Florida Power & Light Company, 6501 S. Ocean Drive, Jensen Beach, FL 34957

FPL

August 5, 2008

L-2008-178
10 CFR 50.4
10 CFR 50.55a

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Re: St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
Fourth Ten-Year Interval In-Service-Test Program Submittal
RAI Reply to Relief Request PR-04 (TAC No. MD7748)

The fourth ten-year in-service-test (IST) interval for St. Lucie Units 1 and 2 was submitted on September 11, 2007 via FPL letter L-2007-144. The submittal also contained relief requests for the fourth ten-year interval requiring NRC approval in accordance with 10 CFR 50.55a(a)(3)(i), 50.55a(a)(3)(ii), and 50.55a(f)(5)(iii), for relief from, or as alternatives to, the requirements of the ASME OM Code. On July 2, 2008, the NRC Staff verbally requested additional information for Relief Request PR-04. This letter contains the information requested by the Staff.

Please contact Ken Frehafer at (772) 467-7748 if there are any questions on this submittal

Very truly yours,

Gordon L. Johnston
Site Vice President
St. Lucie Plant

Attachments

GLJ/KWF

A047
NRR

RAI Reply for Pump Relief Request – PR-04
Low Pressure Safety Injection Pump Group Classification

The following information is provided to supplement Relief Request Number "PR-04" submitted by Florida Power and Light Company under FPL Letter L-2007-144 This information is provided based on a telephone conversation between the NRC and FPL on July 2, 2008. Specifically, the NRC requested that the licensee provide basis and details for accepting the higher vibration values of 0.325 in/sec to 0.5 in/sec seen while testing the Unit 1 low pressure safety injection (LPSI) pumps under mini-recirculation flow conditions as described in previous PR-12 during the 3rd 10-year interval IST program. Additionally, the NRC requested that St. Lucie describe additional non-Code monitoring and spectral analysis activities performed on the LPSI pumps under design flow conditions during outages.

Response

Relief Request PR-04 requests relief from ISTB-1400(b) of the ASME OM Code 2001 Edition through 2003 Addenda. ISTB-1400(b) states that a pump that meets both Group A and Group B definitions shall be categorized as a Group A pump. Relief Request PR-04 proposes that the LPSI pumps will be tested as Group B pump during power operation and Group A pump during refueling operation. In PR-04, Reason for Request, the statement is made that "St. Lucie addressed the Unit 1 pumps normal generation of excess vibration during low flow quarterly testing through the submittal of the 3rd 10-year IST interval Relief Request 12 to increase the Code alert limits from 0.325 in/sec to 0.5 in/sec. This request was approved by NRC Safety Evaluation and dated March 16, 1998. (St. Lucie 3rd Interval Relief Request PR-12). This evaluation provides justification similar to that provided for previous relief request PR-12 for accepting higher vibration values when testing the LPSI pumps on minimum recirculation flow. This additional information is also provided consistent with the previous guidelines contained in NRC Commission Proceedings (Reference NUREG/CP-0152).

As discussed in NUREG / CP-0152, "Code Absolute Vibration Requirements", there are four key components that the staff considers in evaluating alternative requests: 1) vibration history, 2) consultation with pump manufacturer or vibration expert, 3) attempts to lower the vibration through modification, and 4) performance of spectral analysis of the pump-driver system.

Vibration History

The Unit 1 LPSI pumps have been tested quarterly at minimum recirculation flow and during cold shutdowns at design flow in accordance with previously approved Relief Request PR-12. Attachment 2 shows the overall vibration values obtained during this testing. These trends show that vibration levels during recirculation are higher and more unstable than those obtained at design flow. The vibration levels at design flow have been well below the 0.325 in/sec Alert limit and stable.

The Unit 1 LPSI pumps are included in the plant predictive maintenance (PDM) monitoring program, therefore, many years of spectral analysis and trend data from PDM test results are available for review (Attachments 3 and 4). PDM usually collects data when the pumps run at needed shutdown cooling (SDC) flows, but occasionally data is collected at the Section XI full flow and minimum flow tests. From the spectral patterns it can be seen that, at minimum flow conditions, both pumps generate increased vibration levels. At low flow, vibration velocity levels at five running speed frequencies (5X), the vane passing frequency, are significantly increased due to elevated vane pass vibration since the water's velocity vector is not striking the volute tongue at the optimal angle. The increased vibration at the 2X frequency is a result of an abnormal pressure distribution in the volute that acts to asymmetrically load the impeller. Also contributing to the overall vibration increase is hydraulic broadband "spectral floor" energy generated by shock energy due to increased turbulence and internal recirculation flow.

Note that an anomaly occurred on April 21, 1997, when relatively high vibration was experienced by the 1B LPSI Pump at the 1X frequency in the horizontal direction. Based on a review of the data, it was determined that this resulted from a structural condition related to operation at elevated temperature. The most likely cause was postulated to be piping and support system stiffness/natural frequency changes resulting from elevated temperatures. Subsequent runs under similar conditions at non-elevated temperatures resulted in lower vibration.

Expert Opinion

Spectral vibration data of these pumps was collected by plant PDM personnel experienced and trained in the performance monitoring of pumps and other rotating equipment. The spectral data along with historical pump velocity data obtained to comply with Inservice Testing requirements has been reviewed and evaluated by our onsite equipment vibration specialist. In addition, operation of the pump in low flow conditions has been discussed with the original equipment manufacturer. The FPL PDM vibration specialist's conclusion based on the historical data, spectral analysis, hands on data gathering, and especially the observation that at normal (near BEP, the best efficiency point) flows, the vibration patterns and operational performance is normal and stable and that there is no evidence of pump deterioration or mechanical anomalies detrimental to the pump; the LPSI pumps are operating satisfactorily.

Note: There are two formats in the attachments because the PDM data sheets come from 2 separate databases. From '93-'02, data was collected with a Bently Nevada Snapshot system and velocity probes. From '03 to the present, data is collected with a CSI system and accelerometers.

A pump will typically generate 3 forms of vibration patterns based on its construction and operating characteristics. Rotor forces and structural response generate 1X running speed (and sometimes 2X running speed) vibration. The impeller and volute generate vane pass and other hydraulic patterns depending on flow and operation around BEP. Anti-friction (ball) bearings will generate bearing defect frequencies when bearings surfaces degrade.

Casing readings of the 1X and 2X running speed vibration levels are the structural response to the rotor's inherent imbalance condition, as then affected by alignment and clearance forces. If 1X vibration patterns/levels remain low and stable, it is a sign that the rotor forces are not excessive, clearances are not increasing, and the casing response has not changed, indicating no significant machine degradation. As can be seen on Attachments 3 and 4 over 15 years for both Unit 1 LPSI pumps 1X trends and levels are fairly low and stable with maximum radial 1X at 0.11 in/sec (1.2 mils), indicating no signs of poor balance or increasing pump clearances. (Note, as discussed above, on the 1B LPSI there is occasional increased horizontal 1X vibration, due to a structural issue when the pump is operating with hotter water. However, as the 1X vibration levels return to previous normal values with cooler pumped fluid, this is not a significant concern)

The vane pass frequency is generated by the pressure pulse as the pump's impeller vanes pass close to the tongue of the volute. Vane pass frequencies are an expected vibration component from a pump. Typically a pump hydraulically runs the smoothest near its BEP (best efficiency point). The fluid velocity vector would then be at the optimum OEM designed angle to minimize fluid churning and shock between the impeller vanes and the volute tongue.

When a pump is throttled back the fluid vectors change, and there will then be increased churning, increased internal recirculation through wear ring and impeller clearances, and lost efficiency. This condition can generate changes to hydraulic vibration at vane pass frequency (5X running speed in the case of these pumps), as well as broadband "floor energy" showing up in the vibration spectrum.

The 1A and 1B LPSI pumps are minimum flow tested in the 90 gpm range, though the BEP is closer to the 3250 gpm range. This flow difference has a small affect on the 1X running speed vibration, and can generate some 2X running speed vibration from asymmetric rotor loading. The flow differences do significantly affect the hydraulic 5X running speed vibration as well as the floor energy patterns around the vane pass, and explains why operation at low or minimum flows has much higher vibration values than full flow tests.

As can be seen in Attachments 3 and 4 near BEP, the hydraulic vibration patterns are normal and expected. At lower flows there is increased vane pass (5X) and floor energy. As the flows return to near BEP the vibration patterns and levels return to normal. Therefore, though overall vibration can dramatically increase at low flow conditions, reaching 0.45-0.50 in/sec on these pumps, there is little sign that the pump condition would be degrading.

Bearing defect frequencies are generated from anti-friction (ball) bearings when the bearing surfaces are degraded. These frequencies are not present until a defect forms in the bearing itself. Depending on the specific location of the defect, the rolling elements will strike the defect at a certain frequency driven by the bearing geometry and the rotating speed. The bearing defect frequencies (inner race, outer race, ball, and cage) are normally calculated and compared to any spectral frequencies that appear. These frequencies are typically obvious when displayed in the spectral trend format, so changes are quickly apparent. As can be seen in Attachments 3 and 4 there are no bearing defect frequencies that have appeared in the spectrums.

Therefore, though a pump may generate higher vibration levels at minimum flow conditions, depending on internal clearances, as long as the patterns return to normal near BEP flows, the 1X vibration trends do not worsen, and there is no signs of bearing degradation, there should be little concern with the "health" of the pump.

Corrective Actions

As discussed above, the pump vibration history data has been reviewed to ensure that no maintenance related anomalies were evident that could be corrected to improve performance. The pump-piping configuration was also reviewed; however, changes to the pump / piping arrangement, including modification of pump internals and installation of a full flow test recirculation line, would be costly and generally impractical. Based on the data, the elevated levels of vibration experienced during low flow conditions are a result of flow noise and pump dynamics that are not a function of pump degradation. The elevated levels of vibration are not evident at design flows, and therefore do not detract from pump availability or reliability at design flows. Also, the LPSI pumps meet the ASME vibration criteria during outage conditions (substantial flow conditions). Accordingly, the need for substantial plant modification to install full recirculation lines for quarterly surveillance purposes is considered impractical.

Spectral Analysis

The results derived from spectral analyses are provided in Attachments 3 and 4 and are discussed above.

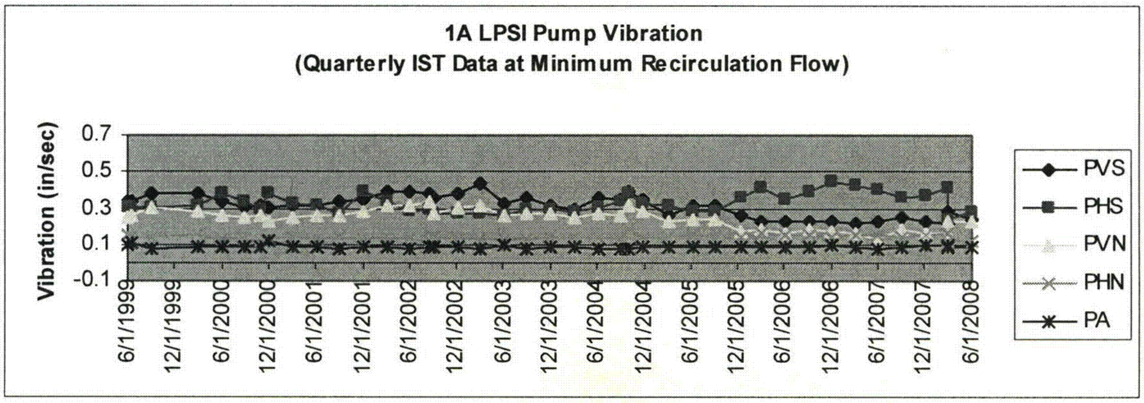
Additional Non-Code Monitoring and Spectral Analysis Activities

These pumps are included in the plant "condition monitoring" program. Each refueling outage the site PDM group will continue to obtain and analyze vibration spectral data from each LPSI pump while it is running at nominal SDC design flow significantly closer to BEP than the minimum flow tests. Additionally, the PDM group collects oil samples from all driver-pump bearing reservoirs which are routinely analyzed for increased wear particles, viscosity, and water. The PDM group will also collect pump data upon request if any issues appear to have developed.

Attachment 2, Unit 1 LPSI Pump IST Vibration Data. (1 page)

Attachment 3, Unit 1 LPSI Pump Spectral Vibration Data 1995 to 2002. (6 pages)

Attachment 4, Unit 1 LPSI Pump Spectral Vibration Data 2004 to 2007. (10 pages)


1A LPSI Pump Vibration
(Quarterly IST Data at Minimum Recirculation Flow)
Vibration (in/sec)
0.7
0.5
0.3
0.1
-0.1
6/1/1999
12/1/1999
6/1/2000
12/1/2000
6/1/2001
12/1/2001
6/1/2002
12/1/2002
6/1/2003
12/1/2003
6/1/2004
12/1/2004
6/1/2005
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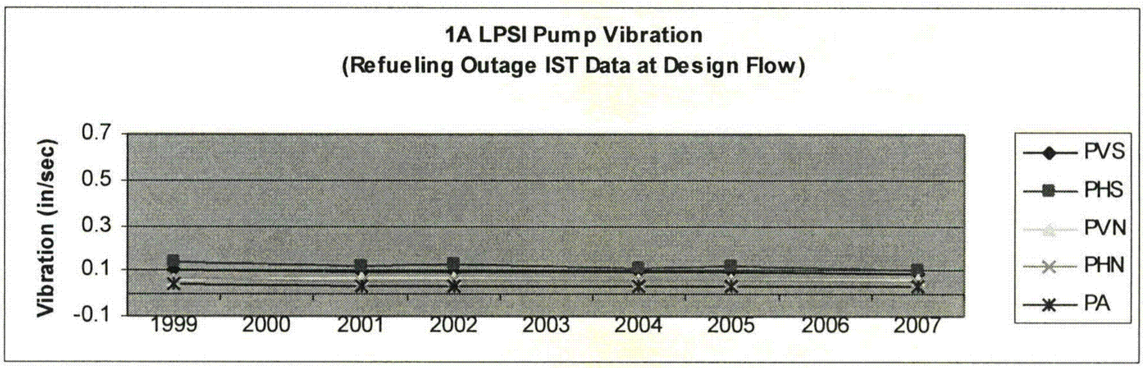
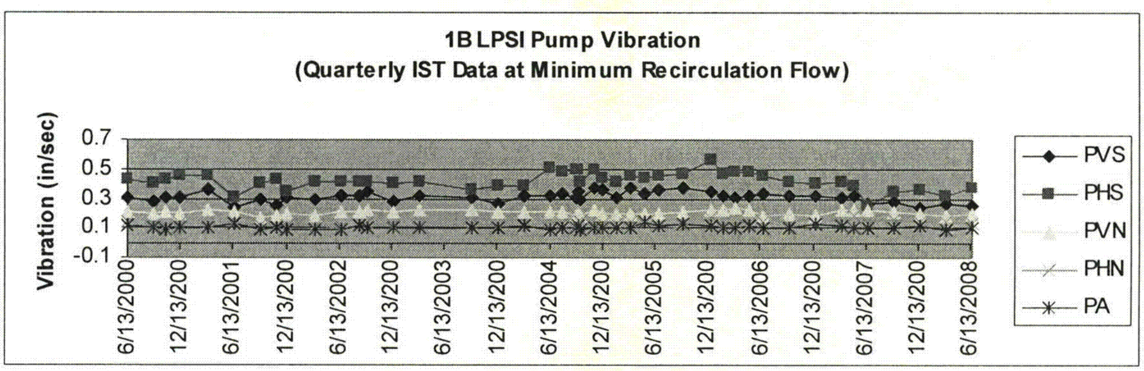
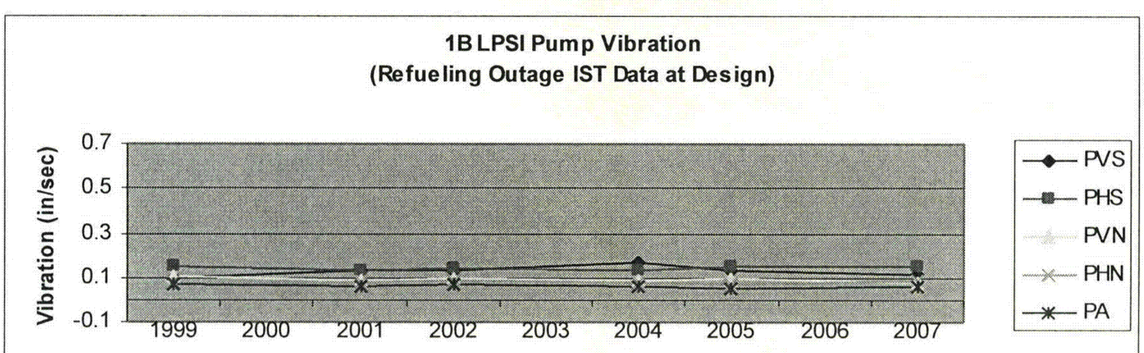
6/1/2008
PVS
PHS
PVN
PHN
PA

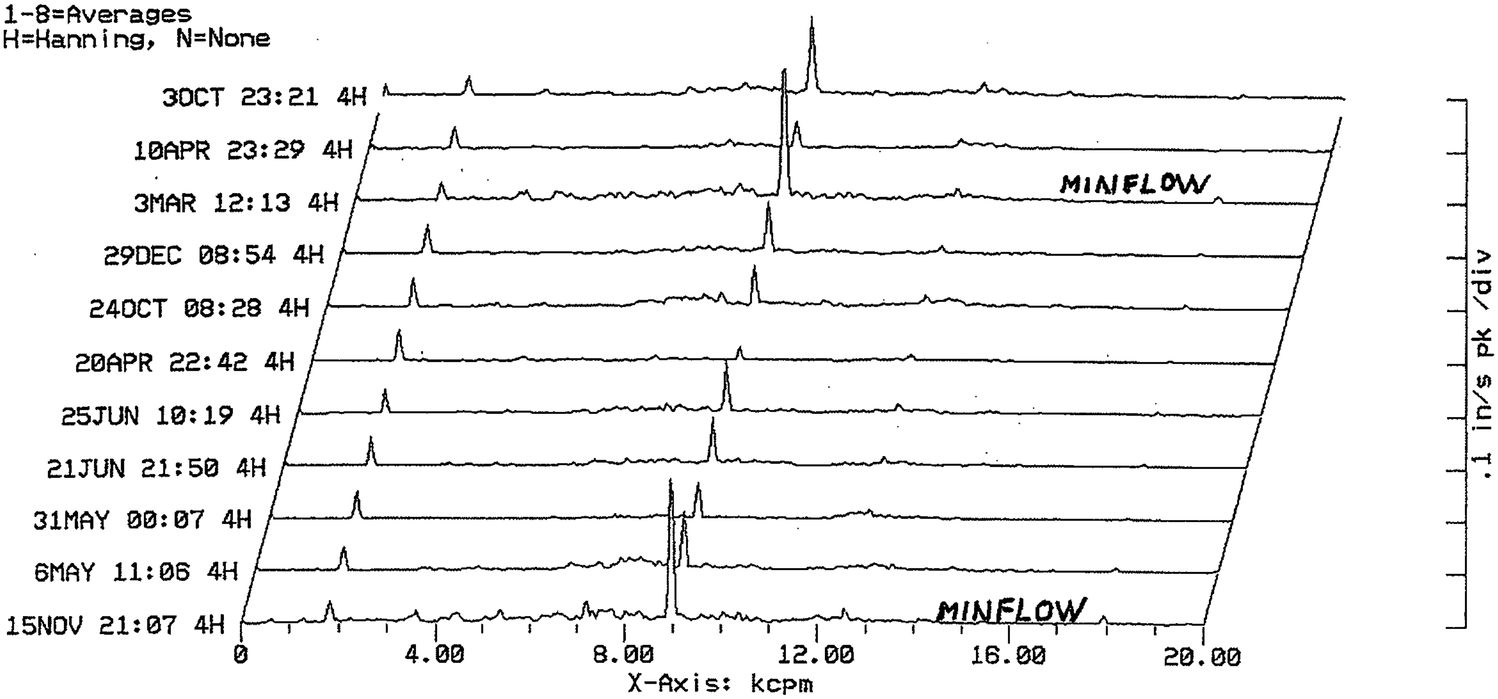

1A LPSI Pump Vibration
(Refueling Outage IST Data at Design Flow)
Vibration (in/sec)
0.7
0.5
0.3
0.1
-0.1
1999
2000
2001
2002
2003
2004
2005
2006
2007
PVS
PHS
PVN
PHN
PA


1B LPSI Pump Vibration
(Quarterly IST Data at Minimum Recirculation Flow)
Vibration (in/sec)
0.7
0.5
0.3
0.1
-0.1
6/13/2000
12/13/200
6/13/2001
12/13/200
6/13/2002
12/13/200
6/13/2003
12/13/200
6/13/2004
12/13/200
6/13/2005
12/13/200
6/13/2006
12/13/200
6/13/2007
12/13/200
6/13/2008
PVS
PHS
PVN
PHN
PA


1B LPSI Pump Vibration
(Refueling Outage IST Data at Design)
Vibration (in/sec)
0.7
0.5
0.3
0.1
-0.1
1999
2000
2001
2002
2003
2004
2005
2006
2007
PVS
PHS
PVN
PHN
PA

PREDICTIVE MAINTENANCE - FPL/PSL

Plant:ST. LUCIE   Train:SAFETY INJ
Plot:Spectrum Trend
Equip:1A LPSI PUMP   Loc:3-YV   0deg
Begin: 15 NOV 95 21:07:26 End: 3 OCT 02 23:21:13
1-8=Averages
H=Hanning, N=None



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Plot:Spectrum Trend
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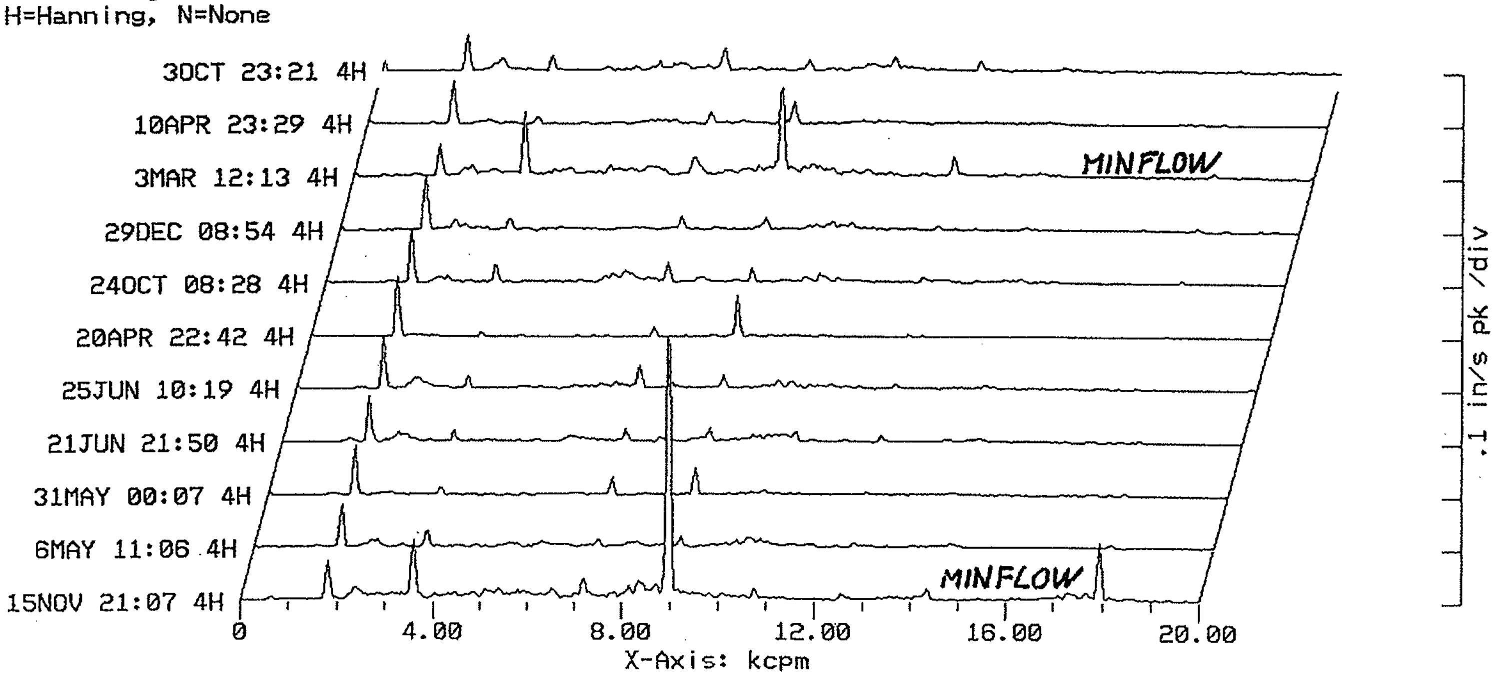
H=Hanning, N=None



BENTLY NEVADA SS+

PREDICTIVE MAINTENANCE - FPL/PSL

Plant:ST. LUCIE Train:SAFETY INJ
Plot:Spectrum Trend
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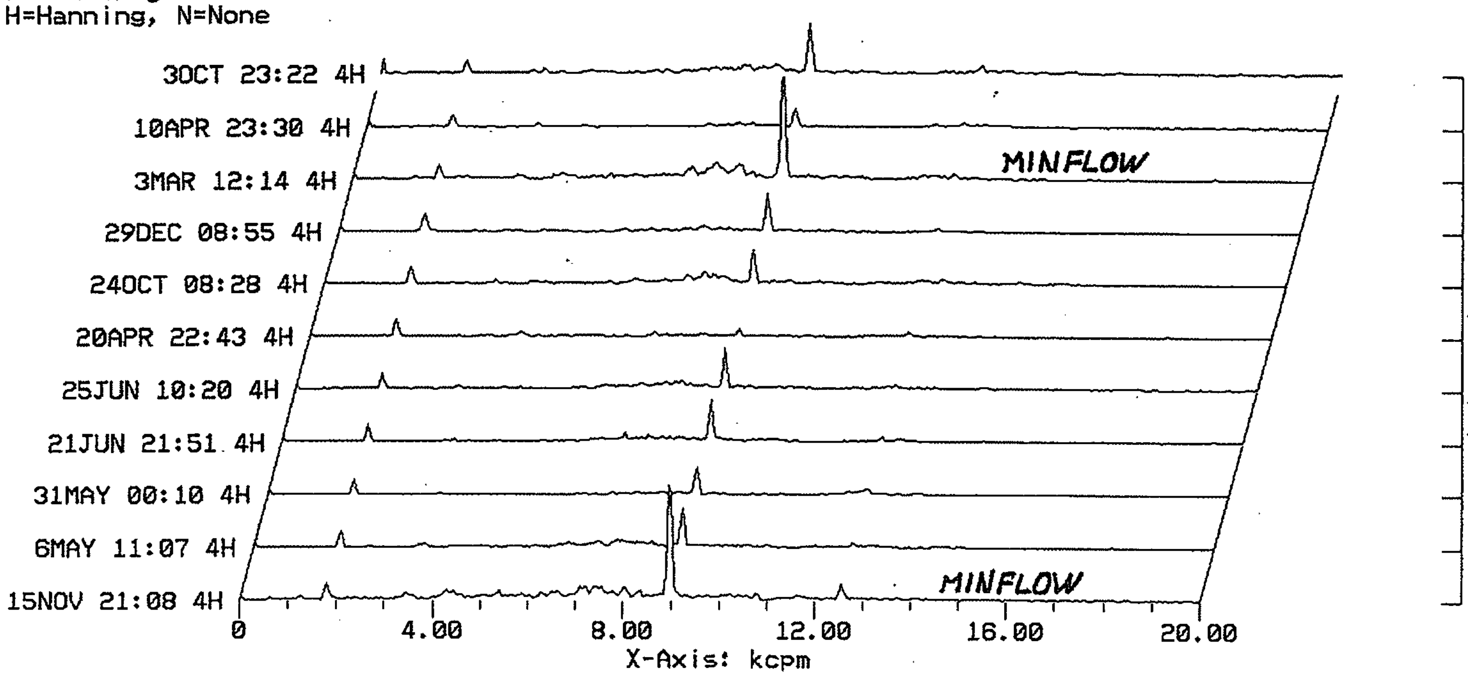
H=Hanning, N=None



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Plot:Spectrum Trend
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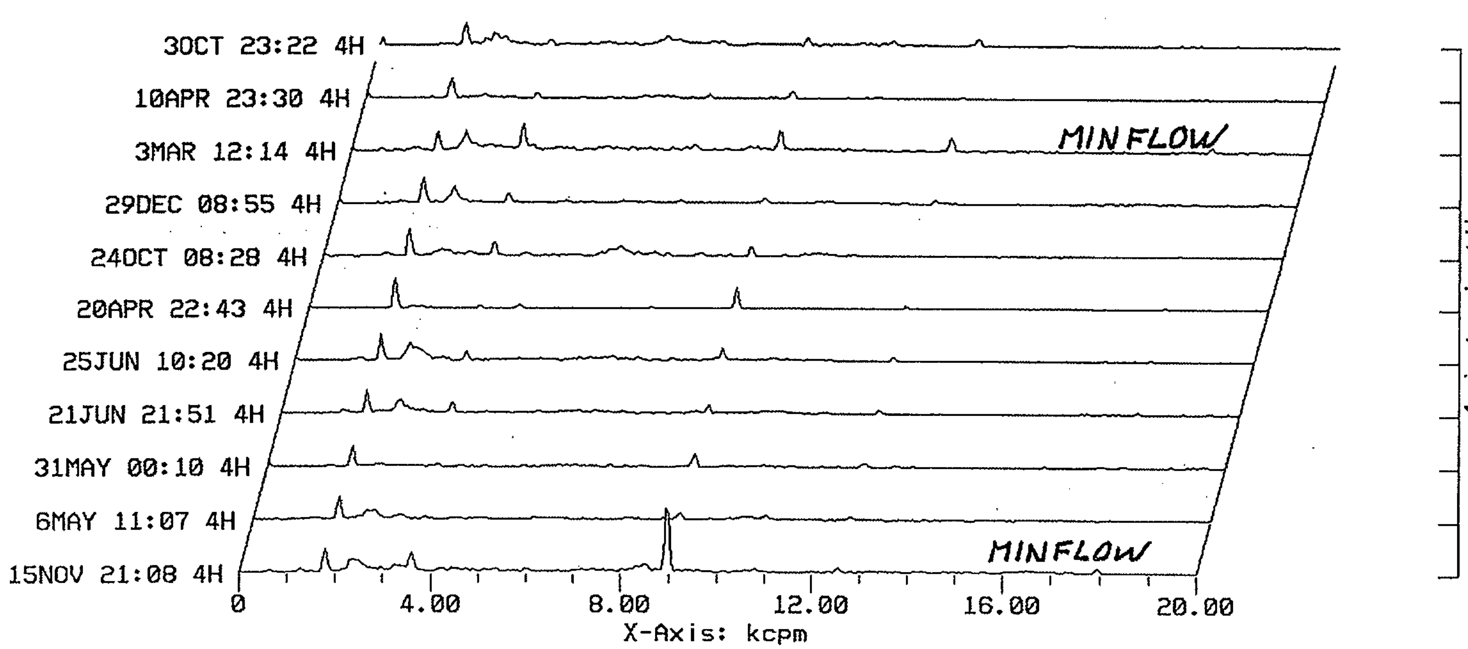
1-8=Averages
H=Hanning, N=None



BENTLY NEVADA SS+

PREDICTIVE MAINTENANCE - FPL/PSL

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Plot:Spectrum Trend
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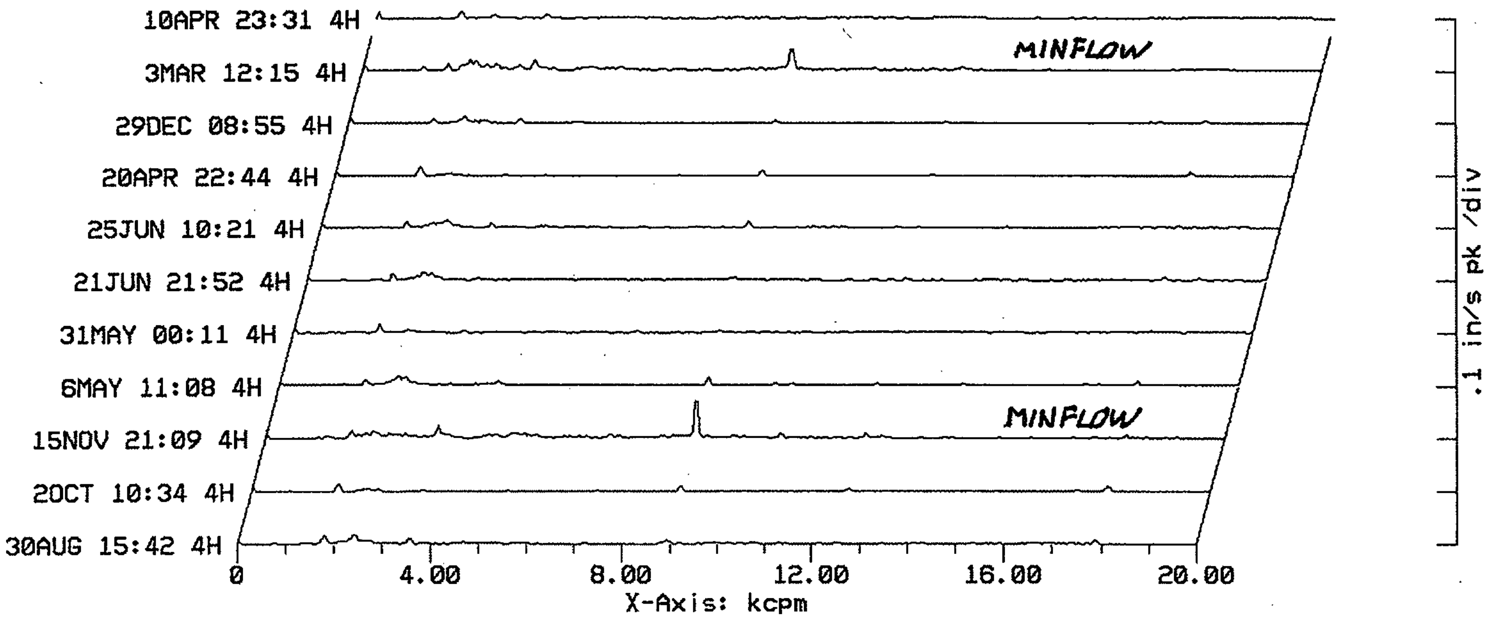
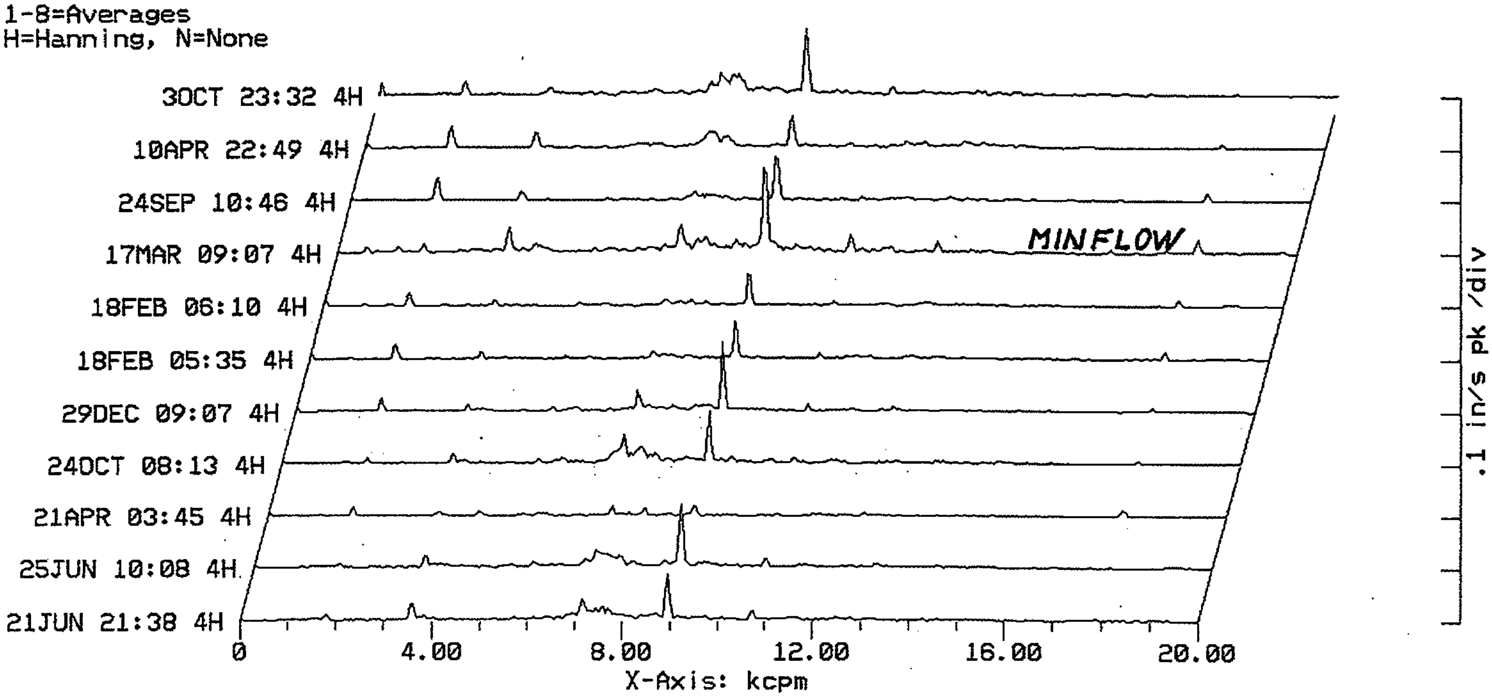
H=Hanning, N=None



BENTLY NEVADA SS+

PREDICTIVE MAINTENANCE - FPL/PSL

Plant:ST. LUCIE Train:SAFETY INJ
Plot:Spectrum Trend
Equip:1B LPSI PUMP Loc:3-YV 0deg
Begin: 21 JUN 96 21:38:54 End: 3 OCT 02 23:32:21
1-8=Averages
H=Hanning, N=None



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Plot:Spectrum Trend
Equip:1B LPSI PUMP Loc:3-XV 90deg
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1-8=Averages
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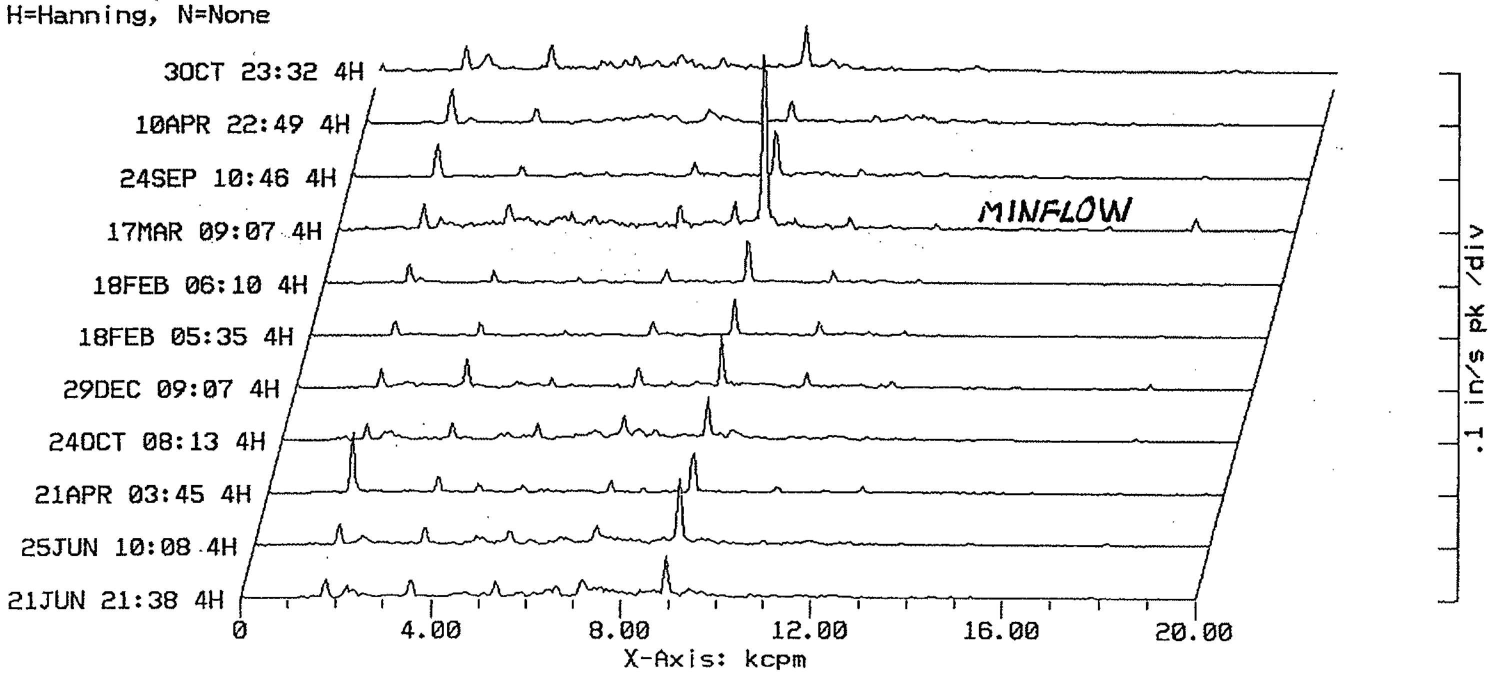

PREDICTIVE MAINTENANCE - FPL/PSL

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Plot:Spectrum Trend
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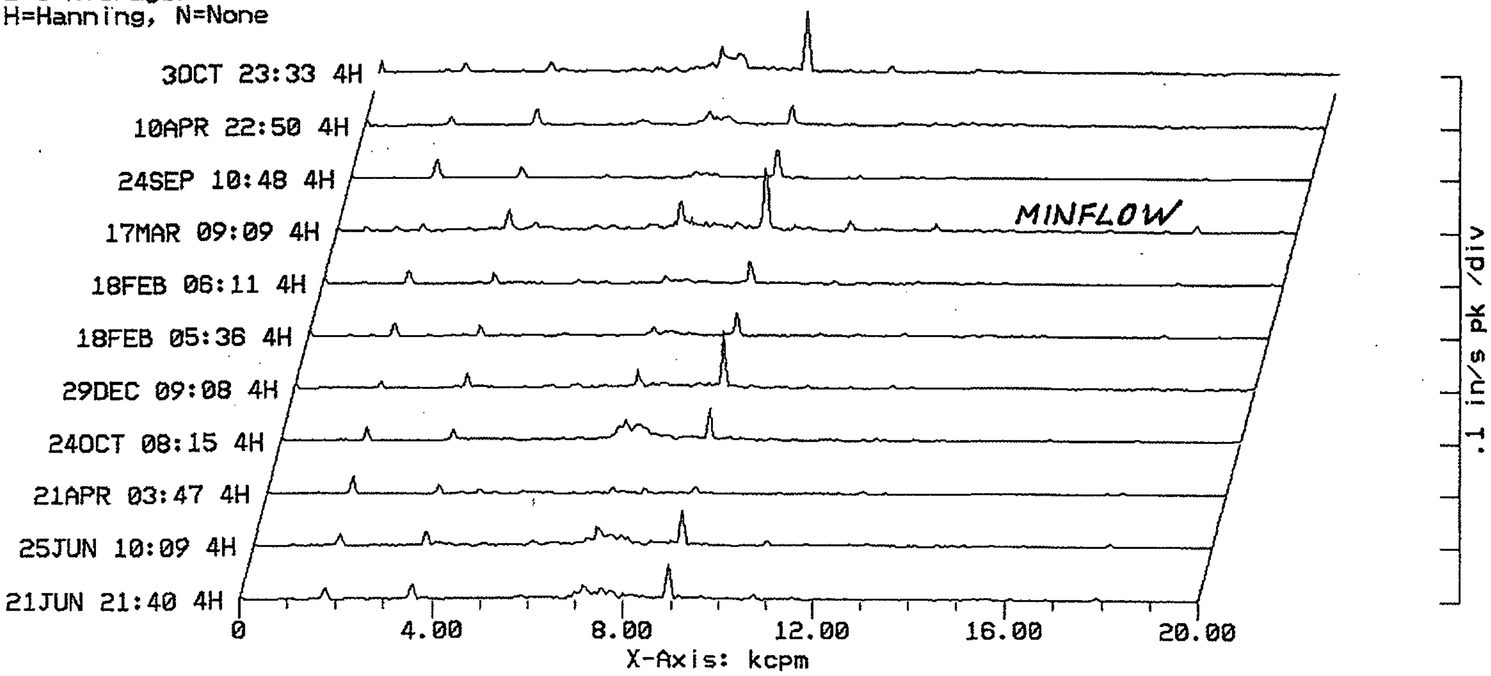

Plant:ST. LUCIE Train:SAFETY INJ
Plot:Spectrum Trend
Equip:1B LPSI PUMP Loc:4-XV 90deg
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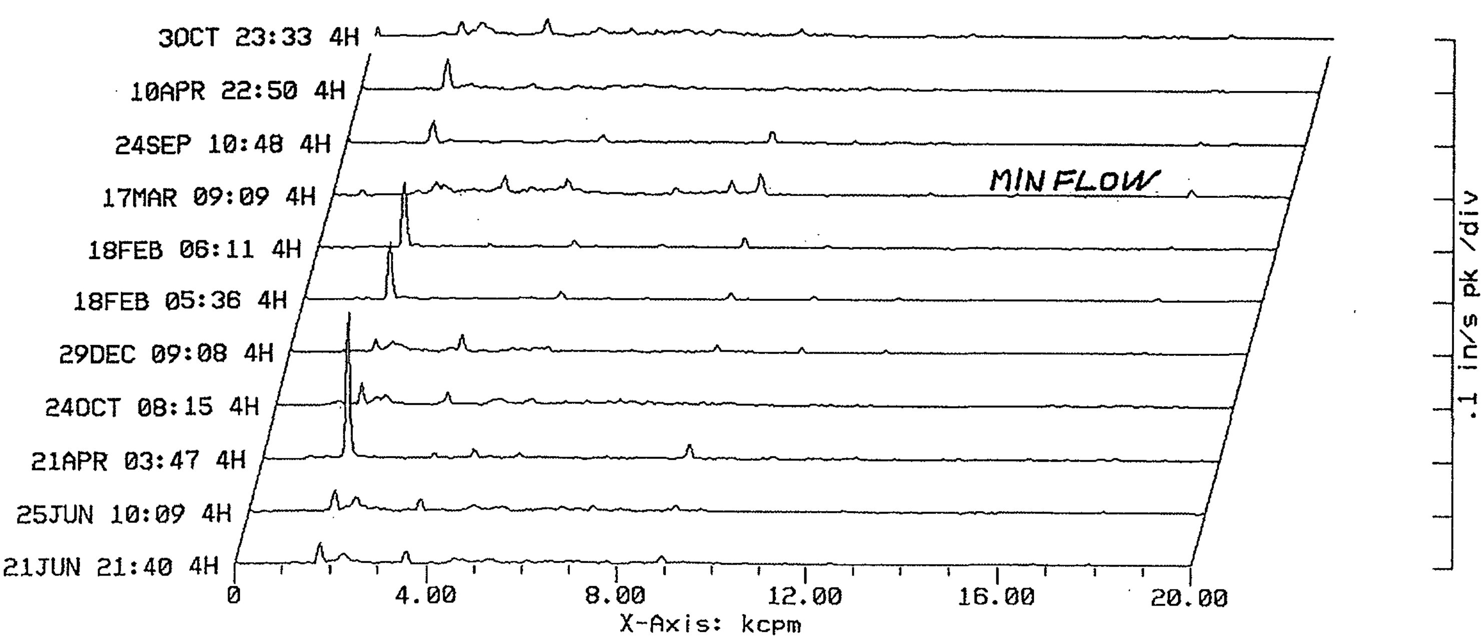
1-8=Averages
H=Hanning, N=None



PREDICTIVE MAINTENANCE - FPL/PSL

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Plot:Spectrum Trend
Equip:1B LPSI PUMP   Loc:4-AV   Axial
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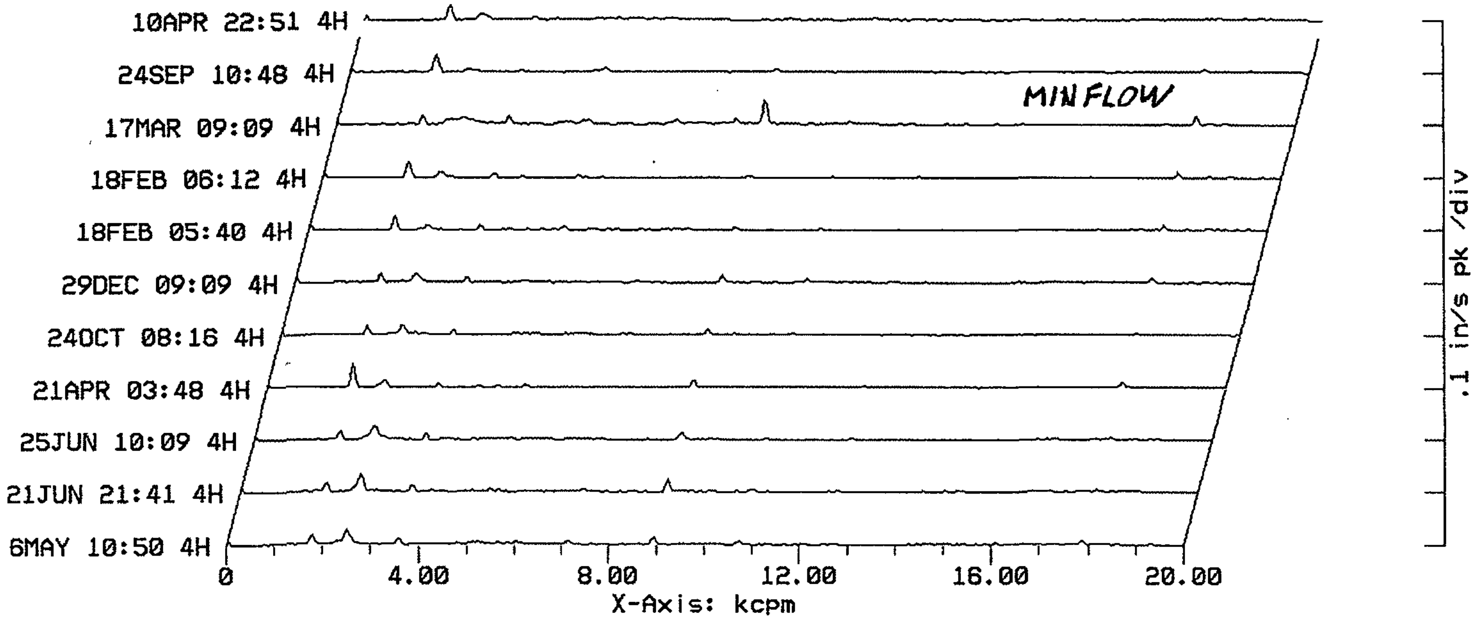
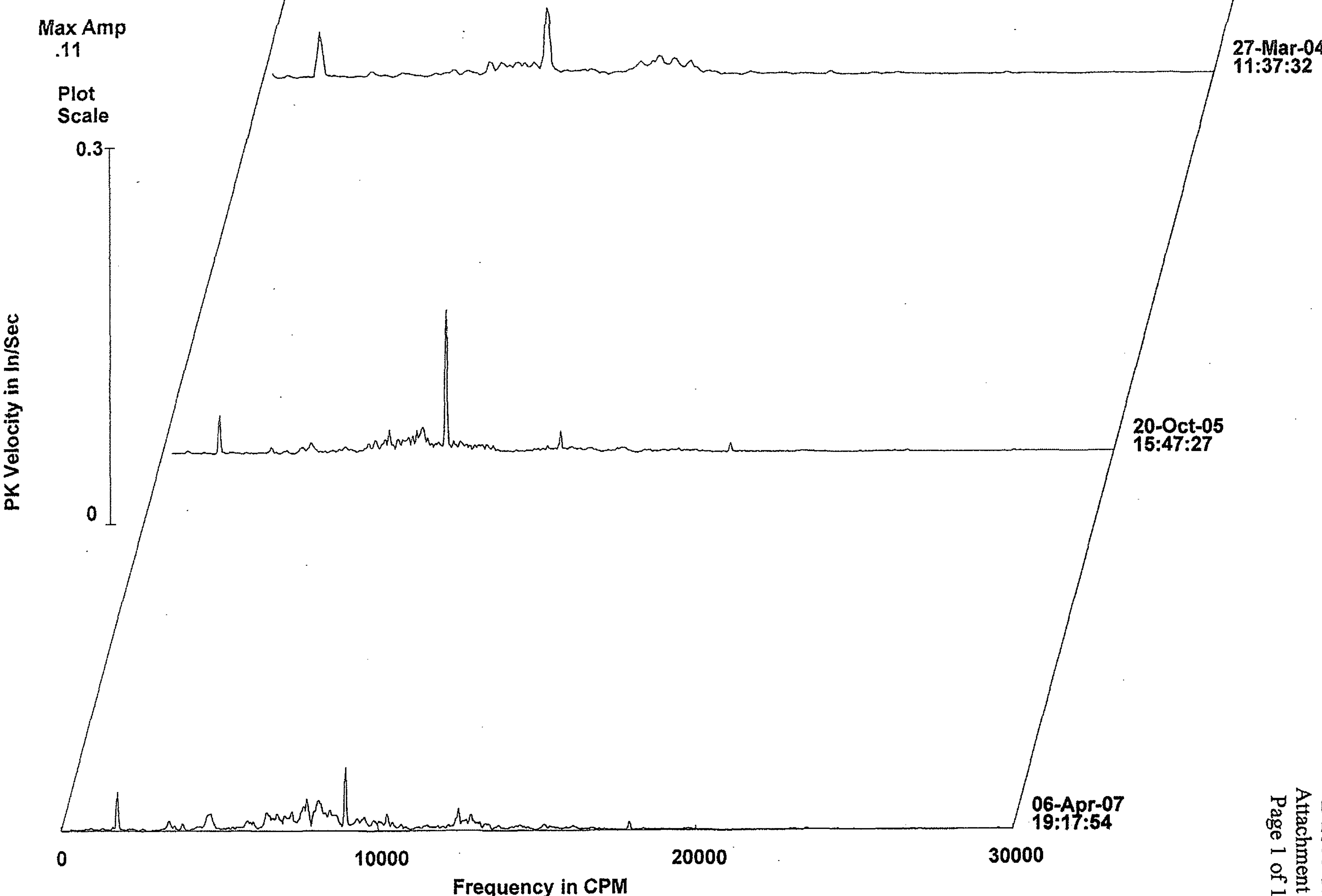
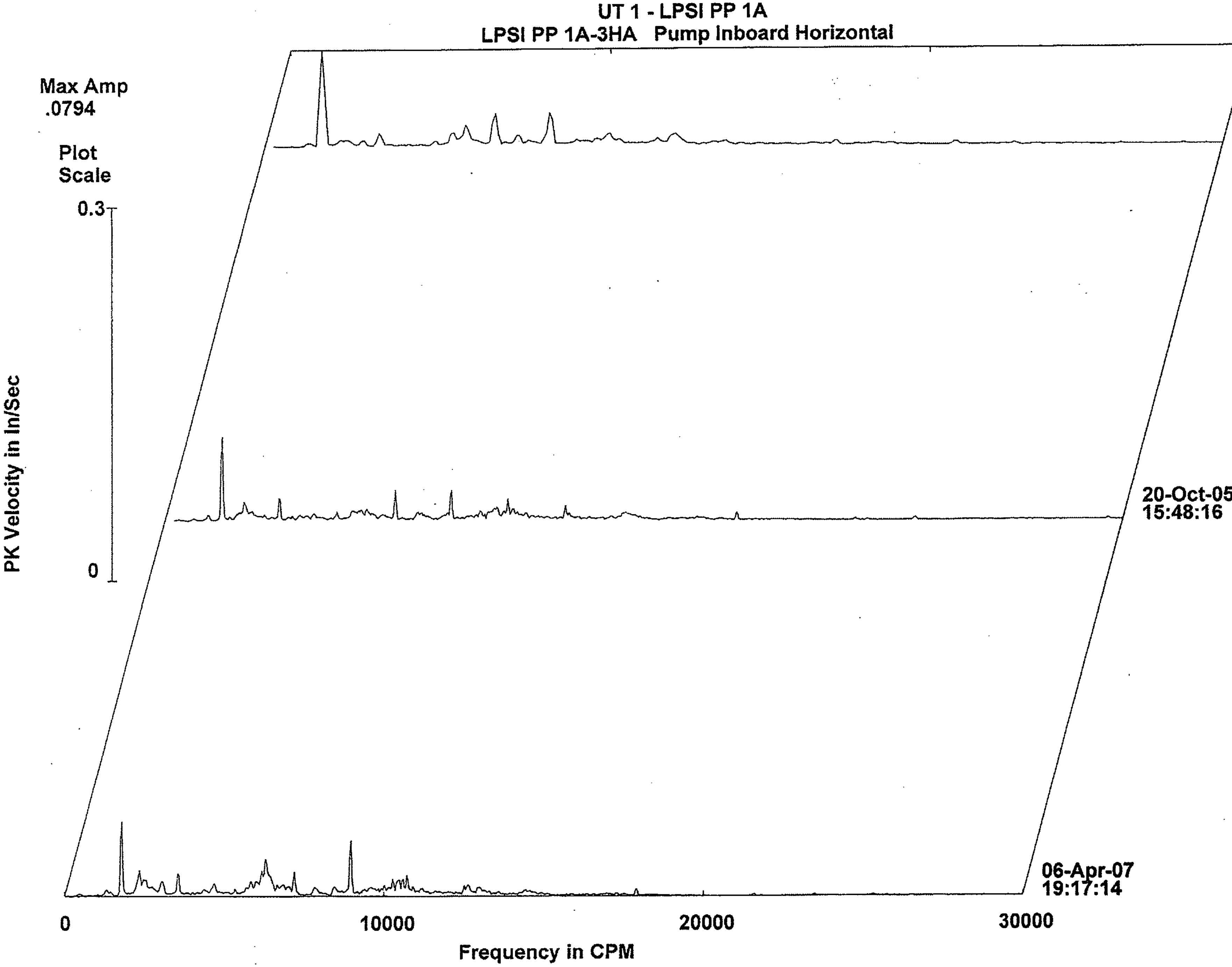


UT 1 - LPSI PP 1A
LPSI PP 1A-3VA Pump Inboard Vertical





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Attachment 4
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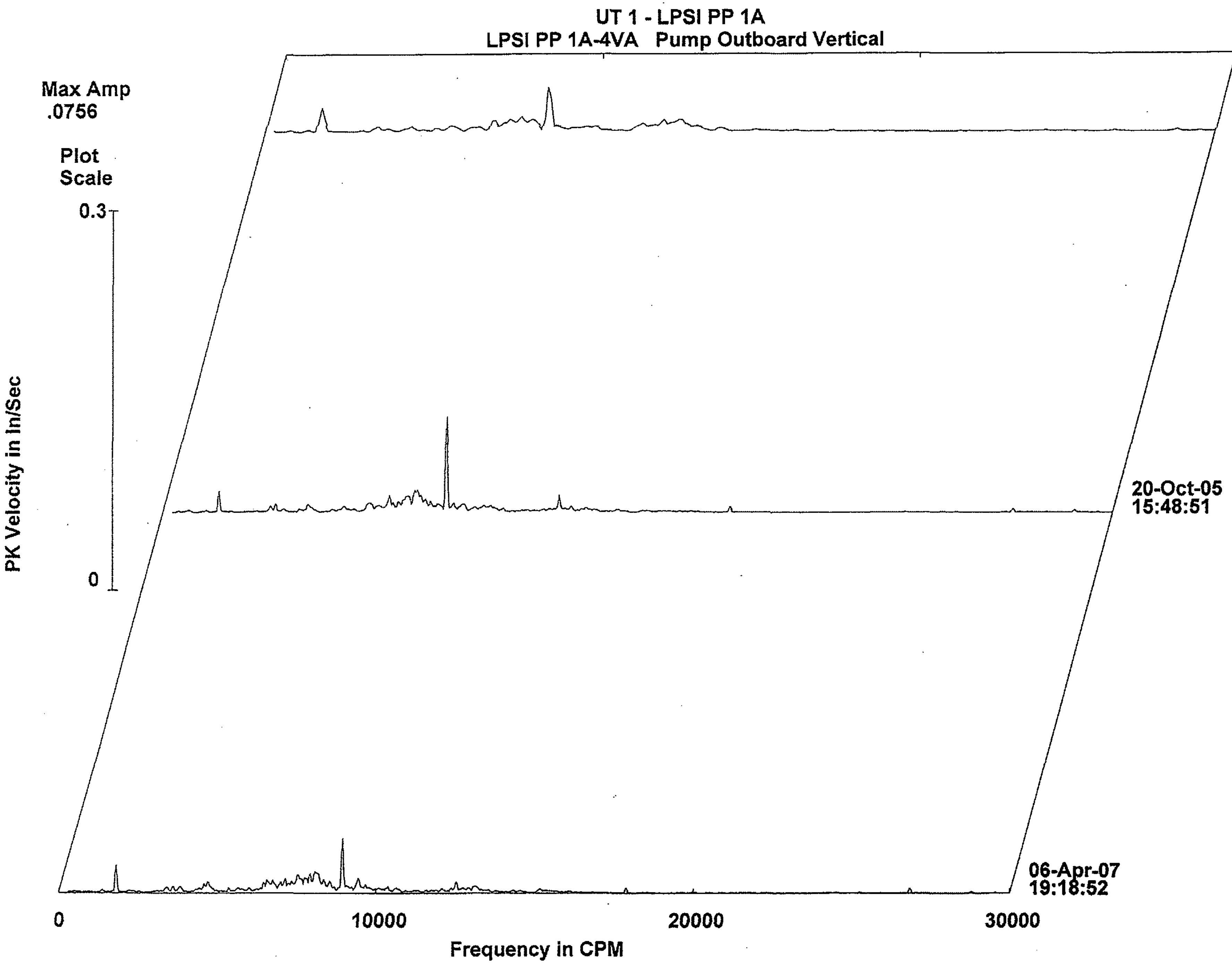
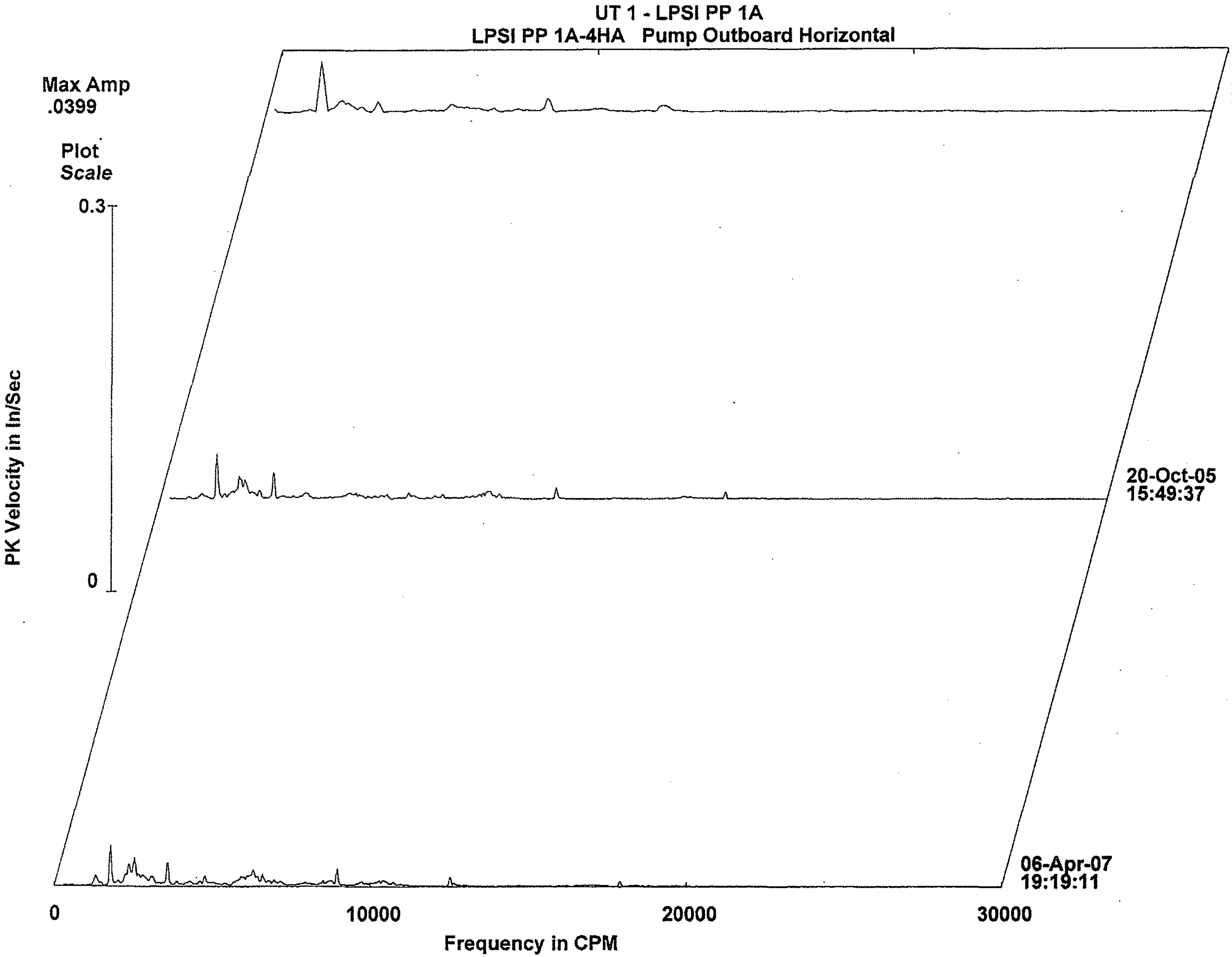

UT 1 - LPSI PP 1A
LPSI PP 1A-4VA Pump Outboard Vertical
Max Amp
.0756
Plot
Scale
0.3
0
PK Velocity in In/Sec
27-Mar-04
11:38:31
20-Oct-05
15:48:51
06-Apr-07
19:18:52
0
10000
20000
30000
Frequency in CPM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LPSI PP 1A-4HA Pump Outboard Horizontal
Max Amp
.0399
Plot
Scale
0.3
0
PK Velocity in In/Sec
27-Mar-04
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20-Oct-05
15:49:37
06-Apr-07
19:19:11
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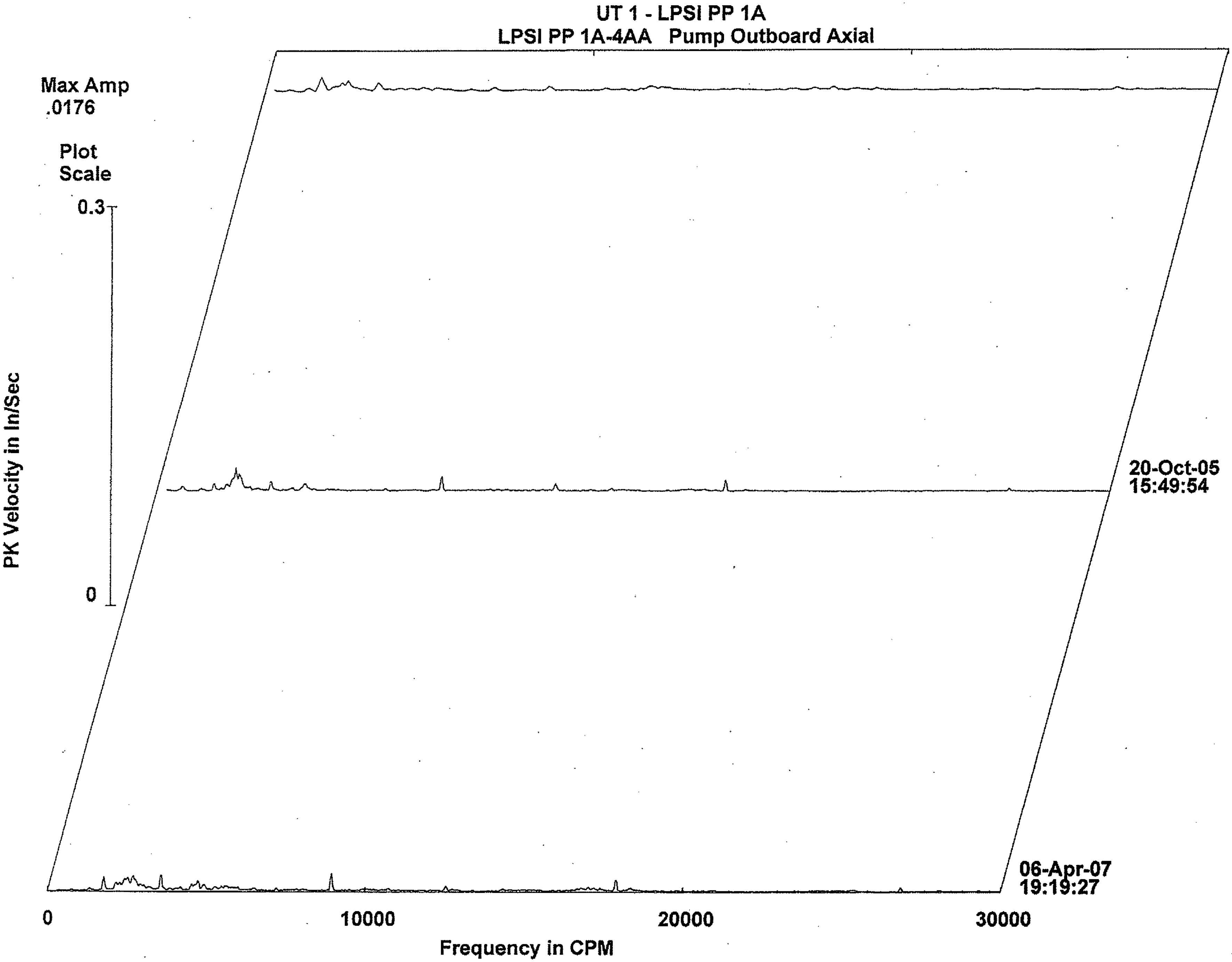
20000
30000
Frequency in CPM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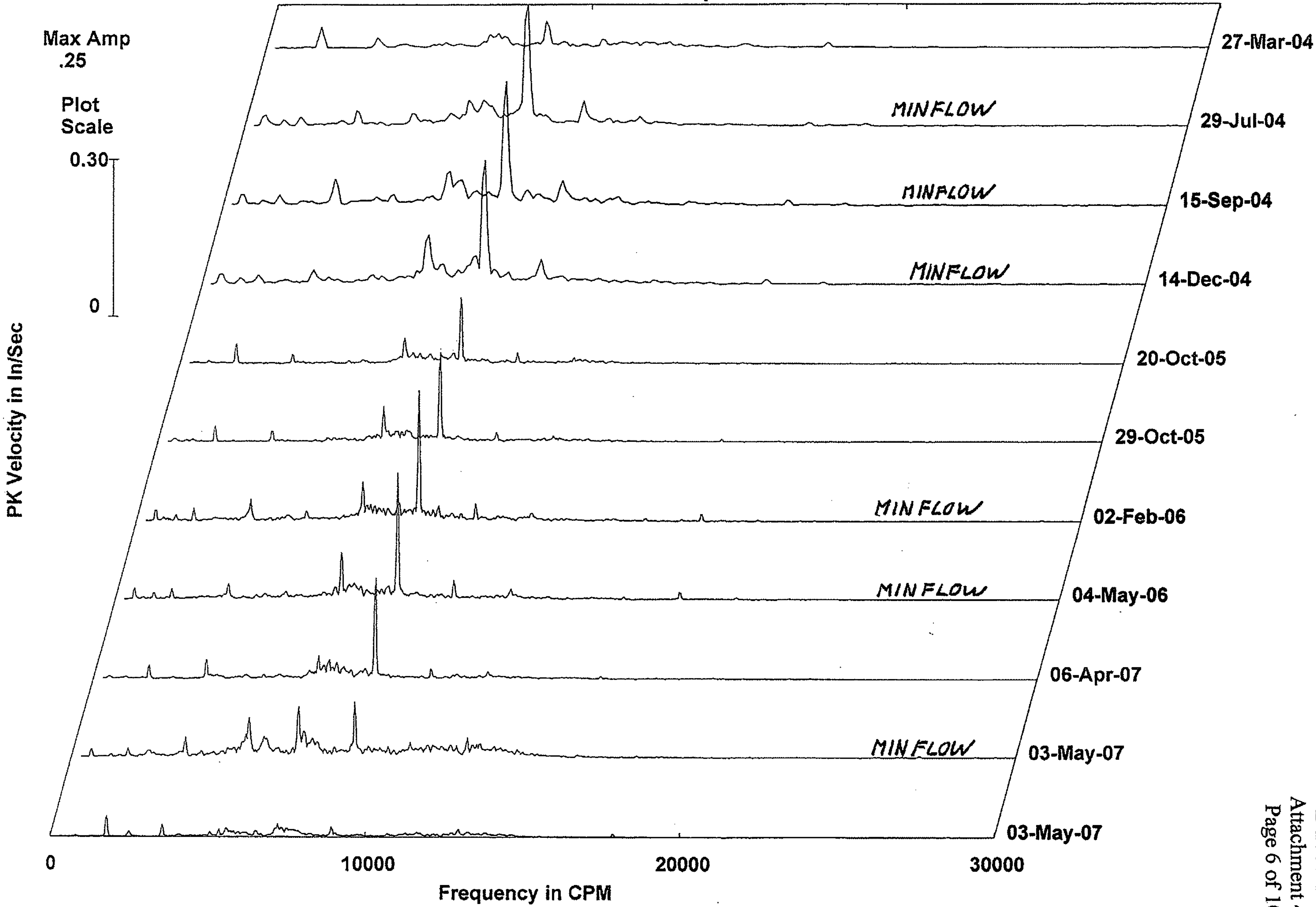
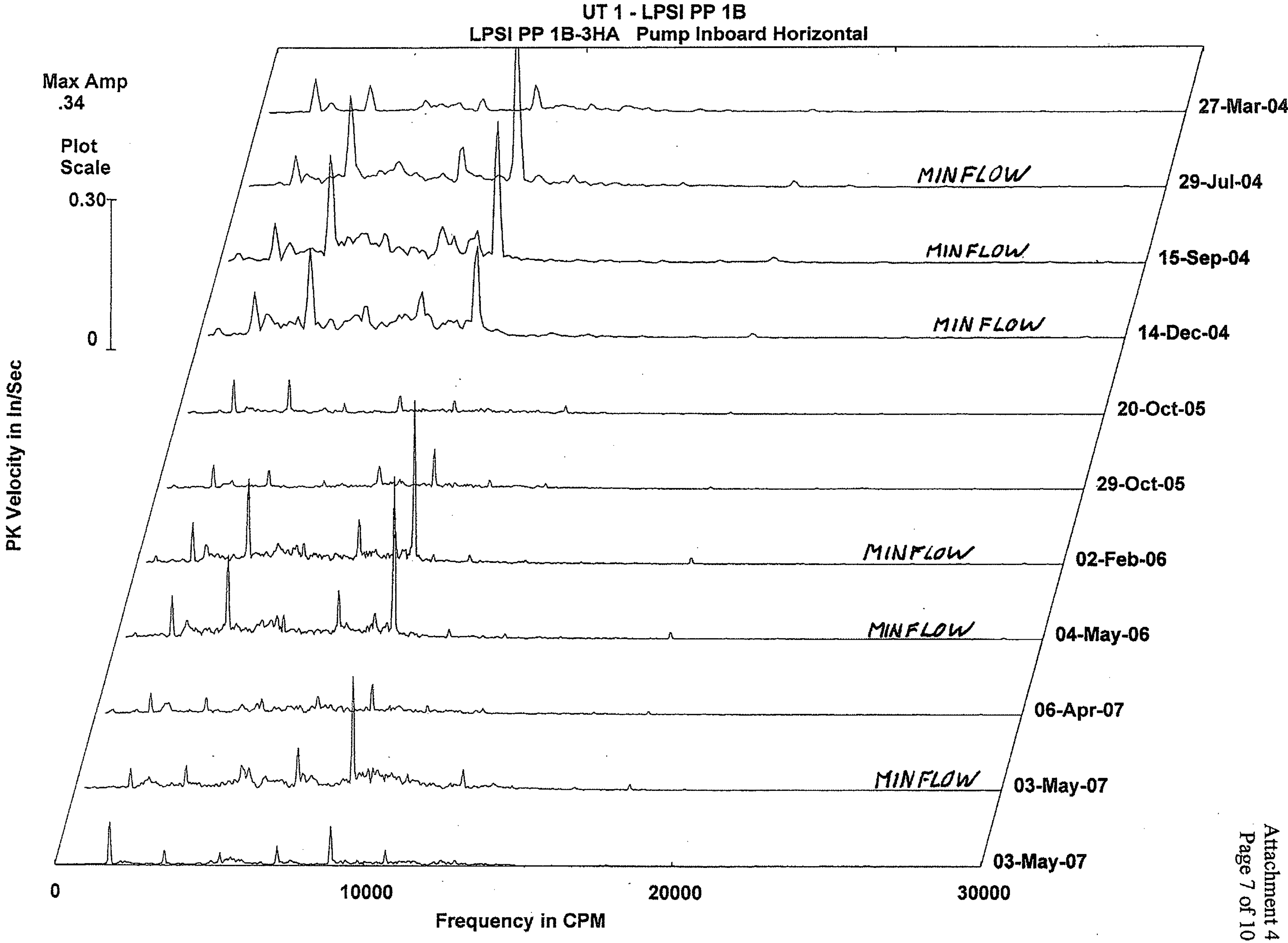
LPSI PP 1A-4AA Pump Outboard Axial
Max Amp
.0176
Plot
Scale
0.3
0
PK Velocity in In/Sec
27-Mar-04
11:39:02
20-Oct-05
15:49:54
06-Apr-07
19:19:27
0
10000
20000
30000
Frequency in CPM

UT 1 - LPSI PP 1B
LPSI PP 1B-3VA Pump Inboard Vertical

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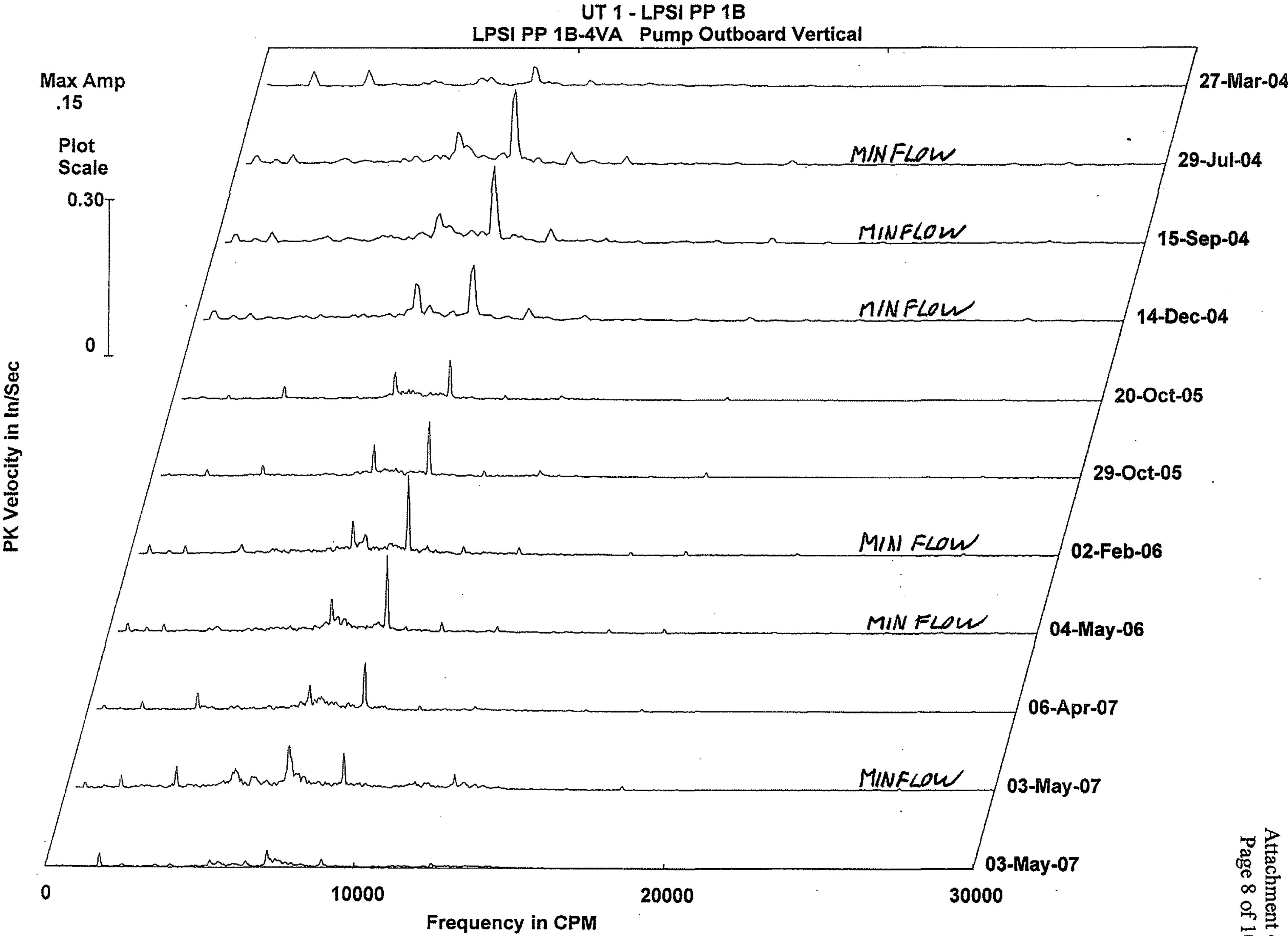
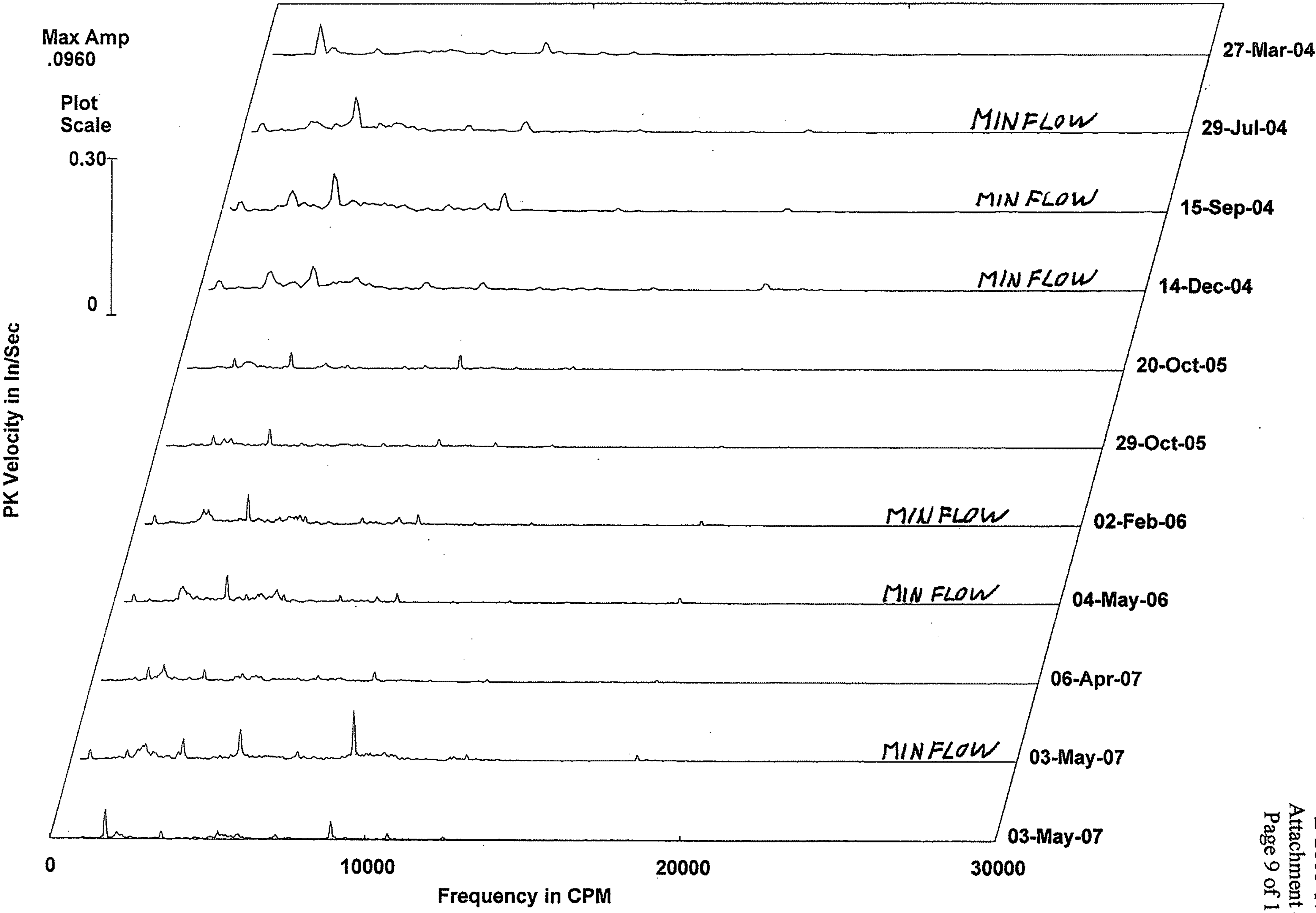
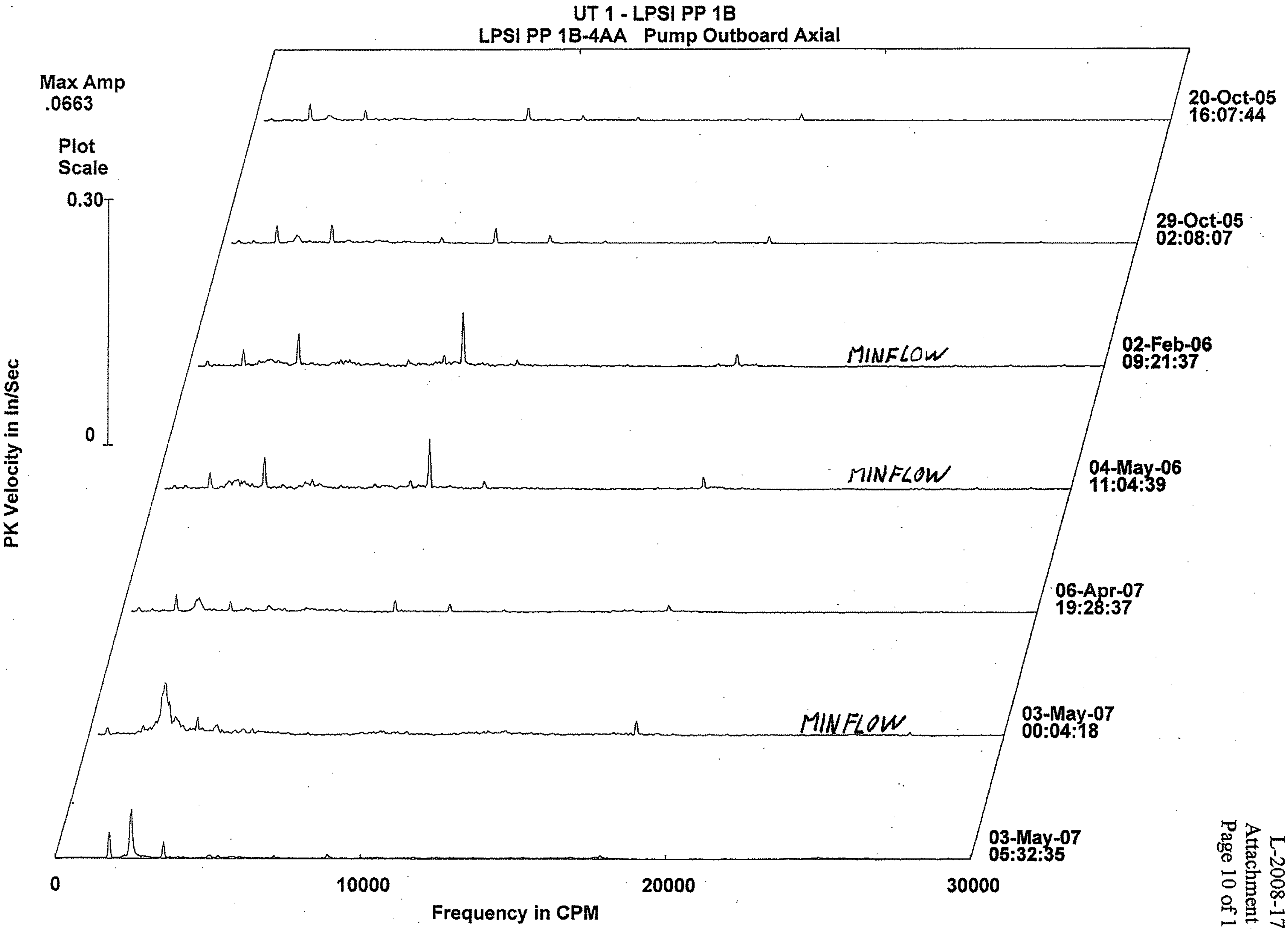
LPSI PP 1B-3HA Pump Inboard Horizontal
Max Amp
.34
Plot
Scale
0.30
0
PK Velocity in In/Sec
27-Mar-04
MINFLOW
29-Jul-04
MINFLOW
15-Sep-04
MIN FLOW
14-Dec-04
20-Oct-05
29-Oct-05
MINFLOW
02-Feb-06
MINFLOW
04-May-06
06-Apr-07
MINFLOW
03-May-07
03-May-07
0
10000
20000
30000
Frequency in CPM


UT 1 - LPSI PP 1B
LPSI PP 1B-4VA Pump Outboard Vertical
Max Amp
.15
Plot
Scale
0.30
0
PK Velocity in In/Sec
27-Mar-04
MINFLOW
29-Jul-04
MINFLOW
15-Sep-04
MINFLOW
14-Dec-04
20-Oct-05
29-Oct-05
MIN FLOW
02-Feb-06
MIN FLOW
04-May-06
06-Apr-07
MINFLOW
03-May-07
03-May-07
0
10000
20000
30000
Frequency in CPM

UT 1 - LPSI PP 1B
LPSI PP 1B-4HA Pump Outboard Horizontal




UT 1 - LPSI PP 1B
LPSI PP 1B-4AA Pump Outboard Axial
Max Amp
.0663
Plot
Scale
0.30
0
PK Velocity in In/Sec
20-Oct-05
16:07:44
29-Oct-05
02:08:07
MINFLOW
02-Feb-06
09:21:37
MINFLOW
04-May-06
11:04:39
06-Apr-07
19:28:37
MINFLOW
03-May-07
00:04:18
03-May-07
05:32:35
0
10000
20000
30000
Frequency in CPM