09	15	158.55	.0111	2.50
4	8.13	.0175	.13	16	159.88	.0102	2.52
5	9.39	.0125	.15	17	201.65	.3574	3.18
6	13.14	.0164	.21	18	253.54	.0150	4.00
7	63.41	.0989	1.00	19	265.06	.0128	4.18
8	69.84	.0104	1.10	20	316.98	.0737	5.00
9	97.86	.0142	1.54	21	380.35	.1965	6.00
10	100.80	.0792	1.59	22	403.29	.0847	6.36
11	126.76	.0298	2.00	23	443.79	.0232	7.00
12	151.24	.0166	2.39	24	760.70	.0138	12.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.4882	.1710 / 12%	.2402 / 24%	.3890 / 64%



Attachment to
NG-95-2961
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LIST OF SPECTRAL PEAKS

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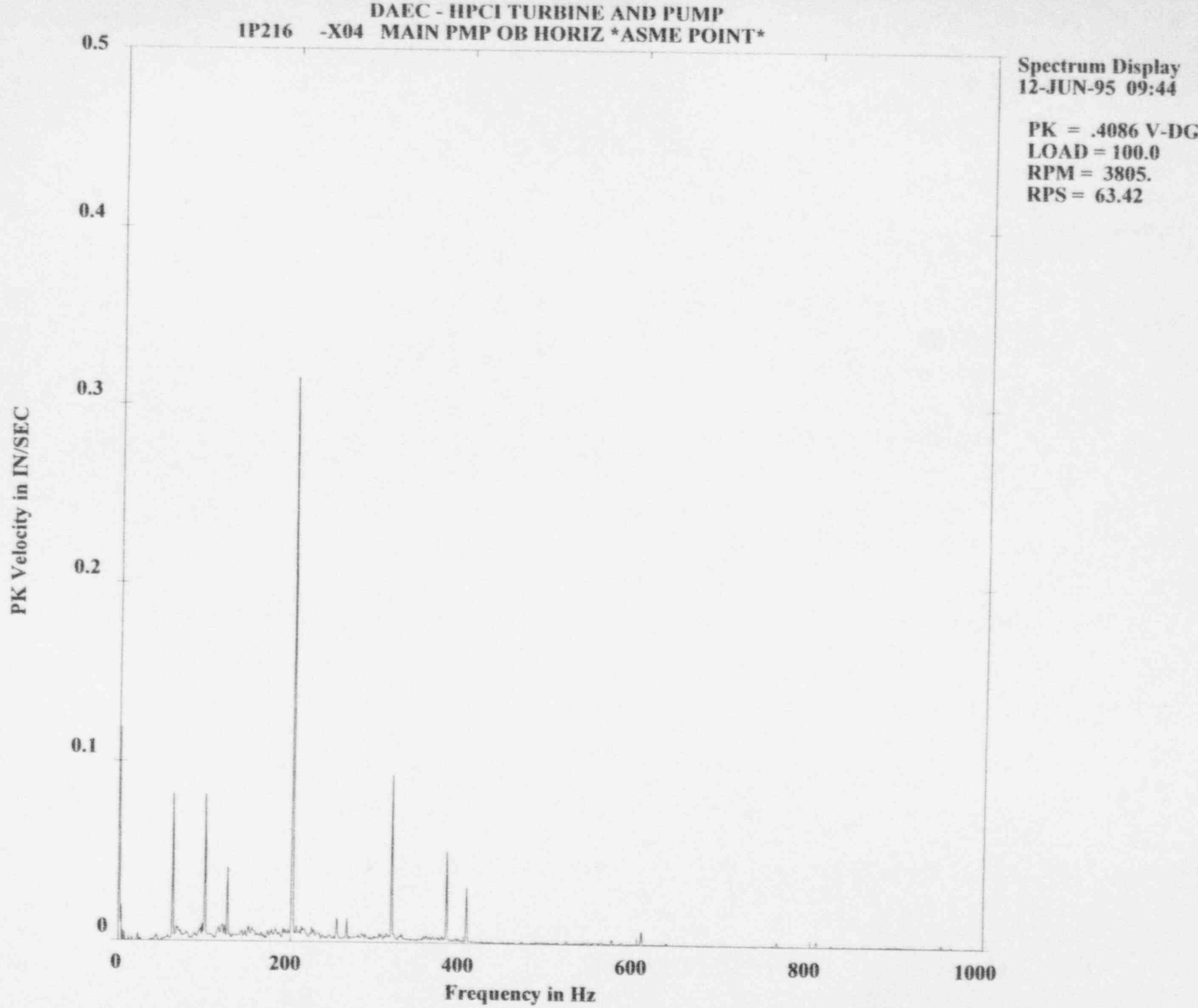
Machine: (DAEC) HPCI TURBINE AND PUMP

Meas. Point: 1P216 -Y03 --> MAIN PMP IB VERT *ASME POINT*

Date/Time: 12-JUN-95 09:52:48 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	1.78	.0674	.03	13	316.91	.1237	5.00
2	3.13	.0564	.05	14	380.28	.0829	6.00
3	4.26	.0240	.07	15	403.22	.0294	6.36
4	5.83	.0175	.09	16	443.76	.0148	7.00
5	8.20	.0086	.13	17	478.33	.0073	7.55
6	9.29	.0072	.15	18	479.53	.0101	7.57
7	13.14	.0082	.21	19	482.58	.0136	7.61
8	63.38	.0220	1.00	20	486.42	.0177	7.67
9	100.79	.0142	1.59	21	488.30	.0135	7.70
10	126.76	.0113	2.00	22	490.25	.0083	7.73
11	201.61	.0934	3.18	23	604.84	.0076	9.54
12	264.93	.0071	4.18	24	760.57	.0170	12.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.2131	.0891 / 17%	.1531 / 52%	.1184 / 31%

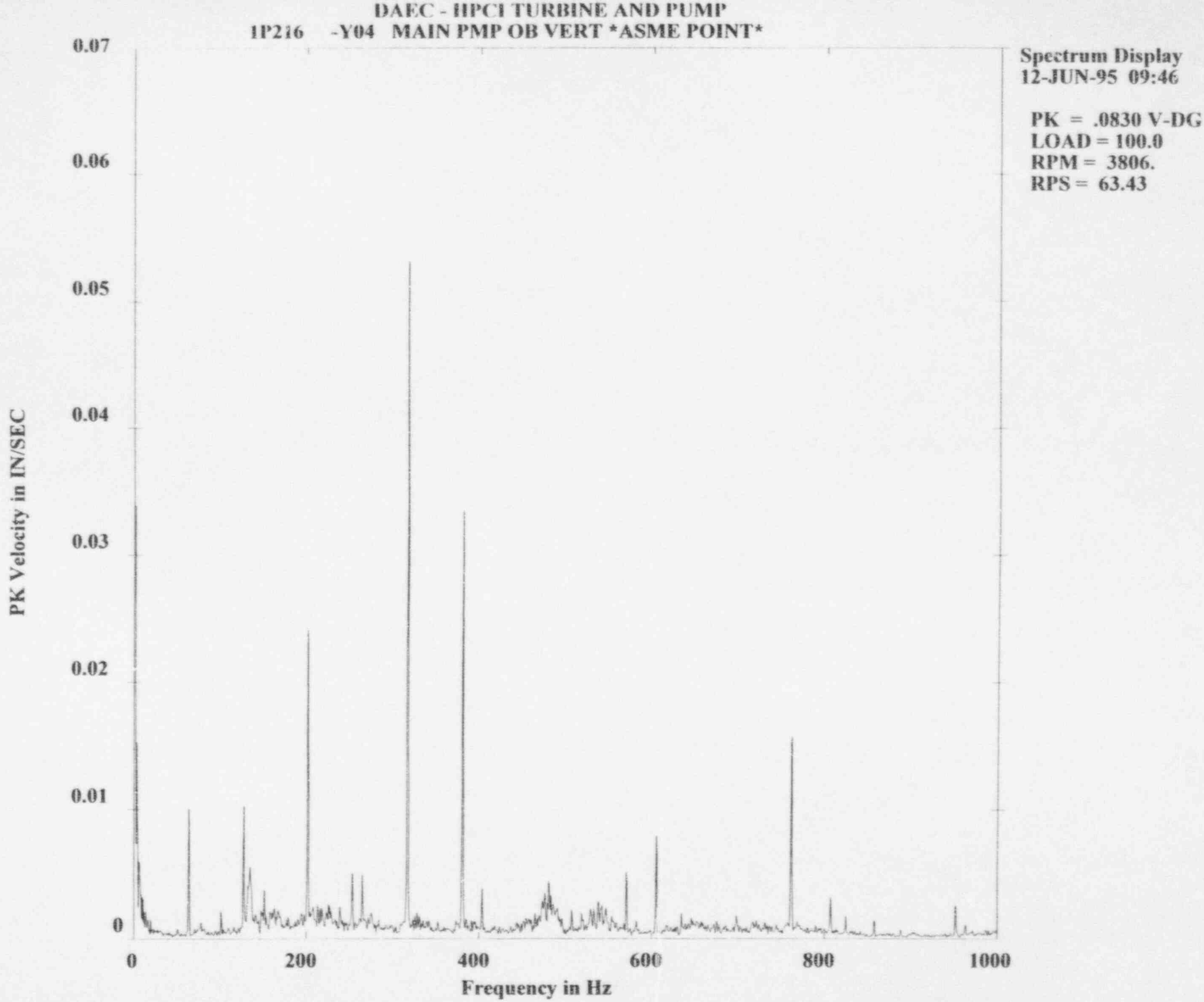

DAEC - HPCI TURBINE AND PUMP
1P216 -X04 MAIN PMP OB HORIZ *ASME POINT*
Spectrum Display
12-JUN-95 09:44
PK = .4086 V-DG
LOAD = 100.0
RPM = 3805.
RPS = 63.42
PK Velocity in IN/SEC
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
Frequency in Hz

LIST OF SPECTRAL PEAKS
****

Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -X04 --> MAIN PMP OB HORIZ *ASME POINT*
Date/Time: 12-JUN-95 09:44:49 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	3.13	.0196	.05	13	182.41	.0084	2.88
2	63.42	.0891	1.00	14	201.75	.3604	3.18
3	67.97	.0090	1.07	15	206.25	.0099	3.25
4	69.17	.0082	1.09	16	212.55	.0089	3.35
5	97.38	.0105	1.54	17	214.27	.0084	3.38
6	100.87	.0845	1.59	18	224.78	.0086	3.54
7	116.75	.0089	1.84	19	253.72	.0154	4.00
8	121.10	.0109	1.91	20	265.17	.0133	4.18
9	123.72	.0093	1.95	21	317.14	.0944	5.00
10	126.83	.0434	2.00	22	380.58	.0531	6.00
11	151.13	.0096	2.38	23	403.47	.0313	6.36
12	155.39	.0083	2.45	24	605.29	.0085	9.54

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.4224	.1019 / 6%	.1491 / 12%	.3819 / 82%



DAEC - HPCI TURBINE AND PUMP
1P216 -Y04 MAIN PMP OB VERT *ASME POINT*
Spectrum Display
12-JUN-95 09:46
PK = .0830 V-DG
LOAD = 100.0
RPM = 3806.
RPS = 63.43
PK Velocity in IN/SEC
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
200
400
600
800
1000
Frequency in Hz

LIST OF SPECTRAL PEAKS
****

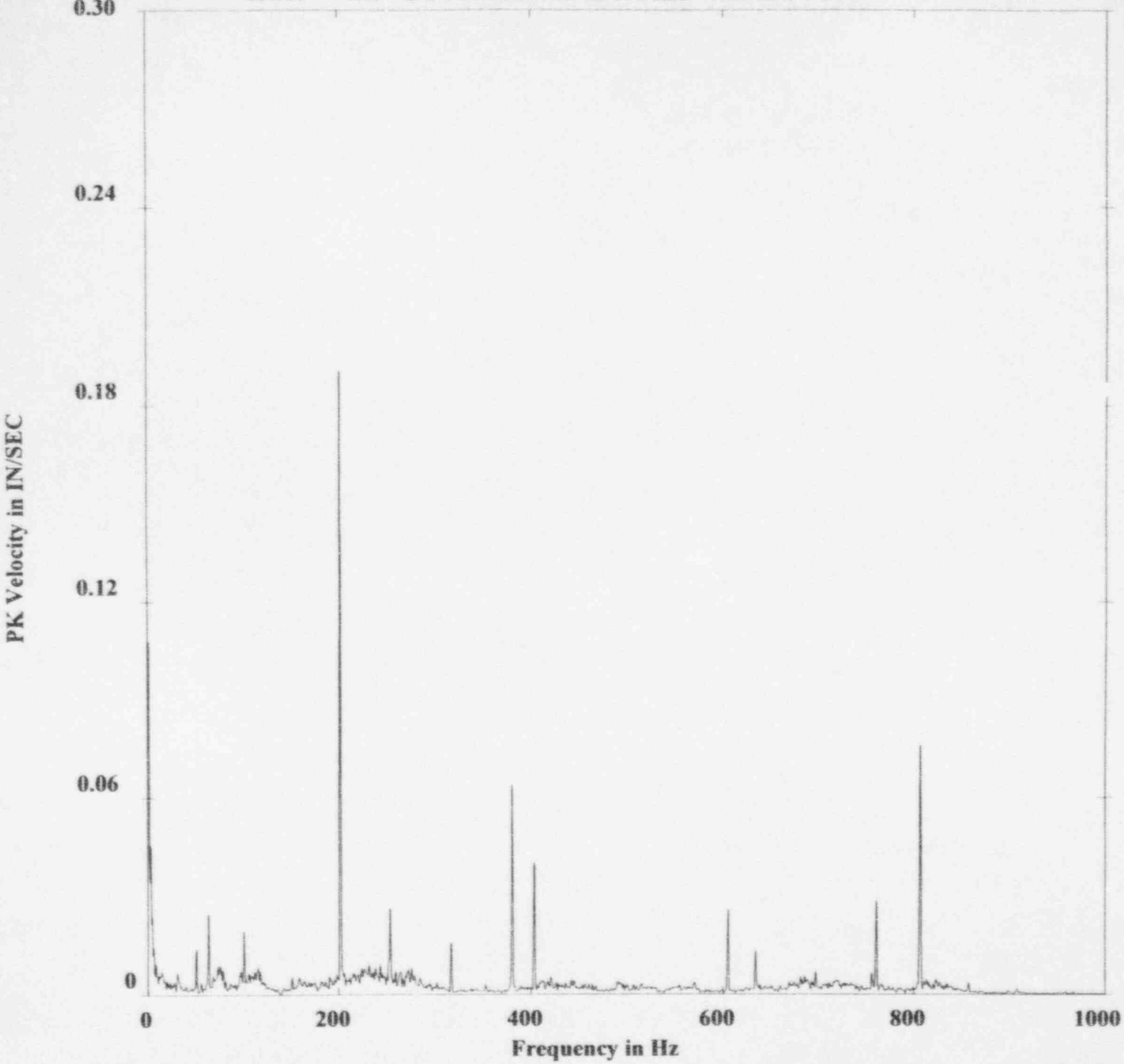
Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -Y04 --> MAIN PMP OB VERT *ASME POINT*
Date/Time: 12-JUN-95 09:46:01 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	3.27	.0151	.05	13	317.13	.0540	5.00
2	6.56	.0066	.10	14	380.59	.0352	6.00
3	7.87	.0040	.12	15	403.41	.0040	6.36
4	9.39	.0033	.15	16	473.42	.0032	7.46
5	63.42	.0109	1.00	17	476.41	.0040	7.51
6	126.84	.0108	2.00	18	480.82	.0051	7.58
7	132.31	.0047	2.09	19	483.33	.0039	7.62
8	134.27	.0062	2.12	20	538.41	.0034	8.49
9	151.27	.0039	2.38	21	570.87	.0057	9.00
10	201.77	.0279	3.18	22	605.27	.0087	9.54
11	253.71	.0059	4.00	23	761.16	.0183	12.00
12	265.14	.0051	4.18	24	806.96	.0034	12.72

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.0916	.0377 / 17%	.0697 / 58%	.0460 / 25%

DAEC - HPCI TURBINE AND PUMP

1P216 -X09 BOOSTER PMP IB HORIZ *ASME POINT



Spectrum Display
12-JUN-95 09:47

PK = .2586 V-DG
LOAD = 100.0
RPM = 3025.
RPS = 50.41

LIST OF SPECTRAL PEAKS
****

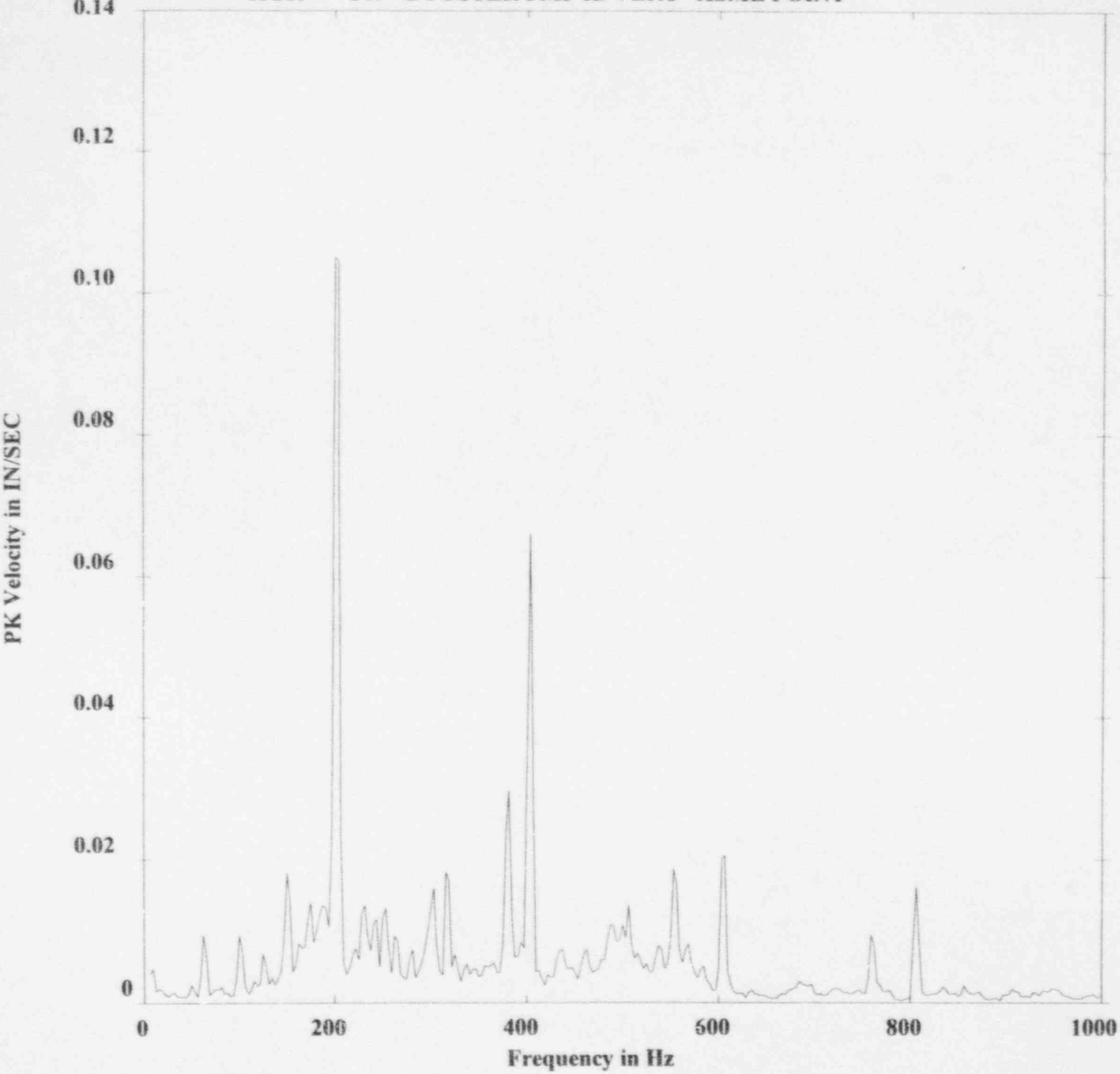
Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -X09 --> BOOSTER PMP IB HORIZ *ASME POINT
Date/Time: 12-JUN-95 09:47:32 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	3.03	.0478	.06	13	224.33	.0091	4.45
2	4.17	.0269	.08	14	226.85	.0091	4.50
3	5.92	.0162	.12	15	231.80	.0104	4.60
4	8.37	.0104	.17	16	243.18	.0099	4.82
5	50.42	.0158	1.00	17	253.57	.0275	5.03
6	63.39	.0262	1.26	18	316.94	.0182	6.29
7	73.36	.0092	1.46	19	380.32	.0647	7.54
8	74.76	.0090	1.48	20	403.26	.0471	8.00
9	75.49	.0099	1.50	21	604.85	.0276	12.00
10	100.77	.0195	2.00	22	634.01	.0143	12.58
11	115.49	.0096	2.29	23	760.66	.0300	15.09
12	201.65	.2002	4.00	24	806.67	.0788	16.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.2837	.1129 / 16%	.2283 / 65%	.1250 / 19%

DAEC - HPCI TURBINE AND PUMP

1P216 -Y09 BOOSTER PMP IB VERT *ASME POINT*



Spectrum Display
12-JUN-95 09:59

PK = .1670
LOAD = 100.0
RPM = 3024.
RPS = 50.40

LIST OF SPECTRAL PEAKS
****

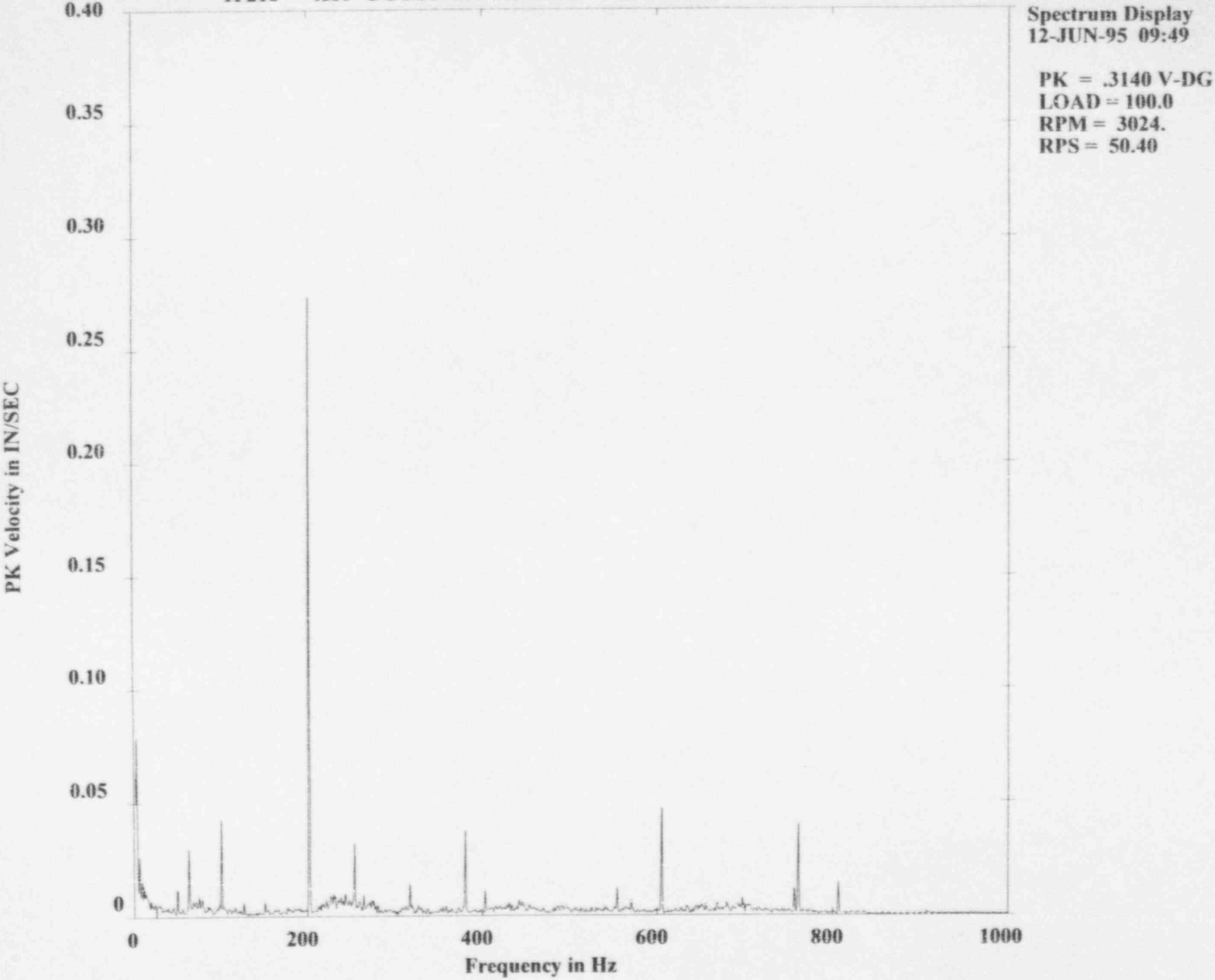
Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -Y09 --> BOOSTER PMP IB VERT *ASME POINT*
Date/Time: 12-JUN-95 09:59:08 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	63.20	.0096	1.25	13	317.03	.0206	6.29
2	100.99	.0099	2.00	14	380.24	.0317	7.54
3	151.07	.0193	3.00	15	395.11	.0095	7.84
4	163.92	.0093	3.25	16	403.13	.0660	8.00
5	173.93	.0151	3.45	17	489.04	.0127	9.70
6	189.04	.0158	3.75	18	501.18	.0117	9.94
7	201.59	.1234	4.00	19	505.64	.0139	10.03
8	229.94	.0153	4.56	20	554.40	.0207	11.00
9	242.37	.0133	4.81	21	567.45	.0091	11.26
10	251.87	.0147	5.00	22	604.75	.0239	12.00
11	263.90	.0105	5.24	23	760.51	.0102	15.09
12	302.03	.0173	5.99	24	806.42	.0161	16.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.1670	.0061 / 0%	.1485 / 79%	.0760 / 21%

DAEC - HPCI TURBINE AND PUMP

1P216 -X10 BOOSTER PMP OB HORIZ *ASME POINT

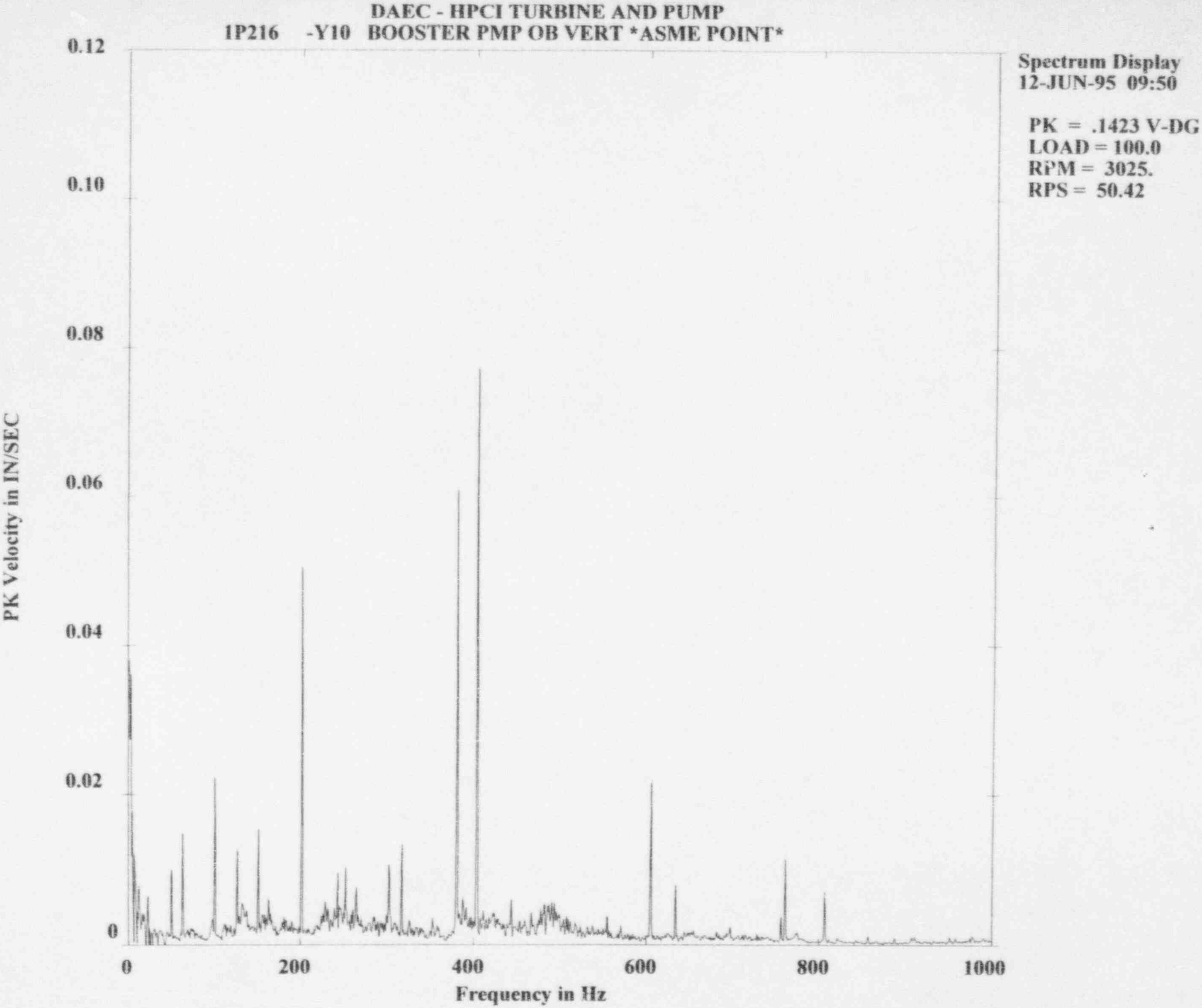


LIST OF SPECTRAL PEAKS
****

Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -X10 --> BOOSTER PMP OB HORIZ *ASME POINT
Date/Time: 12-JUN-95 09:49:28 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	3.28	.0780	.07	13	229.42	.0103	4.55
2	6.50	.0277	.13	14	231.20	.0100	4.59
3	9.01	.0178	.18	15	243.11	.0111	4.82
4	10.76	.0141	.21	16	253.55	.0329	5.03
5	12.07	.0122	.24	17	316.89	.0158	6.29
6	13.42	.0114	.27	18	380.28	.0383	7.55
7	15.32	.0096	.30	19	403.21	.0121	8.00
8	50.37	.0139	1.00	20	554.44	.0118	11.00
9	63.43	.0325	1.26	21	604.81	.0513	12.00
10	100.81	.0429	2.00	22	756.11	.0132	15.00
11	201.60	.2818	4.00	23	760.59	.0440	15.09
12	226.76	.0100	4.50	24	806.36	.0148	16.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.3381	.1234 / 13%	.2927 / 75%	.1159 / 12%


DAEC - HPCI TURBINE AND PUMP
1P216 -Y10 BOOSTER PMP OB VERT *ASME POINT*
Spectrum Display
12-JUN-95 09:50
PK = .1423 V-DG
LOAD = 100.0
RPM = 3025.
RPS = 50.42
PK Velocity in IN/SEC
0.12
0.10
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
Frequency in Hz

LIST OF SPECTRAL PEAKS
****

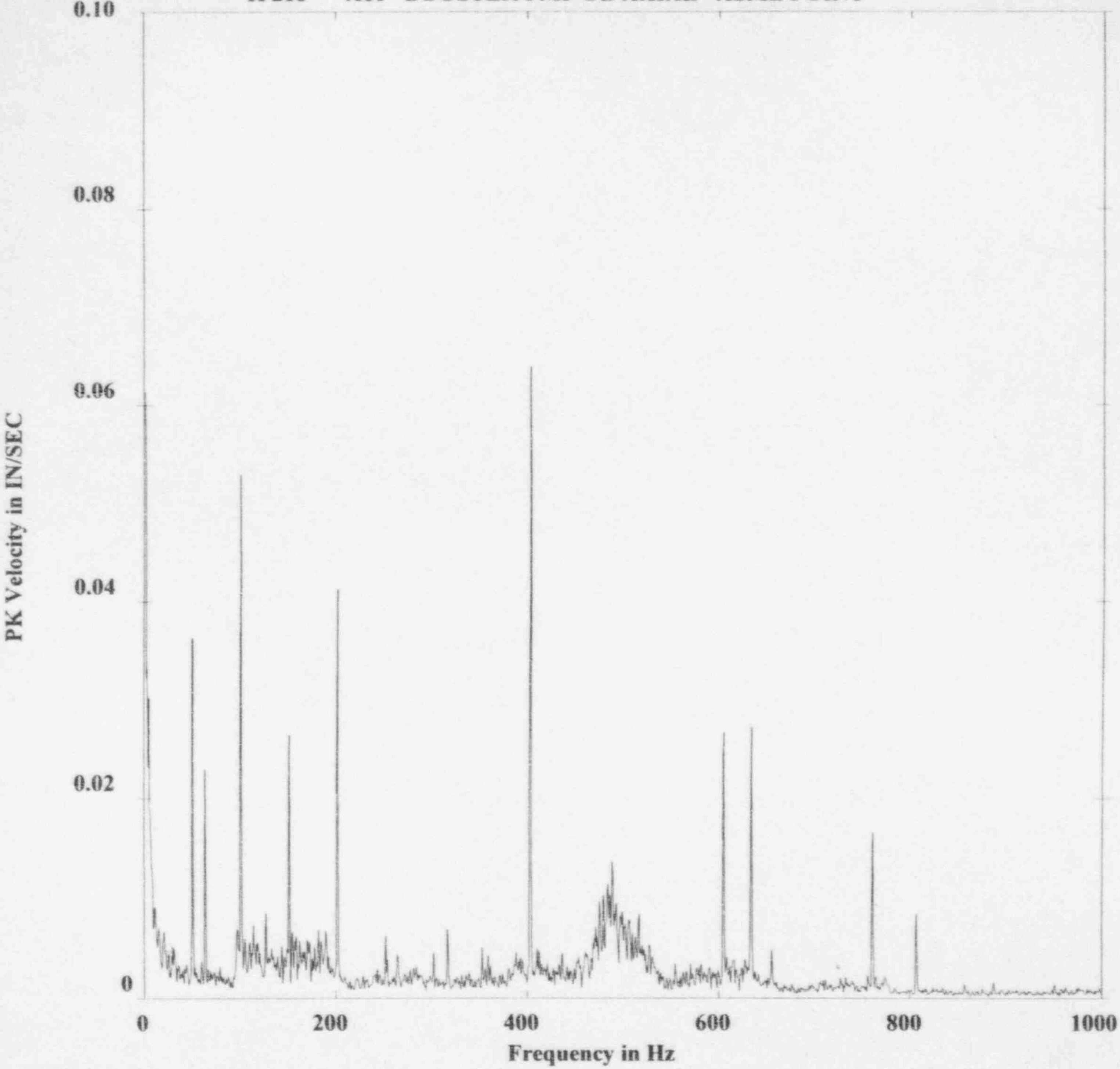
Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -Y10 --> BOOSTER PMP OB VERT *ASME POINT*
Date/Time: 12-JUN-95 09:50:13 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	2.95	.0407	.06	13	201.67	.0540	4.00
2	4.49	.0176	.09	14	243.23	.0101	4.82
3	7.14	.0131	.14	15	252.10	.0104	5.00
4	7.85	.0116	.16	16	264.44	.0084	5.24
5	12.20	.0091	.24	17	302.47	.0119	6.00
6	22.88	.0075	.45	18	317.01	.0144	6.29
7	50.41	.0114	1.00	19	380.41	.0609	7.55
8	63.40	.0159	1.26	20	403.34	.0840	8.00
9	100.85	.0227	2.00	21	604.98	.0220	12.00
10	126.80	.0137	2.51	22	634.02	.0086	12.58
11	151.26	.0162	3.00	23	760.87	.0116	15.09
12	163.60	.0070	3.24	24	806.70	.0076	16.00

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.1564	.0636 / 17%	.1084 / 48%	.0931 / 35%

DAEC - HPCI TURBINE AND PUMP

1P216 -A10 BOOSTER PMP OB AXIAL *ASME POINT



Spectrum Display
12-JUN-95 09:50

PK = .1527 V-DG
LOAD = 100.0
RPM = 3024.
RPS = 50.39

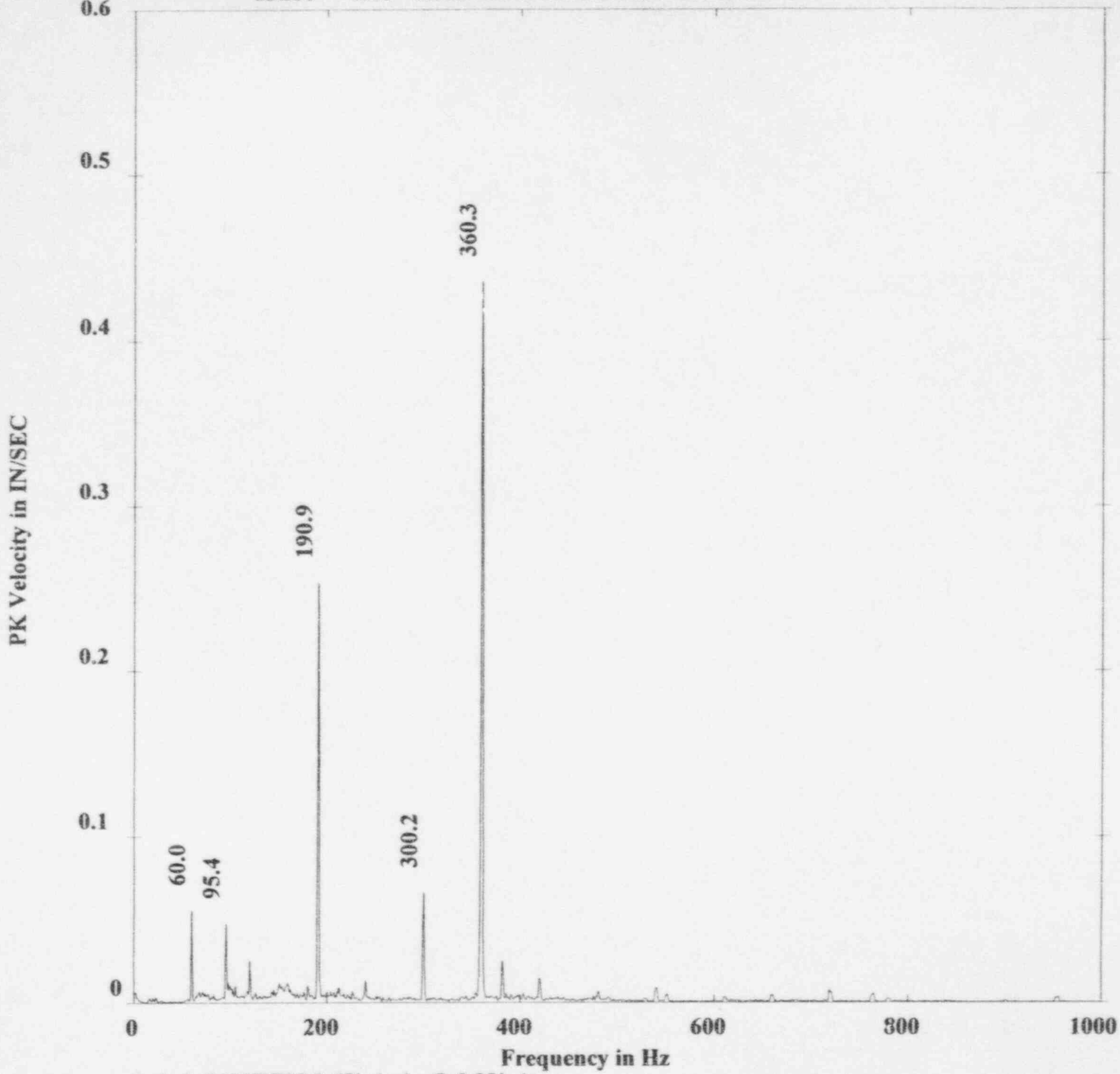
LIST OF SPECTRAL PEAKS
****

Machine: (DAEC) HPCI TURBINE AND PUMP
Meas. Point: 1P216 -A10 --> BOOSTER PMP OB AXIAL *ASME POINT
Date/Time: 12-JUN-95 09:50:58 Amplitude Units: IN/SEC PK

PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE	PEAK NO.	FREQUENCY (Hz)	PEAK VALUE	ORDER VALUE
1	1.65	.0685	.03	13	475.77	.0107	9.44
2	3.45	.0369	.07	14	479.58	.0120	9.52
3	5.15	.0304	.10	15	483.99	.0132	9.60
4	6.56	.0204	.13	16	486.46	.0120	9.65
5	7.85	.0153	.16	17	488.93	.0155	9.70
6	10.97	.0108	.22	18	492.74	.0111	9.78
7	50.37	.0427	1.00	19	497.13	.0097	9.86
8	63.37	.0240	1.26	20	499.55	.0097	9.91
9	100.78	.0531	2.00	21	516.54	.0096	10.25
10	151.19	.0288	3.00	22	604.77	.0301	12.00
11	201.61	.0427	4.00	23	633.73	.0275	12.58
12	403.19	.0707	8.00	24	760.55	.0190	15.09

TOTAL MAG	SUBSYNCHRONOUS	SYNCHRONOUS	NONSYNCHRONOUS
.1801	.0961 / 28%	.1160 / 41%	.0987 / 30%

DAEC - HPCI TURBINE AND PUMP
1P216 -X03 MAIN PMP IB HORIZ *ASME POINT*



Spectrum Display
15-APR-94 09:41

PK = .6778
LOAD = 100.0
RPM = 3602.
RPS = 60.04

Label: 3601RPM 0.68in/s;4x @ 0.29in/sec

BEARING FREQUENCIES FOR SKF 7411
****

Thrust bearing for HPCI Booster Pump, 1P216 at the DAEC

PHYSICAL DATA

Number of Balls/Rollers: 10
Ball/Roller Diameter: 1.0620
Pitch Diameter of Races: 3.838
Contact Angle (Degrees): 35.0

HARMONICS	SHAFT RPS	TRAIN (FTF)	SPIN (BSF)	OUTER (BPFO)	INNER (BPFI)
1	50.42	19.50	86.43	194.96	309.24
2	100.84	38.99	172.85	389.92	618.48
3	151.26	58.49	259.28	584.87	927.73
4	201.68	77.98	345.71	779.83	1236.97

HARMONICS	OUTER RACE PASS (BPFO) PLUS SIDEBANDS			INNER RACE PASS (BPFI) PLUS SIDEBANDS		
1		194.96			309.24	
	144.54		245.38	258.82		359.66
	94.12		295.80	208.40		410.08
2		389.92			618.48	
	339.50		440.34	568.06		668.90
	289.08		490.76	517.64		719.32
3		584.87			927.73	
	534.45		635.29	877.31		978.15
	484.03		685.71	826.89		1028.57
4		779.83			1236.97	
	729.41		830.25	1186.55		1287.39
	678.99		880.67	1136.13		1337.81

Frequencies in Hz

BEARING FREQUENCIES FOR SKF 216

****

Radial Bearing for HPCI Booster Pump, 1P216 at the DAEC

PHYSICAL DATA

Number of Balls/Rollers:	16
Ball/Roller Diameter:	.7500
Pitch Diameter of Races:	4.134
Contact Angle (Degrees):	.0

HARMONICS	SHAFT RPM	TRAIN (FTF)	SPIN (BSF)	OUTER (BPFO)	INNER (BPFI)
1	50.42	20.64	134.38	330.18	476.54
2	100.84	41.27	268.77	660.36	953.08
3	151.26	61.91	403.15	990.54	1429.62
4	201.68	82.55	537.54	1320.73	1906.15

HARMONICS	OUTER RACE PASS (BPFO) PLUS SIDEBANDS			INNER RACE PASS (BPFI) PLUS SIDEBANDS		
1		330.18			476.54	
	279.76		380.60	426.12		526.96
	229.34		431.02	375.70		577.38
2		660.36			953.08	
	609.94		710.78	902.66		1003.50
	559.52		761.20	852.24		1053.92
3		990.54			1429.62	
	940.12		1040.96	1379.20		1480.04
	889.70		1091.38	1328.78		1530.46
4		1320.73			1906.15	
	1270.31		1371.15	1855.73		1956.57
	1219.89		1421.57	1805.31		2006.99

Frequencies in Hz