A Vibration Problem in Vertical Circulating Water Pumps

April 24, 2008

Presented by:

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Vertical Circulating Water Pumps

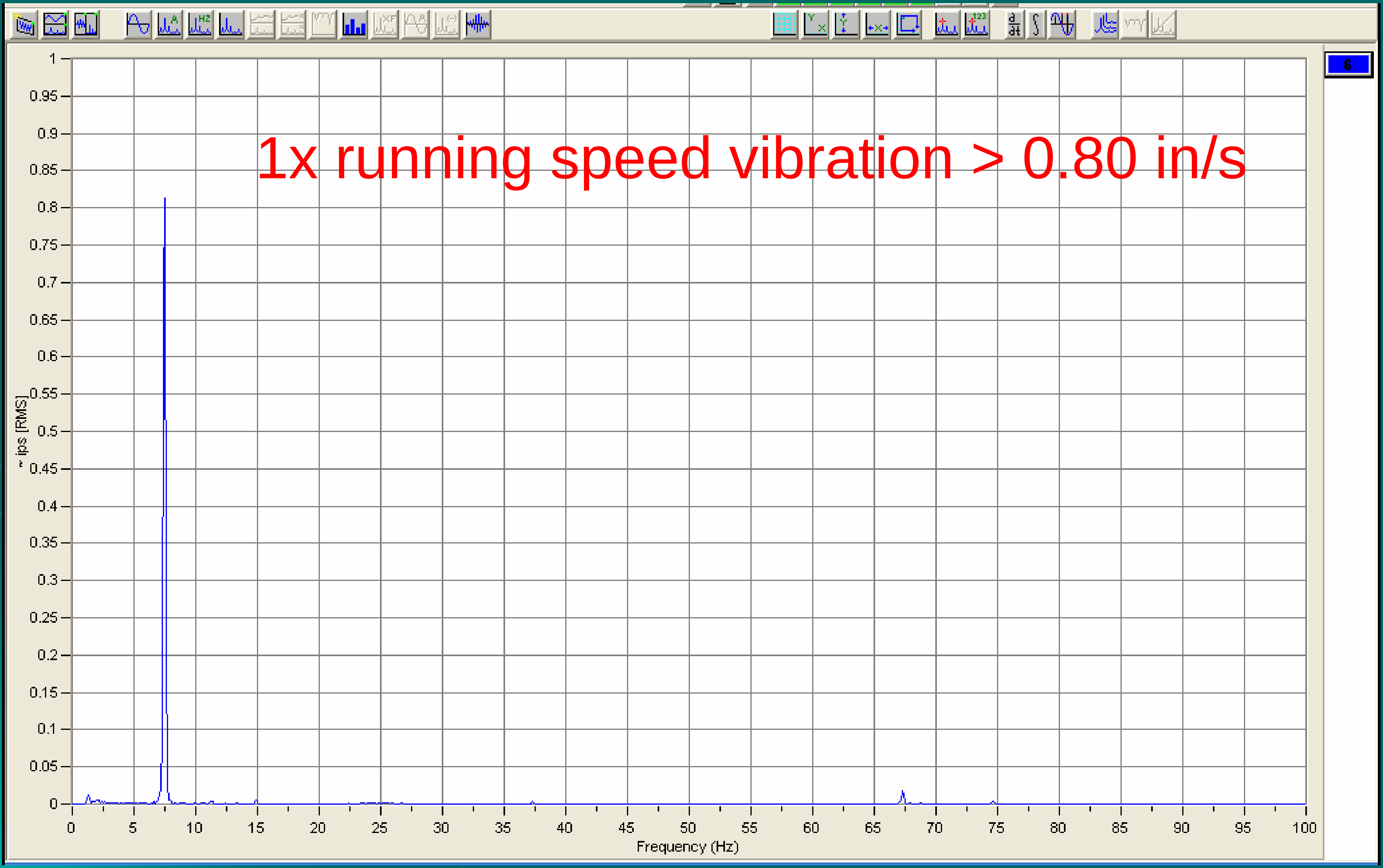
- Two Pumps Operating in Parallel on Cooling Tower
- Single-Stage Mixed-Flow Type Pump
  - Semi-open Impeller Design
  - 77” Bowl Diameter / 54” Discharge
- Direct Drive with Induction Motor
  - 445 rpm (7.42 Hz)
  - 2,138 bhp
- Rated Condition:
  - 86,000 gpm
  - 86 feet

Vibration Amplitude

- Factory Test
  - Acceptance: ISO 10816-3, Group 3, Flexible Support Class, Zone B/C (0.28 in/s RMS)
    - Top of Motor (parallel-to-discharge): 0.22 in/s RMS
    - Top of Motor (perpendicular-to-discharge): 0.16 in/s RMS
- Field Test
  - Acceptance: ISO 10816-3, Group 3, Rigid Support Class, Zone B/C (0.18 in/s RMS)
    - Top of Motor (parallel-to-discharge): 0.13 in/s RMS
    - Top of Motor (perpendicular-to-discharge): 0.80 in/s RMS
    - Dominate frequency at 1X running speed.

Initial Field Vibration Spectrum

(perpendicular-to-discharge)



Design-Phase FEA Results

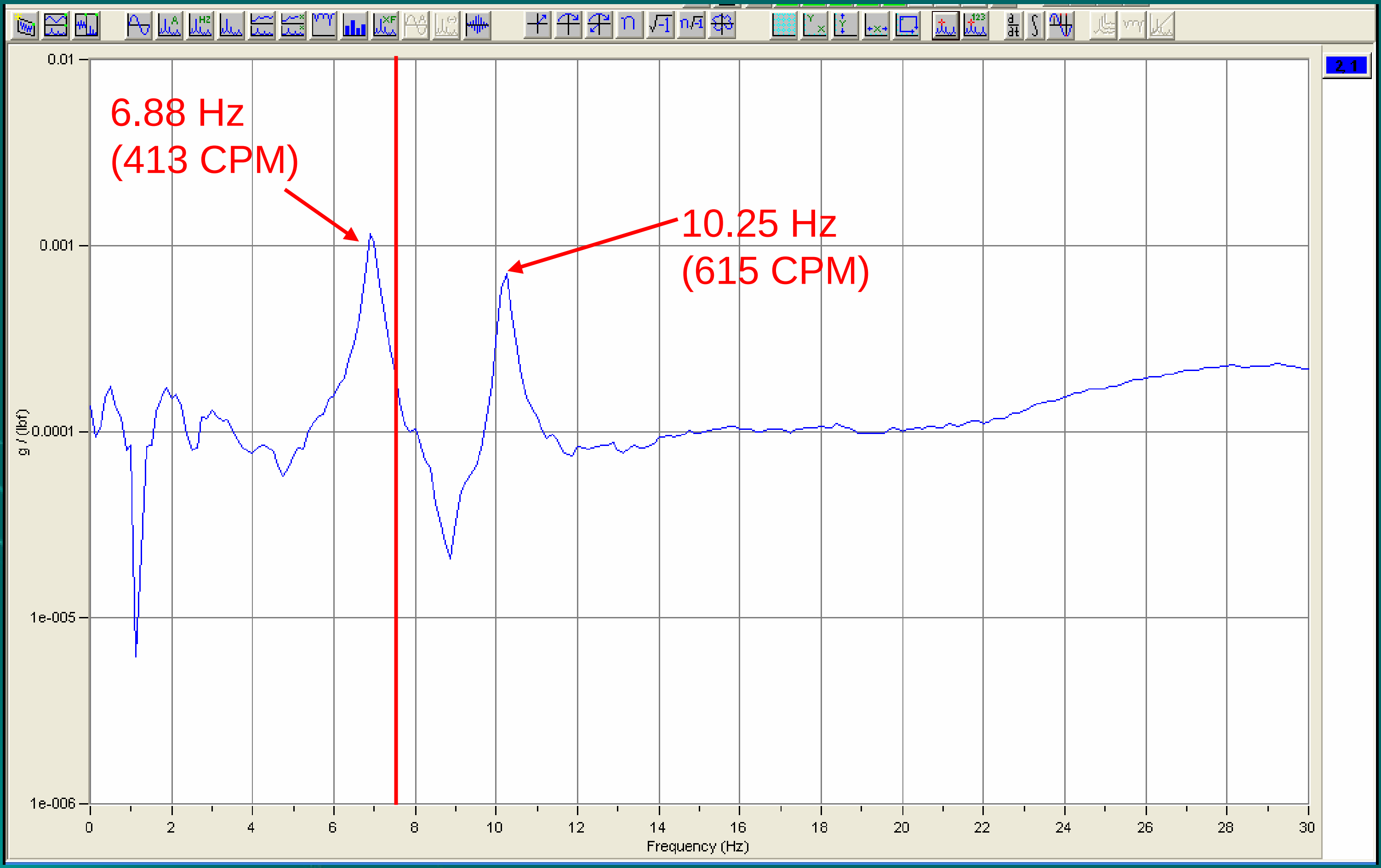
- Foundation flexibility – Based on concrete properties from Civil Engineering design
- Motor reed critical frequency – Based on motor vendor information (+/- 15% margin)

Running Speed = 7.42 Hz		
Mode	Natural Frequency (Hz)	Separation Margin
1 Parallel	4.70	-36.7%
1 Perpendicular	5.13	-30.8%
2 Parallel	8.32	12.1%
2 Perpendicular	8.73	17.7%

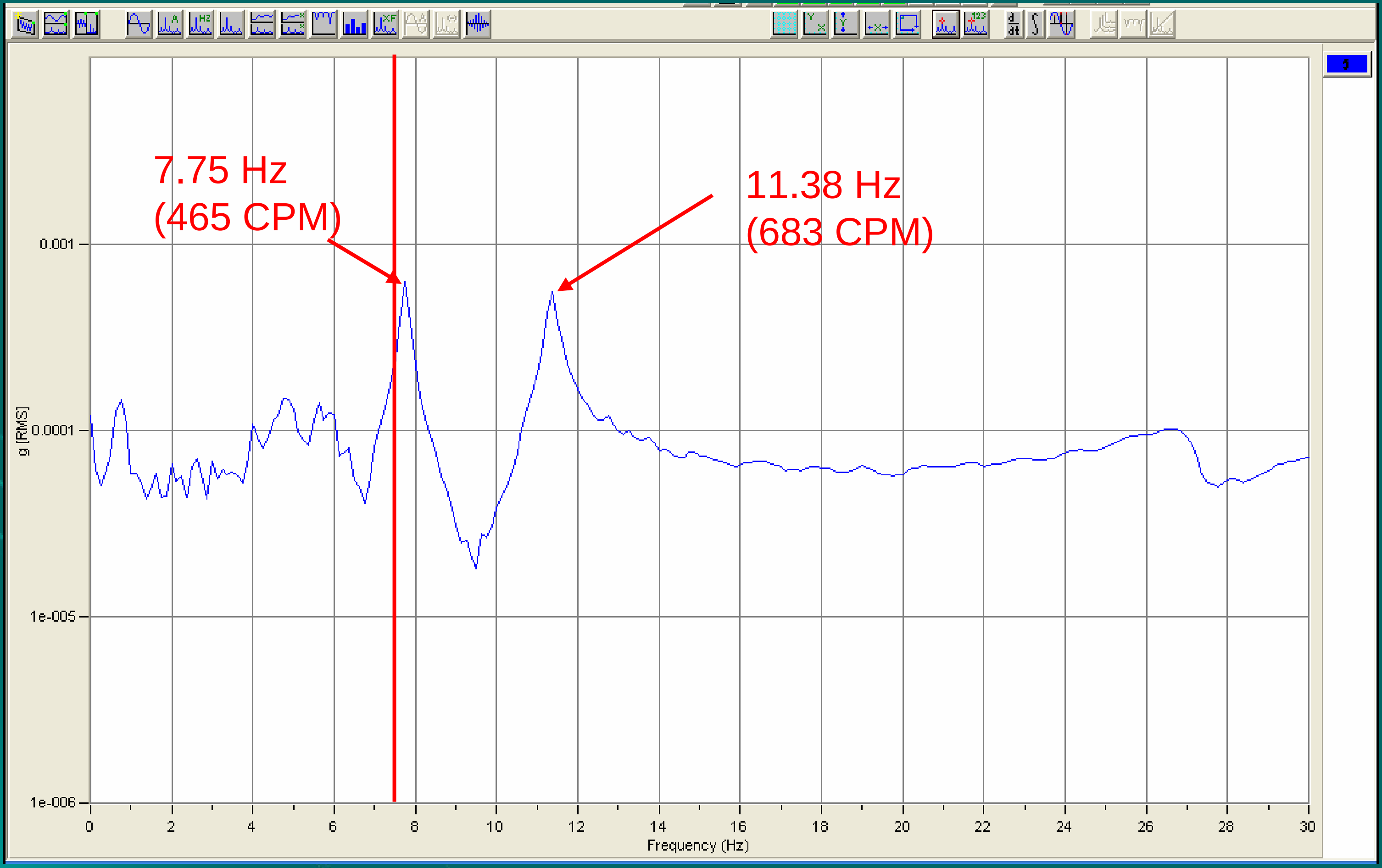
Field Impact Test Conditions

- Pump installed per manufacturer's recommendations
- Pump not running and forebay filled with water
  - Accounts for partial entrained water mass
- Motor coupled and rotor lift set
  - Weight of pump rotor is supported at motor thrust bearing
- Discharge piping connected with flexible expansion joint

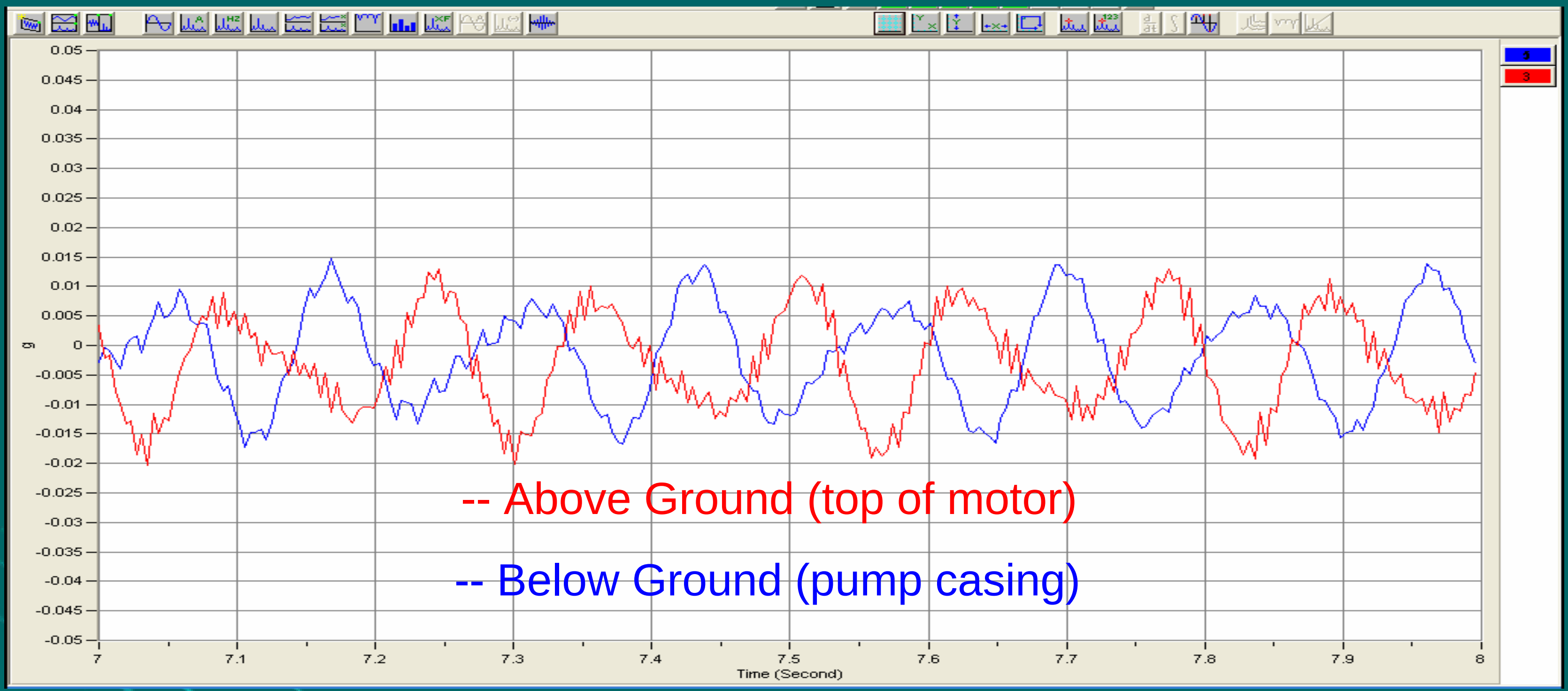
Field Impact Test Results
(parallel-to-discharge)



Field Impact Test Results
(perpendicular-to-discharge)



Field No-Load Motor Test
(uncoupled from pump)



- Traces indicate out-of-phase motion of top of motor compared to pump casing
- 1st pump bending mode

Field Natural Frequencies
(semi-wet)

Running speed = 7.42 Hz (445 RPM)		
A Pump		
Direction	**Natural Frequency (Hz)**	**Separation Margin**
Parallel (1st Mode)	6.88	-7.3%
Perpendicular (1st Mode)	7.75	**4.4%**
B Pump		
Direction	**Natural Frequency (Hz)**	**Separation Margin**
Parallel (1st Mode)	6.75	-9.0%
Perpendicular (1st Mode)	7.50	**1.1%**

Note: A pump vibrations were more than 5 times those on the B pump, indicating that the operating natural frequencies shift down by approximately 0.25 Hz.

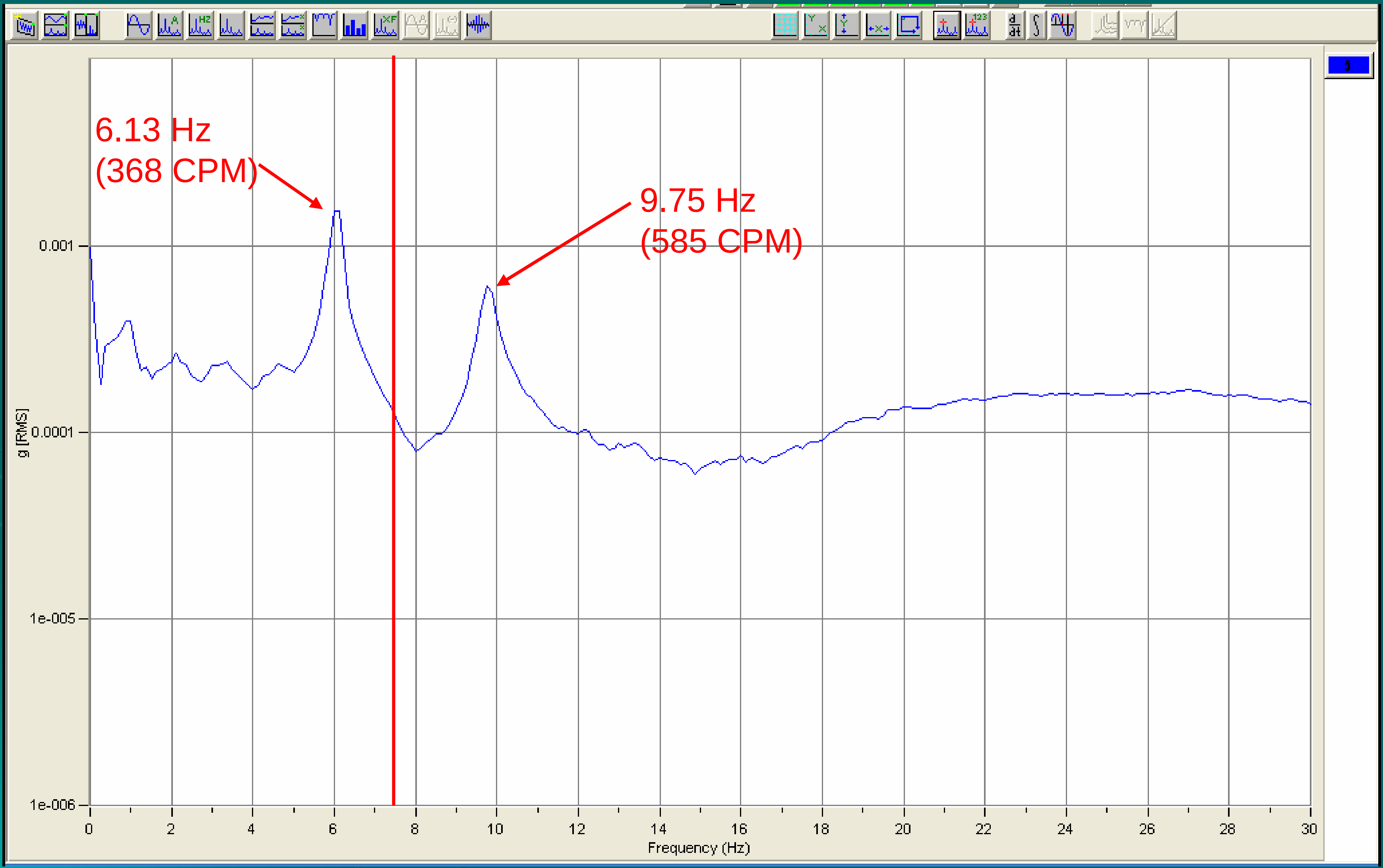
Fixing the Problem

- Finite Element Analysis
  - Adjusted model to match field measurements, “Model Calibration”
    - Infinitely stiff foundation
    - Doubled motor reed critical frequency
  - Analyzed corrective action options with FEA to assure success
- Cut Slots in Stiffening Ribs to De-Tune Natural Frequencies
  - FEA predicted a minimum separation margin of 15% for the first mode (perpendicular)
  - Achieved as-measured separation margin of 12.4% first mode (perpendicular).

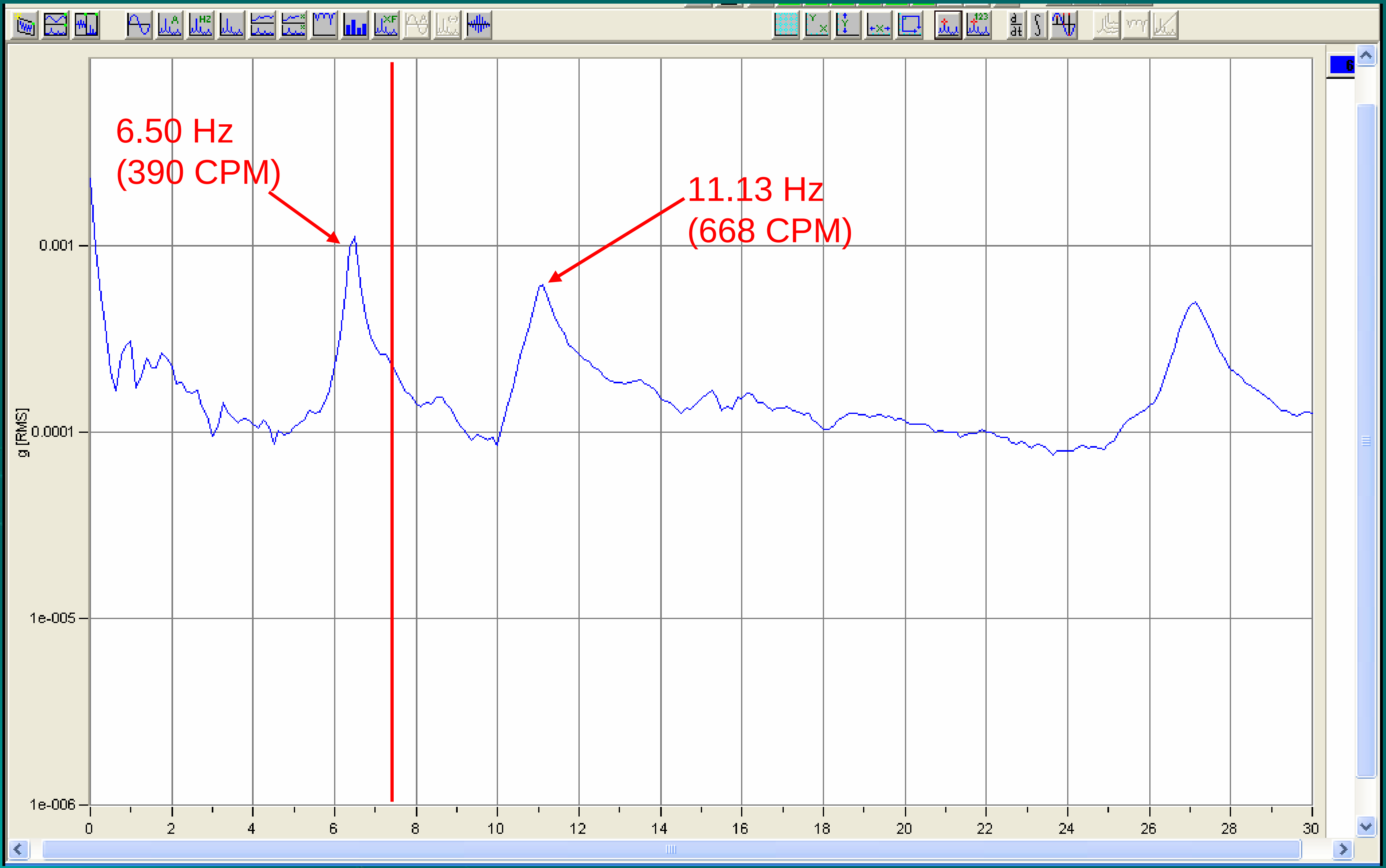

CAUTION

Modified Pump Impact Test Results

(parallel-to-discharge)



Modified Pump Impact Test Results
(perpendicular-to-discharge)



Final Natural Frequencies

A Pump	Natural frequency (Hz)			
Direction	**Before**	**After**	**% Change**	**% Separation**
In Line (1st Mode)	6.88	6.13	10.90%	18.27%
Perpendicular (1st Mode)	7.75	6.50	16.13%	13.33%

B Pump	Natural frequency (Hz)			
Direction	**Before**	**After**	**% Change**	**% Separation**
In Line (1st Mode)	6.75	6.13	9.19%	18.27%
Perpendicular (1st Mode)	7.50	6.50	13.33%	13.33%

Operational vibrations were 0.12 in/s RMS or less on both pumps in both directions and were acceptable.

Final Vibration Amplitudes

- Operational vibrations less than 0.12 in/s RMS on both pumps in all direction.
- Vibration meets acceptance standards.
- Pumps accepted by customer.

Conclusions

- Factory testing results cannot always ensure acceptable field vibration levels.
- FEA combined with field vibration measurements is an excellent tool for properly diagnosing and correcting unexpected field vibration problems.
- Without field vibration measurement, FEA is only as good as its input data assumptions
  - Foundation information
  - Motor reed critical frequency