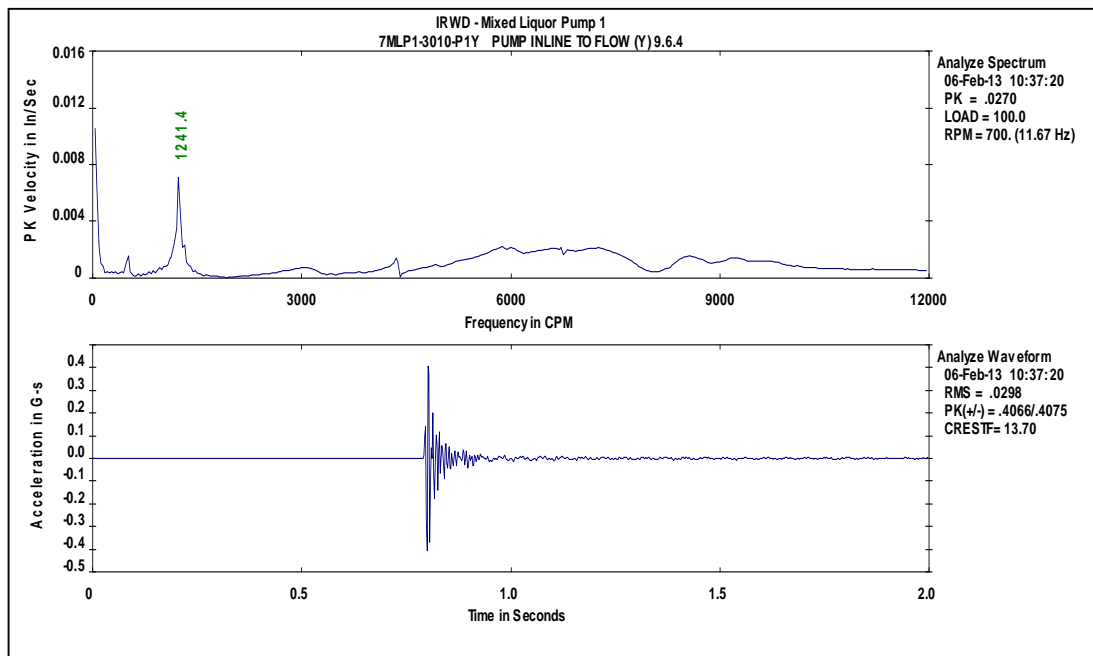


VIBRATION ACCEPTANCE TEST REPORT

Sample Report

Mixed Liquor Pumps 1, 2, 3, 4, 6

DATA COLLECTED: 2/6/13



Sample Report
Mixed Liquor Pumps

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Certified Field Pump Acceptance Test

February 24, 2013

RE: Sample Project Phase II
Mixed Liquor Feed Pumps

Prepared for:
Sample Report

To whom it may concern,

Please find below and on the following pages the results of the acceptance testing done at Sample Facility District on February 6, 2013 as per requested.

Scope

The scope of this report is to document the results of field vibration testing on the Mixed Liquor Feed Pumps associated with Sample Facility Project MWRP Phase II. Data was collected on pump A. The purpose of the test and this document is to verify the compliance of requirements set forth by Sample Facility Water District that field vibration testing be done to verify the pumps were installed and operating free of mechanical, electrical, installation and resonance conditions. These pumps were operated at a minimum flow of 40 Hz, then at three additional speeds 50Hz, 55Hz, and 60Hz, which represents their expected normal operating band. The data was then analyzed for common faults including: imbalance, misalignment, bent shaft, bearing issues, looseness, resonance, structural issues, electrical related problems, excessive cavitation, motor stator reed resonance, and other specific component defects that would be associated with these particular pumps and motors. In addition to the equipment mechanical diagnosis, values were reviewed for compliance to meet standards as per Hydraulic Institute Publication 9.6.4-2009 for the pumps and ISO Standard 10816-3 applied to motor data.

Based on my interpretation of the IRWD specifications, these units must pass both the mechanical analysis review and the above mentioned overall acceptance levels for both ANSI/HI and ISO Standards. The mechanical review will identify defective conditions that are frequency based without regard to overall amplitude. For instance, non-synchronous vibration that would indicate bearing raceway defects would result in rejection of acceptance although the overall vibration levels meet HI acceptance criteria. Conversely, if overall vibration levels exceed ISO and ANSI/HI Standards by a slight margin, but in my opinion reliability would not be affected, then comments would be made accordingly. Facility Engineering may then consider some allowance with respect to acceptance if the net benefit is minimal to address and resolve.



Summary of Findings

All of these pumps are performing as expected with no indication of mechanical or installation related conditions that would adversely affect equipment reliability. Overall vibration levels as recorded easily meet both the minimum standards as per ISO 10816-3 and ANSI/HI 9.6.4 at all operating speeds, including minimum flow. Resonance testing and cascade plot analysis indicates resonant frequencies are outside of the 25% band of operating speeds between 40 – 60 Hz at both 1x shaft rpm and vane pass frequency of 5x shaft speed. In summary, these pumps are running well under acceptable limits with maximum values under 20% of threshold limits.

Procedures

Field acceptance procedures were performed as per Sample Facility Specifications listed as “Vibration Monitoring and Testing” in Section 3.6 of the “Vertical Pumps 11070 “ section of MRWP Phase II Expansion Specification March 2009 documentation.

Vibration data was collected on the Motor Top and Bottom bearing locations in radial (inline with flow) and tangential planes (crossline with flow) with an axial data point taken on the motor bottom flange so that a condition diagnosis of the motor component can be performed as outlined above and pursuant to the requirement in Section 3.6 Par B.4. Additional data was collected on the motor support flange of the pump discharge head as per standards set forth in Hydraulic Institute Publication 9.6.4 rev. 2009. Hydraulic Institute limits are based on pump type & KW (or BHP) rating, flow conditions, and with regards to vertical pumps there is an added variation in acceptance criteria based on overall height.

Acceptance criteria in this report with regards to ANSI/HI standards will reference Inches/Sec RMS Velocity. For this classification of pump (VS1), there are additional allowances when flow conditions are outside of the Preferred Operating Range, but since all vibration data returns very low levels regardless of test conditions, there seemed to be little benefit to add additional technical layers when existing criteria is already easily met.

Data was collected at each point utilizing a CSI 2130 Portable analyzer and magnetically mounted accelerometer with 70lb pull rating, and then reviewed in acceleration and velocity. To verify data repeatability, two readings were collected for each data point.

To address the determination of resonant or transient related frequencies the units were bump tested in both X and Y directions and cascade plots were also recorded on X, Y, and axial planes that encompassed the full band of 40-60Hz operating speed at .5 Hz intervals.

Site Specific Conditions and Acceptance Criteria

To allow for correct flow and anti-siphoning, manual back pressure was used to keep the hydraulic forces within pump curve specifications. When applying ANSI/HI testing standards, reference is made to test the pumps within their Preferred Operating Range (POR). An allowance of 30% additional margin is provided when the pump flow exceeds POR but is above minimum flow and within what is referred to as the Acceptable Operating Range (AOR). To determine this range, data may be provided by the vendor on the pump curve, and when absent then standards as per API 610 (which sets the standards for POR at 80-110% of BEP, and AOR at 70-120% of BEP) is applied. From a technical point of view the data collected at 50 Hz returns flows just outside of the AOR by a very slight margin, but so close that since the values remained well under .05 Inches/Sec RMS, I have included as part of the pass/fail data.



Based on the machine classification and onsite flow test conditions, the maximum allowable vibration on these units as per ANSI/HI standards would be .13 in/sec POR, and .169 in/sec AOR.

ISO 10816-3 standards for the Class 2 Flexible base motor would be .05 in/sec RMS for excellent values and .18 in/sec as acceptable values. Values above .18 in/sec would be considered unacceptable with respect to equipment reliability. All calculations are based on these units pumping clear liquids @ 1.00 Specific Gravity.

To simplify the following report format and content, an acceptance level of .12 in/sec RMS is used on all points as this meets or exceeds any criteria set forth above and the equipment test results returns values well under this threshold. Also this level is referenced in IRWD specifications as recommended.

Equipment Classification:

The Hydraulic Institute refers to a “vertical single or multistage, short setting, open line shaft” as a VS1 pump which would appear to apply in this case. Regardless, all vertical line shaft pumps fall within the same classification. The measured height of all the motor support flanges is less than 60”, so there is no consideration for extended height allowances. These pumps are under 200KW (268 BHP), so vibration acceptance criteria with respect of velocity amplitude RMS will be the same for all pump data and applies to measurement points P1X, P1Y, and P1A.

ISO Standard 10816-3 addresses standards for Mechanical Vibration: “Evaluation of machine vibration by measurements on non-rotating parts”. Part 3 applies to Industrial Machines with nominal power above 15kW and nominal speeds between 120 and 15000 rpm. Within this document is the classification of machines and acceptance criteria that is intended to address the assessment of vibration influences with regards to mechanical reliability. These pumps fall within a classification as Group 2 machines with flexible base support. This standard was applied to the motor data points listed as M1X, M1Y, M2X, M2Y and M2A. Supporting documentation is provided at the end of this report for references.

Content of the report:

This report provides the following information on each of 5 pumps tested:

- Analyst summary overview
- Pump specific information
- Tested flow ranges
- Applied standards
- Bar Graph showing frequency based band values vs. threshold limits of .12 in/sec. RMS.
- Trend data showing results of all speeds in RMS Velocity vs. flow, speed and discharge pressure. Two trends are provided, one in overall and a second in the 5-21x rpm is included. This 5-21x band is the frequency that encompasses vane pass and flow stability issues.
- Tabular information with regards to the various test conditions and results of PASS/FAIL in percentage of threshold
- FFT Plot data on all data points at or near BEP of 11000 GPM / 705 rpm / 60 Hz with significant peaks labeled in frequency CPM.
- Results of bump test data and with response frequencies from 3-12000 CPM.
- Cascade plots spaced at .5 Hz from 40 – 60 Hz operating band with primary 1x and 5x rpm band peak located.



- Supplemental Attachments
 - Customer supplied equipment information
 - Analyst ANSI Level III Vibration Certification
 - Analyzer and Accelerometer Calibration Certification
 - ISO 10816-3 Acceptance Table.

I trust this report meets your requirements. If I can be additional assistance please do not hesitate to contact me at the below.

Sincerely,

Kirk F. Corman

President/ Certified ANSI Level III Vibration Analyst
805-478-0797
Condition Monitoring Services, Inc.

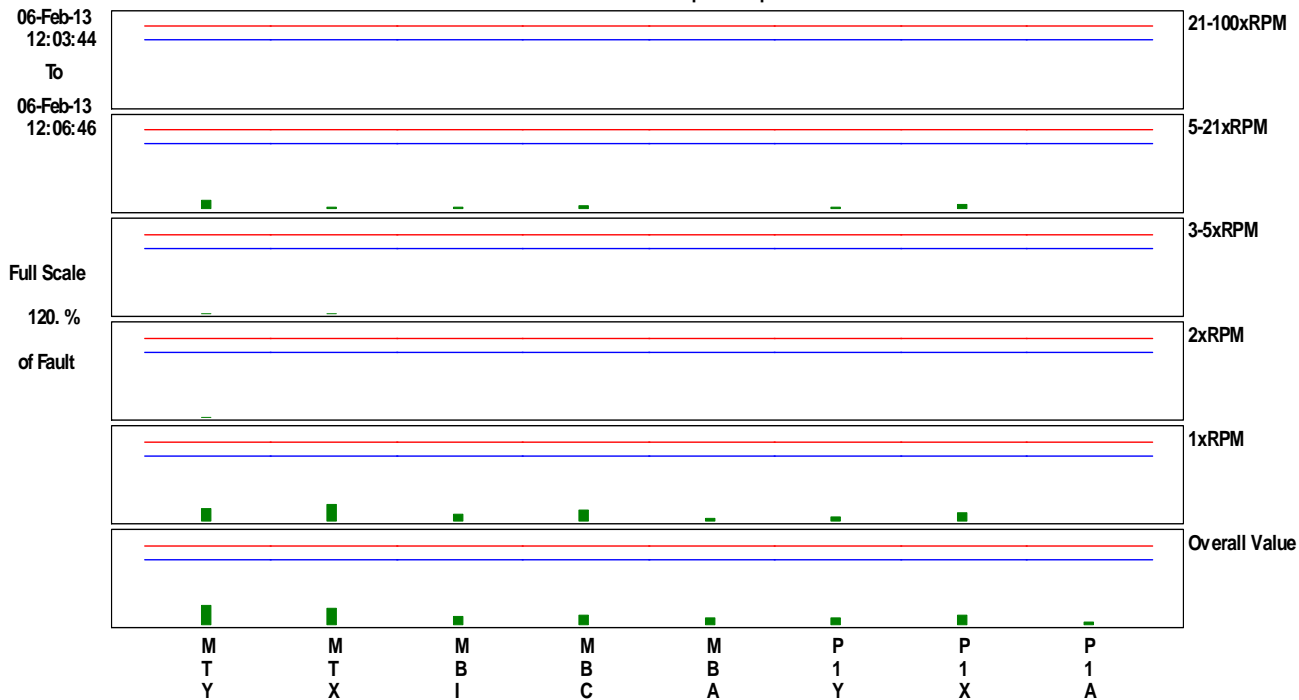
VIBRATION ACCEPTANCE TEST REPORT - Pump A

Contractor:	Sample	Machine name:	Mixed Liquor Pump A
End User:	Sample	Project Name	PHASE II
Machine Make/Model:	Sulzer 20 PS -5V	Serial Number:	12345
Time period reviewed:	2/25/2013	Tag Number	Pump A
Rated HP	100 HP	Rated BEP	11000 GPM @ 18 FT Total Head
Reference Test Criteria	ANSI HI 9.6.4 & ISO 10816-3	Machine Type:	ANSI/Hi - VSI, ISO 10816-3 Group 2 Flexible Base
Pass / Fail	PASS	Tested flow	3972-11152 GPM

OBSERVATIONS:

RESONANT RESPONSES WERE PRESENT WITHIN THIS UNIT AT 1241 AND 5895 CPM AND ARE OUTSIDE OF THE 25% BAND OF OPERATIONAL FREQUENCIES AT 1X AND 5X RPM THAT WOULD BE CONSIDERED UNACCEPTABLE. VIBRATION ON THIS UNIT DOES NOT EXCEED .016 IPS/RMS AND IS CONSIDERED TO BE WITHIN EXCELLENT TOLERANCES AT ALL SPEEDS. SPECTRAL AND WAVEFORM ANALYSIS DOES NOT INDICATE THE PRESENCE OF MECHANICAL OR BEARING RELATED DEFECTS THAT WOULD AFFECT EQUIPMENT RELIABILITY.

IN THE ALARM GRAPH BELOW, THE ALERT LEVEL IS SET AT .10 ips/RMS AND IS REPRESENTED BY THE BLUE HORIZONTAL LINE IN EACH BAND. THE FAULT LEVEL, REPRESENTED BY THE RED LINE, IS SET AT .12 ips/RMS AS PER IRWD VIBRATION LIMITS. ALL VIBRATION LEVELS WITHIN THIS UNIT CAN BE SEEN TO BE WITHIN ACCEPTABLE LEVELS.



X-Axis Measurement Point Key:

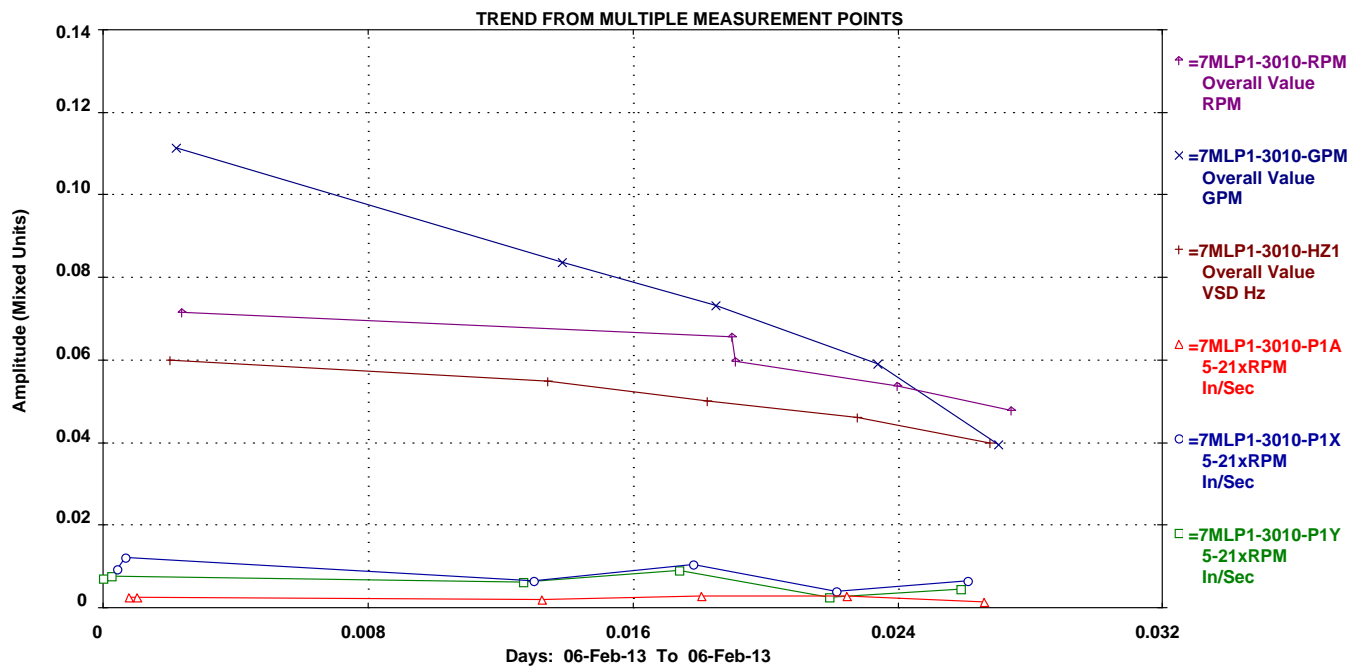
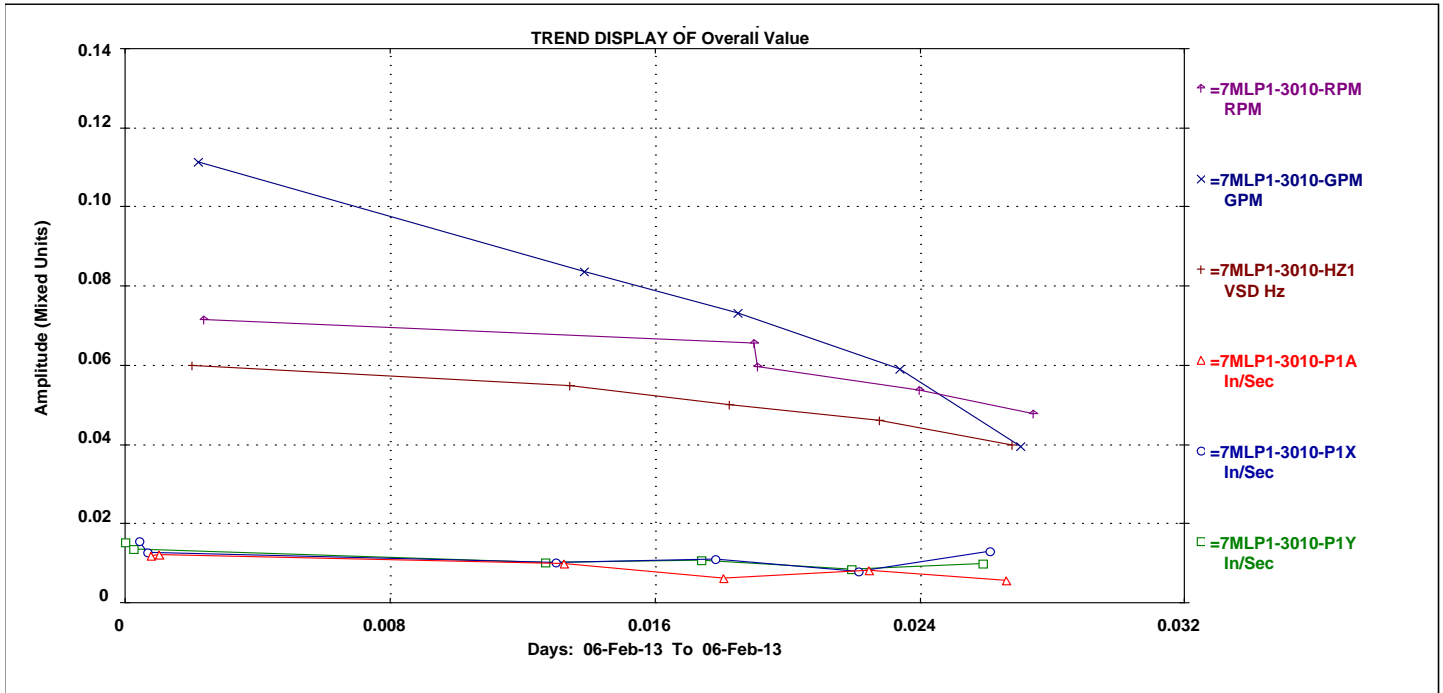
MTY --> MOTOR TOP BEARING INLINE (Y)
 MBI --> MOTOR BTTM INLINE TO FLOW (Y)
 MBA --> MOTOR BTTM AXIAL CROSSLINE (A)
 P1X --> PUMP CROSSLINE TO FLOW (X) 9.6.4

MTX --> MOTOR TOP BEARING CROSSLINE (X)
 MBC --> MOTOR BTTM CROSSLINE TO FLOW (X)
 P1Y --> PUMP INLINE TO FLOW (Y) 9.6.4
 P1A --> PUMP AXIAL (A) 9.6.4

VIBRATION ACCEPTANCE TEST REPORT - Pump A

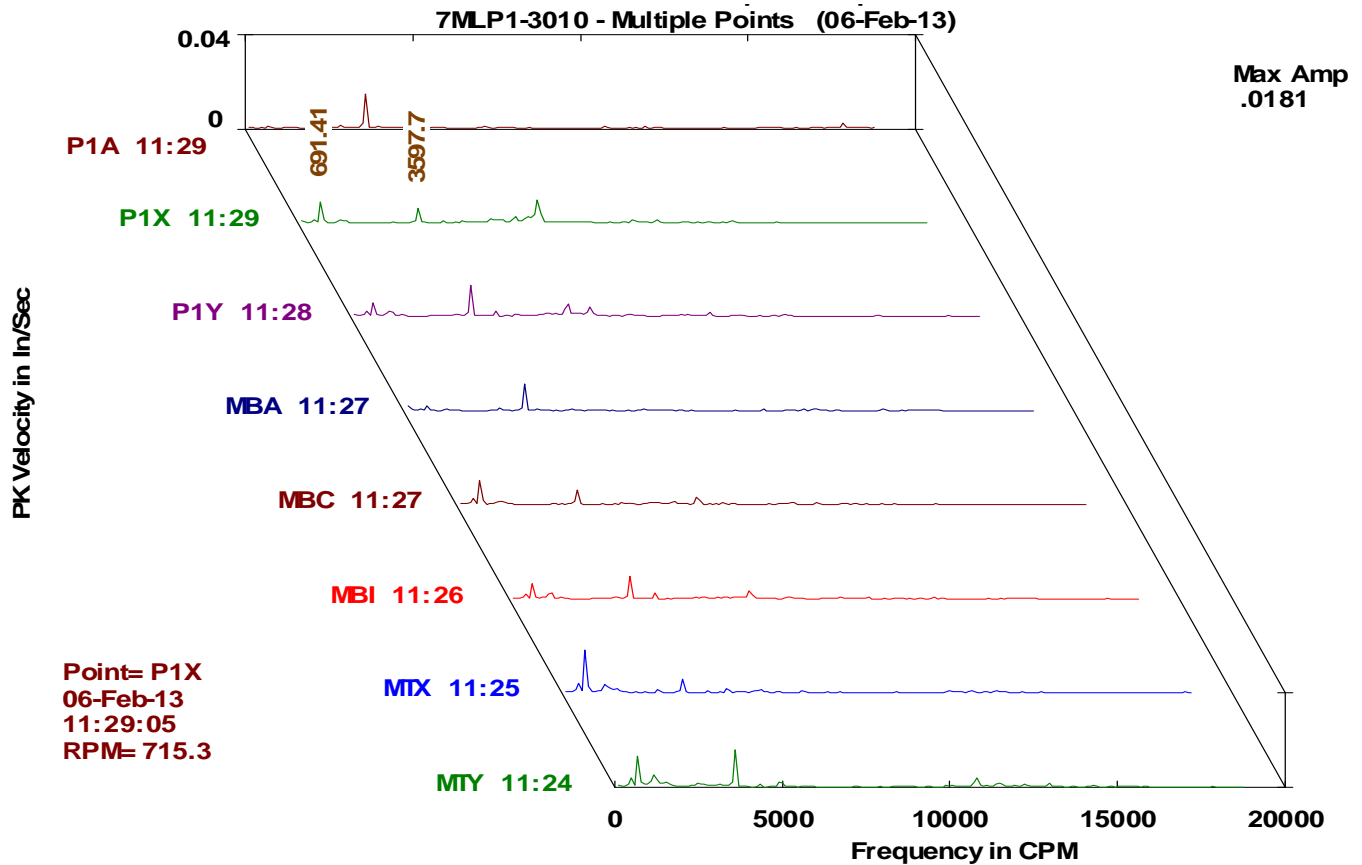
Trend Data

THE FIRST GRAPH ON THIS PAGE TRENDS OVERALL VIBRATION LEVELS ON P1A, P1X, AND P1Y AGAINST RPM, GPM, AND Hz. THE VALUES FOR RPM, GPM, AND Hz HAVE BEEN MULTIPLIED BY .001 SO THAT COMPARISON AGAINST VIBRATION LEVELS CAN BE MADE. THE SECOND TREND GRAPH IS OF THE SAME DATA POINTS BUT IN THE 5-21X BAND. THIS VIBRATION BAND ENCOMPASSES VANE PASS, FLOW TURBULENCE, AND OTHER DEFECTS THAT MAY NOT NECESSARILY SHOW UP IN THE OVERALL BAND.




VIBRATION ACCEPTANCE TEST REPORT - Pump A
FFT Data

FFT DATA BELOW AT FULL SPEED SHOWS ALL POINTS UNDER .018 IPS/RMS. PEAKS ARE LABELED AT 1X AND 5X SHAFT SPEED.

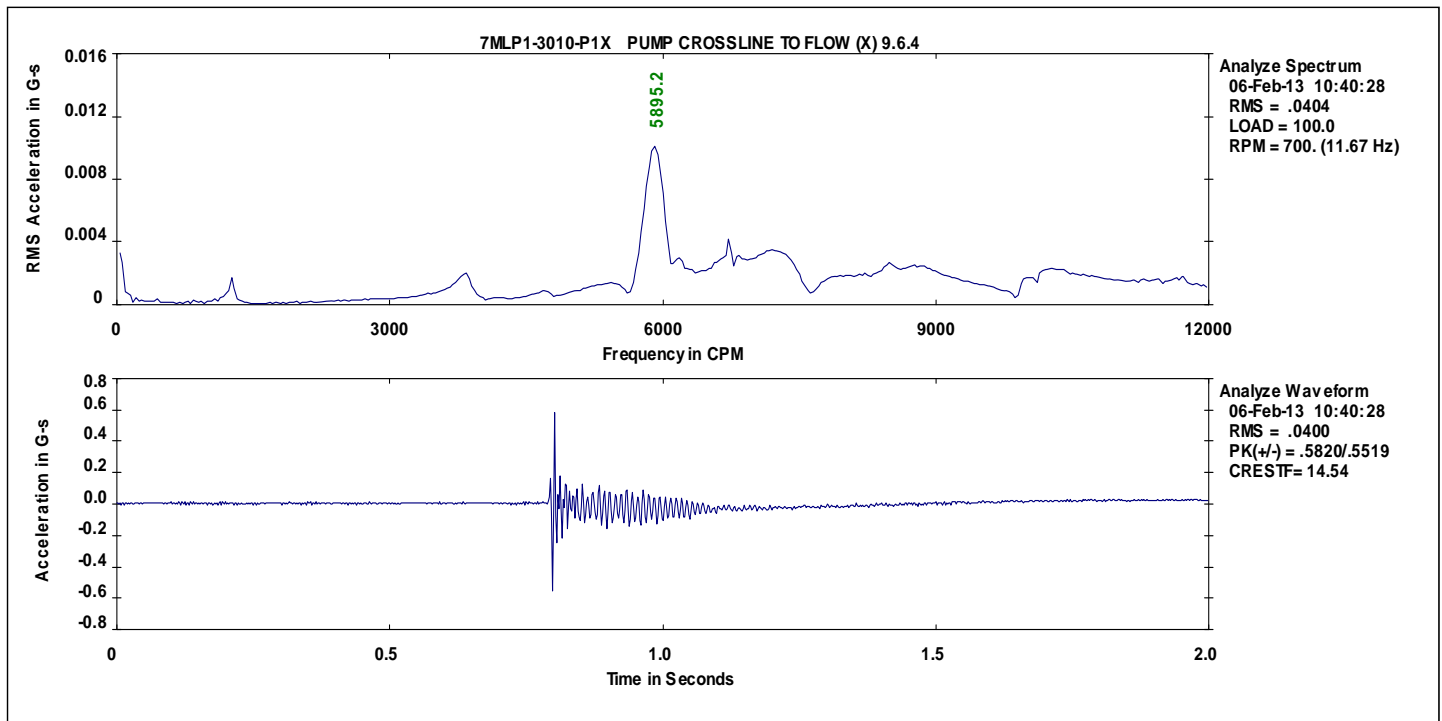
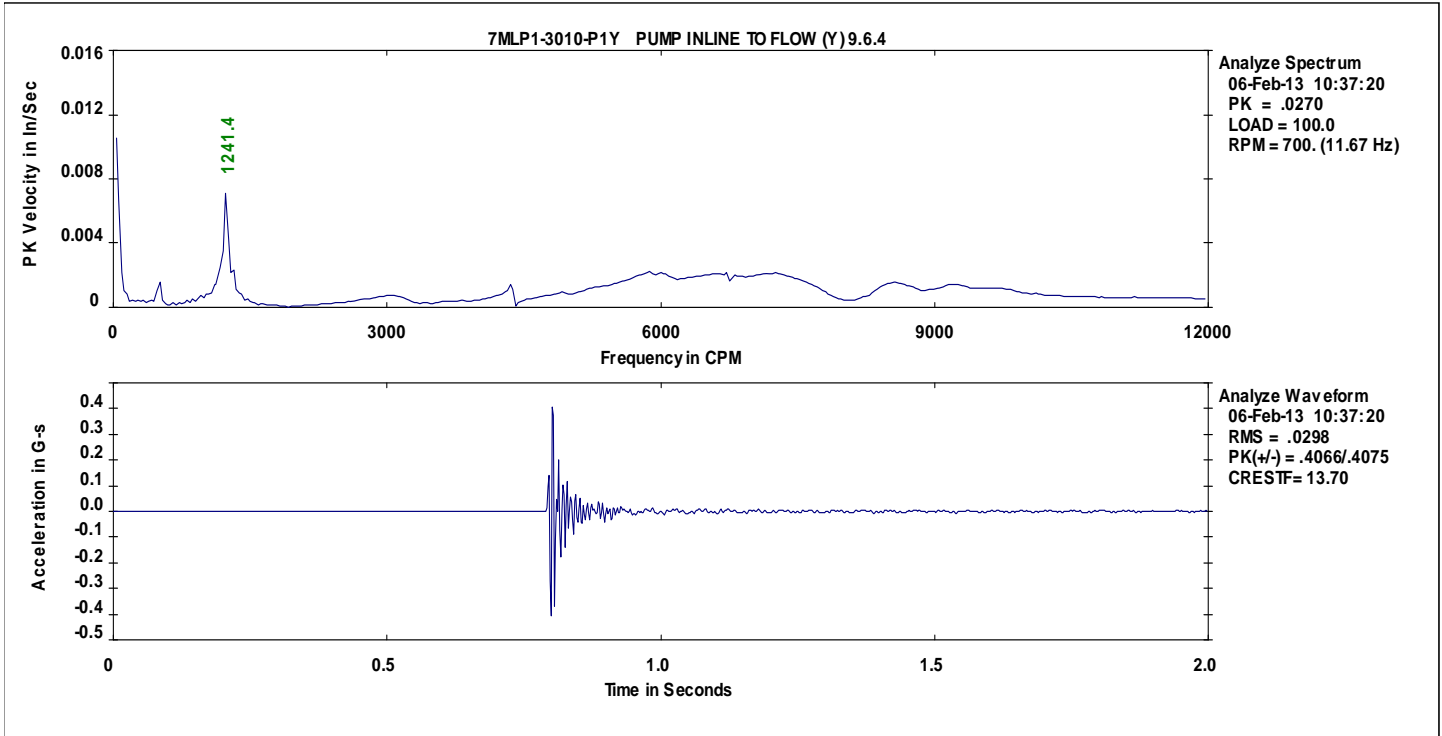

Measurement Point Key:

MTY --> MOTOR TOP BEARING INLINE (Y)
 MTX --> MOTOR TOP BEARING CROSSLINE (X)
 MBI --> MOTOR BTTM INLINE TO FLOW (Y)
 MBC --> MOTOR BTTM CROSSLINE TO FLOW (X)
 MBA --> MOTOR BTTM AXIAL CROSSLINE (A)
 P1Y --> PUMP INLINE TO FLOW (Y) 9.6.4
 P1X --> PUMP CROSSLINE TO FLOW (X) 9.6.4
 P1A --> PUMP AXIAL (A) 9.6.4

VIBRATION ACCEPTANCE TEST REPORT - Pump A

Results of Bump Testing:

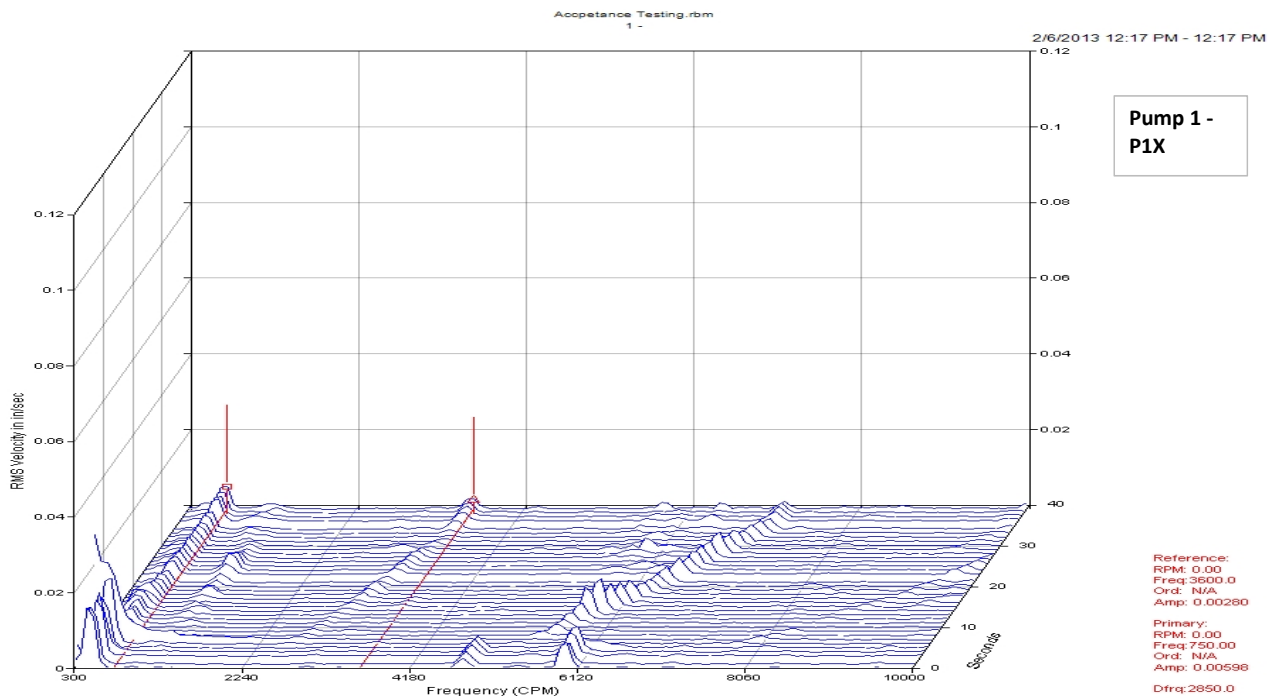
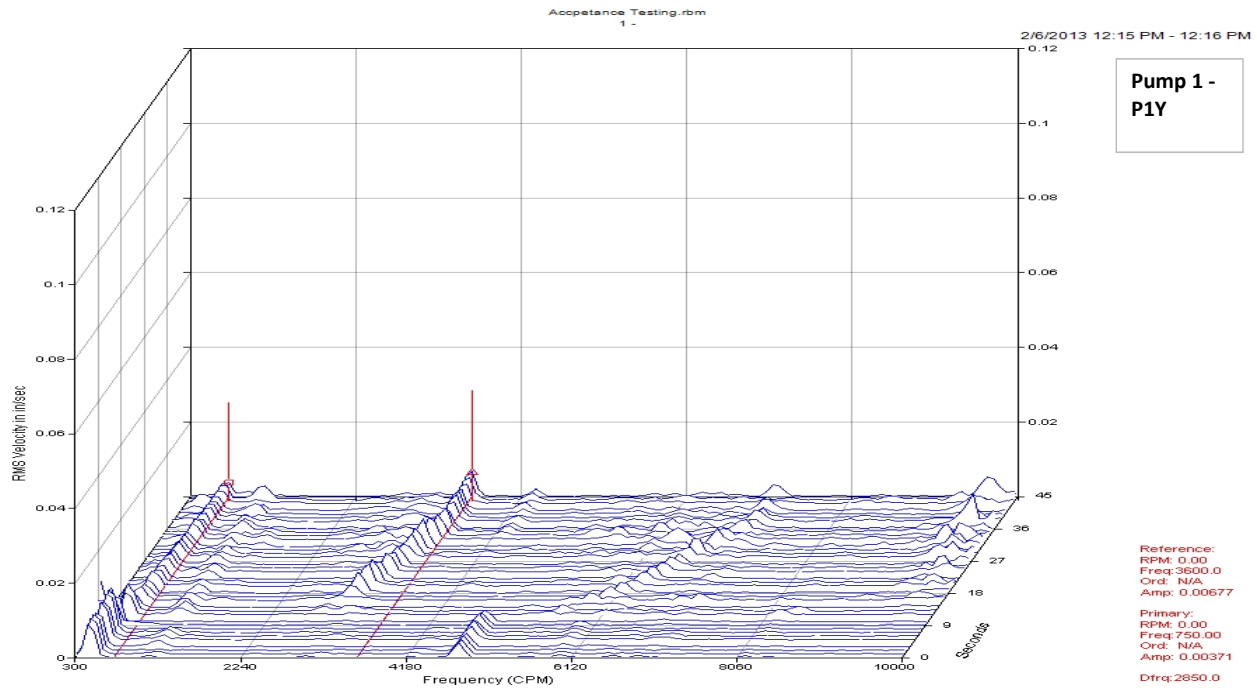
THE FFT GRAPHS BELOW ILLUSTRATE THE RESONANT PEAKS PRESENT WITHIN THIS UNIT AT 1241 AND 5895 CPM. THE WAVEFORM GRAPHS ILLUSTRATE A VISUAL IMPACT RESPONSE AND RESULTING RINGDOWN TO THE IMPULSE OF THE ENERGY FROM THE IMPACT HAMMER.



VIBRATION ACCEPTANCE TEST REPORT - Pump A

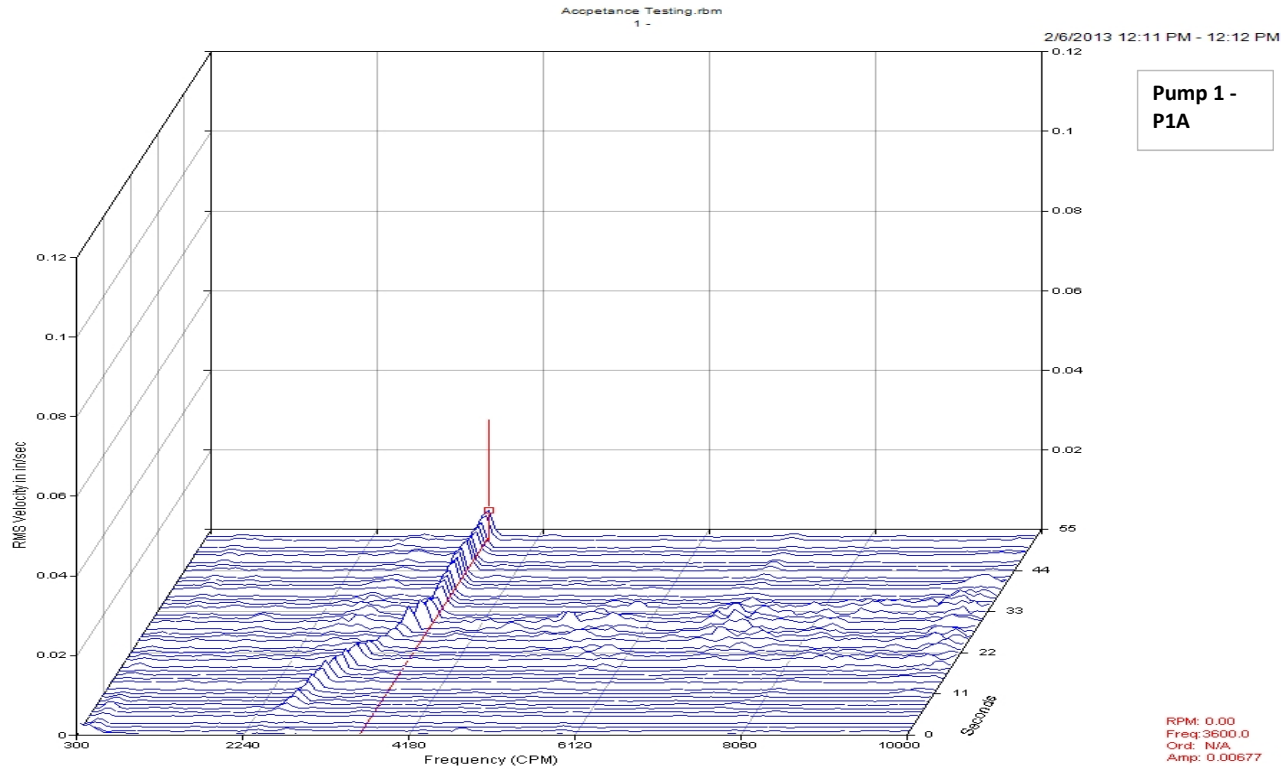
CASCADE WATERFALL

THE BELOW CASCADE PLOTS ARE A RESULT OF MONITORING DURING TRANSITION FROM 40-60 HZ. RED CURSOR LINES MARK FULL SPEED 1X SHAFT SPEED OF 715 RPM AND 5X SHAFT SPEED OF 3575 RPM. NOTE THE DATA COLLECTION WAS AT APPROXIMATELY .5 HZ INTERVALS.



VIBRATION ACCEPTANCE TEST REPORT - Pump A

CASCADE WATERFALL





VIBRATION ACCEPTANCE TEST REPORT - Pump A

Tabular Information and Results of Field Testing - Pump A

PumpA - P1Y-PUMP INLINE TO FLOW (Y)

Date	Time	Overall Velocity Peak	Overall Velocity RMS	Limit in ips/RMS	Percent Threshold	
6-Feb-13	11:28	0.022	0.016	0.12	13%	PASS
6-Feb-13	11:28	0.019	0.013	0.12	11%	PASS
6-Feb-13	11:46	0.014	0.010	0.12	8%	PASS
6-Feb-13	11:53	0.015	0.011	0.12	9%	PASS
6-Feb-13	11:59	0.012	0.008	0.12	7%	PASS
6-Feb-13	12:05	0.014	0.010	0.12	8%	PASS

PumpA - P1X-PUMP CROSSLINE TO FLOW (X)

Date	Time	Overall Velocity Peak	Overall Velocity RMS	Limit in ips/RMS	Percent Threshold	
6-Feb-13	11:29	0.022	0.016	0.12	13%	PASS
6-Feb-13	11:29	0.018	0.013	0.12	11%	PASS
6-Feb-13	11:47	0.014	0.010	0.12	8%	PASS
6-Feb-13	11:54	0.016	0.011	0.12	9%	PASS
6-Feb-13	12:00	0.011	0.008	0.12	6%	PASS
6-Feb-13	12:06	0.019	0.013	0.12	11%	PASS

Pump A - P1A-PUMP AXIAL INLINE WITH FLOW (A)

Date	Time	Overall Velocity Peak	Overall Velocity RMS	Limit in ips/RMS	Percent Threshold	
6-Feb-13	11:29	0.017	0.012	0.12	10%	PASS
6-Feb-13	11:29	0.017	0.012	0.12	10%	PASS
6-Feb-13	11:47	0.014	0.010	0.12	8%	PASS
6-Feb-13	11:54	0.0087	0.006	0.12	5%	PASS
6-Feb-13	12:00	0.012	0.008	0.12	7%	PASS
6-Feb-13	12:06	0.008	0.006	0.12	5%	PASS

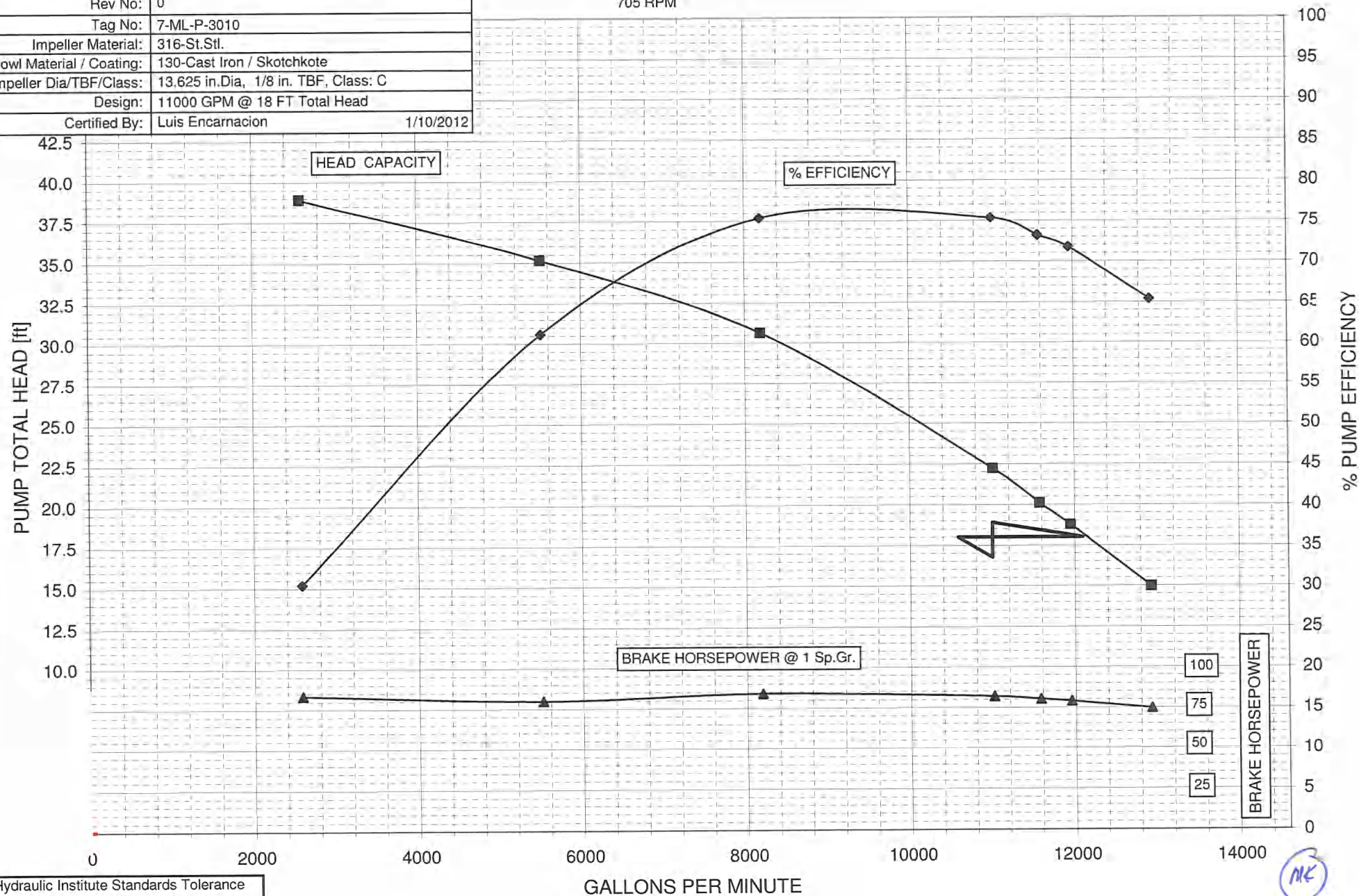
Model / Stages:	20PS / 1
Customer:	
End User:	
Fluid:	Water
Job No:	100050871-50
Test Curve No:	16043
Rev No:	0
Tag No:	7-ML-P-3010
Impeller Material:	316-St.Stl.
Bowl Material / Coating:	130-Cast Iron / Scotchkote
Impeller Dia/TBF/Class:	13.625 in.Dia, 1/8 in. TBF, Class: C
Design:	11000 GPM @ 18 FT Total Head
Certified By:	Luis Encarnacion 1/10/2012

Sulzer Pumps (US) Inc.
 Brookshire, TX
PERFORMANCE TEST CURVE

Pump Performance Test (Job Motor)

705 RPM

SULZER



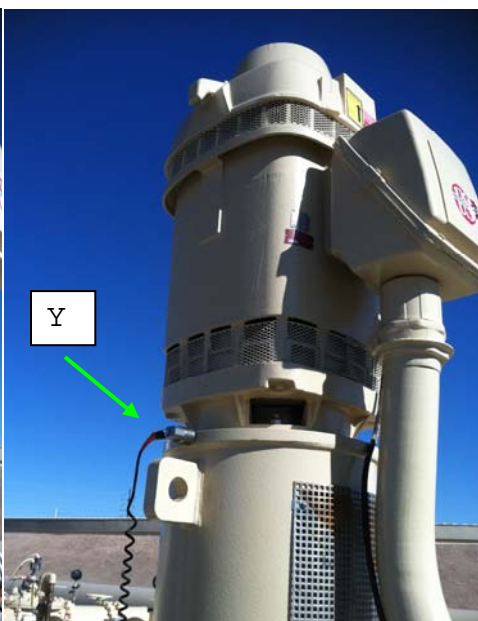
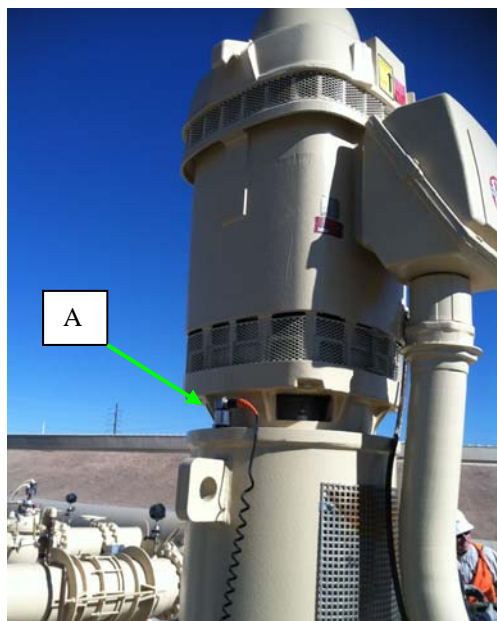
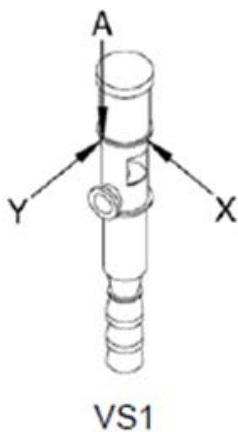
Hydraulic Institute Standards Tolerance
 105% of Rated Head at Design Flow or
 110% of Rated Flow at Design Head

MK

Acceptance Table

VIBRATION SEVERITY PER ISO 10816						
Machine			Class I small machines	Class II medium machines	Class III large rigid foundation	Class IV large soft foundation
	in/s	mm/s				
Vibration Velocity Vrms	0.01	0.28				
	0.02	0.45				
	0.03	0.71		good		
	0.04	1.12				
	0.07	1.80				
	0.11	2.80		satisfactory		
	0.18	4.50				
	0.28	7.10		unsatisfactory		
	0.44	11.2				
	0.70	18.0				
	0.71	28.0		unacceptable		
	1.10	45.0				

HYDRAULIC INSTITUTE DATA COLLECTION LOCATIONS





Calibration Certificate

Model # B21300Q Repair Order # 273636

Serial # 001276720000

Machinery Health Management hereby certifies the calibration of the above equipment was performed following MHM quality procedure QP 7600 and MHM calibration procedure number CP 41 (ISO 9001:2008). All measuring and test equipment used to monitor critical parameters is supported by valid certificates traceable to the National Institute of Standards and Technology (NIST) and in accordance with ANSI/NCSL Z540-1. These standards have four times greater accuracy than the items tested.

<u>Equipment #</u>	<u>Equipment Type</u>	<u>Calibration Due Date</u>
<u>M65</u>	<u>HP 33120A Function Generator</u>	<u>May 9, 2012</u>
<u>M37</u>	<u>HP 34401A Multimeter</u>	<u>May 7, 2012</u>
<u>S17</u>	<u>Leader Oscilloscope 1041</u>	<u>May 10, 2012</u>

Analyzer Calibration Factors

	<u>A Channel</u>	<u>/</u>	<u>B Channel (If Installed)</u>		
Gain Factor	<u>0.9921</u>	<u>/</u>	<u>1.0361</u>	Temperature:	<u>73 °F</u>
Single Analog Int	<u>3.4373</u>	<u>/</u>	<u>3.3723</u>	Humidity:	<u>43 %</u>
Double Analog Int	<u>7.8477</u>	<u>/</u>	<u>7.7371</u>		
Accel Input	<u>1</u>	<u>/</u>	<u>0.9998</u>		
Volts Input	<u>1.0013</u>	<u>/</u>	<u>1.0048</u>	Calibration Date:	<u>December 27, 2012</u>
DC Offset	<u>0.0011</u>	<u>/</u>	<u>0.0026</u>	Calibration Due:	<u>December 28, 2013</u>

All readings taken after calibration were found to be within the manufacturer's specification in accordance with the above calibration procedure(s).

Tested by  Date: December 27, 2012

Kenneth P. Thomas
Senior Product Service Center Technician



Vibration Analysis Hardware

CERTIFICATE OF CALIBRATION

The voltage sensitivity of the transducer under calibration was determined by back to back comparison with the output from a reference grade accelerometer. The fundamental calibration of the reference accelerometer is traceable to NIST.

Transducer Under Test

Manufacturer: CTC
Model Number: AC140-3D
Serial Number: 1278

Manufacturers Specifications

Nominal Sensitivity: 100 mV/g \pm 15.0 %
Frequency Response: .5 Hz to 15000 Hz

Results

Measured Sensitivity: 97.02 mV/g at 100 Hz, 1g RMS

Bias Voltage: 12.05 V

Date of Calibration: 11/08/2012

Tested By: Sandra Wolfanger



Certificate of Achievement

This is to certify that at the examinations held on November 7th, 2008

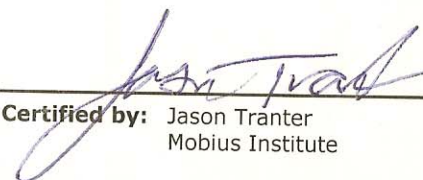
Kirk Cormany

Passed the Mobius Institute exam:

VIBRATION ANALYST

ISO Category III

Certification follows ISO 18436.2 and under the Mobius Institute Written Practice


Certified by: Jason Tranter
Mobius Institute

Certificate Number: **081573**
Date of Issue: December 2nd, 2008

This certificate is not official without the Mobius Institute Gold Seal.





TECHNICAL ASSOCIATES OF CHARLOTTE, P.C.

VIBRATION ANALYSIS III

By Presentation of This

CERTIFICATE OF ACHIEVEMENT

Hereby Certifies

KIRK F. CORMANY

has completed the 24 hours of training "Introduction To Special Vibration Diagnostic Techniques And How To Analyze Low, High And Variable Speed Machines" and has successfully passed a closed-book written examination for the Level III Vibration Analysis Method under the ASNT curriculum guidelines stipulated in SNT-TC-1A

TECHNICAL ASSOCIATES OF CHARLOTTE, P.C.
Class Time 24-Hours - Test Time 4-Hours

Seminar Authorized By:
Technical Associates of Charlotte, P.C.
347 North Caswell Road
Charlotte, NC 28204
Tel: 704/333-9011 Fax: 704/333-1728

Test Dates: October 29, 2004



James E. Berry, P.E., Analytical Group
Certification Examination Author