TRANSMITTAL OF SUBMITTAL

DATE: 04/31/25

New X -Submittal Resubmittal __

TO: Eddie MCMichael Young

Hazen
5775 Peachtree Dunwoody, Ste D520
Atlanta, GA 30342

Project: JW Smith Water Production Plant
High Service Pump Station Upgrades
Specification Section No. : 432147

Supplier/Vendor: Cease Vibration

FROM: LAKESHORE ENGINEERING

1259 Ellsworth Drive

Atlanta, GA 30318

Manufacturer: Patterson Pump

The following items are hereby submitted:

Number of Copies	Description of Item Submitted (Type, Size, Model Number, Etc.)	Submittal number	Submittal Type	Contains Variation to Contract	
				No	Yes
Procore	High Service Pump 3 – Vibration Results	43 21 47-74.00	Product Data		X

Comments/Variation: Attached are pump 3 vibration test results. Please advise if the recommendation to add mass is approved.

CONTRACTOR hereby certifies that (i) CONTRACTOR has complied with the requirements of Contract Documents in preparation, review, and submission of designated Submittal and (ii) the Submittal is complete and in accordance with the Contract Documents and requirements of laws and regulations and governing agencies.

By:______ ______________________

Brandon Dow

Cease Industrial Consulting
122 Berkshire Drive
Charleston, SC 29492
843-200-9705

To: Mr. Brandon Dow

From: Barry Cease, Cease Industrial Consulting (CIC)

Subject: Vibration Report, JW Smith Station, High Service Pump 1, April 1st, 2025

On April 1st, 2025 Cease Industrial Consulting (CIC) was contracted to perform vibration analysis on two newly installed pumps at the JW Smith Pumping Station in Hampton, GA. The pumps tested were the High Service Pump 1 and the Wash Water Pump 2. Both pumps are vertical types pumping potable water and are best classified as type VS3 per the HI 9.6.4 specifications. This report will detail the results from testing of High Service Pump 1.

Vibration data was collected from High Service Pump 1 (HS Pump 1) while operating under load and at normal speeds. Additional impact vibration data was obtained while the pump was not running; the impact testing was performed to determine the relevant natural frequencies present at the pump. Finally, after the vibration testing was complete, motion amplified video of HS Pump 1 was shot to determine the shape of the motion (vibration) present.

What follows below is my presentation of the vibration data collected from HS Pump 1, comparison of the measured vibration levels versus the HI specs, observations from the motion amplified video shot, and my conclusions & recommendations.

FIGURE 1: High Service Pump 1 at the JW Smith Pumping Station.

HIGH SERVICE PUMP 1

The High Service Pump 1 at the JW Smith Pumping Station is a Patterson 17 JMC 4-stage vertical turbine pump directly coupled to a 400 HP, 4-pole motor operating on a VFD. The operating speed range of the pump is 70 to 100% full speed or 42 to 60 Hz at the VFD. The motor is bolted to the top of the pump assembly via a flange fit while the pump is anchored to a rigid base grouted into the floor. The motor weight is listed as 3,300 lbs. Following an initial vibration analysis of this pump, additional structural supports were added to the discharge piping leading out of the pump. The pump base consists of a top flange assembly which bolts to the motor, four supporting steel columns and a bottom base which bolts to the soleplate (see figure 1 above).

Vibration data was collected from High Service Pump 1 from various points along the machine which are detailed in table 1 below. For the purposes of acceptance, only points 2D, 2T & 2V are relevant (per HI 9.6.4 specification).

SYMBOL	DESCRIPTION	HI SPEC DIRECTION
1D	Motor, Top Bearing, Discharge Direction	Y
1T	Motor, Top Bearing, Transverse Discharge Direction	X
2D	Motor, Bottom Bearing, Discharge Direction	Y
2T	Motor, Bottom Bearing, Transverse Discharge Direction	X
3D	Pump, Top Bearing, Discharge Direction	Y
3T	Pump, Top Bearing, Transverse Discharge Direction	X
1V	Motor, Top Bearing, Vertical Direction	Z
2V	Motor, Bottom Bearing, Vertical Direction	Z

TABLE 1: Vibration measurement point symbols & descriptions used for the pumps tested at the JW Smith Station on 4/1/25.

OPERATING VIBRATION DATA

Vibration data was collected along High Service Pump 1 at the measurement points described in table 1 above while it was operating under load and at various speeds. The pump speed was varied from 70-100% full speed (42-60 Hz at VFD) at increments of 1 Hz. Per the HI specs, vibration data was collected in units of velocity (ips-rms) from 5 to 1,000 Hz using 3,200 lines of resolution. A laser tach was setup to accurately measure the pump speed during testing and provide a phase reference for analysis purposes. An Io-Tech 618 Zonicbook multi-channel vibration analyzer was used to simultaneously collect the operating vibration data from all points as the speed was changed.

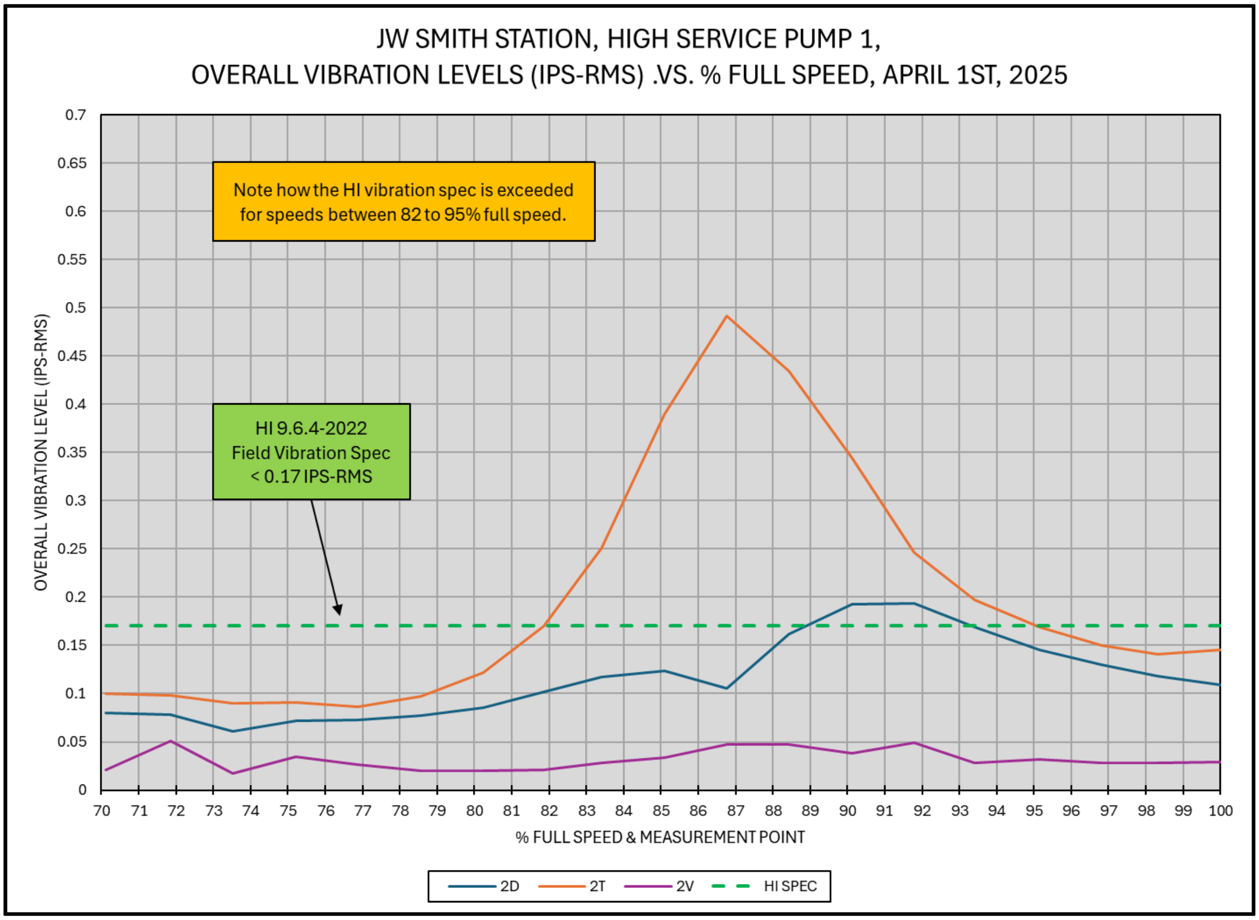
Per the HI specs, acceptance of this VS3 type vertical pump requires that all three specified measurement points (2D, 2T & 2V) maintain overall vibration levels below 0.17 ips-rms throughout their operating speed range while under load. Table 2 and plot 1 below show the overall vibration levels measured on 4/1/25 at each specified point along with the HI specified vibration tolerance. *From this data note how the worst vibration levels occurred not at 100% full speed but instead at 87% full speed. Note also how unacceptable levels occurred while the pump was operated at speeds from 82 thru 93% full speed. The worst vibration levels by far occurred at the transverse discharge direction measurement (2T) with the vertical measurement (2V) never exceeding the HI vibration limits.*

OPERATING VIBRATION DATA (cont):

OPERATING SPEEDS			OA VIBRATION LEVELS (IPS-RMS)		
SPEED (RPM)	VFD (HZ)	% FULL SPEED	2D	2T	2V
1,256	42	70	0.08	0.1	0.021
1,287	43	72	0.078	0.098	0.051
1,317	44	74	0.061	0.09	0.017
1,347	45	75	0.072	0.091	0.035
1,377	46	77	0.073	0.086	0.026
1,407	47	79	0.077	0.097	0.02
1,437	48	80	0.085	0.122	0.02
1,466	49	82	0.102	0.17	0.021
1,494	50	83	0.117	0.251	0.028
1,524	51	85	0.124	0.39	0.034
1,554	52	87	0.105	0.492	0.047
1,584	53	88	0.162	0.434	0.047
1,614	54	90	0.193	0.344	0.038
1,644	55	92	0.194	0.246	0.049
1,673	56	93	0.169	0.197	0.028
1,704	57	95	0.145	0.169	0.032
1,734	58	97	0.13	0.15	0.028
1,761	59	98	0.118	0.141	0.028
1,791	60	100	0.109	0.145	0.029
ACCEPTANCE		< 0.17	UNACCEPTABLE		> 0.17

TABLE 2: 4/1/25 overall vibration levels measured along the High Service Pump 1 at the JW Smith Pumping Station. The relevant HI 9.6.4 vibration tolerances are shown at bottom. The speeds resulting in acceptable vibration levels are shaded GREEN. The speed resulting in the worst vibration level is shaded RED (87% full speed) while those at other unacceptable levels are progressively shaded ORANGE then YELLOW, etc.

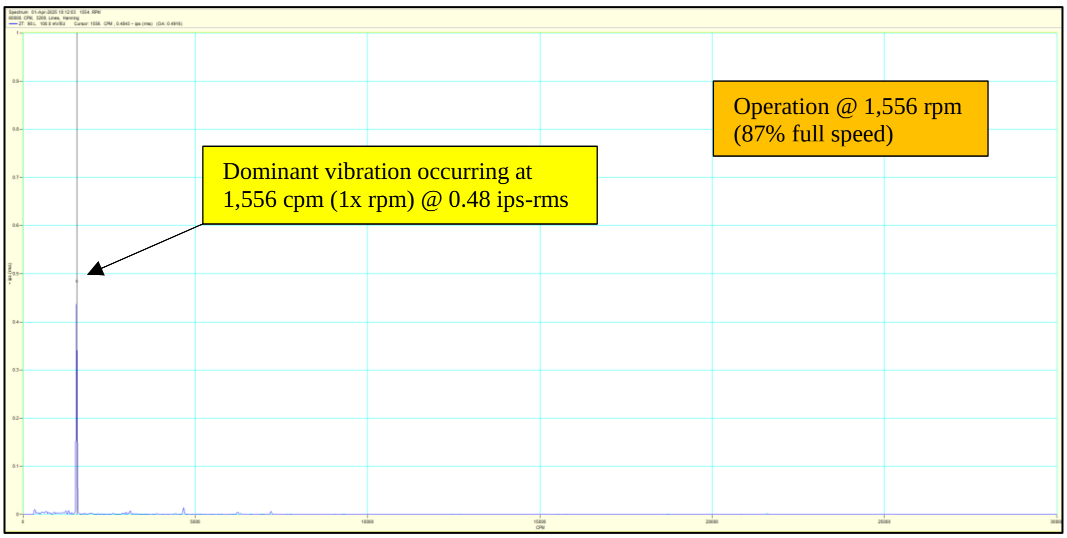
OPERATING VIBRATION DATA (cont):



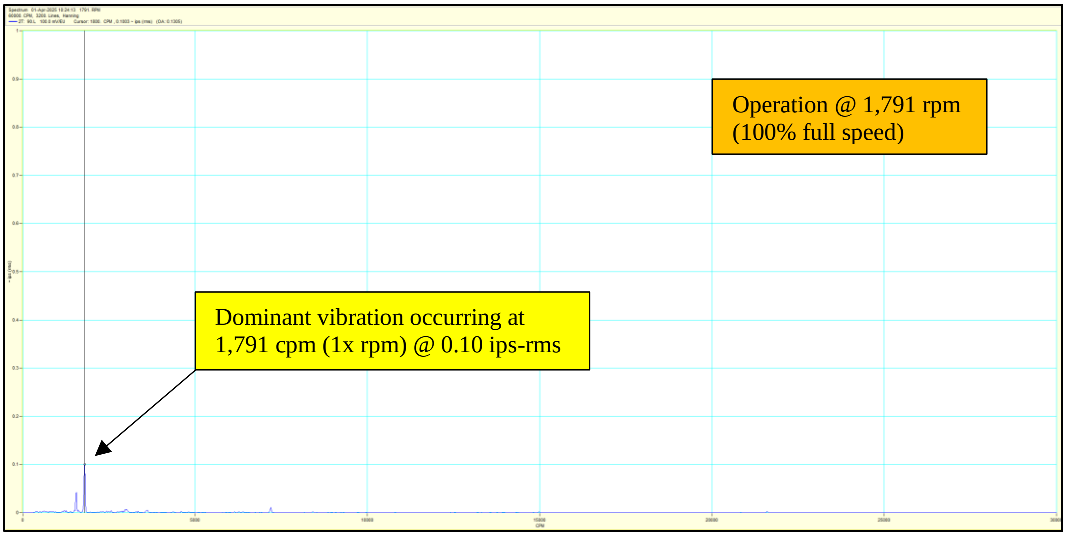
PLOT 1: 4/1/25 overall vibration levels measured along the High Service Pump 1 at the JW Smith Pumping Station. Note how the HI spec of < 0.17 ips-rms was violated at speeds from 82 thru 95% full speed. The highest vibration levels by far were measured at point 2T (motor, bottom bearing, transverse discharge direction) with peak vibration occurring at ~ 87% full speed.

SPECTRAL VIBRATION DATA

Analysis of the spectral vibration data from High Service Pump 1 was performed to determine the dominant frequency of vibration responsible for the unacceptable vibration levels. *This analysis found dominant vibration occurring at the pump speed (1x rpm) with vibration at all other frequencies being quite small by comparison.* In addition, the speed versus vibration plot above showed vibration levels dropping as the speed was INCREASED from 95 to 100% full speed. If unbalance or misalignment were the primary sources of this vibration, the vibration would have only gotten worse as we increased the speed - this was not the case. The only vibration source I know where levels are seen to decrease as the speed increases is RESONANCE or the excitation of a natural frequency. See plots 2 & 3 below.



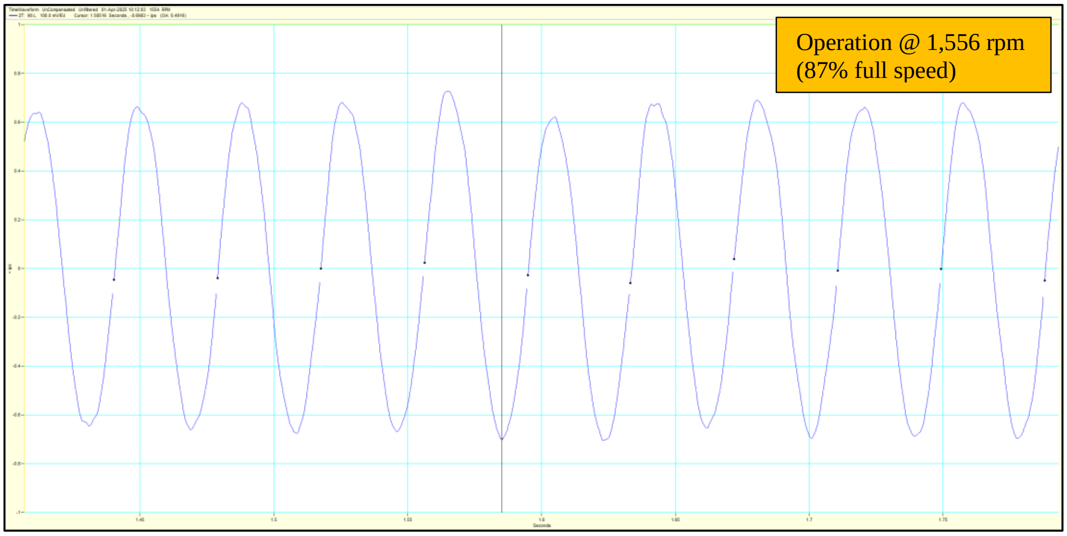
PLOT 2: Spectral vibration data from HS Pump 1, point 2T while operating at 87% full speed.



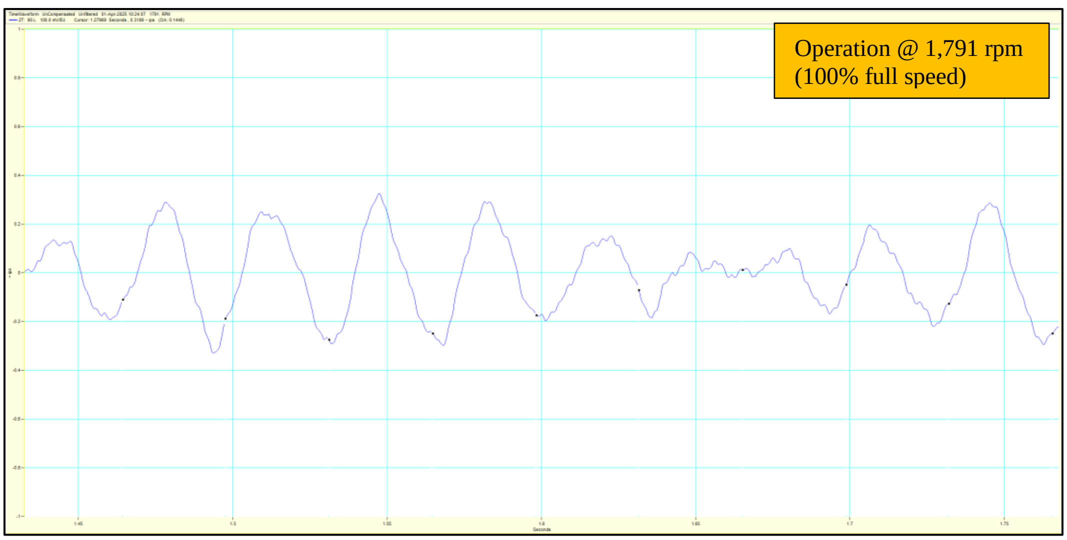
PLOT 3: Spectral vibration data from HS Pump 1, point 2T while operating at 100% full speed.

WAVEFORM VIBRATION DATA

Waveform & orbit vibration data from the HS Pump 1 was also analyzed to better characterize the vibration occurring especially when operating at or near 87% full speed. *This waveform data found high 1x rpm vibration levels with clear sinusoidal motion when the pump was operating at 87% full speed and beating vibration at much lower levels when the pump was operating at 100% full speed. No signs of either impacting or asymmetric motion were observed in either plot.* See plots 4 & 5 below.



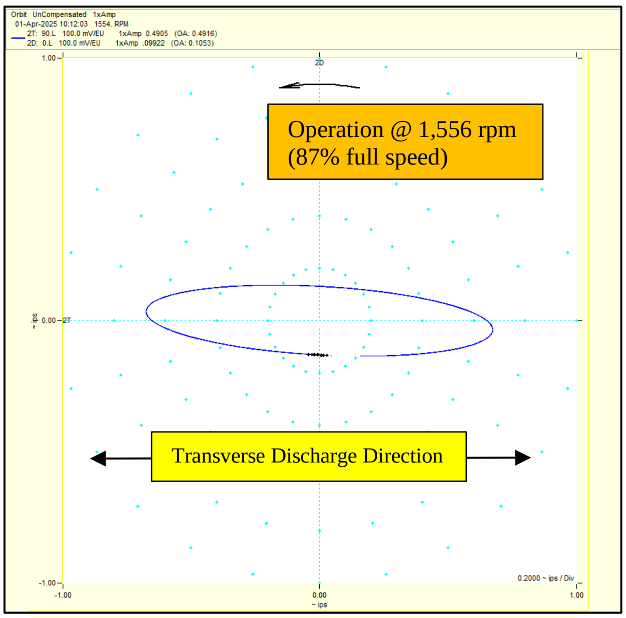
PLOT 4: Waveform vibration data from HS Pump 1, point 2T while operating at 87% full speed.



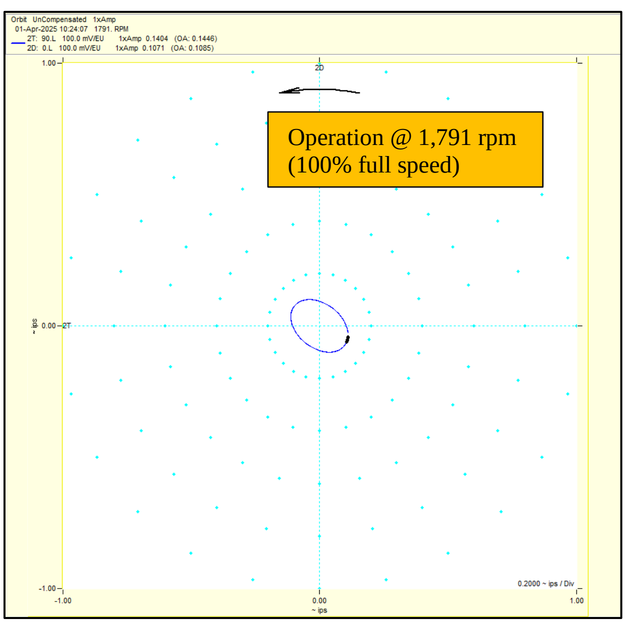
PLOT 5: Waveform vibration data from HS Pump 1, point 2T while operating at 100% full speed.

ORBIT VIBRATION DATA

In addition to the spectral & waveform vibration data described above, orbit vibration data was analyzed from HS Pump 1 especially when operating at 87% full speed. Orbit data plots the waveform data from one radial direction versus another when they are separated by exactly 90 deg. It shows the literal "shape" of the motion (vibration) at that point on the machine in the radial directions. Two orbit plots from HS Pump 1, bottom motor bearing (2T versus 2D) are shown below. The first plot is when the pump was operating at 87% full speed and the second plot is when operating at 100% full speed. *Note how much larger the motion (vibration) is when operating at 87% full speed and how motion in the transverse discharge direction is dominant. If unbalance of the pump or coupling, etc were the primary cause of high vibration, the orbit at 100% full speed would be much larger than at 87% full speed.*



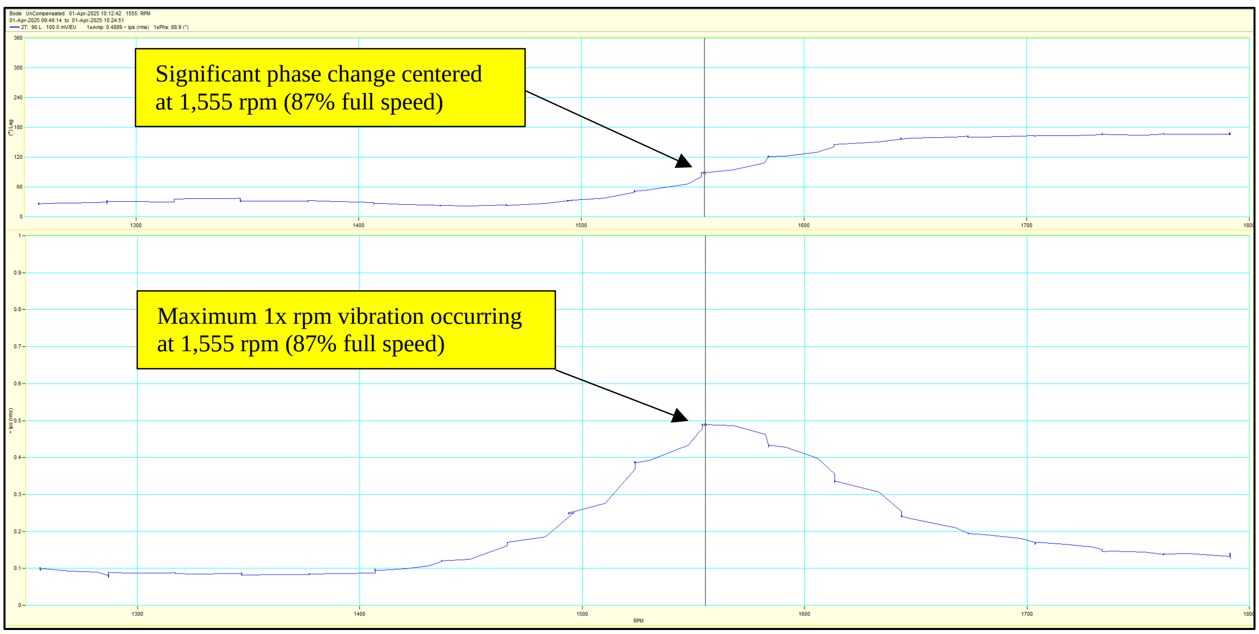
PLOT 6: 4/1/25 Orbit vibration data from HS Pump 1, bottom motor bearing while the pump was operating at 87% full speed. Note the large orbit diameter (high vibration) and how dominant motion occurs in the transverse discharge direction.



PLOT 7: 4/1/25 Orbit vibration data from HS Pump 1, bottom motor bearing while the pump was operating at 100% full speed. Note the much smaller orbit diameter (low vibration) and how the orbit is much more circular than above.

1X PEAK-PHASE DATA (TRANSIENT DATA)

In addition to the spectral, waveform & orbit vibration data shown above, 1x rpm peak-phase data was also analyzed at the various speeds the pump was operated. This peak-phase data looks at how vibration at 1x rpm changes with changing machine speed and is often used to identify or confirm a resonance condition. The plot below shows 1x peak-phase vibration data versus the machine speed at point 2T along HS Pump 1. The top plot shows the phase change associated with this data while the bottom plot shows 1x rpm vibration levels (ips-rms) versus machine speed. *Note how 1x rpm vibration levels are a maximum not at the maximum speed but at the intermediate speed of ~ 1,555 rpm (87% full speed). From the top plot of 1x rpm phase note how a significant phase change occurs with its center at or very near 87% full speed. Both observations are entirely consistent with resonance being the primary cause of this vibration.*



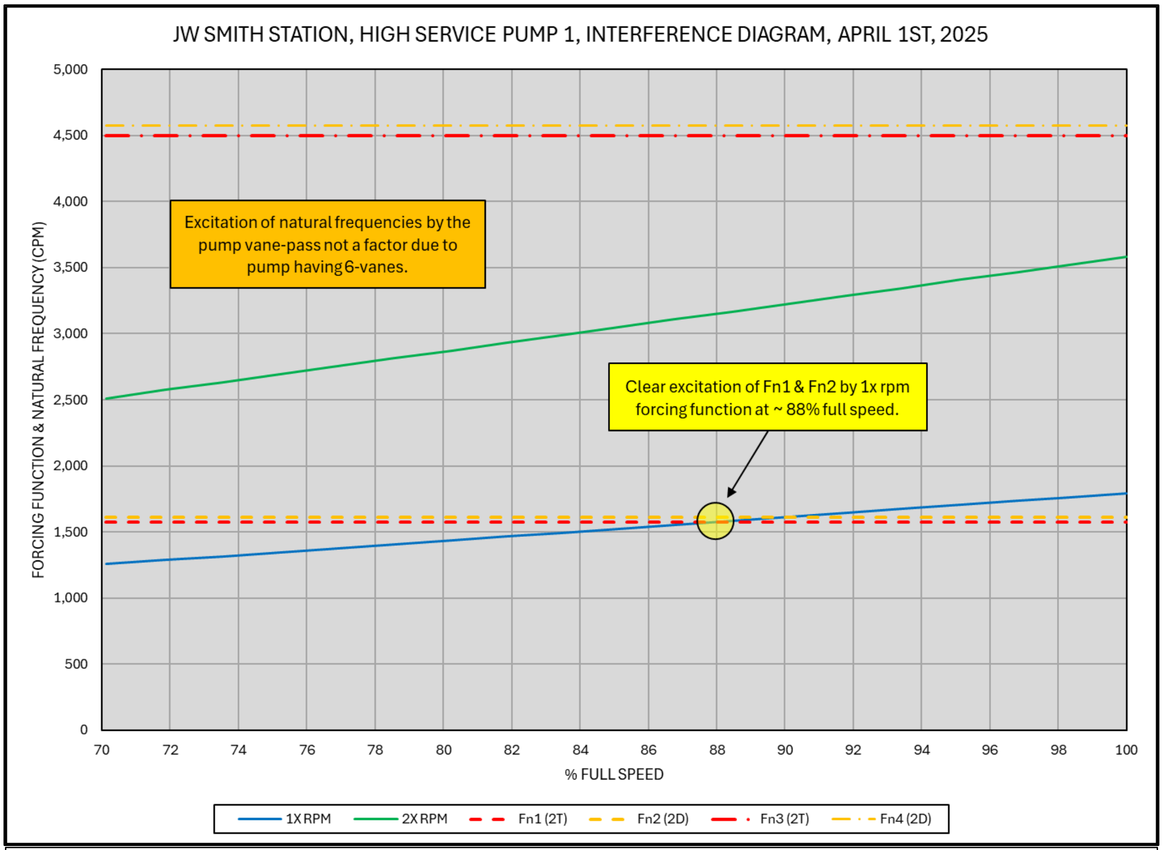
PLOT 8: 1x rpm Peak-Phase data collected from HS Pump 1, point 2T on 4/1/25.

IMPACT VIBRATION DATA

In addition to operating vibration data collected at HS Pump 1, impact vibration data was collected at various locations in both the discharge piping & transverse piping directions. A modal hammer is used along with a vibration sensor while the unit is down and not running to produce a cause & effect scenario; the measured vibration being the result of the impact. Impact vibration data is collected to determine the natural frequencies of a machine or structure. When a force developed by a machine such as 1x rpm or vane-pass, etc coincides with a natural frequency within about 20%, a state of resonance will most likely exist which amplifies normal vibration levels by 10 to 30 times or more! Resonance is a condition that should be avoided to improve the reliability of machinery. Results from impact testing of HS Pump 1 are shown in the table below along with the mobility level (inverse of stiffness, ips/lbf) of each natural frequency and its amplification factor.

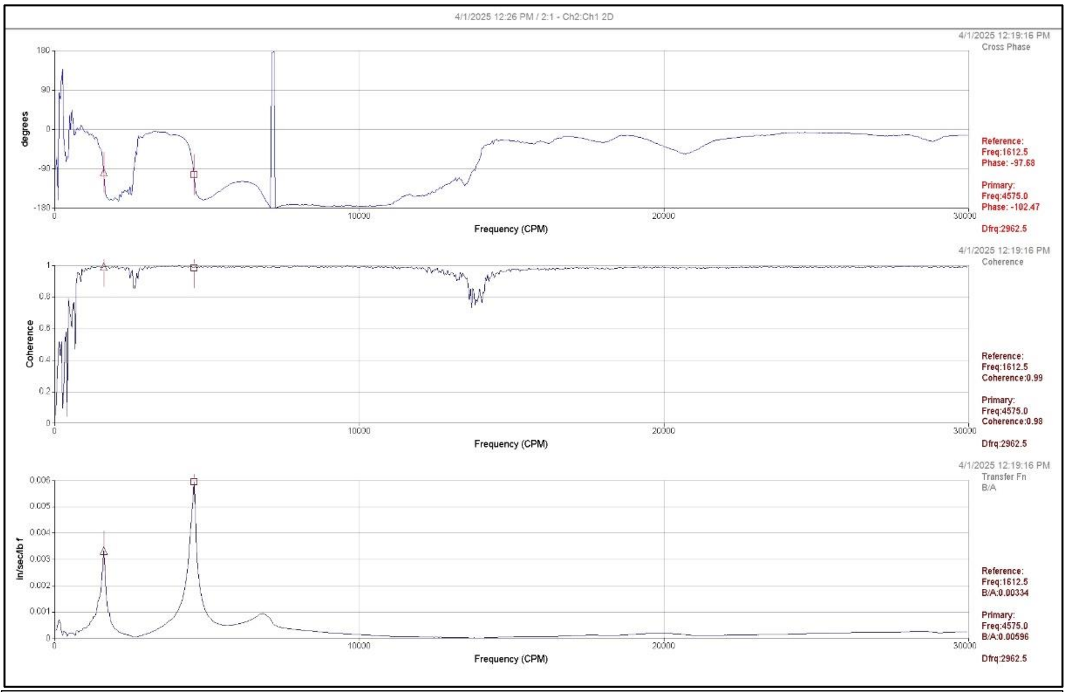
POINT	NATURAL FREQUENCY (CPM/HZ)	MOBILITY (IPS/LBF)	AMPLIFICATION FACTOR (Q)
2T	Fn1 - 1575 CPM / 26.3 HZ	0.007	25
2D	Fn2 - 1613 CPM / 26.9 HZ	0.003	12
2T	Fn3 - 4500 CPM / 75 HZ	0.004	40
2D	Fn4 - 4575 CPM / 76 HZ	0.006	26

TABLE 3: Results from 4/5/25 impact vibration testing of High Service Pump 1. Impact testing was performed at the bottom motor bearing in both the discharge and transverse discharge directions (points 2D & 2T). The natural frequencies of concern are 1,575 cpm (2T) and 1,613 cpm (2D) which interact with 1x rpm at or near 87% full speed.

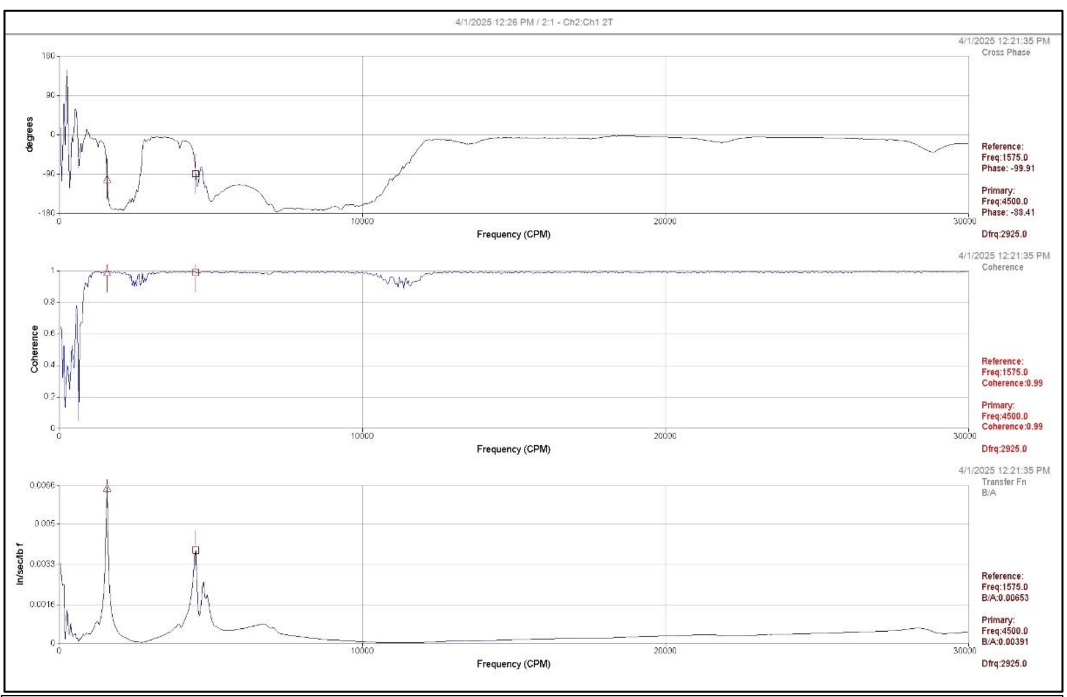


PLOT 9: Interference diagram resulting from the 4/1/25 impact testing of HS Pump 1.

IMPACT VIBRATION DATA (cont):



PLOT 10: 4/1/25 impact testing data from measurements at point 2D (motor, bottom bearing, discharge direction). Note the large peaks (natural frequencies) at bottom associated with significant phase shifts at top and high coherence at middle.



PLOT 11: 4/1/25 impact testing data from measurements at point 2T (motor, bottom bearing, transverse discharge direction). Note the large peaks (natural frequencies) at bottom associated with significant phase shifts at top and high coherence at middle.

MOTION AMPLIFIED (MA) VIDEO

In addition to the vibration data collected along HS Pump 1, motion amplified video was shot on-site of the pump from different viewpoints to aid in our understanding of what was going on. Each video has been filtered to only show motion (vibration) at 26 Hz (1x rpm @ 87% full speed) as our vibration data had already proven this being the dominant frequency of vibration. These 6-ea videos can be best viewed in Windows Media Player (or equivalent) with the repeat or loop function turned on. My primary observations from these videos are listed below:

1) The pump base & motor are swaying primarily in the transverse discharge direction at 26 Hz (1x rpm @ 87% full speed).

2) The concrete pedestal supporting the pump base is moving along with the pump base at 26 Hz primarily in the transverse discharge direction albeit at a much lower vibration level.

CONCLUSIONS

Unfortunately, the April 1st, 2025 vibration levels measured at the JW Smith Station, HS Pump 1 were excessive versus the HI specified field limits and thus acceptance cannot be recommended at this time. My analysis of the vibration data collected shows the excessive vibration levels are due to resonance or excitation of two natural frequencies (1,575 cpm & 1,613 cpm) when the pump is operated at or near 87% full speed. Solving this resonance problem will involve separating the natural frequencies from the force to eliminate or at least mitigate excitation. We move the natural frequencies by either changing the mass or stiffness of the structure or machine at or near the locations where vibration is high. By adding mass we move the natural frequencies lower. By increasing/adding stiffness we move the natural frequencies higher. Stiffening is generally preferred over adding mass as a solution to these problems, however, in this case, if stiffness is added, it must be rather significant otherwise we will simply push the natural frequencies from ~ 1,600 cpm to perhaps 1,700 cpm and shift our problems from occurring at 87% full speed to instead occurring at ~ 95%. For my part, I would try adding significant mass just under the motor flange area and perhaps also to the top of the motor. From the impact data I collected on-site, I can estimate the amount of mass that would need to be added to achieve a sufficient drop in our natural frequencies. We could then experimentally apply this mass to the HS Pump 1 in the field during follow-up testing to prove its effectiveness prior to implementing a permanent change.

I appreciate the opportunity to perform this work for Lakeshore Engineering. Please contact me with any questions or comments you may have concerning this report.

Regards,

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