WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

RIVER WATER PUMP CYCLIC VIBRATION

TOM MANNING, DAVE SERGE

E. I. DUPONT DE NEMOURS

42nd Turbomachinery
29th Pump SYMPOSIA

GEORGE R. BROWN CONVENTION CENTER
9.30 – 10.3.2013

TEXAS A&M ENGINEERING TEES TURBOMACHINERY LABORATORY

A&M

Biographies

Thomas W. Manning Jr. is currently an engineer in the Engineering Mechanics Group at E. I. DuPont in Wilmington DE. His primary role is to work with DuPont business units to improve manufacturing process quality, yield and capacity. In this diagnostic role Tom applies his experience in design, analysis, and dynamic measurements to solve process or equipment problems.

Prior to transferring to the engineering department, Tom spent 16 years in DuPont's Lycra® business in Waynesboro, VA. During that assignment, he worked on design and development programs for new process equipment, winding equipment, drive systems, and package delivery improvements.

Tom joined DuPont in 1984, when he received his B.S. and M.S. Degrees in Mechanical Engineering from Drexel University, Philadelphia, PA. He is a member of ASME and ASHRAE.

David J. Serge is currently a leveraged reliability & rotating equipment consultant at E. I. DuPont in Wilmington, DE. He supports various sites improving the reliability of rotating equipment by working on vibration analysis, RCFAs and new or repair equipment specifications.

Dave joined DuPont in 2005. Previously he worked at the Delaware City, Delaware refinery as a machinery reliability engineer working for Getty, Texaco, Star Enterprise and Motiva. While there he specified upgrades and replacements for pumps, compressors, turbines and miscellaneous mechanical equipment. He also worked for Conrail at a diesel & electric facility servicing the Metropolitan Transportation Authority of New York City, NY.

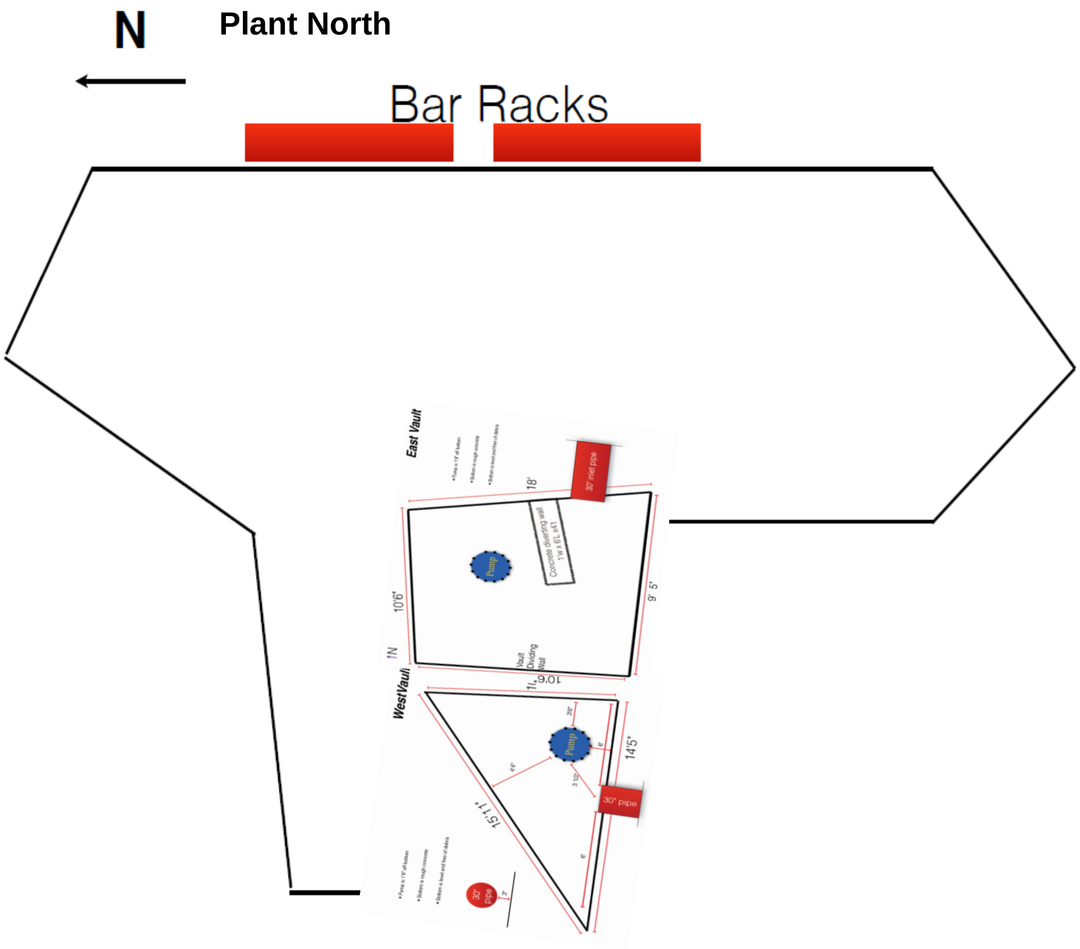
Dave received his B.S. from Temple University in Philadelphia, PA and MBAs from Goldey-Beacom College in Wilmington, DE. He is certified by SMRP and is a member of ASME, the Vibration Institute and STLE.

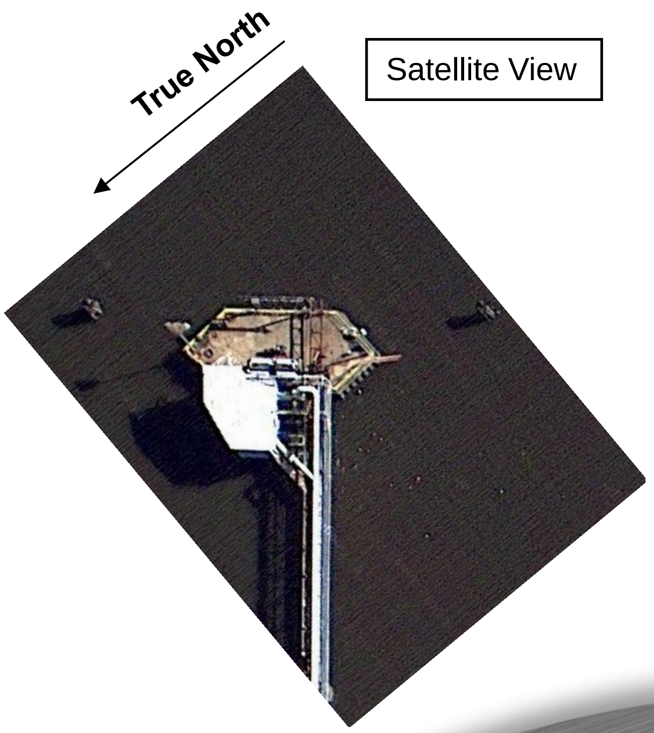
Presentation Topics

- Pump History and Related Reliability
- Pump Capability
- Discovery
- Testing Setup
- Cyclic Vibration
- FEA Analysis

Pump History and Related Reliability

River Water Pump Vault Layout





Abbreviated History of Unreliability

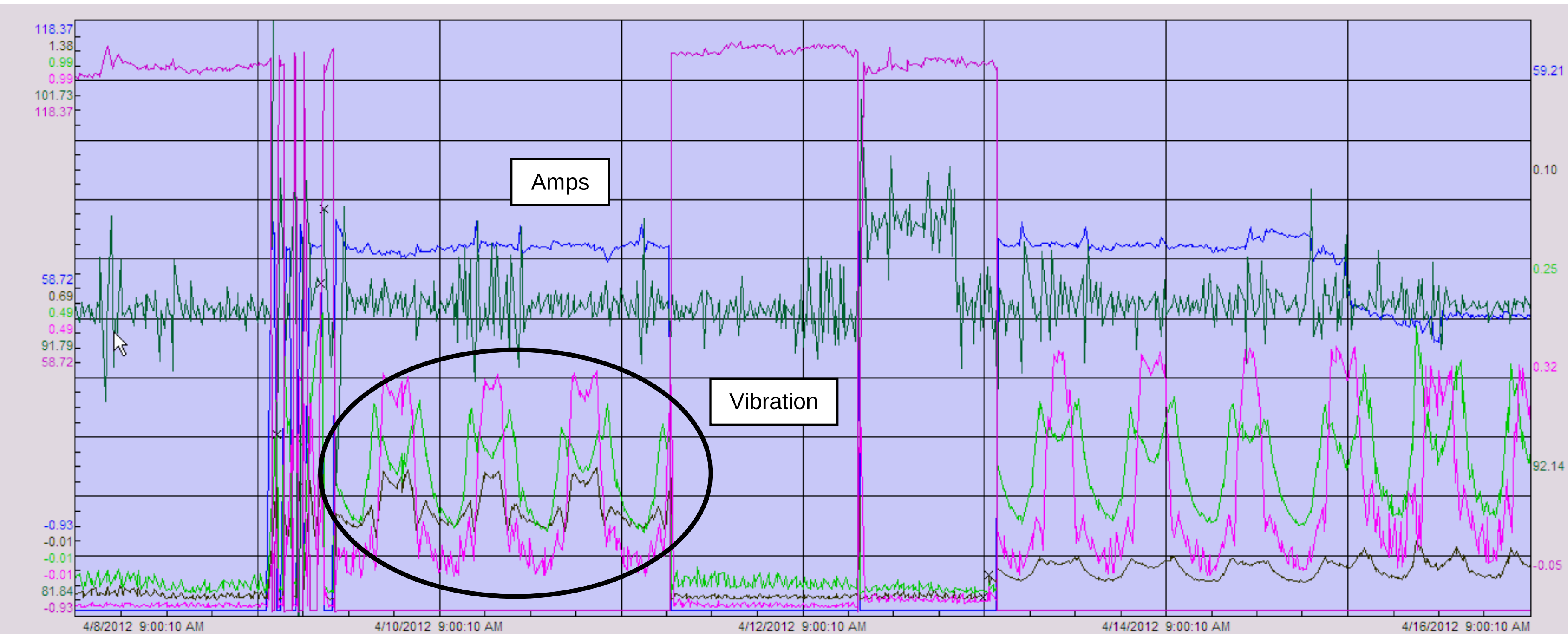
- #4 River Water Pump required the assistance of at least one On-Shore pump to maintain the plant requirements.
- Replaced pump on October 23, 2011 with Vibration sensor attached to bowl section.
- Balanced Motor and installed vibration sensors.
- Activated sensors in DCS November 2011.
- Experienced continually increasing vibration on pump motor.
- Had divers inspect & repair the vault area.
- Motor running with high 1X vibration that disappears when power switch is thrown.

Abbreviated History of Unreliability (cont)

- Replaced motor with spare
- Vibration changed from high at low vault water level to high at high vault water level.
- Attempted balancing motor due to high 1X vibration but could not influence a change
- Ran motor uncoupled and vibration dropped from 0.42 ips to 0.07 ips
- Pulled pump to look for cause of 1X - potential imbalance with no findings except a small stick and some rope. Changed impeller mounting and hard faced shaft bearing journals. Cleaned layered corrosion from pump sole plate.
- Reinstalled pump and only slight improvement in vibration
- Elicited help from DuPont Corporate Engineering to look further into cause.

#4 River Water Pump

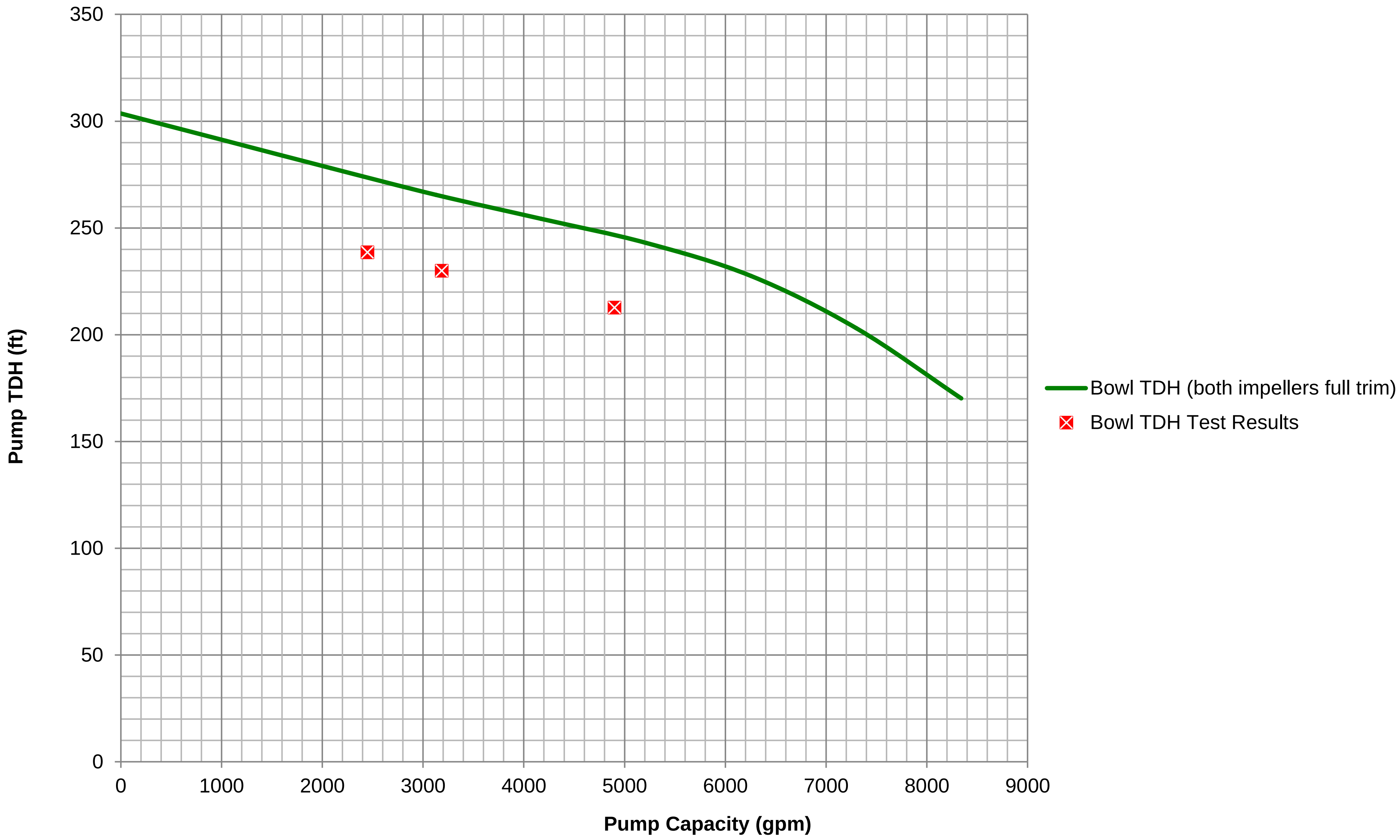
April 8-16



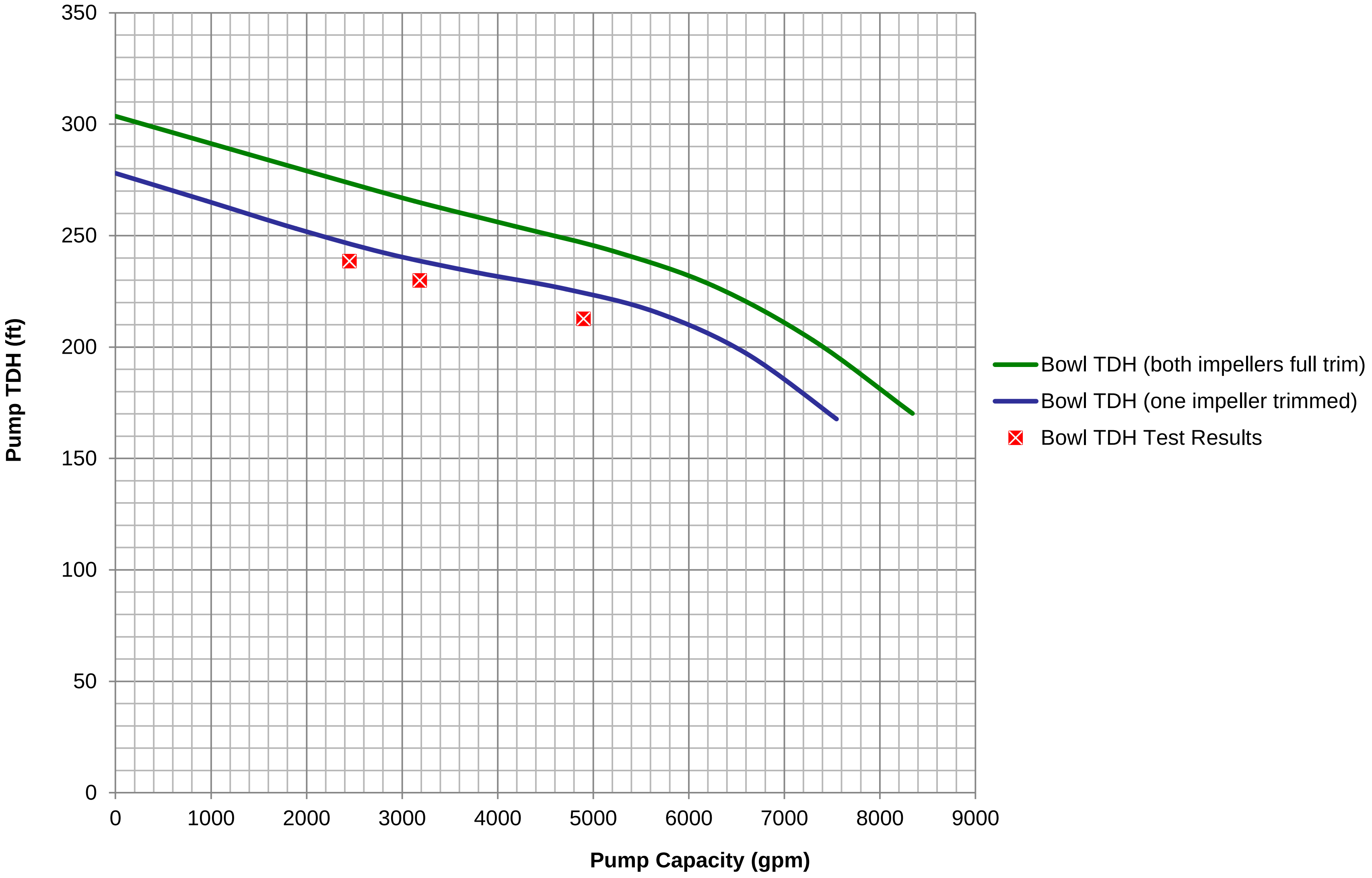
Name	Data Source	Map	Description	Value	Units	Aut	Plot Min	Plot Max	Level	Status	Shift	TZ	Type	Period	Method	Ste	Ext
5094wg	EMRS3	PMCANALOGRAWMAP	#4 RIVER H2O PUMP LOAD	59.14	AMP	☐	-0.93	118.37	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐
5094wg3	EMRS3	PMCANALOGRAWMAP	5094PB Vibration Probe 3	0.10	I/S	☐	-0.01	1.38	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐
5094wg2	EMRS3	PMCANALOGRAWMAP	5094PB Vibration Probe 2	0.25	I/S	☐	-0.01	0.99	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐
5094wg1	EMRS3	PMCANALOGRAWMAP	5094PB Vibration Probe 1	0.33	I/S	☐	-0.01	0.99	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐
5086LC1	EMRS3	PMCANALOGRAWMAP	R/WATER TK/LVL #5 CONTRL	92.17	PCT	☐	81.84	101.73	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐
5095wg	EMRS3	PMCANALOGRAWMAP	#5 RIVER H2O PUMP LOAD	-0.05	AMP	☐	-0.93	118.37	Good	Good	0 0:00:0		Best Fit	1 Hour		☐	☐

Pump Capability

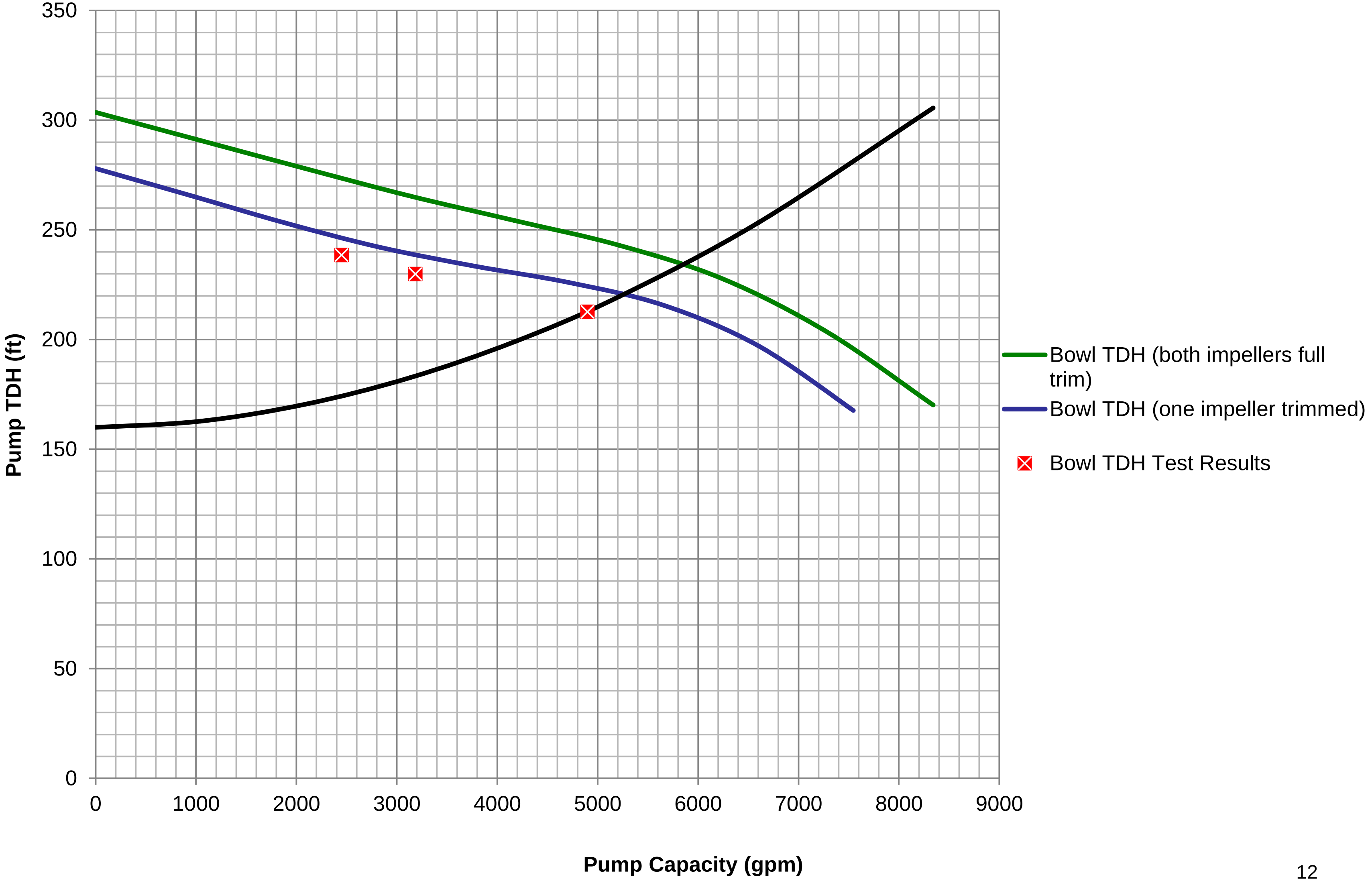
Head vs. Capacity Curves and Test Data



Head vs. Capacity Curves and Test Data



Head vs. Capacity Curves and Test Data

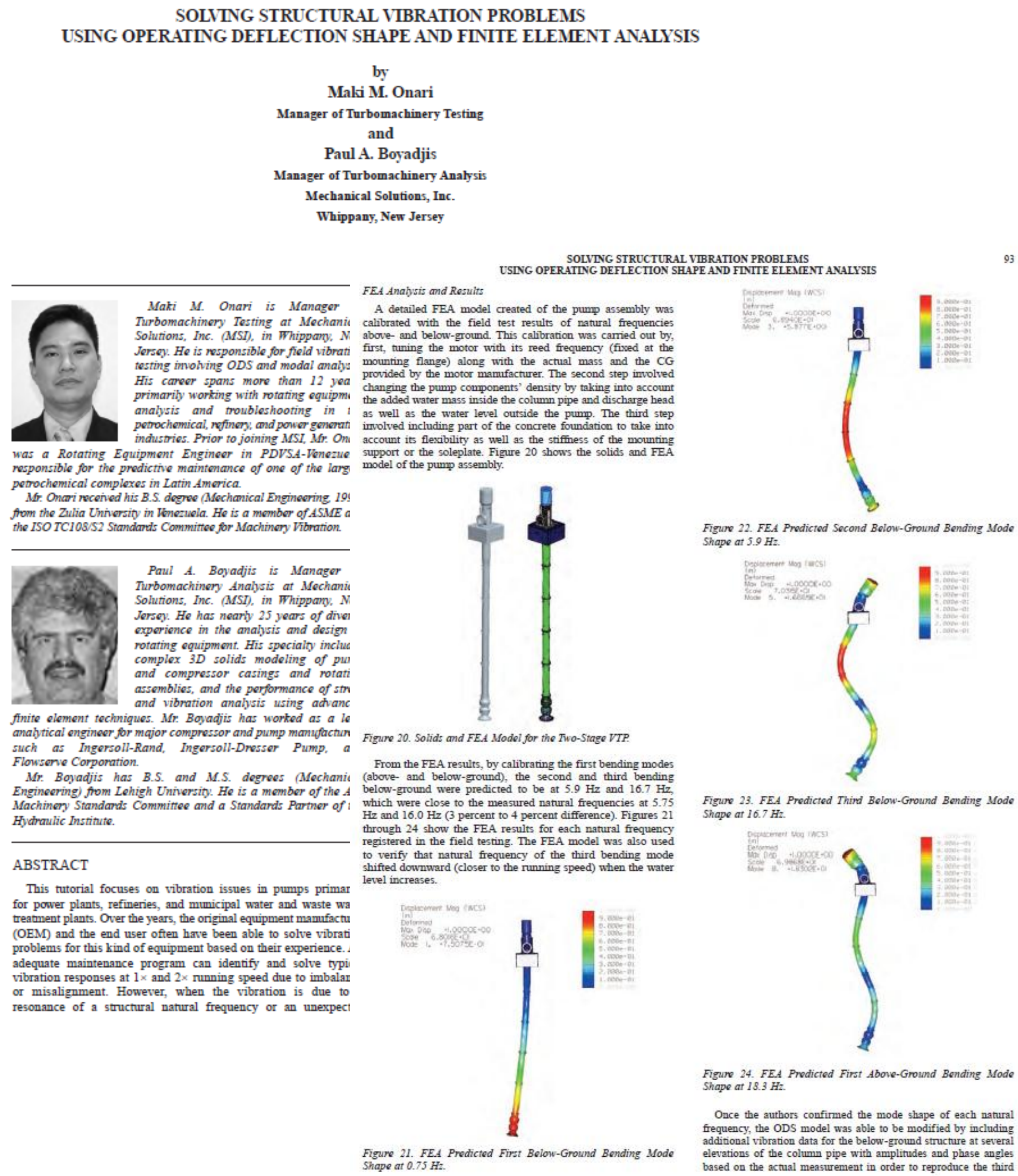


Conclusions

- During the testing period, the #4 river water pump had to be supplemented at times with the onshore pumps.
- The pump was ordered as a direct replacement per the original design. The bowl section used was the spare for the cooling tower pumps. Per records, the #4 river water pump is intended to have full size impellers for both stages to meet head requirements.
- The cooling tower pumps on site have the 2nd stage impeller trimmed to minimize amp load on the drive motors.

Discovery

- A literature search was done In parallel with our preparation to instrument the pump for experimental analysis
- Other instances of column resonance have been documented in industry
- At first it was not clear how a resonance would explain the scalloped time plots
- We recognized that we needed a way to attach an accelerometer to the bottom of the pump but the only access was through an 8” hole through the 24” thick floor . . . .



SOLVING STRUCTURAL VIBRATION PROBLEMS
USING OPERATING DEFLECTION SHAPE AND FINITE ELEMENT ANALYSIS

by
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and
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Maki M. Onari is Manager Turbomachinery Testing at Mechani Solutions, Inc. (MSI), in Whippany, N Jersey. He is responsible for field vibrati testing involving ODS and modal analys His career spans more than 12 yea primarily working with rotating equipm analysis and troubleshooting in t petrochemical, refinery, and power generati industries. Prior to joining MSI, Mr. On was a Rotating Equipment Engineer in PDVSA-Venezue responsible for the predictive maintenance of one of the larg petrochemical complexes in Latin America.

Mr. Onari received his B.S. degree (Mechanical Engineering, 19 from the Zulia University in Venezuela. He is a member of ASME a the ISO TC108/S2 Standards Committee for Machinery Vibration.

Paul A. Boyadjis is Manager Turbomachinery Analysis at Mechani Solutions, Inc. (MSI), in Whippany, N Jersey. He has nearly 25 years of dive experience in the analysis and design rotating equipment. His specialty inclu complex 3D solids modeling of pu and compressor casings and rotati assemblies, and the performance of str and vibration analysis using advanc finite element techniques. Mr. Boyadjis has worked as a le analytical engineer for major compressor and pump manufactur such as Ingersoll-Rand, Ingersoll-Dresser Pump, a Flowserve Corporation.

Mr. Boyadjis has B.S. and M.S. degrees (Mechani Engineering) from Lehigh University. He is a member of the A Machinery Standards Committee and a Standards Partner of t Hydraulic Institute.

ABSTRACT

This tutorial focuses on vibration issues in pumps primar for power plants, refineries, and municipal water and waste wa treatment plants. Over the years, the original equipment manufactu (OEM) and the end user often have been able to solve vibrati problems for this kind of equipment based on their experience. adequate maintenance program can identify and solve typi vibration responses at 1× and 2× running speed due to imbalan or misalignment. However, when the vibration is due to resonance of a structural natural frequency or an unexpect

SOLVING STRUCTURAL VIBRATION PROBLEMS
USING OPERATING DEFLECTION SHAPE AND FINITE ELEMENT ANALYSIS 93

FEA Analysis and Results

A detailed FEA model created of the pump assembly was calibrated with the field test results of natural frequencies above- and below-ground. This calibration was carried out by, first, tuning the motor with its reed frequency (fixed at the mounting flange) along with the actual mass and the CG provided by the motor manufacturer. The second step involved changing the pump components' density by taking into account the added water mass inside the column pipe and discharge head as well as the water level outside the pump. The third step involved including part of the concrete foundation to take into account its flexibility as well as the stiffness of the mounting support or the soleplate. Figure 20 shows the solids and FEA model of the pump assembly.

Figure 20. Solids and FEA Model for the Two-Stage VTP.

From the FEA results, by calibrating the first bending modes (above- and below-ground), the second and third bending below-ground were predicted to be at 5.9 Hz and 16.7 Hz, which were close to the measured natural frequencies at 5.75 Hz and 16.0 Hz (3 percent to 4 percent difference). Figures 21 through 24 show the FEA results for each natural frequency registered in the field testing. The FEA model was also used to verify that natural frequency of the third bending mode shifted downward (closer to the running speed) when the water level increases.

Figure 21. FEA Predicted First Below-Ground Bending Mode Shape at 0.75 Hz.

Figure 22. FEA Predicted Second Below-Ground Bending Mode Shape at 5.9 Hz.

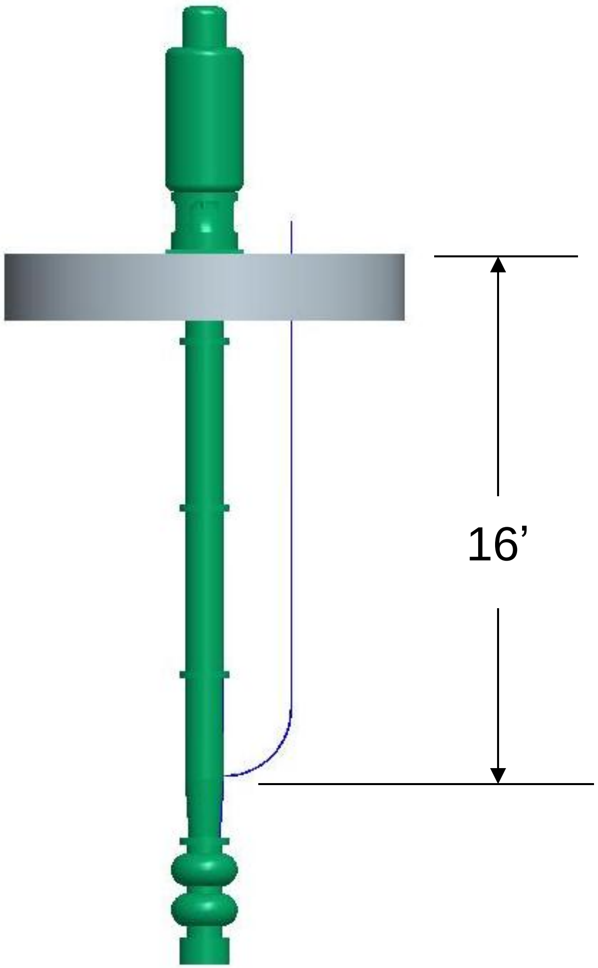
Figure 23. FEA Predicted Third Below-Ground Bending Mode Shape at 16.7 Hz.

Figure 24. FEA Predicted First Above-Ground Bending Mode Shape at 18.3 Hz.

Once the authors confirmed the mode shape of each natural frequency, the ODS model was able to be modified by including additional vibration data for the below-ground structure at several elevations of the column pipe with amplitudes and phase angles based on the actual measurement in order to reproduce the third

Testing Setup

Lower Pump Accelerometer Installation



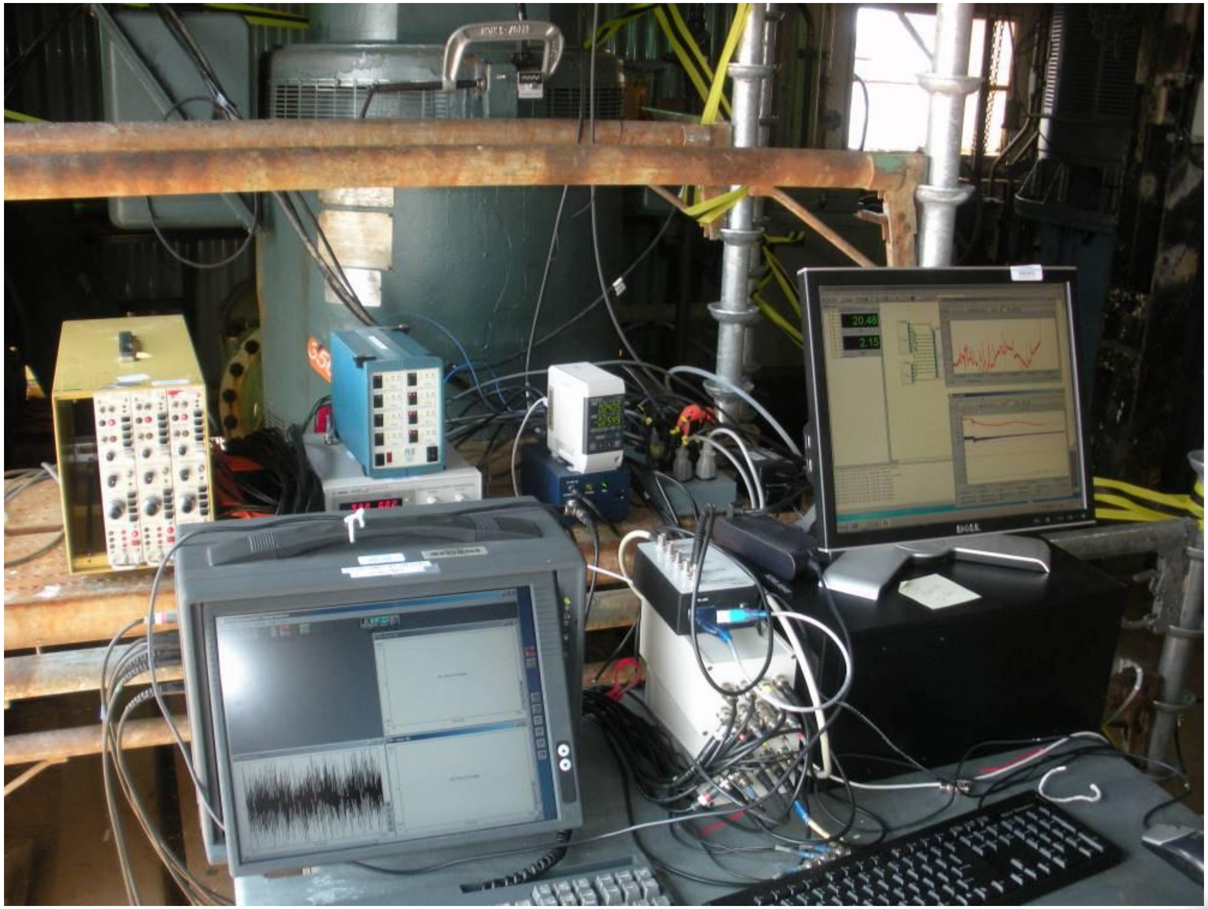
- Installed 20’ catheter to guide and attach an accelerometer to bottom of pump
  - Catheter was made from ¾” SS Tubing
  - Attached through 8” Access hole in floor
- Attached accelerometer to end of nylon tube to seal signal wire from water
- Accelerometer was attached to pump with magnet

- *In hindsight, we could have added a weight to the end of the catheter so it could be used as an impact hammer*
- *Hammer would be operated by pushing down on nylon tube and then releasing*

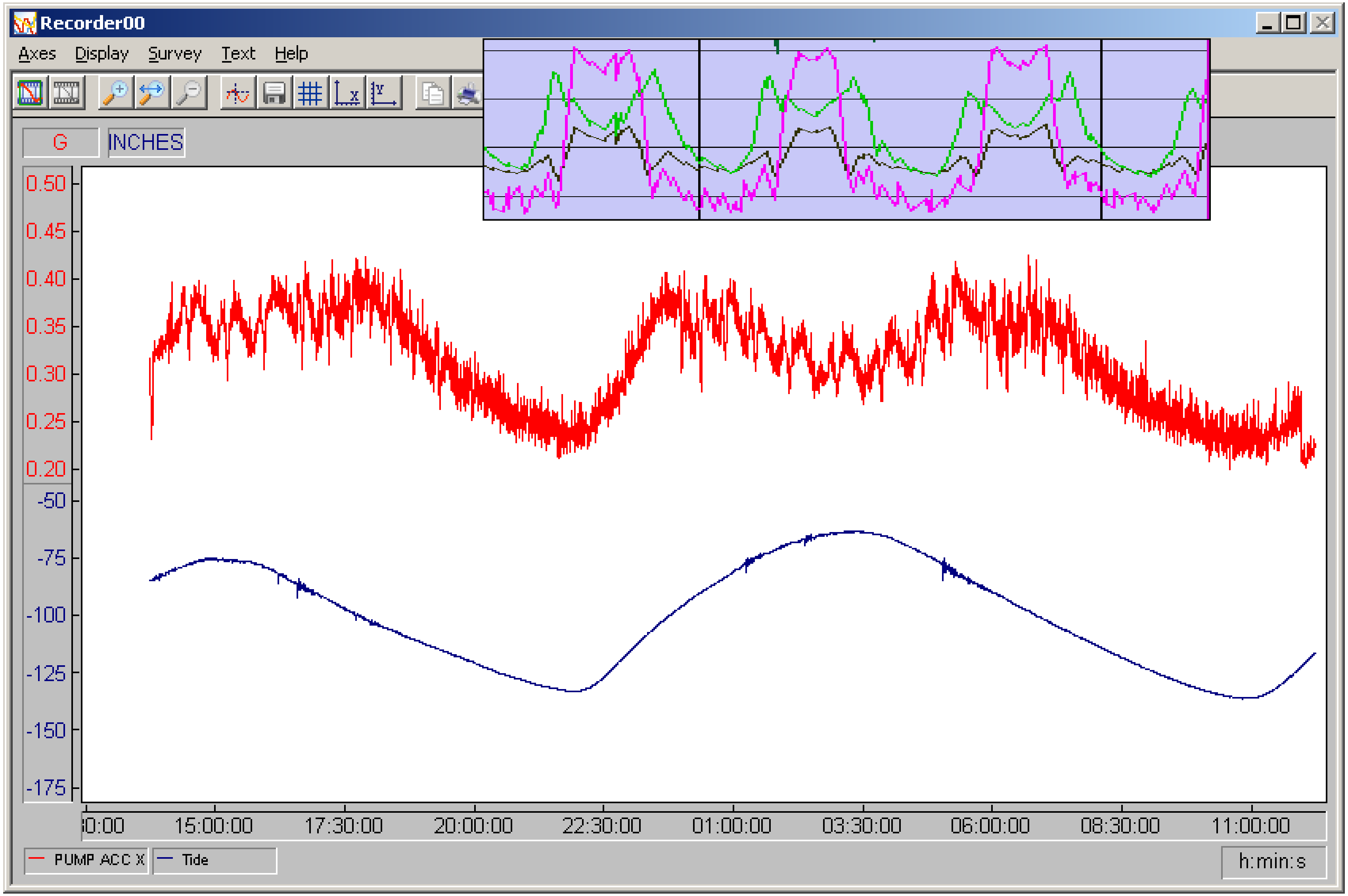
Water Level Sensor, Accelerometer Catheter

Time of flight displacement sensor used to measure float position. Plate was clamped to floor with threaded rod.

Data Acquisition

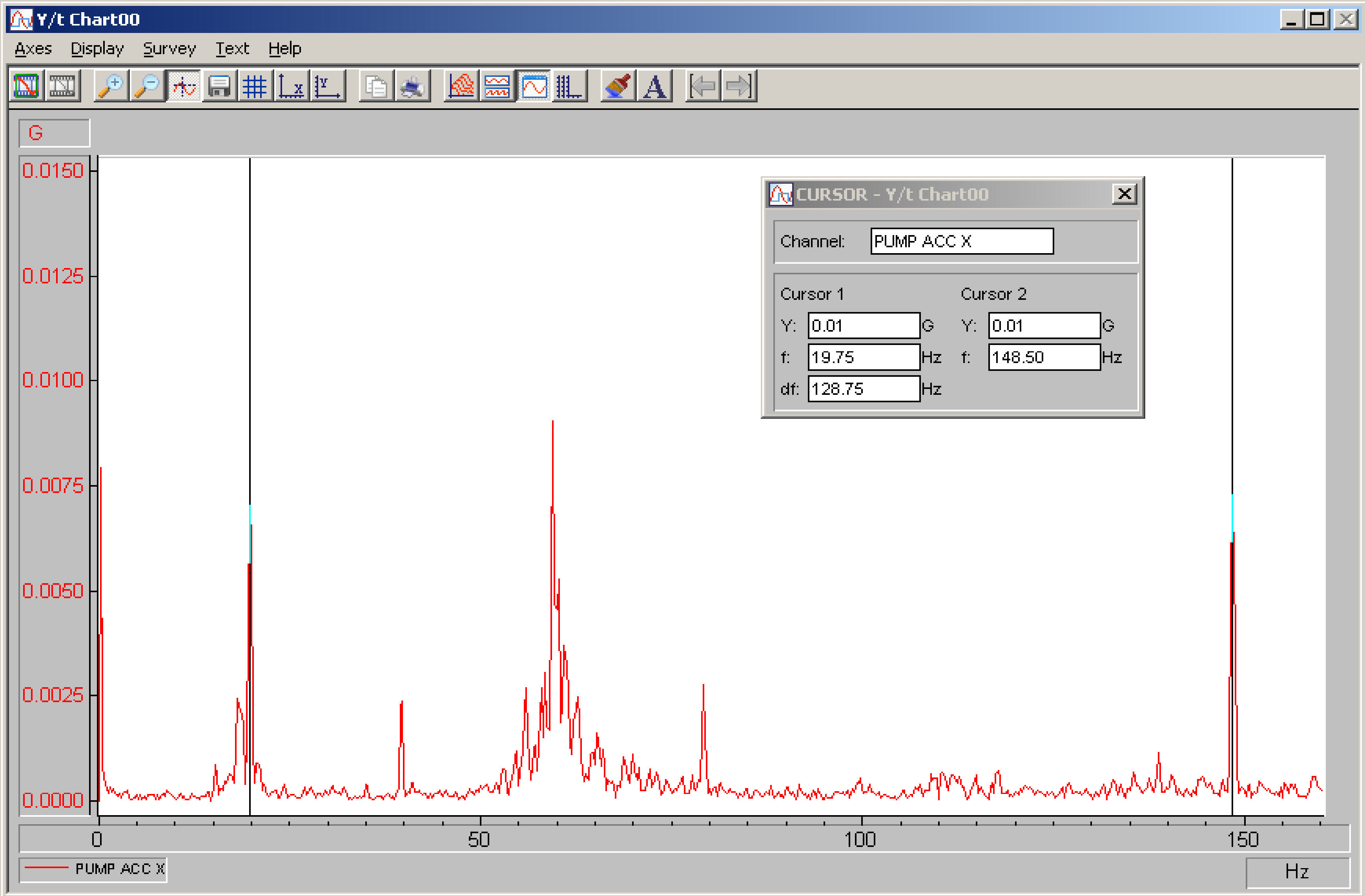


We set up to measure many parameters since the cause was initially unknown.

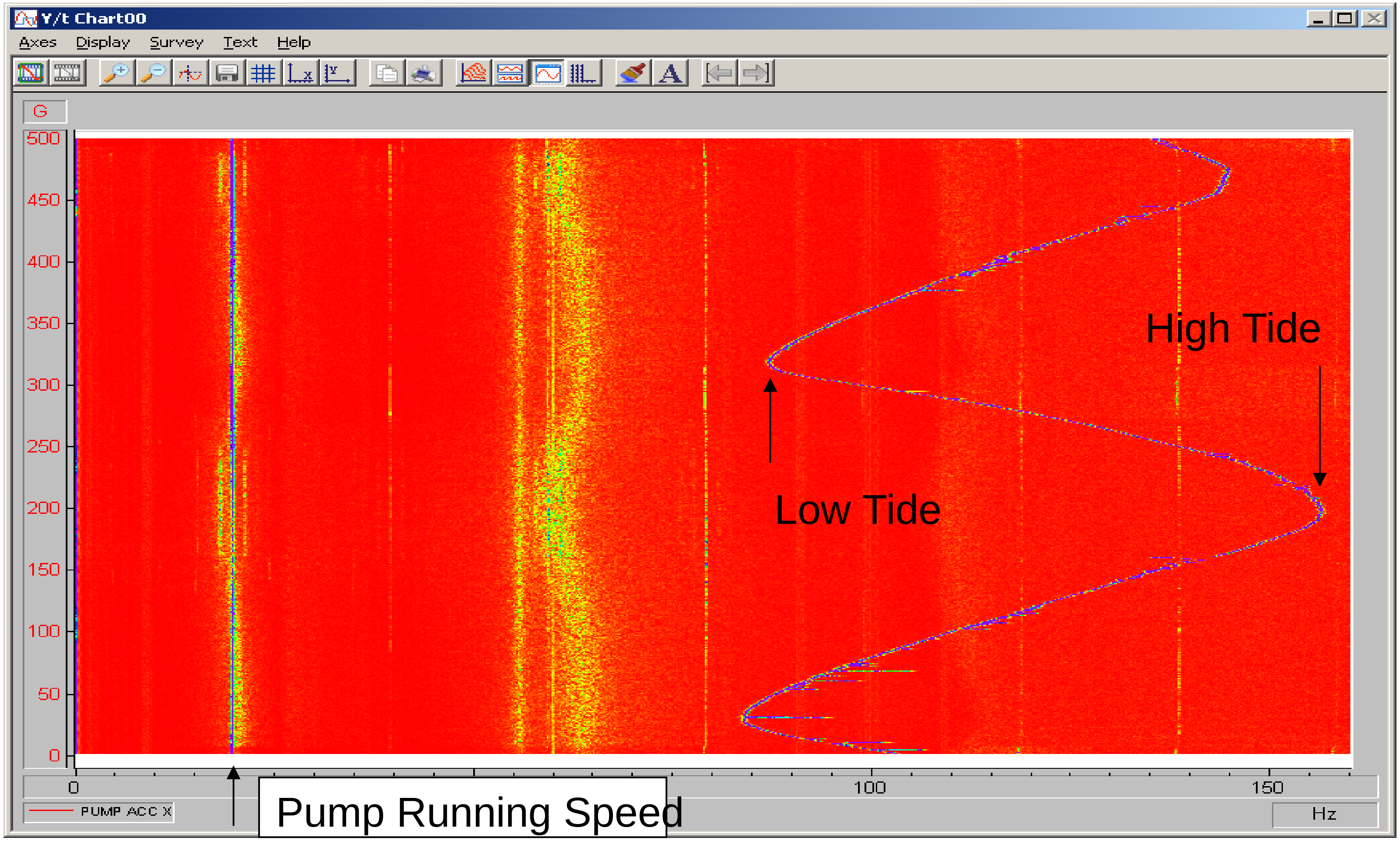


Vibration measured at bottom of pump and water level measured in vault. Vibration amplitude changes with water level. Peak vibration level occurs near high tide.

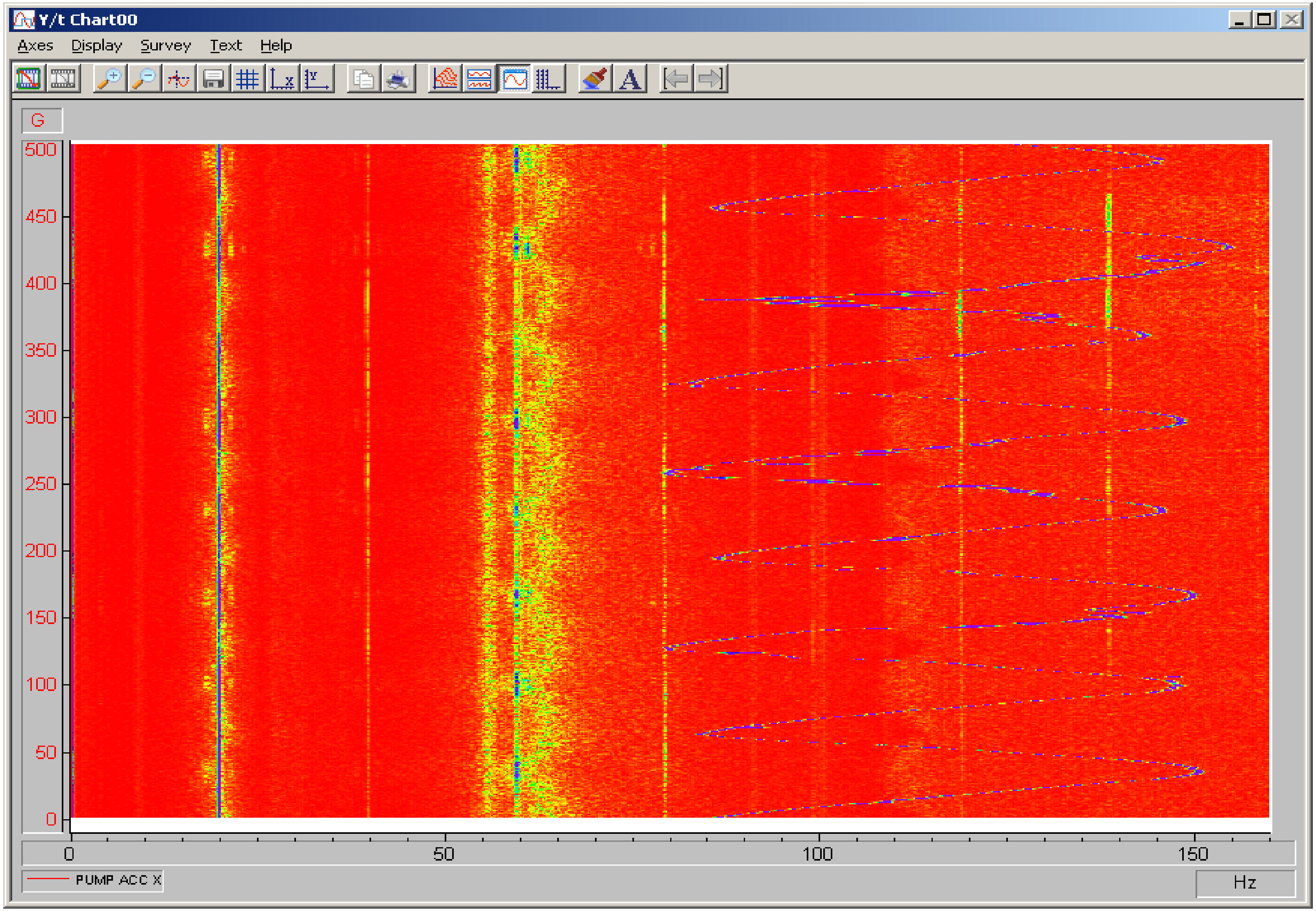
FFT of Time Trace



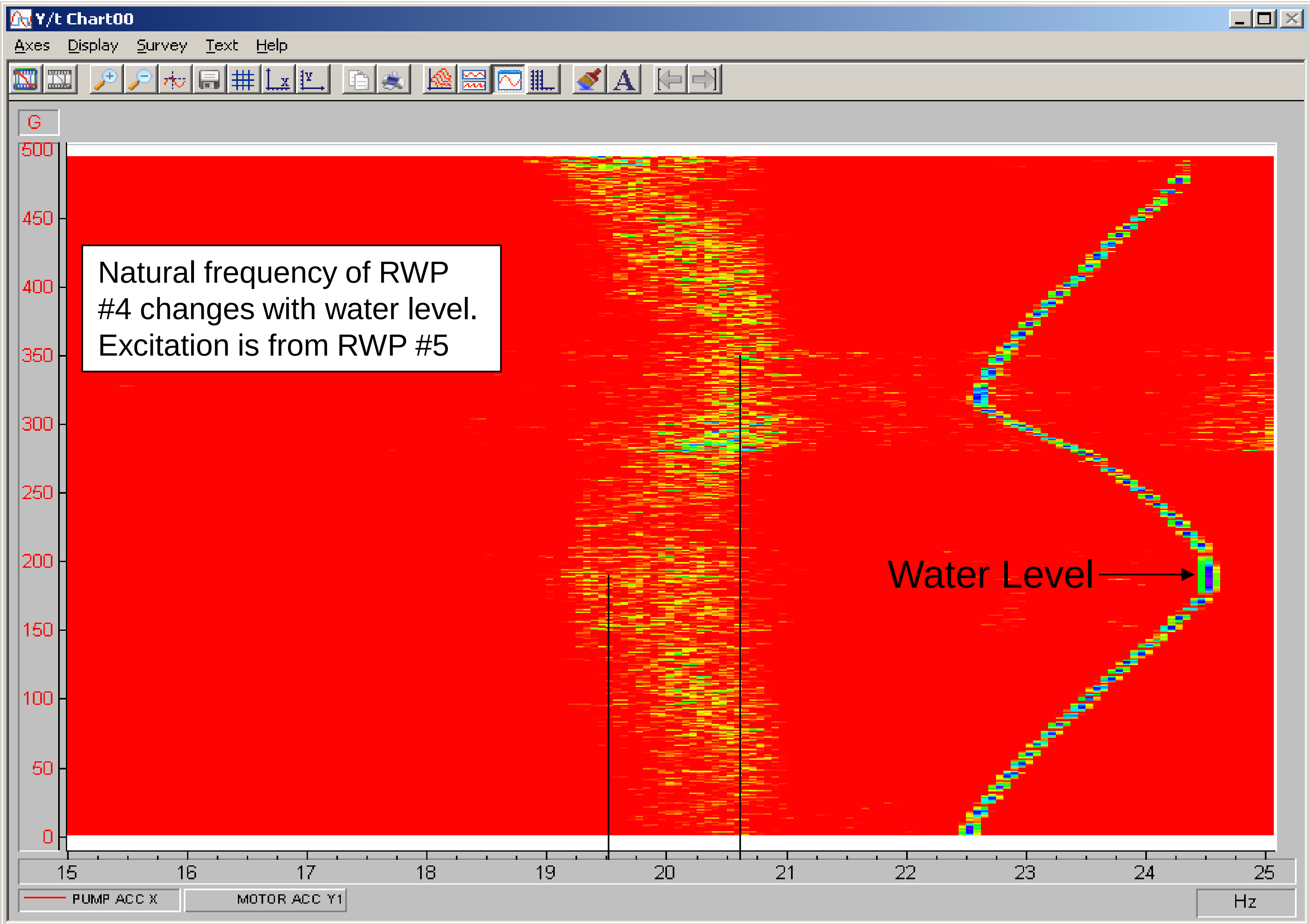
Contour Plot of FFT



Natural frequency changes with tide and intersects running speed of pump. Tide measurement was represented as a modulating frequency in FFT plot to correlate data.



Pattern repeats every tide cycle

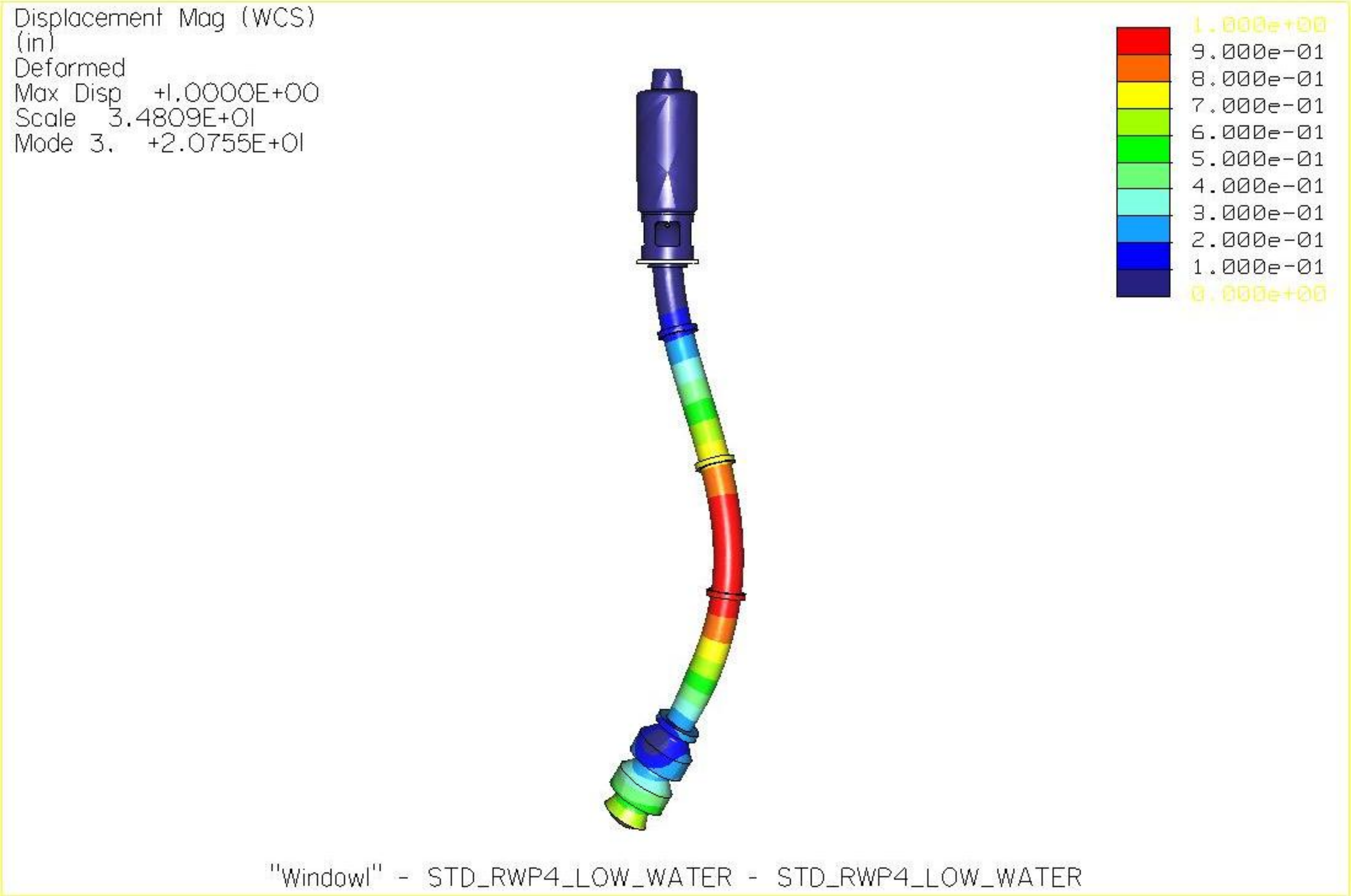

Y/t Chart00
Axes Display Survey Text Help
G
500
450
400
350
300
250
200
150
100
50
0
Natural frequency of RWP #4 changes with water level. Excitation is from RWP #5
Water Level
15 16 17 18 19 20 21 22 23 24 25
PUMP ACC X
MOTOR ACC Y1
Hz

FEA Analysis

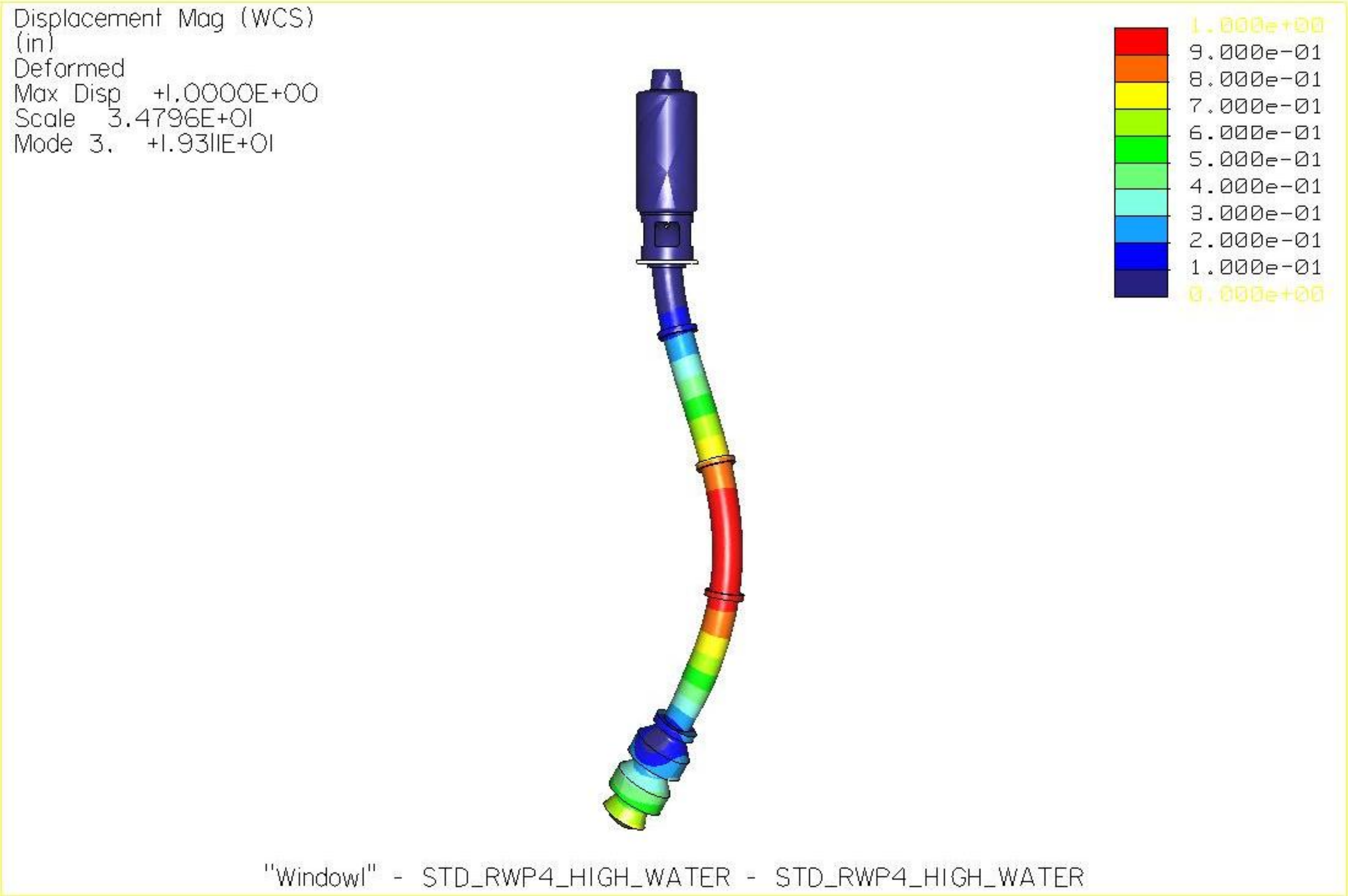
FEA Analysis

- Pump geometry was modeled to explore design changes.
- Weight of internal water was added by adjusting the density of internally wetted metal parts.
- Density of parts wetted by external water were adjusted to match measured frequency.
- Calibrated model was used to recommend design change.

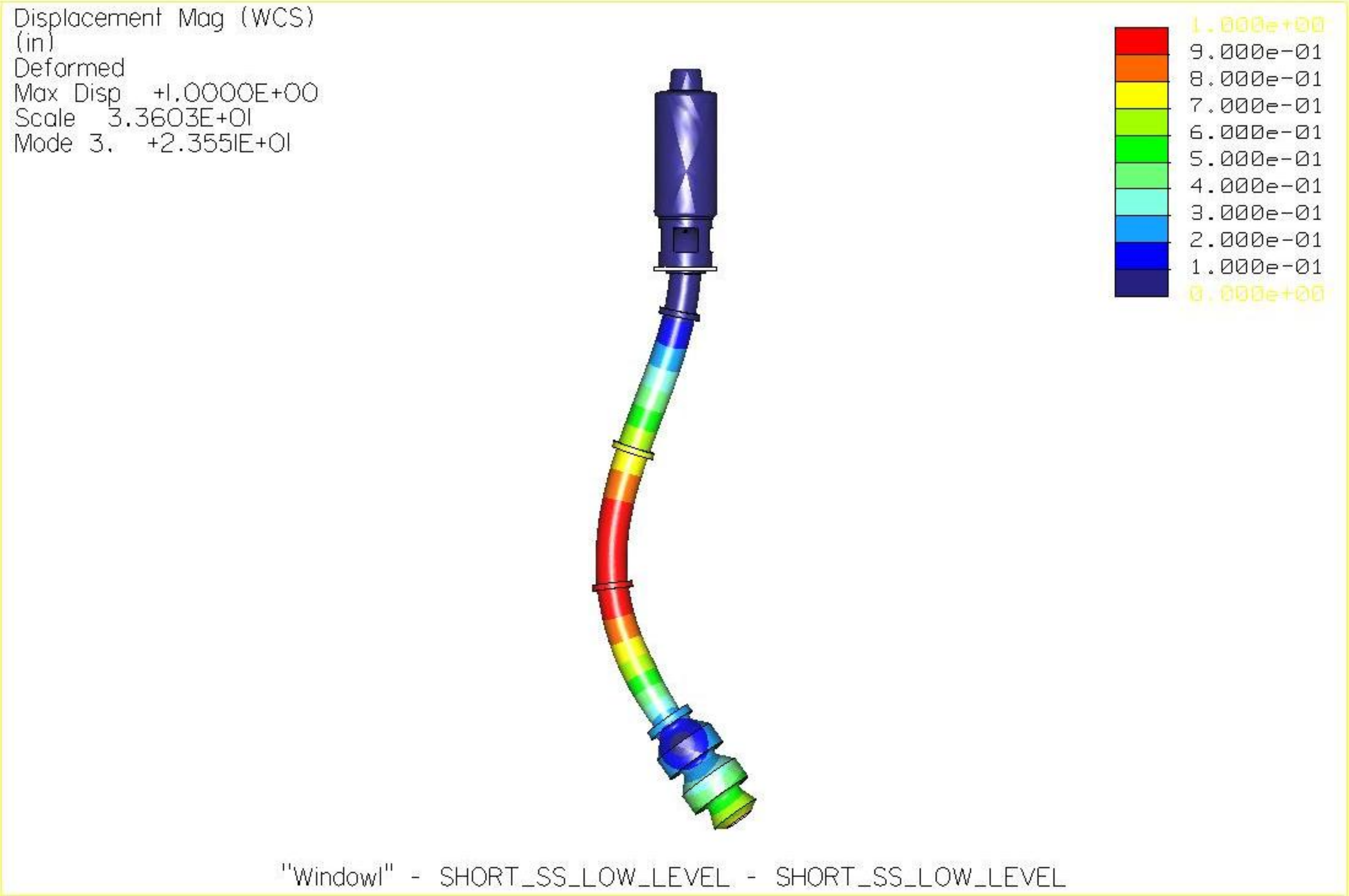
Standard Pump Low Tide
20.75 Hz



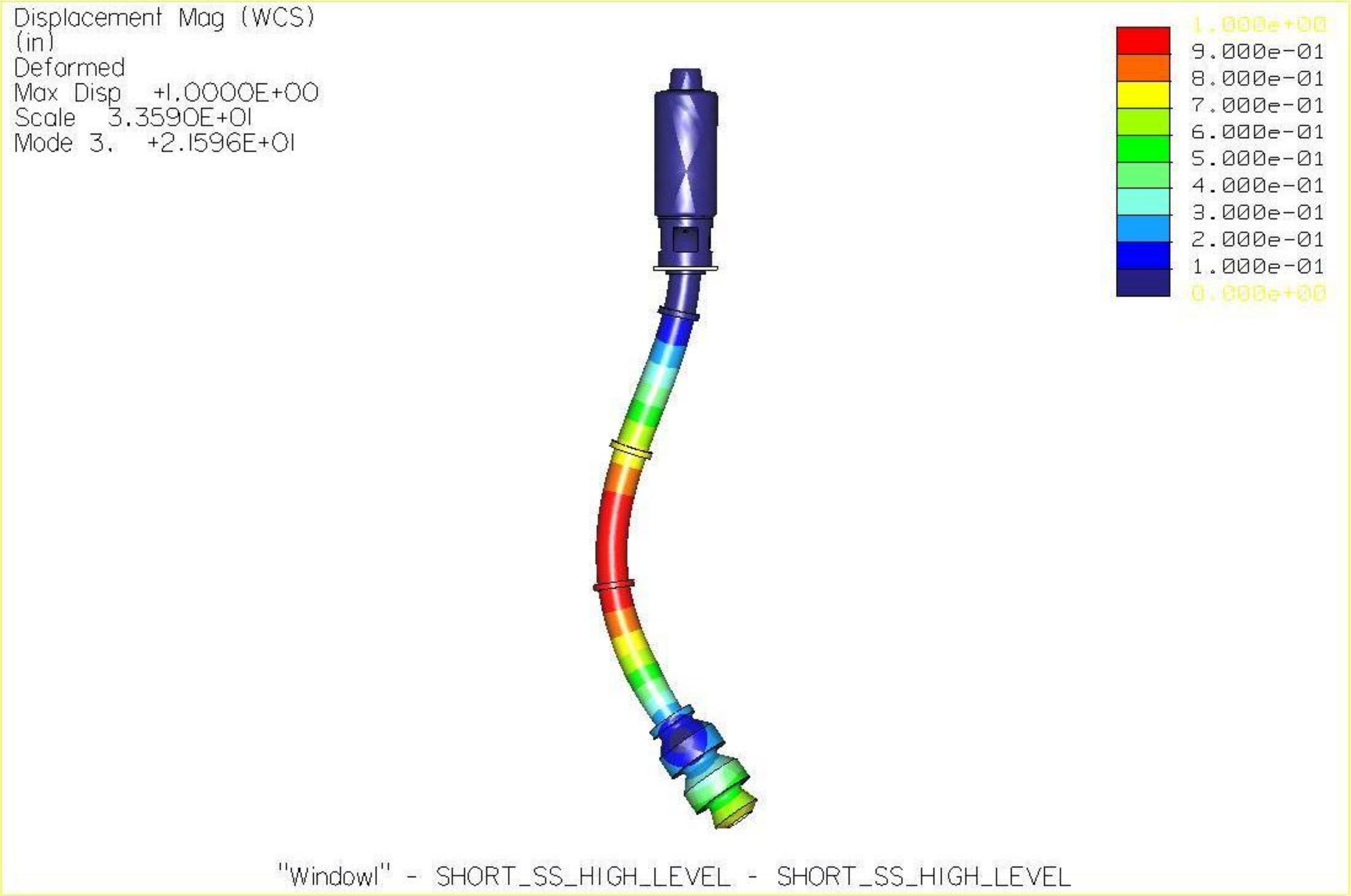
Standard Pump High Water Level
19.31 Hz



Shortened Column, SS Impeller Low Level
23.55 Hz



Shortened Column, SS Impeller High Level
21.60 Hz



FEA Summary

Condition	Model	Column Length	Column Diameter	Level	Frequency	RPM	% Running Speed (1180) RPM
Standard Low Tide	W3061052	211	14	Low	20.75	1245	106%
Standard High Tide	W3061052	211	14	High	19.31	1158.6	98%
Short Low Tide	W3060146	199	14	Low	23.55	1413	120%
Short High Tide	W3060146	199	14	High	21.60	1296	110%

Recommendation

- Replace trimmed impeller in #4 river water pump with full size impeller. Consider using duplex stainless steel as material of construction for increased resistance against river silt abrasion and salt attack.
- Reduce pump column length by 12” so that natural frequency will remain above running speed. The pump installed inadvertently had the column section increased by 12” but matched the original design for the pump.

Actions

- Ordered a complete new pump with a 12" shorter column length and proper diameter CD4MCUN impellers. Impellers were sized to meet head requirements but not overload the 400 HP motor.
- Installation planned for late fall 2013