

Four Vibration Case Histories

Barry T. Cease
Cease Industrial Consulting
ceasevibration@icloud.com
(843) 200-9705

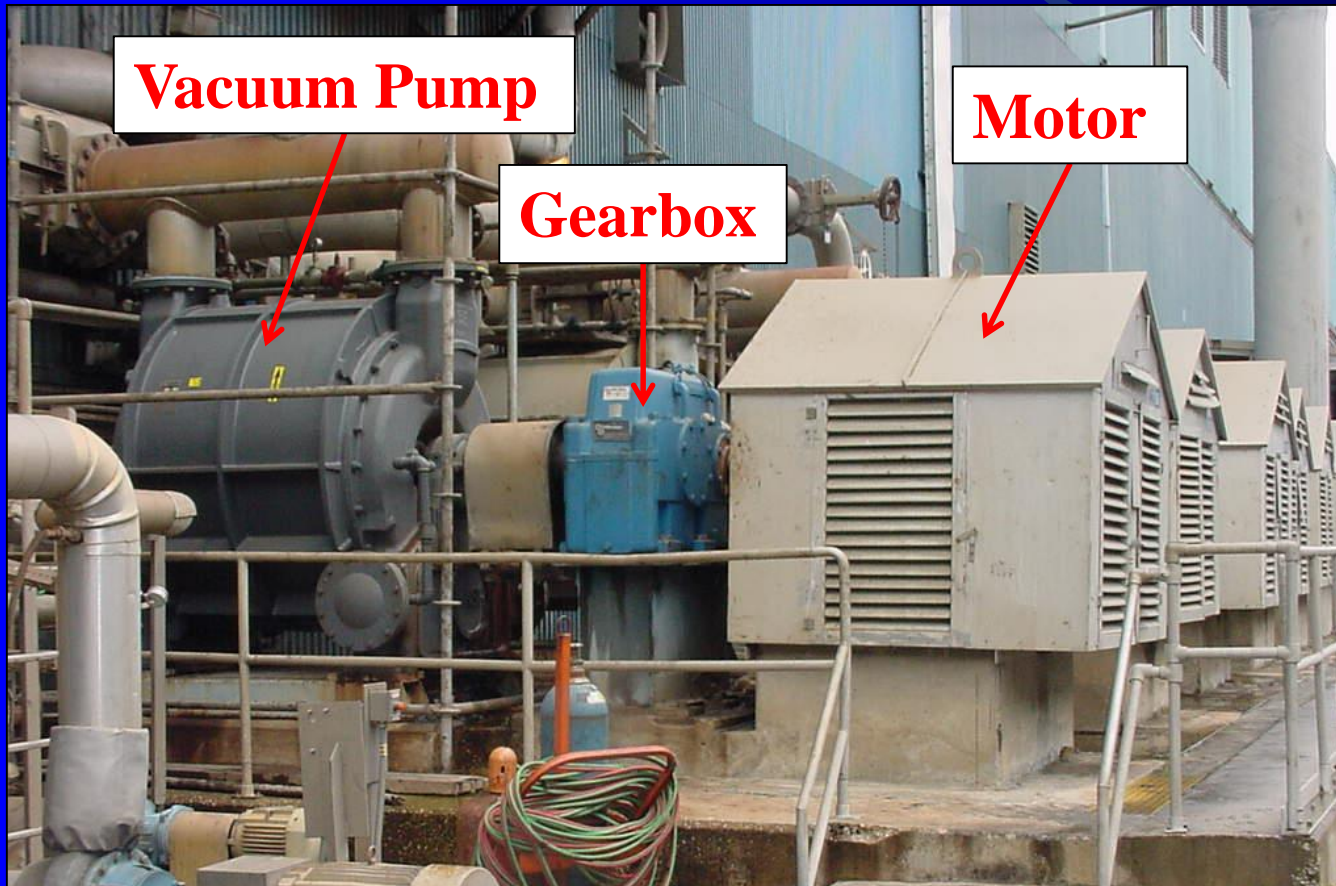
Introduction

- Case History#1 – Excessive vibration of motor
- Case History#2 – Strange motor & gearbox vibration
- Case History#3 – Repeat fan bearing failures
- Case History#4 – Pump bearing cage failure

Case History#1, Excessive Vibration Of Motor

- EQUIPMENT: 700 HP synchronous motor driving a Nash 9000 series vacuum pump through a single reduction, parallel gearbox.
- The vacuum pump was one of many used to pull water out of the paper (dry it) as it moves thru the process.

CH#1 – Equipment Layout



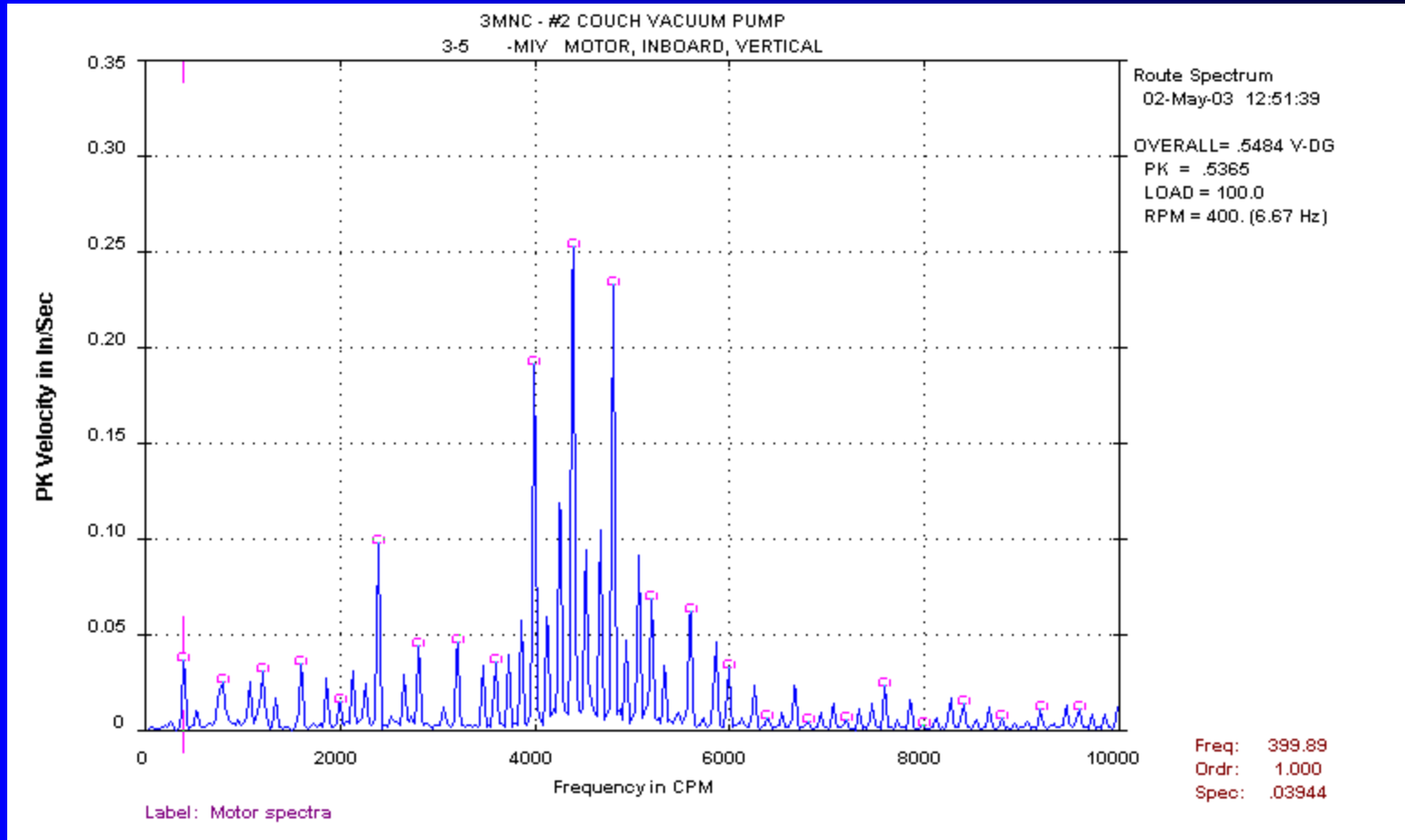
CH#1 - Problem

- Excessive & noisy vibration at the motor.
- This problem could be heard & felt clearly at the motor.
- It sounded like something was rubbing and/or loose.

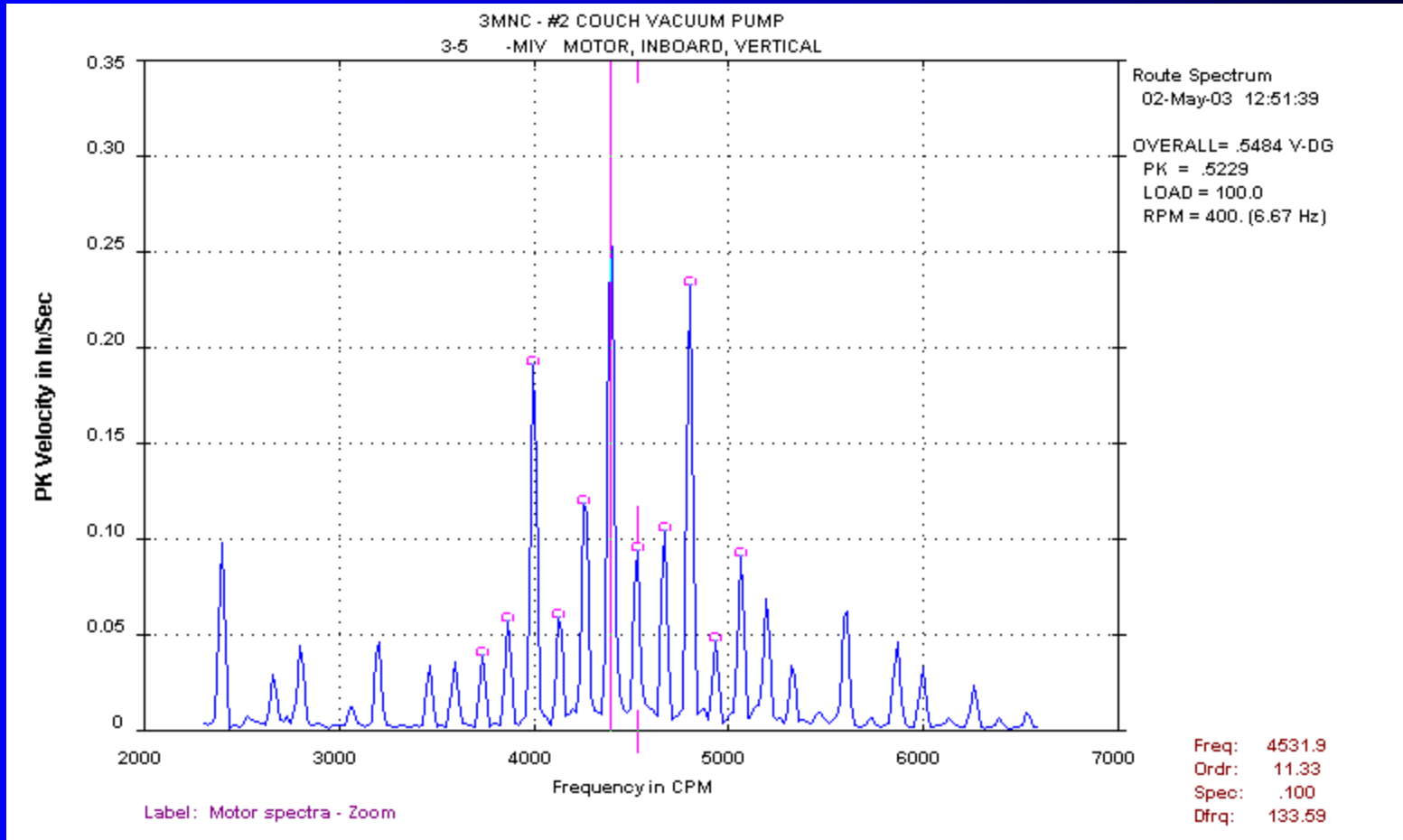
CH#1 – Test Data & Observations (Motor)

- Motor speed was exactly 400 rpm.
- Pump speed was 267 rpm.
- Pump vibration data showed no abnormal patterns or levels.
- Motor spectra showed many harmonics of running speed and of 133 cpm (1/3 x rpm).
- Motor waveform showed impacting at 400 & 133 cpm.

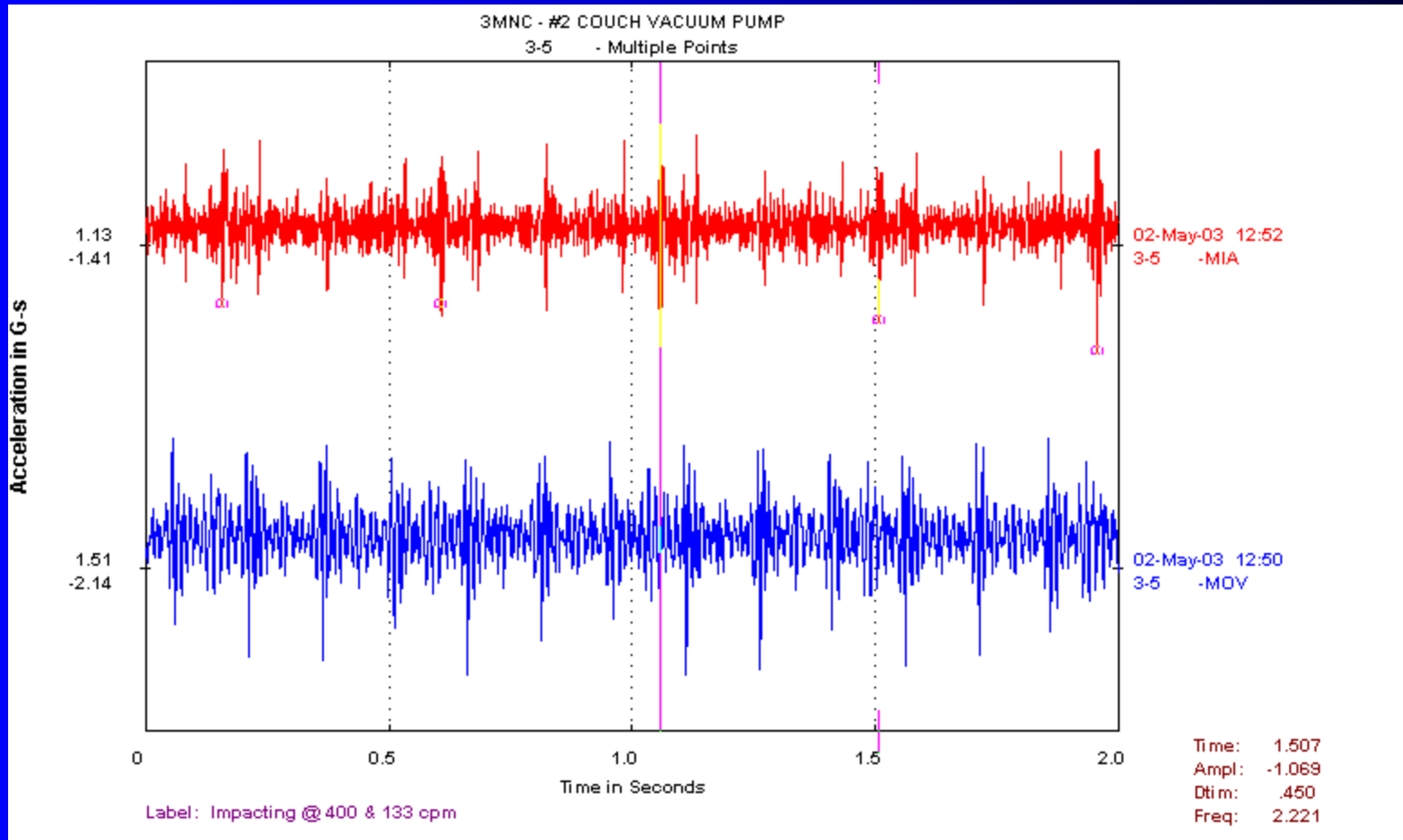
CH#1 - Motor Spectra



CH#1 – Motor Spectra Zoom



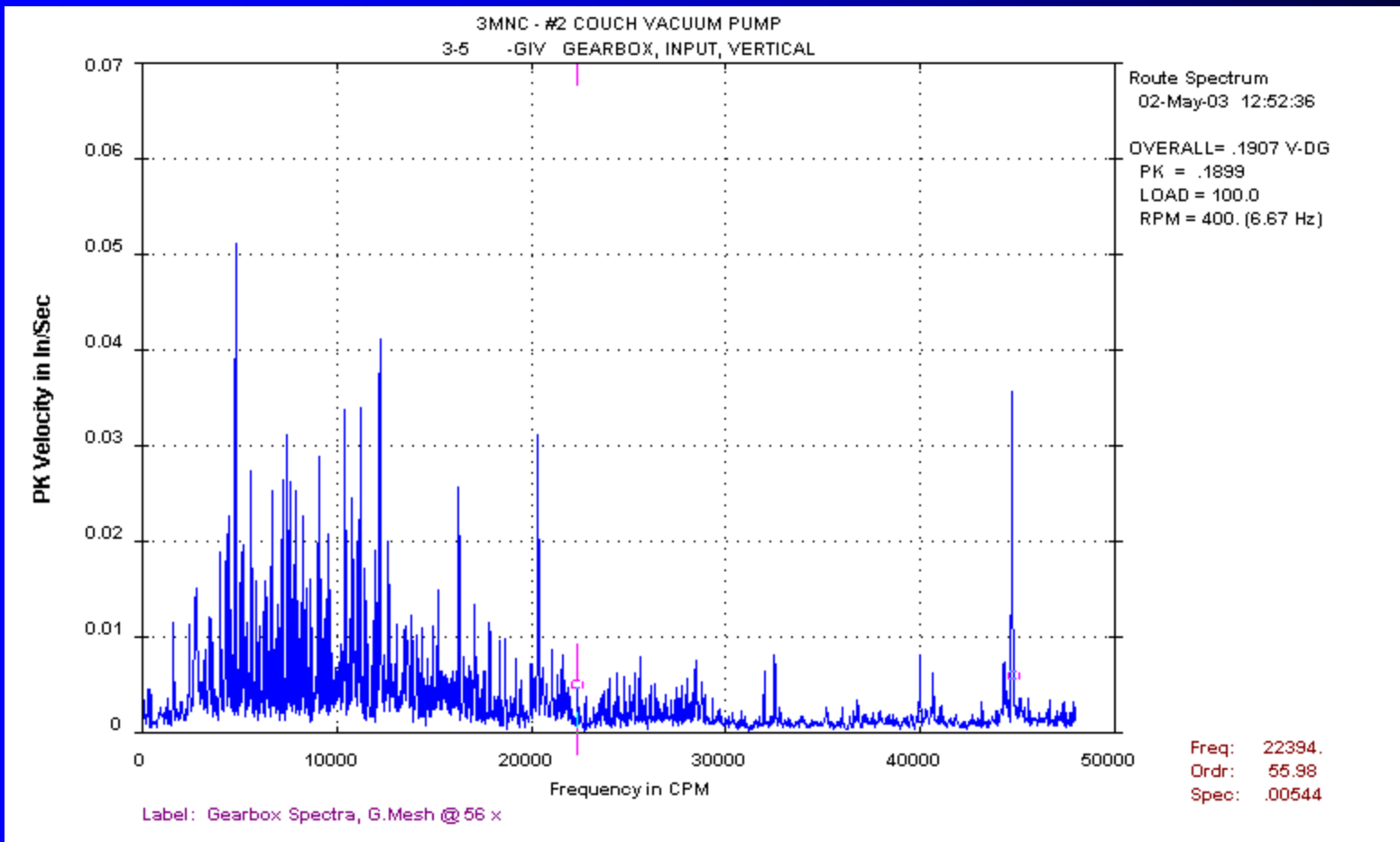
CH#1 – Motor Waveform



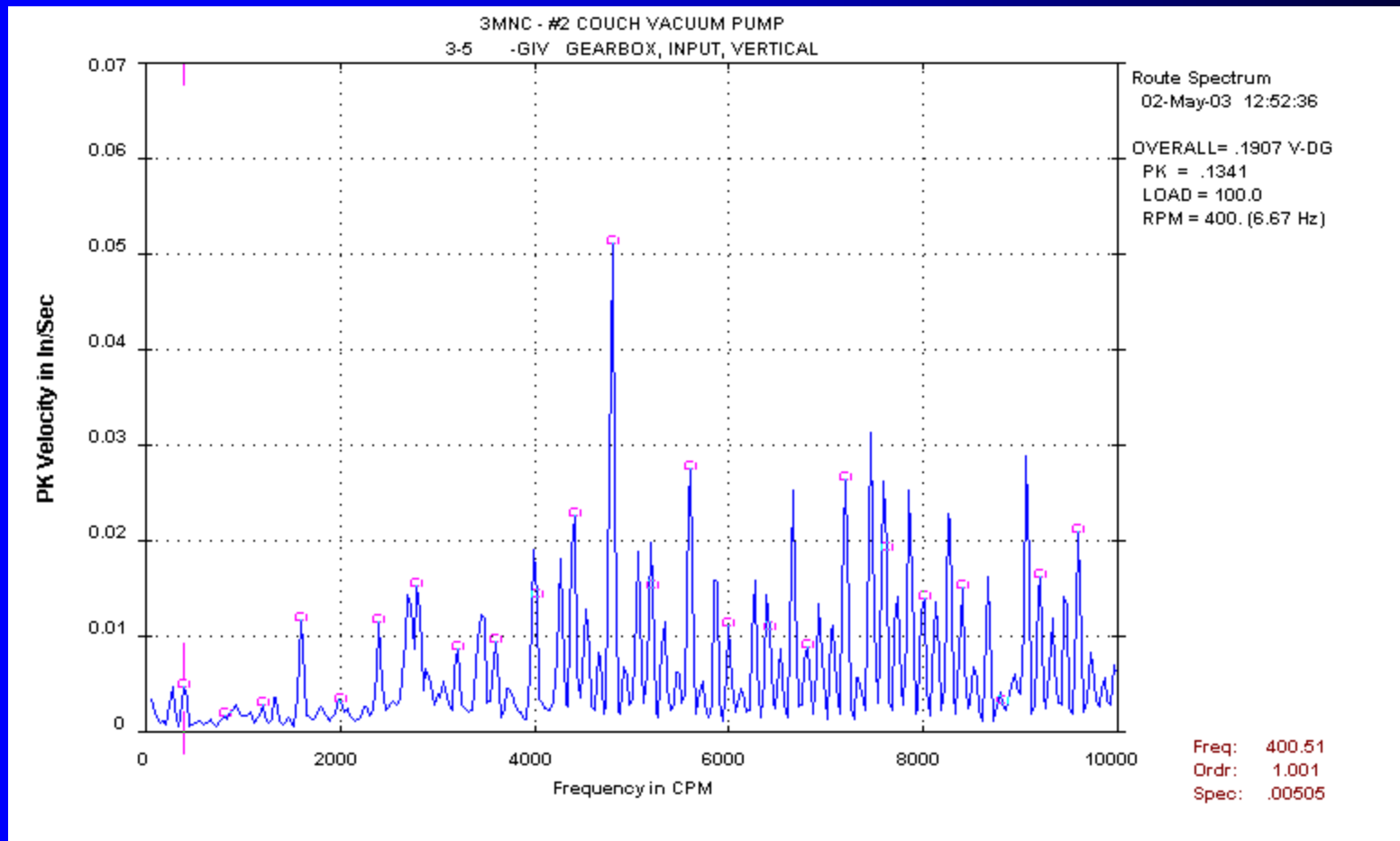
CH#1 – Test Data & Observations (Gearbox)

- Gearbox input speed was 400 rpm.
- Gearbox output speed was 267 rpm (1.5:1 ratio and 56T/84T).
- Gearbox spectra showed many harmonics of both input & output speed and 133 cpm (1/2 x output).
- Gearbox spectra didn't show high gearmesh frequency at 22,400 cpm.
- Gearbox waveform showed heavy impacting at 400 cpm.
- Gearbox Peakvue data showed many harmonics of 400 cpm.

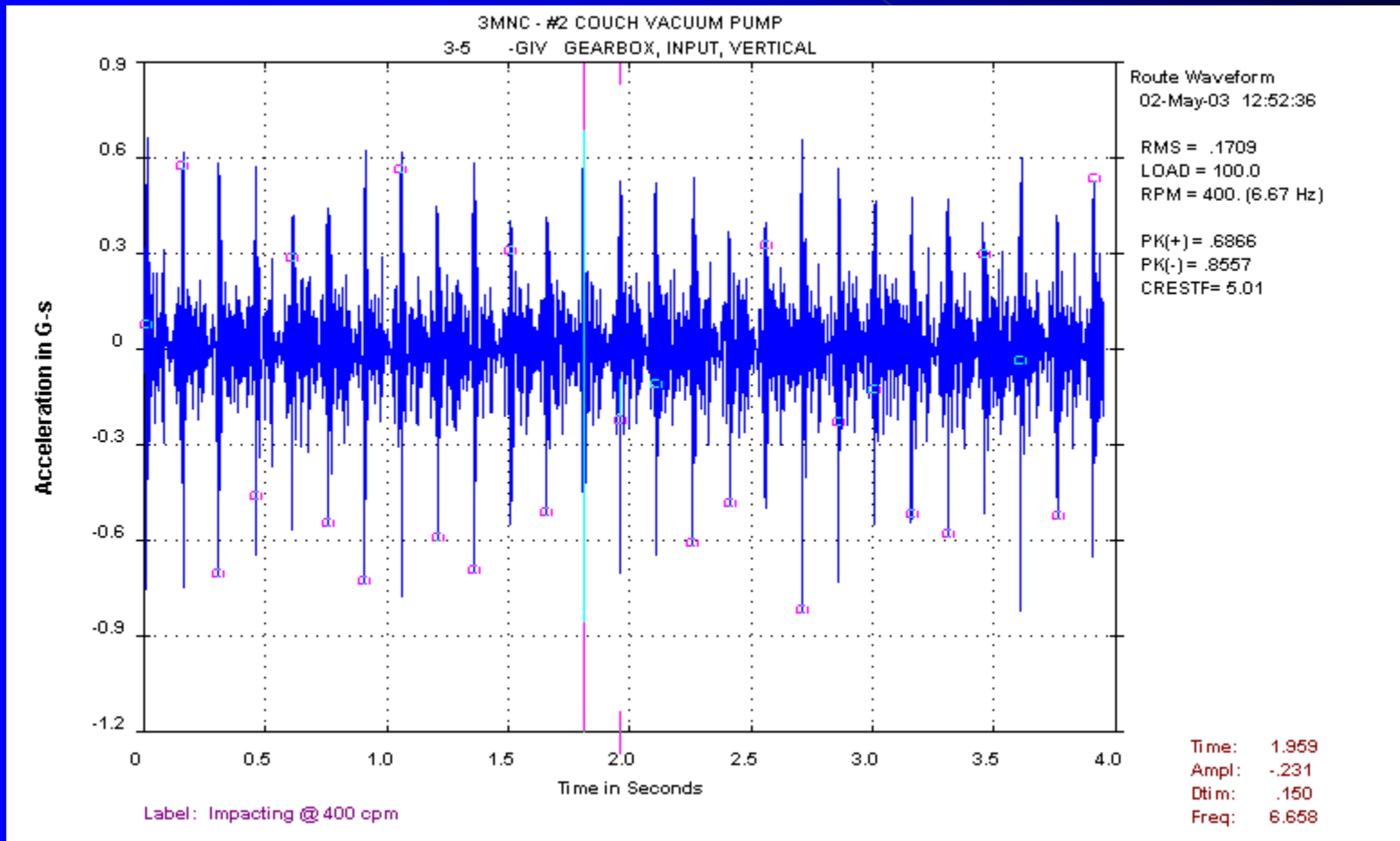
CH#1 – Gearbox Spectra



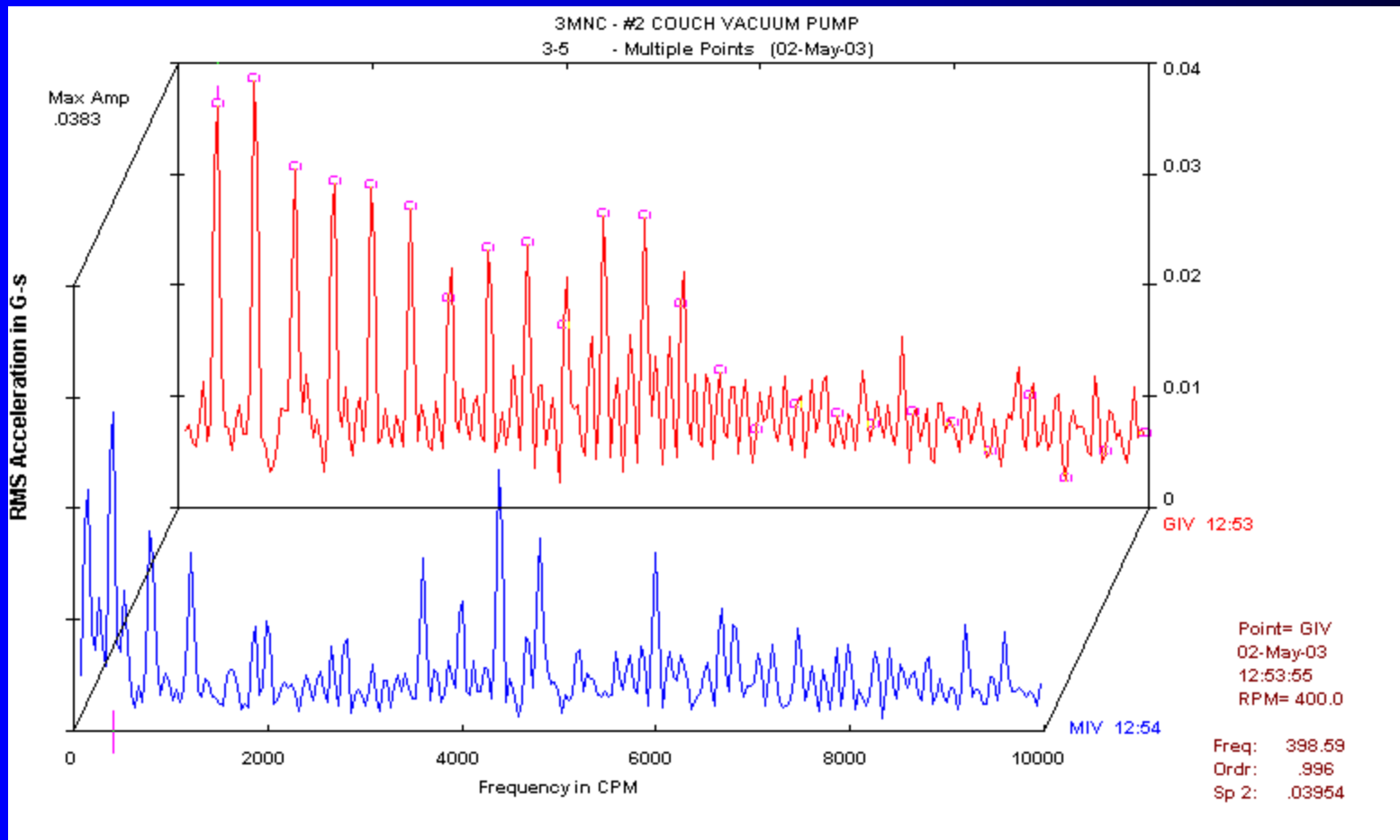
CH#1 – Gearbox Spectra Zoom



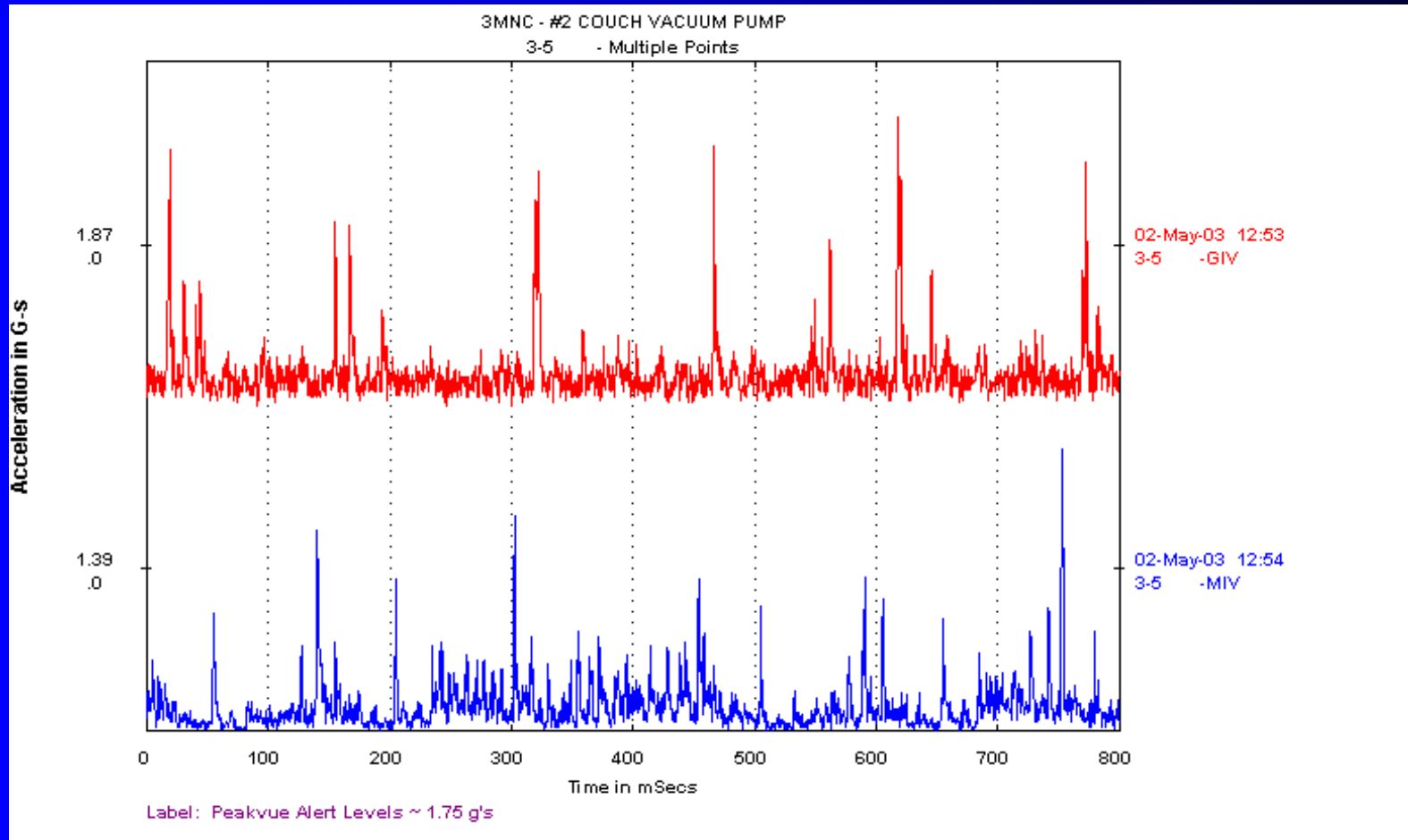
CH#1 – Gearbox Waveform



CH#1 – Peakvue Spectra



CH#1 – Peakvue Waveform



CH#1 – Maintenance History

- The motor was changed out in 7/02 and the gearbox was changed in 8/02.
- After motor change in 7/02, motor vibration levels initially dropped, but eventually resumed previous levels.
- The gearbox installed in 8/02 had been used before, but was the only spare available at the time.

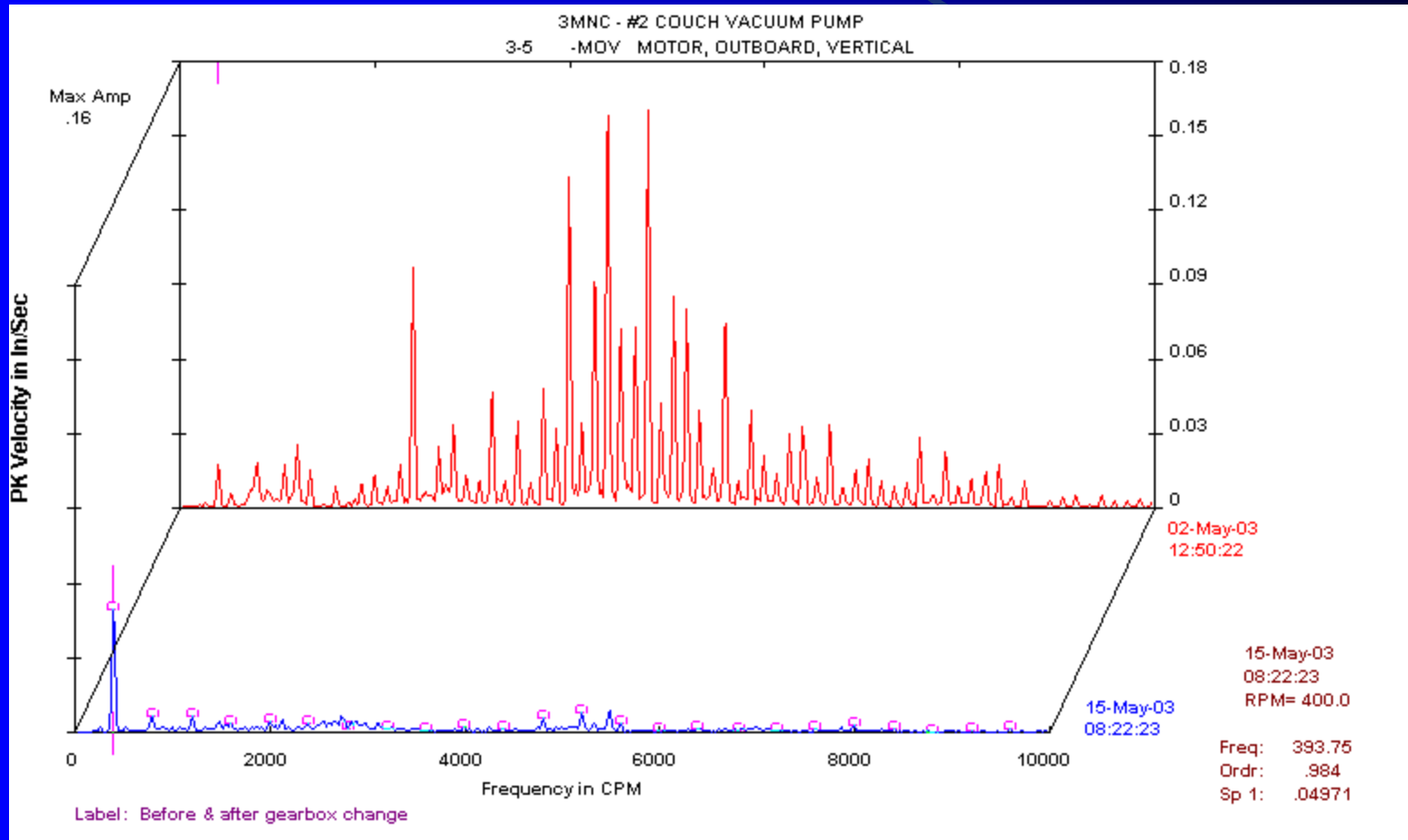
CH#1 – Conclusions & Recommendations

- It was recommended that the gearbox be changed out when possible due to a probable gear fault.
- The gearbox was changed in 5/03.
- An inspection of the gearbox showed many gear teeth broken off on the pinion gear with significant wear on both gears.
- Follow-up data on both machines after the gearbox change showed much lower vibration levels – the problem vanished.

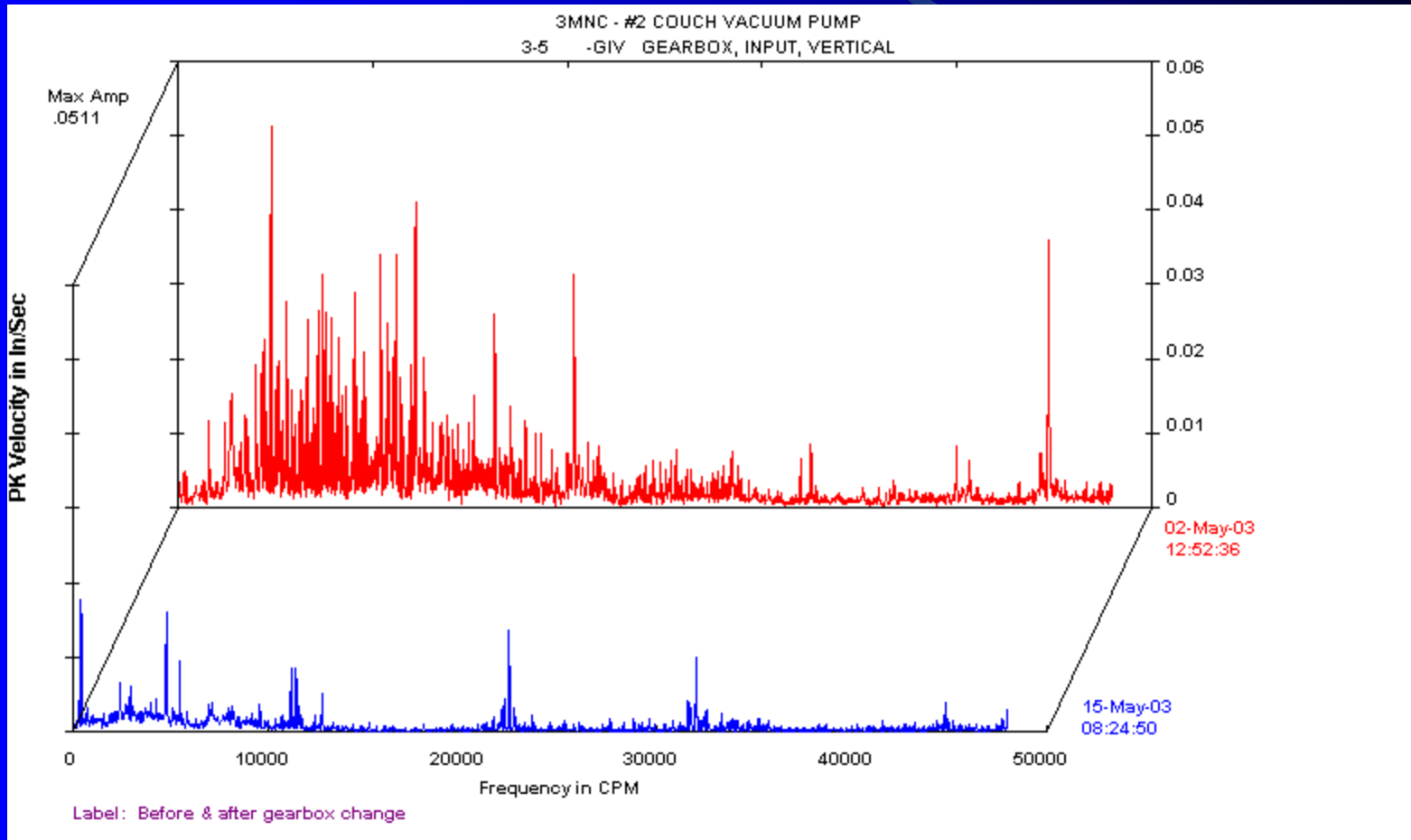
CH#1 – Gearbox Inspection



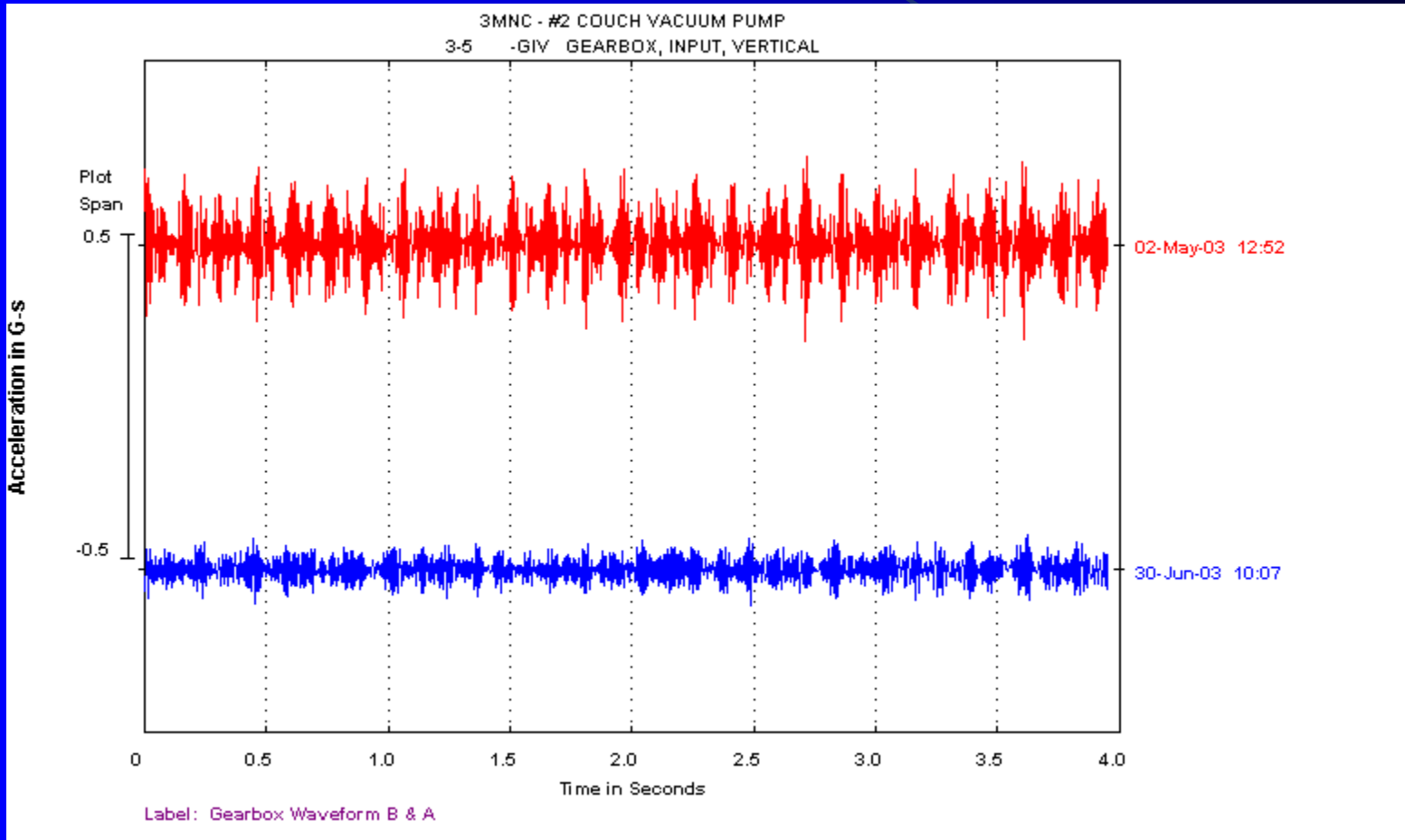
CH#1 – Motor Data, B & A



CH#1 – Gearbox Spectra, B & A



CH#1 – Gearbox Wave, B & A



Case History#2, Strange Motor & Gearbox Vibration

- EQUIPMENT: Agitator driven thru single reduction, parallel gearbox by an induction motor.
- This agitator helps maintain the consistency of the stock in a hydra-pulper tank.

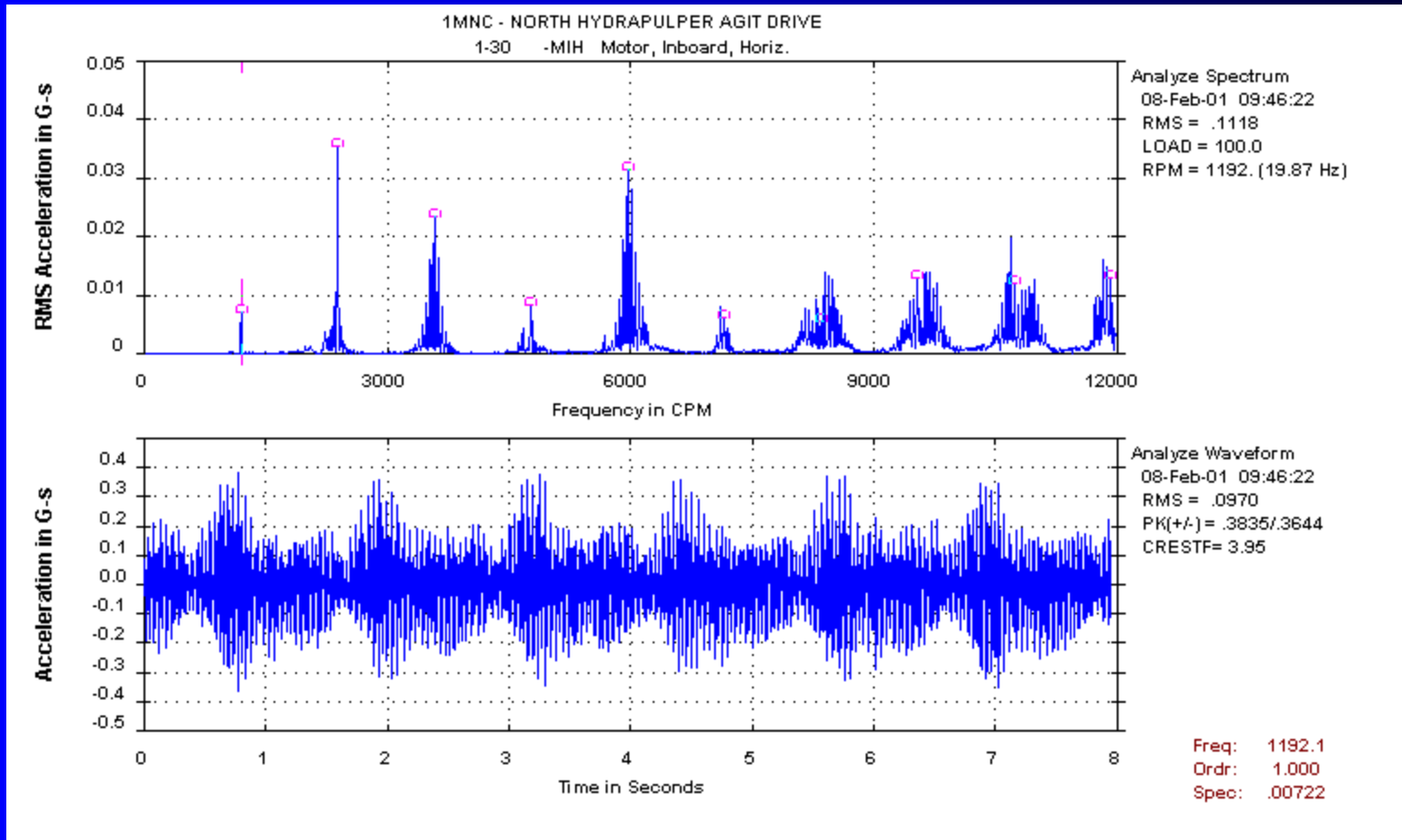
CH#2 - Problem

- Strange pulsing noise coming from motor & gearbox.

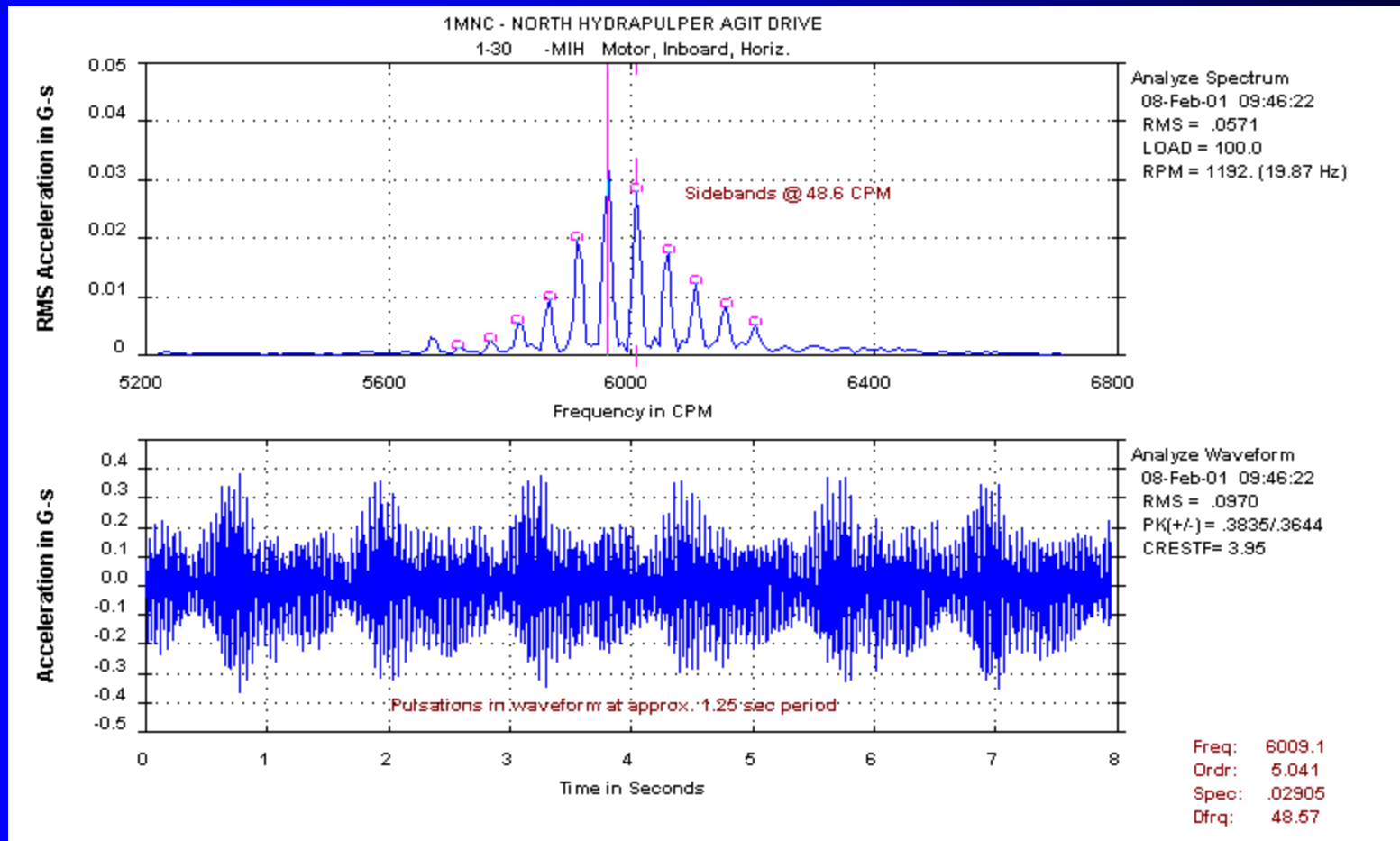
CH#2 – Test Data & Observations (Motor)

- Motor speed was exactly 1192 rpm.
- Agitator speed was 236 rpm (5:1 ratio).
- Motor spectra showed many harmonics of running speed & closer inspection showed 48 cpm sidebands around each harmonic.
- Motor waveform showed pulsations or modulation at a period of approx. 1.25 sec or 48 cpm.

CH#2 – Motor Data



CH#2 - Motor Zoom



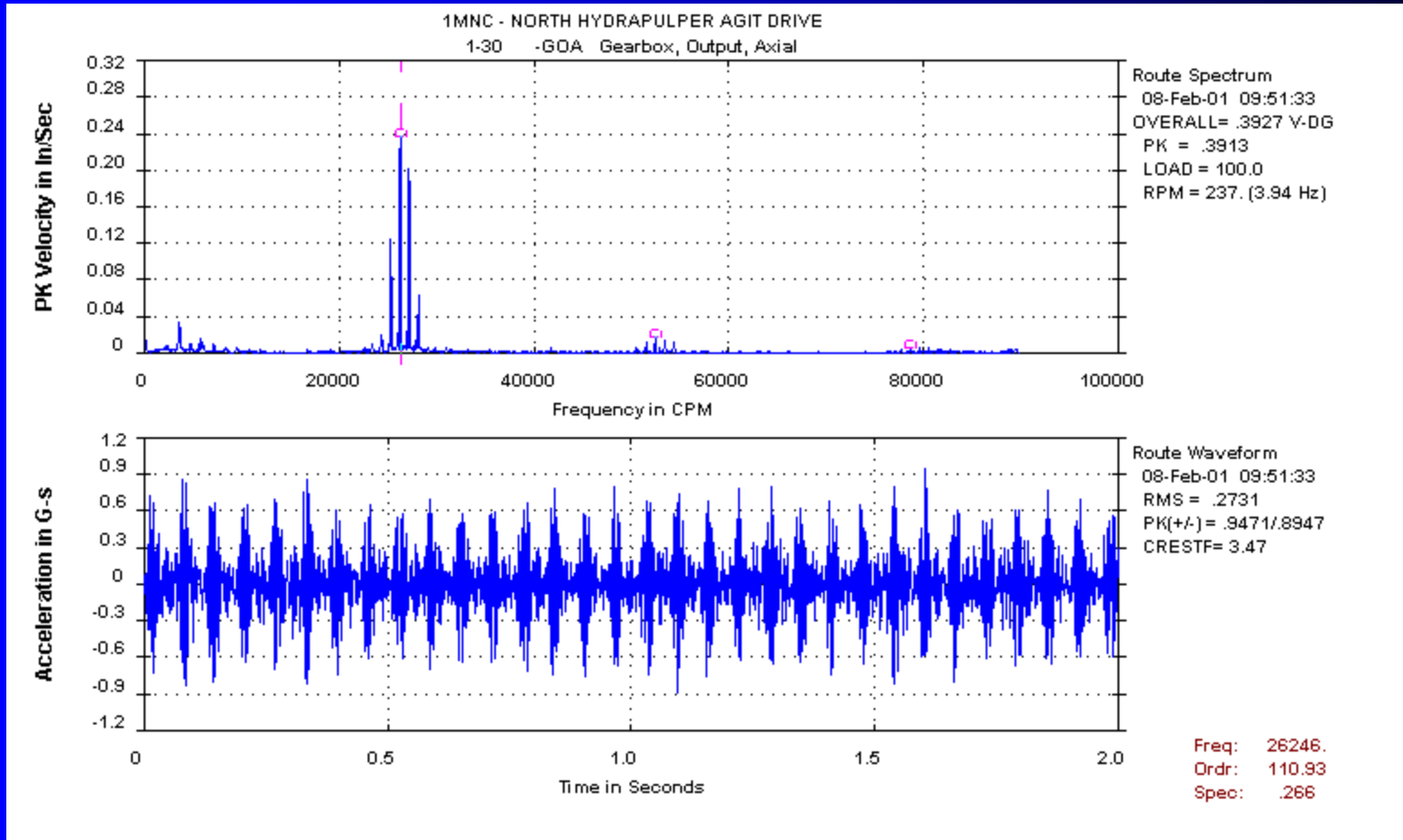
CH#2 – Test Data & Observations (Gearbox), Part 1

- Gearbox speed was 1192 rpm input & 236 rpm output (single reduction @ 5:1 ratio).
- Gearbox spectra showed high gearmesh frequency (26,200 cpm) with sidebands at 945 cpm.
- Gearmesh sidebands usually relate to one of the gear speeds, but 945 cpm didn't correlate to either speed (1192 or 236 rpm).

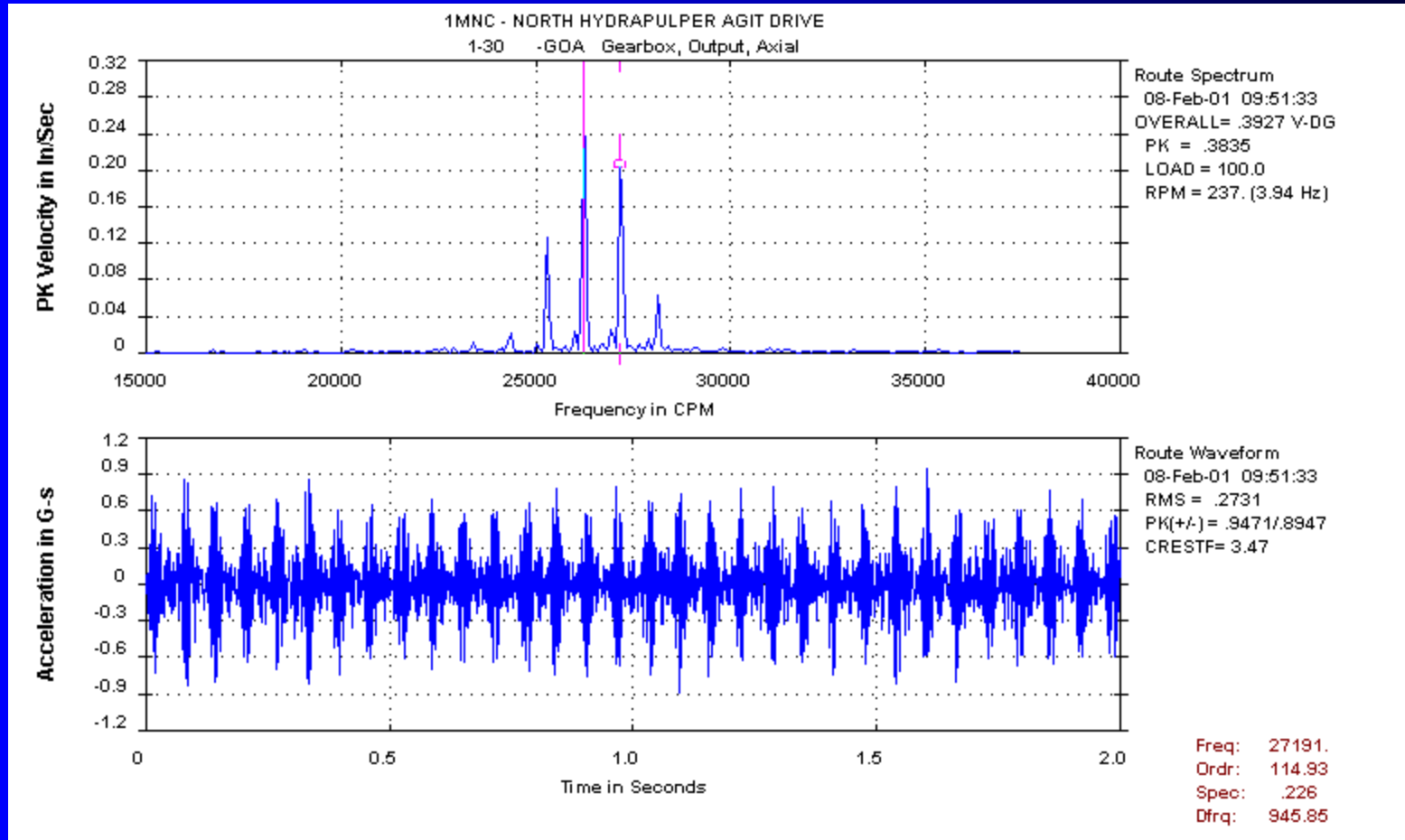
CH#2 – Test Data & Observations (Gearbox), Part 2

- Gearbox waveform showed impacting or modulation at 945 cpm.
- Agitator data showed nothing abnormal.

CH#2 – Gearbox Data



CH#2 – Gearbox Zoom



CH#2 – Conclusions & Recommendations (Motor), P1

- It was concluded that the strange vibration data on the motor was the result of broken rotor bars.
- The 48 cpm sidebands around the motor harmonics was a perfect match to its pole pass frequency.
- The classic spectral pattern of broken rotor bars is running speed harmonics with sidebands at pole pass frequency.
- The classic waveform pattern of broken rotor bars is pulsations at pole pass frequency.

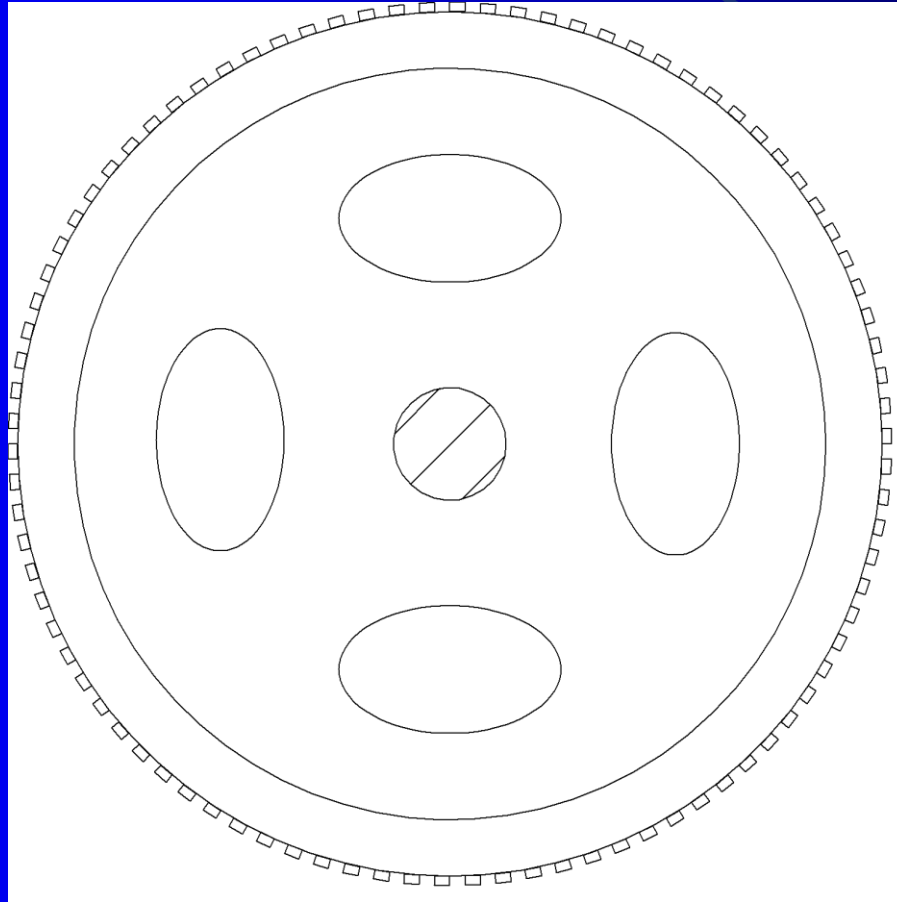
CH#2 – Conclusions & Recommendations (Motor), P2

- Pole Pass Frequency =
(Theoretical RPM – True RPM) * #Poles.
- PPF = (1200 – 1192) * 6 = 48 cpm.
- The recommendation was made to changeout the motor at the next outage.
- Later inspection by a motor repair shop showed many broken rotor bars.

CH#2 – Conclusions & Recommendations (Gearbox)

- After consultation with the gearbox OEM, it was concluded that the strange data from the gearbox was likely due to the 4-yoke design of the bull gear.
- The 4-yokes in the gear hub result in minor deviations from the gear pitch circle causing modulation each time the effected teeth move in and out of the mesh.
- $4 * 236 \text{ rpm} = 945 \text{ cpm}$.

CH#2 - 4-Yoke Gear



CH#2 – Conclusions & Recommendations (Gearbox), Part 2

- The gearbox vendor indicated the vibration measured shouldn't be a problem, but recommended an annual gear inspection & continued vibration monitoring looking for any change in condition.

Case History #3, Repeat Fan Bearing Failures

- EQUIPMENT: Overhung, centrifugal fan belt-driven by a 60 HP induction motor.
- This is a critical fan necessary to the process. When this fan is down, the process stops.

CH#3 – Equipment Layout



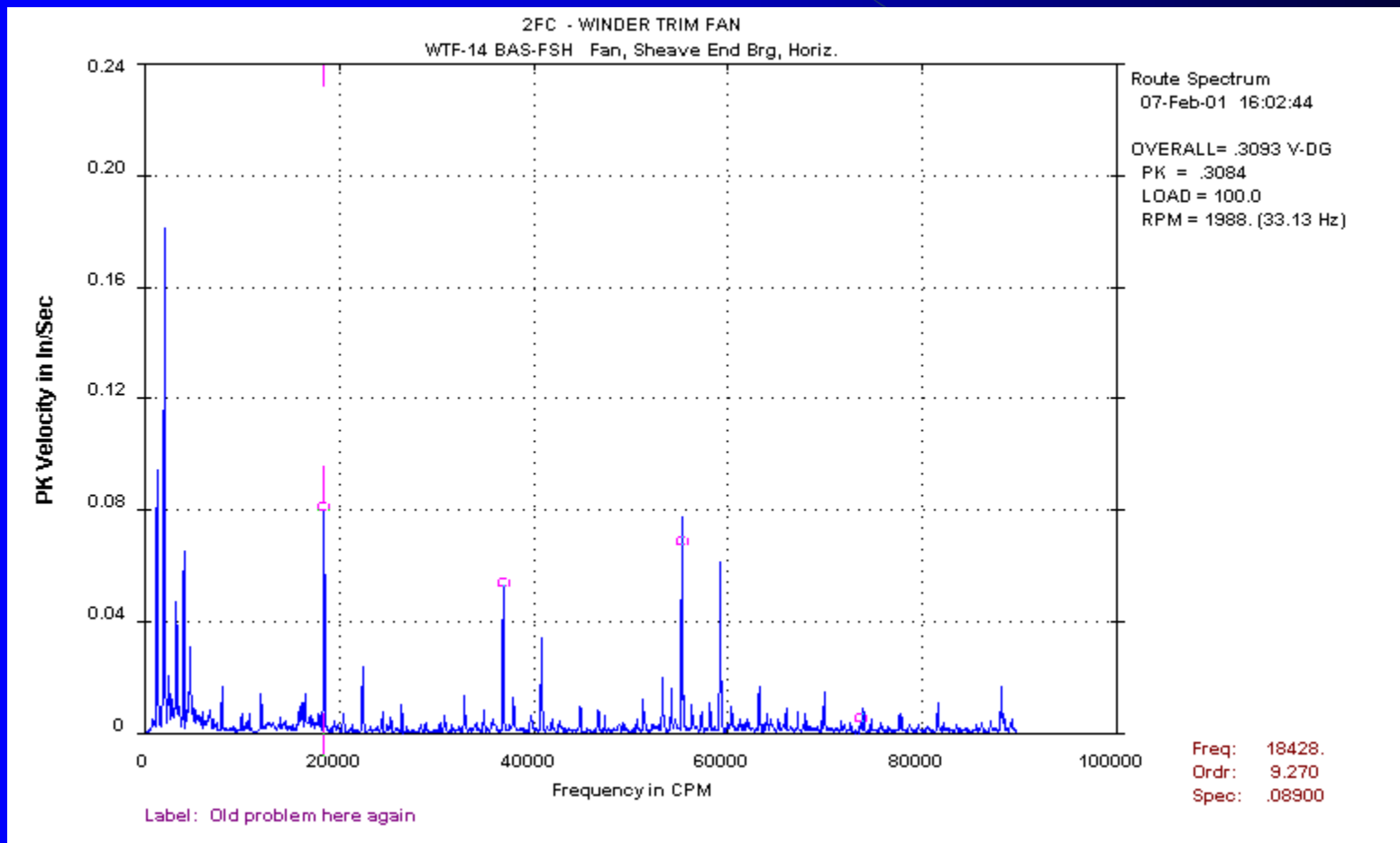
CH#3 - Problem

- Repeat fan bearing failures.
- In one instance, vibration detected bearing faults on this fan less than a month after their changeout.
- Predictive maintenance was able to detect these failures early enough to perform repairs during scheduled outages, but after three fan bearing changeouts in 12 months, we knew something had to be done differently.

CH#3 – Test Data & Observations, Part 1

- Motor speed was 1786 rpm
- Fan speed was 1985 rpm
- Motor spectra showed running speed & harmonics, fan speed & harmonics, belt frequencies & little else.
- Fan spectra was similar to motor data, but also showed fan bearing defect frequencies (BPFO & harmonics).

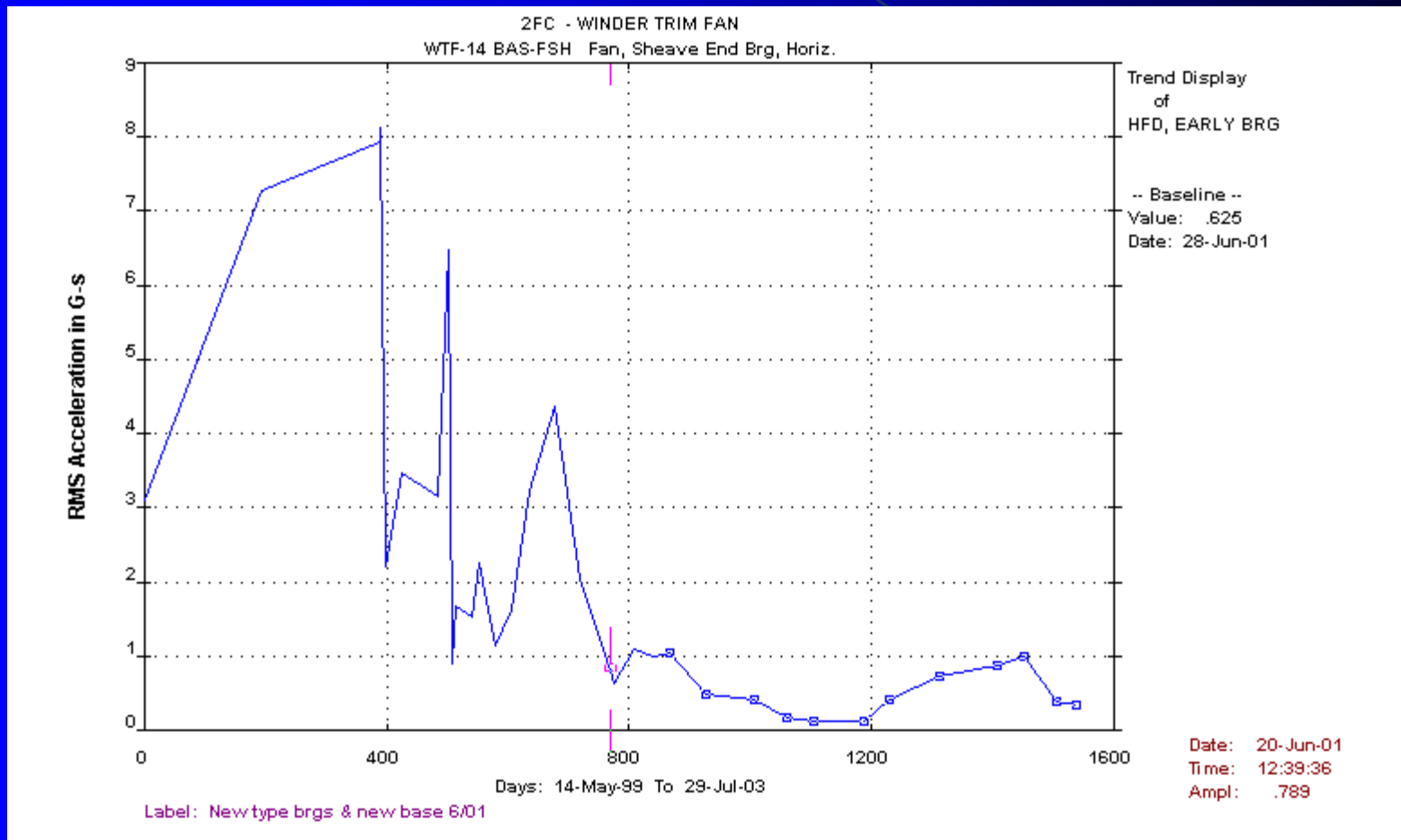
CH#3 – Fan Spectra



CH#3 – Test Data & Observations, Part 2

- Fan trend data showed initial drop when bearings were changed, but soon rose to previous high levels days or weeks after changeout.
- After conversations with mechanics involved in the bearing change we learned that “it took us over an hour to get the bearings aligned to where the shaft would even turn”.

CH#3 – Fan Trend Data



CH#3 – Test Data & Observations, Part 3

- The fan bearings were standard pillow block style housings with tapered roller bearings inside.
- We assumed these were self-aligning bearings as most pillow blocks are, but this assumption turned out to be false.

CH#3 – Conclusion & Recommendations, Part 1

- The relatively tight alignment tolerances of the existing tapered roller bearings combined with the poor condition of the fan base made for short bearing life.
- We asked our bearing supplier for a replacement bearing that would carry similar loads, but be more forgiving for misalignment.
- We also had our machine shop fabricate a new fan base that was machined flat & line bored to perfectly fit the new pillow block bolt pattern.

CH#3 – Conclusions & Recommendations, Part 2

- After installation of the new type bearings & new fan base we have not had another bearing failure.
- Our bearing life has went from an average of 4-months to 26 months and counting.
- Further inspection of maintenance history showed a fan speed increase which corresponded quite well to our increased rate of failure.

CH#3 – Conclusions & Recommendations, Part 3

- This case history is a good example of both predictive & proactive maintenance.
- Predictive maintenance allowed us to avoid catastrophic fan bearing failures and perform repairs during scheduled outages.
- Proactive maintenance extended the life & reliability of the fan bearings.

Case History#4, Pump Outboard Bearing Cage Failure

- Equipment: Double-suction, centrifugal pump driven by a 1250 HP synchronous motor turning at 514 rpm.
- This is the most critical pump in the process directly providing the product (stock) used to make paper on the paper machine.

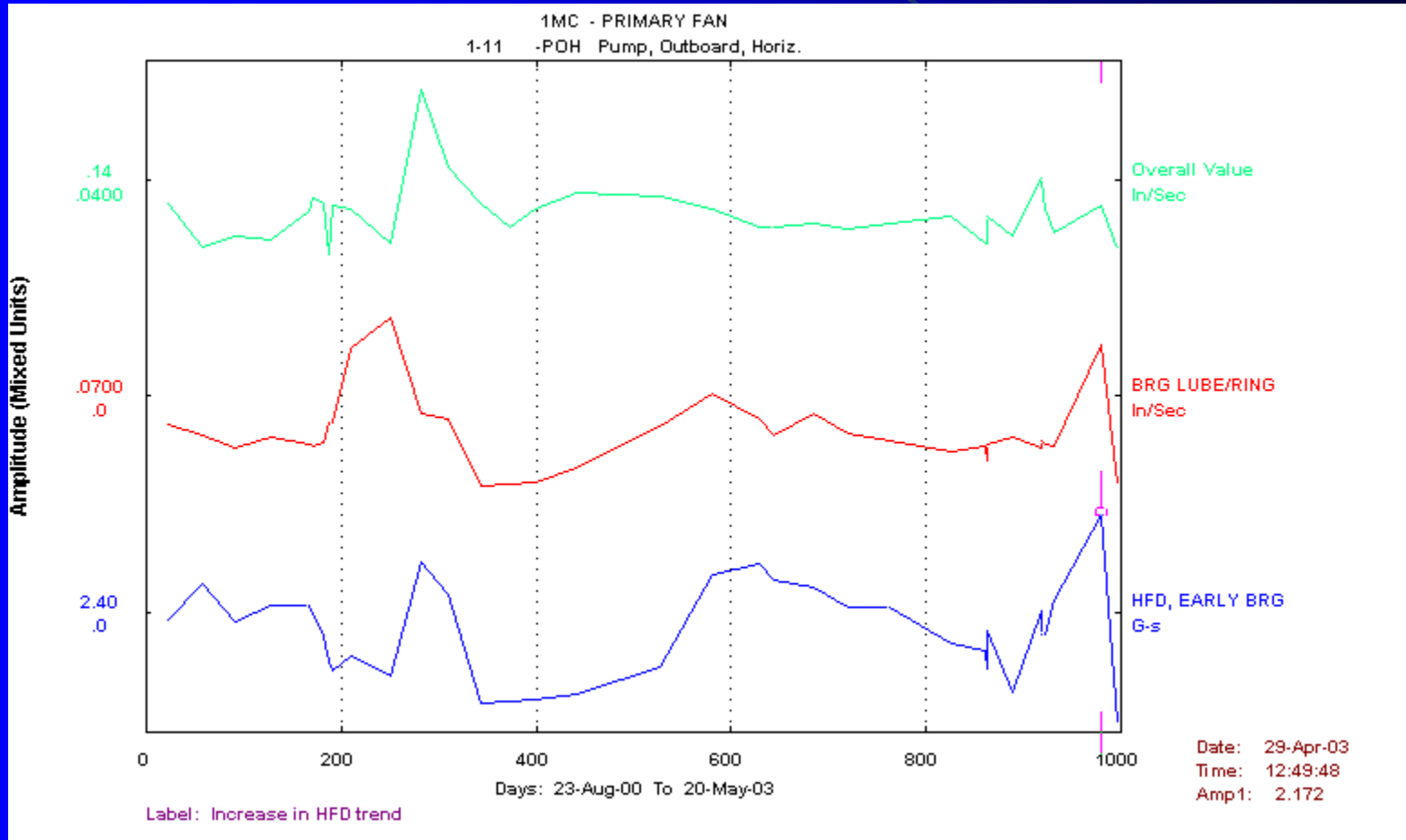
CH#4 - Problem

- Increasing HFD vibration levels at pump outboard. Current levels had exceeded maximum of long term trend.

CH#4 – Test Data & Observations, Part 1

- Since the bearing was oil lubricated, an analysis of the outboard bearing oil was requested.
- Oil analysis results showed very high copper levels indicating cage wear.
- Vibration data showed very high HFD levels on outboard bearing.

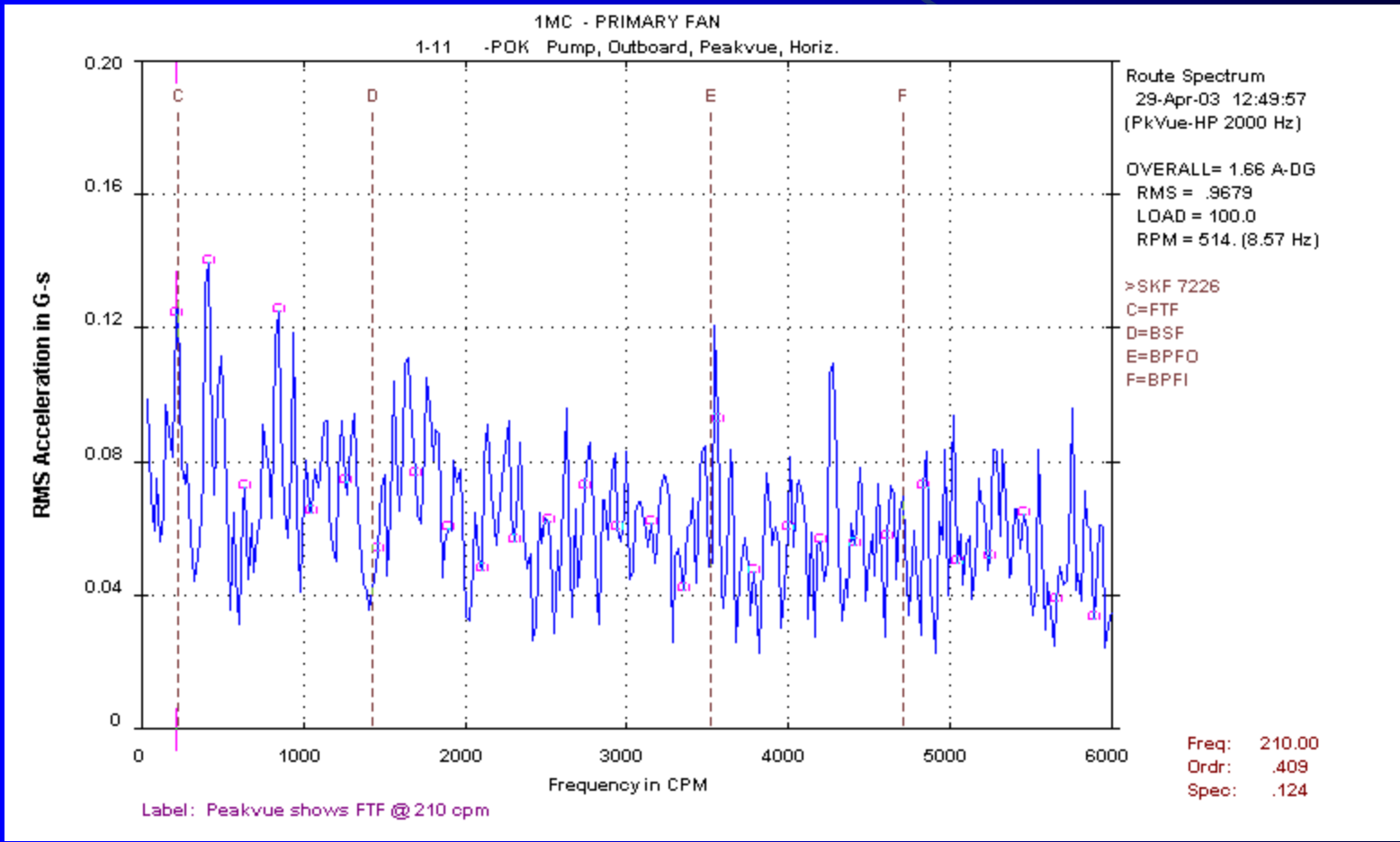
CH#4 – Vibration & HFD Trends



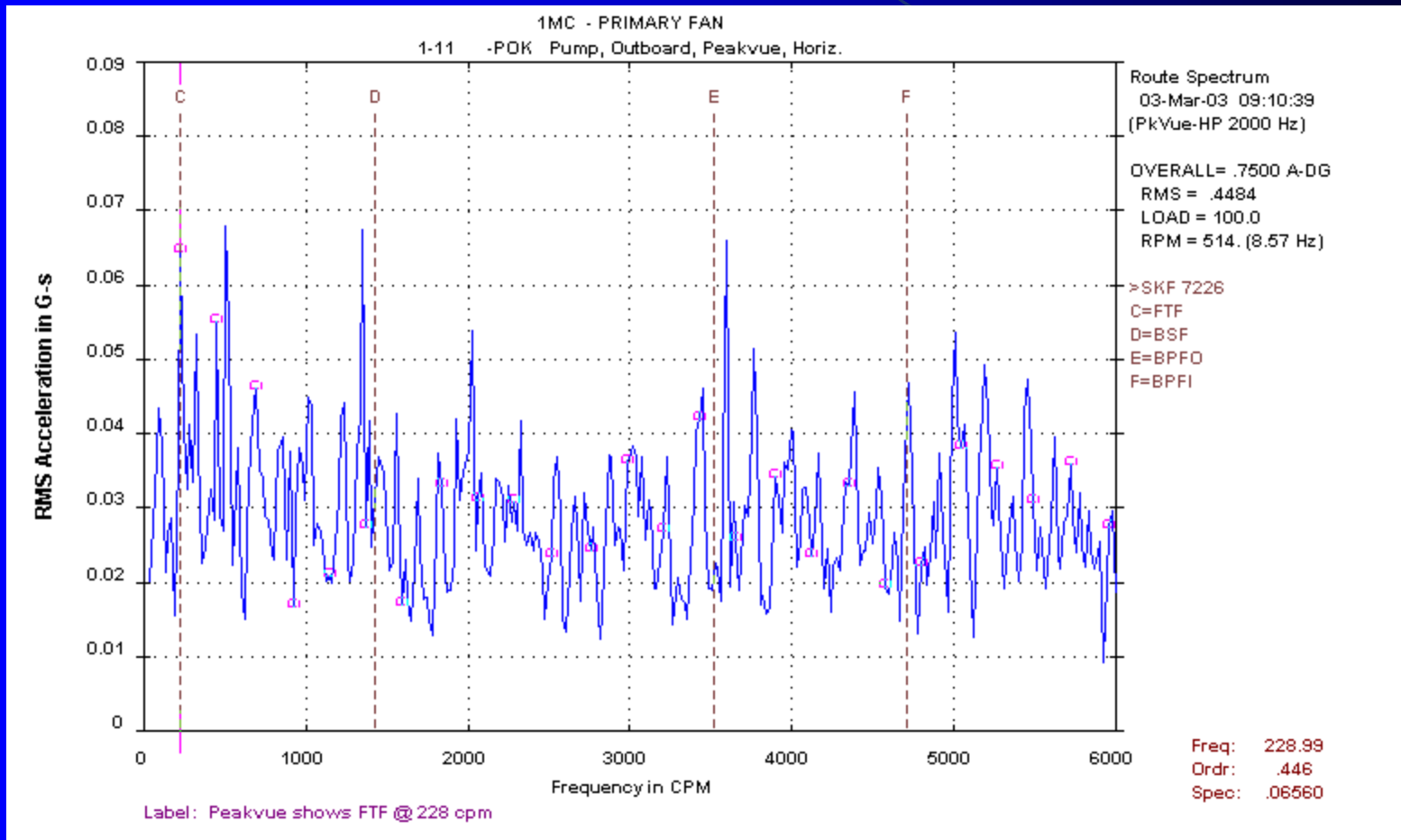
CH#4 – Test Data & Observations, Part 2

- Peakvue spectra showed harmonics of fundamental train frequency (cage).
- An 10/01 paper by J. Robinson & J. Berry recommended a Peakvue fault level of 4.0 g's pk-to-pk for a 500 rpm machine.
- Peakvue waveform on outboard bearing showed levels at 11.3 g's pk-to-pk!!!
- Maintenance history showed a continuing problem of a leaking pump outboard seal.

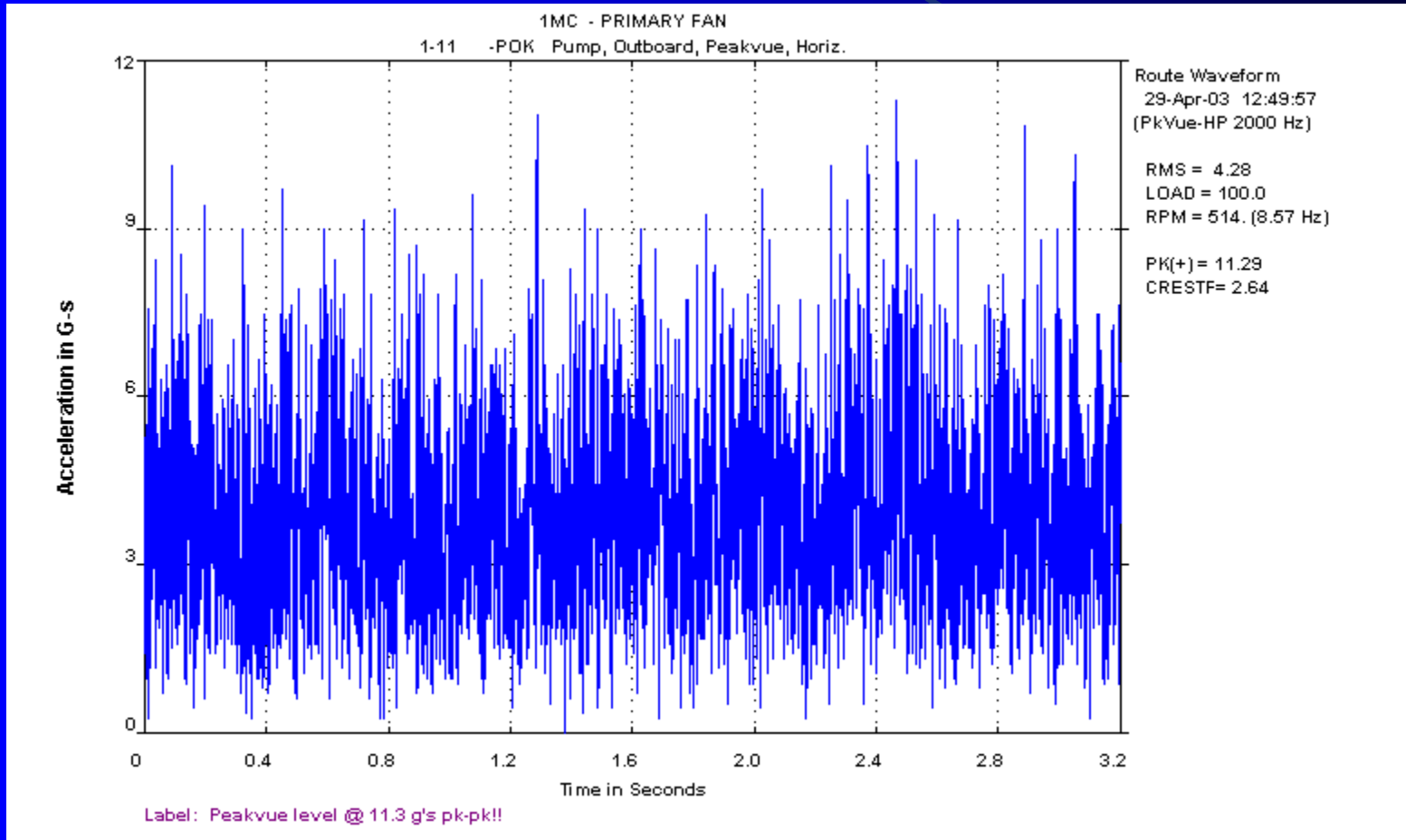
CH#4 – Peakvue Spectra, P1



CH#4 – Peakvue Spectra, P2



CH#4 – Peakvue Waveform



CH#4 – Conclusion & Recommendations, Part 1

- The recommendation was made to changeout the pump outboard bearing.
- Later inspection of the bearing showed the cage worn badly particularly in the area separating the rolling elements from one another.
- During the bearing change, shims were found under the bearing making up the fit with the housing.

CH#4 – Conclusion & Recommendations, Part 2

- Later failure analysis of the bearing found lube contamination and skidding as the primary causes of failure. Corrective actions were as follows:
 - 1) Replace the outboard bearing housing,
 - 2) Repair or replace the pump outboard packing gland,
 - 3) Replace the worn pump rotor causing abnormal thrust loading, and
 - 4) Upgrade the lube from an ISO 68 to an ISO 150 weight oil (temporarily use grease until packing gland repaired).