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Vibration Survey for

Boiler Feed Pump 6
Boiler Feed Pump 7
Circulating Water Pump 6
Circulating Water Pump 7
Condensate Pump 6
Condensate Pump 7
Condensate Pump 8

Submitted to

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Boiler Feed Pumps 6 & 7

BFP 6

No bearing defect frequencies that indicate failing anti-friction bearings (roller bearings) were detected. All the amplitudes of the casing data are within levels that indicate good to fair operation, but phase data indicates some probable misalignment between the motor and fluid drive, with the vertical/vertical across coupling measurements being 180^0 out of phase and the horizontal/horizontal more than 120^0 out of phase.

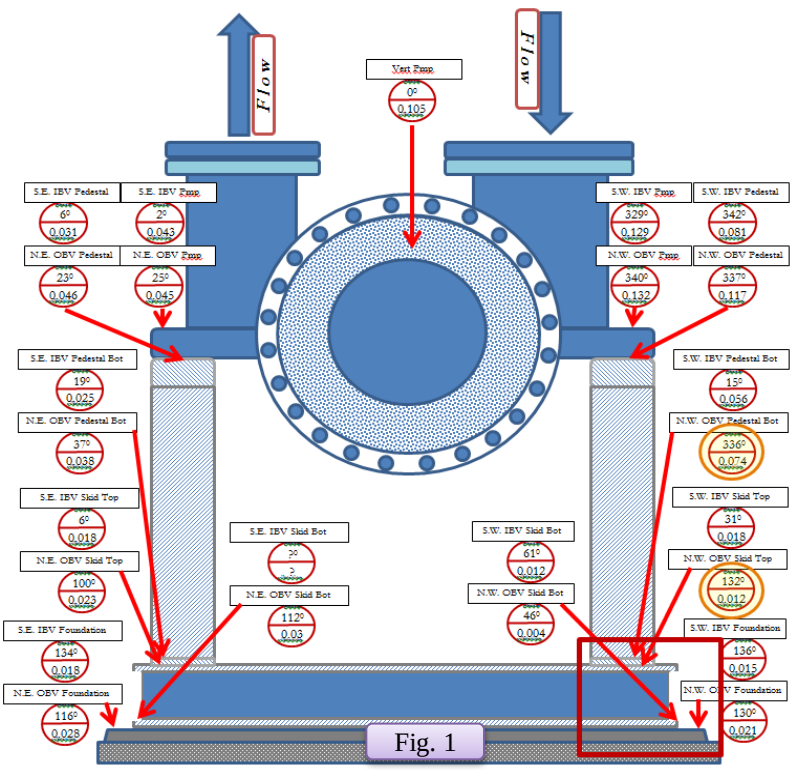
To fully ascertain the severity of the misalignment requires that the proximity probe data from the mounted probes (which we have requested) needs to be analyzed.

Recommendations for BFP 6 Fluid Drive to Pump:
Permalign data to verify actual thermal growth should be collected to determine future action on this machine.

BFP 6 Booster Pump

Casing amplitudes on the booster pump are in acceptable ranges. A phase analysis was done on the booster pump and its related mounting components at vane pass frequency. One area showed an anomaly in the analysis that needs to be cleaned and inspected closely for cracks or loosened fasteners. This is the area of the bottom of the pedestal through the skid to the foundation on the Northwest corner (see Figures 1 and 2). This can be done immediately.

Boiler Feed Pump 6 Booster Pump Phase and Amplitude @ Vane Pass



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Recommendation for BFP 6 Booster Pump:

Clean and inspect closely for cracks or loosened fasteners, the area of the bottom of the pedestal through the skid to the foundation on the Northwest corner.

BFP 7

Our findings indicate that the primary area of concern for the feed pumps at this time is in the area of BFP 7 fluid drive.

As with 6, no bearing defect frequencies that indicate failing anti-friction bearings were detected, however; there are some casing amplitudes that indicate a problem at the output of the fluid drive. Here too, the proximity probe data needs to be analyzed. The amplitudes and phase of the vibrations Ludeca measured indicate either or both of:

1. Unbalance of the output shaft/coupling of the fluid drive. (The torque converter is a part of this assembly and its contribution to a possible unbalance is not fully known at this time.)
2. Misalignment of the fluid drive to pump.

Recommendations for BFP 7 Fluid Drive to Pump:

1. The thermal growth should be empirically determined with Permalign during cool down.
    a. After unbalance of the output shaft (see #2) is determined to be within specifications, the motor/fluid drive/pump should be precision aligned to assure low cost long term reliability.
2. The motor/fluid drive should be run un-coupled with the feed pump (if possible) to verify how much of the vibration is due to unbalance of the fluid drive output shaft.
    a. If excessive unbalance is verified, precision balance rotor.

BFP 7 Booster Pump

As with 6 booster, casing amplitudes on this booster pump are in acceptable ranges. A phase analysis was also done on this booster pump and its related mounting components at vane pass frequency. Two areas showed slight anomalies in the analysis that should be cleaned and inspected closely for cracks or loosened fasteners. This is the area of the bottom of the pedestal through the skid to the foundation on the Southeast corner and the interface between the pump foot and pedestal on the Southwest (inboard) corner (see Fig. 3). This also can be done immediately.

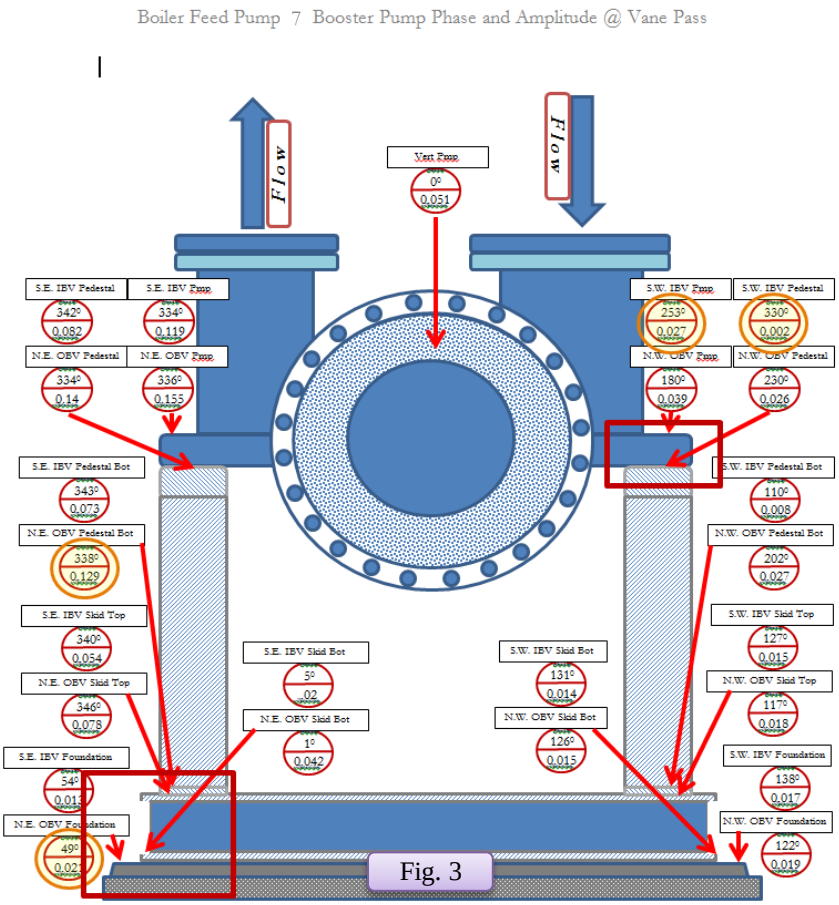

Fig. 3

Recommendation for BFP 7 Booster Pump:

Clean and inspect closely for cracks or loosened fasteners, the area of the bottom of the pedestal through the skid to the foundation on the Southeast corner and the interface between the pump foot and pedestal on the Southwest (inboard) corner.

Circulation Pumps 6 & 7

The amplitude of vibration for the circulating pumps at turning speed is somewhat above acceptable levels but, even more troubling is the fact that both circulating pumps have very high vibration amplitude at a frequency below turning speed (turning speed is 396rpm/6.6hz). The long term effect of such a vibration could be to fatigue the structure and foundation. If this vibration is new, it could also be increasing over time.

Below are vibration comparisons of pump 1A time waveforms in line with the discharge as opposed to perpendicular to the discharge. The first two TWFs (time wave forms)(Fig. 4) show that the peak to peak vibration in line with the discharge, at the turning speed frequency of the pump is averaging over 10 mils p-p, while perpendicular to discharge is averaging around 6 mils p-p. The other two TWFs (Fig. 5) are ½ minute in duration and show the severity of movement at the very low frequency, as much as 1/8 of an inch.

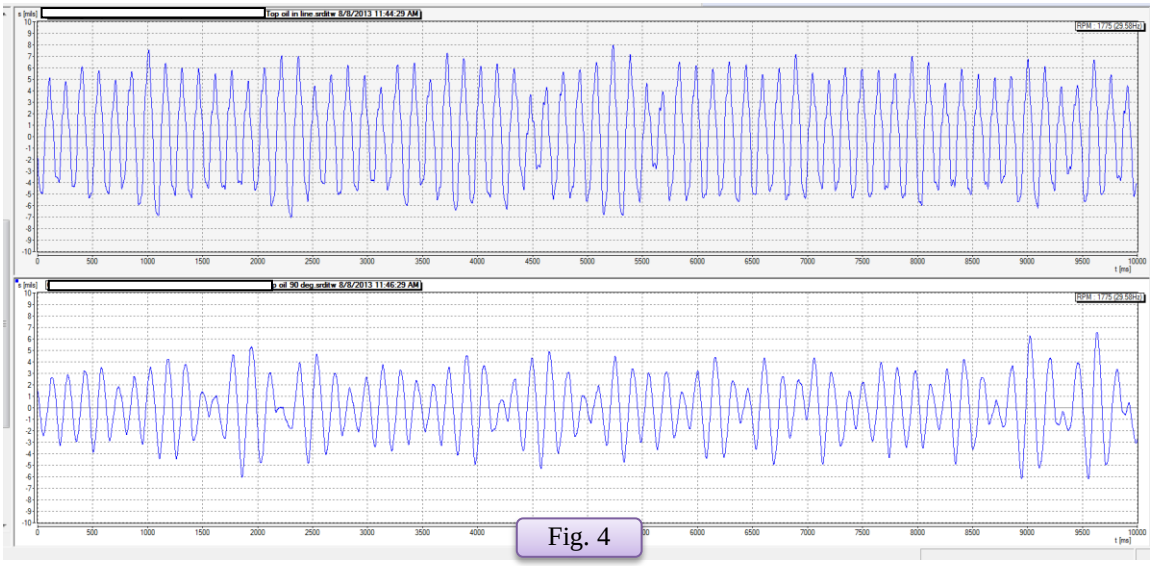

Fig. 4

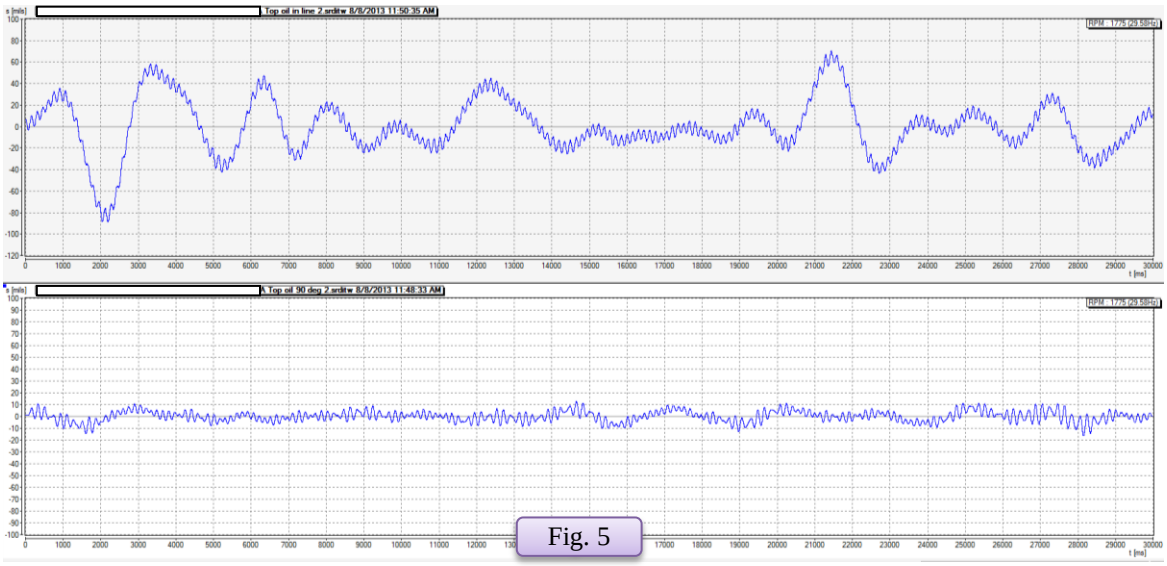

Fig. 5

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While there is a slight difference in the vibration levels of the 2 pumps, the difference is not great, with pump 7 showing even less stiffness than 6 in the direction perpendicular to outflow. The lack of historical data showing the presence (or absence) of the very low frequency vibration/high amplitude movement is motivation to thoroughly inspect the pump, motor, and piping apparatus to exclude the possibility of a mechanical defect being its source.

Recommendation for Circulation Pumps 6 and 7:

1. Pull Pumps, dis-assemble and inspect each pump assembly for excessive clearance in guide bushings. Check all shafts for TIR and inspect all line shaft bearings and impeller for wear, and repair or replace as necessary. Precision balance the pump rotating assembly to API recommended unbalance tolerance of 4W/N.
2. After the pump has been reinstalled perform precision laser alignment between pump and motor.
3. Perform field trim balancing of motor and pump as an assembly after re-installation.
4. Inspect downstream piping to make sure turning vanes (if present) are not damaged or no foreign object is lodged anywhere to cause flow problems.

Upon re-assembly of the pump/motors, new data should be collected to re-evaluate for the presence of the low frequency movement. If the low frequency vibration is not greatly diminished, we recommend an “operational deflection shape”(ODS) analysis of pump structures and piping to attempt to determine exactly how and why the pumps are moving the way they are and, most importantly, if this movement is destructive. We feel that this is necessary to facilitate long term reliability for these pumps and make sure their cost of ownership is minimized for the long term future.

The Installation of sensors on the pump impeller housing is very desirable for future condition monitoring and early detection of mechanical defects and trending. The data from these could help avoid future costly invasive exploratory maintenance.

Condensate Pumps

The overall vibration levels for both of the 6 & 7 Condensate Pumps are well below the recommended limits based on the 1994 Hydraulic Institute Standard].

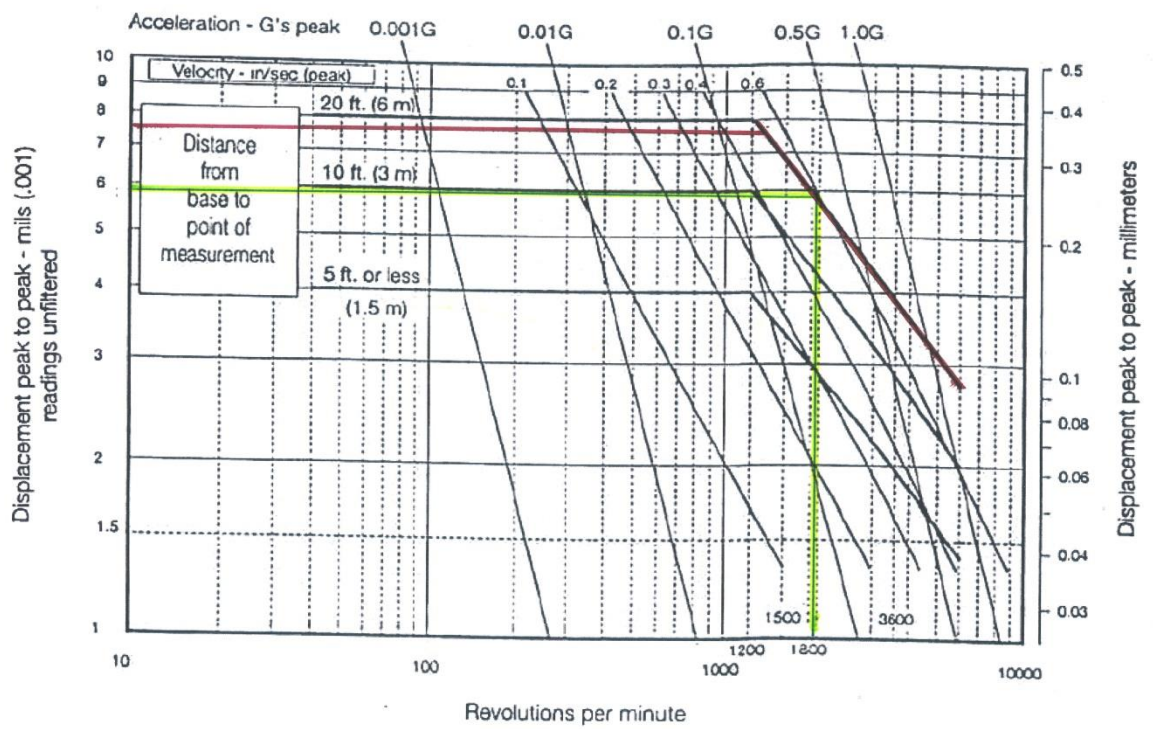

Figure 2.41 — Acceptable field vibration limits for vertical turbine pumps, mixed flow and axial flow pumps at best efficiency at top motor bearing housing

Fig. 6

The Condensate pumps operate at a constant speed of 29.88 Hz (1792 rpm) and have a height of approximately 18 feet measured from the floor to the top of the motor. Follow the "X" axis along the bottom of the chart until we reach the desired machine rpm and then follow that rpm line up towards the top of the chart until it intercepts with the field measured machine height line. A red line on the chart indicates the motor height.

For the Condensate pumps the recommended maximum overall vibration level is 5.8 Mils pk – pk (.39 In/sec RMS).

The measured overall values at the top of the motors are:

6 Condensate Pump		7 Condensate Pump	
Inline Pump Discharge	.10 In/sec RMS	Inline Pump Discharge	.13 In/sec RMS
90 Degrees Pump Discharge	.09 In/Sec RMS	90 Degrees Pump Discharge	.11 In/sec RMS

The spectral data which was collected shows the highest amplitude to be at running speed (1x) which is normal and is caused by residual unbalance which remains in the rotating assemblies of the motor and pump.

Condensate Pump 6 – Spectrum

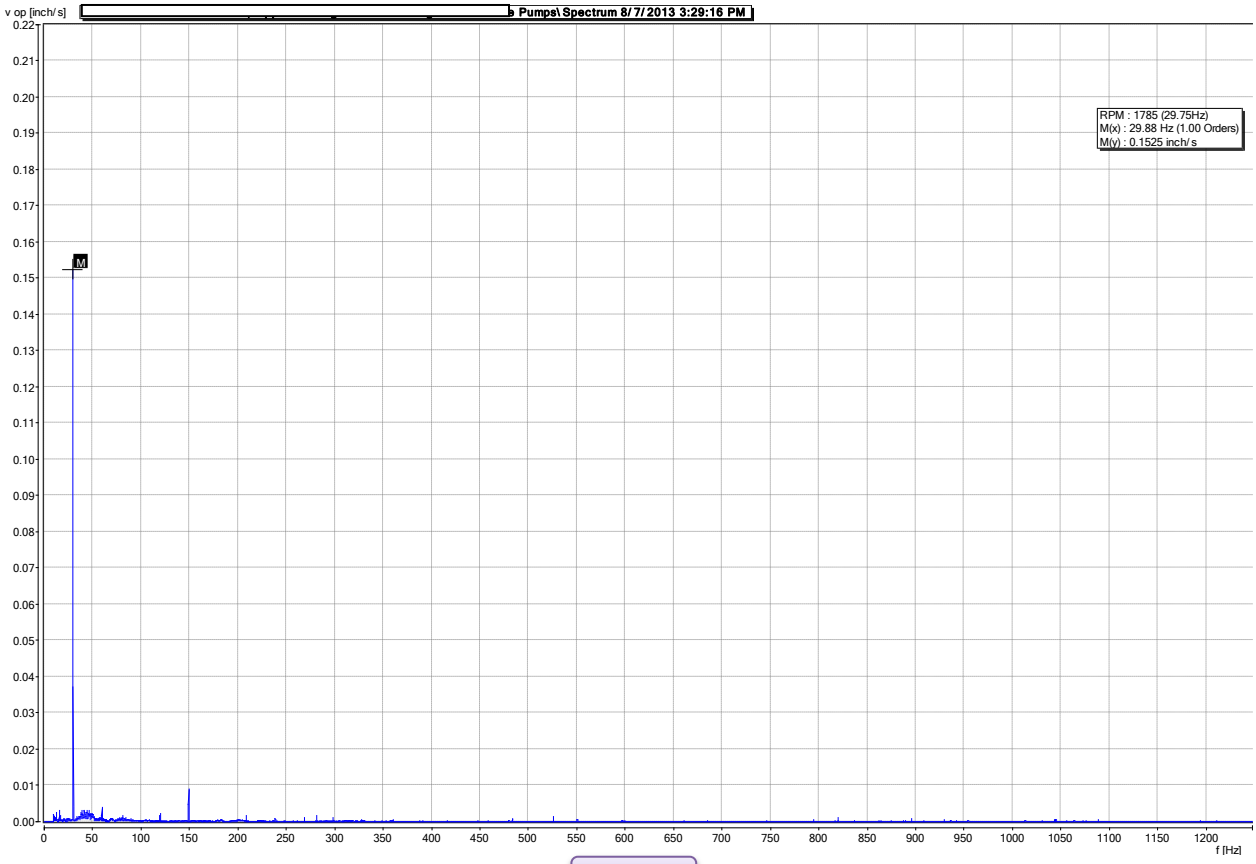

Fig. 7

Condensate Pump 7 – Spectrum

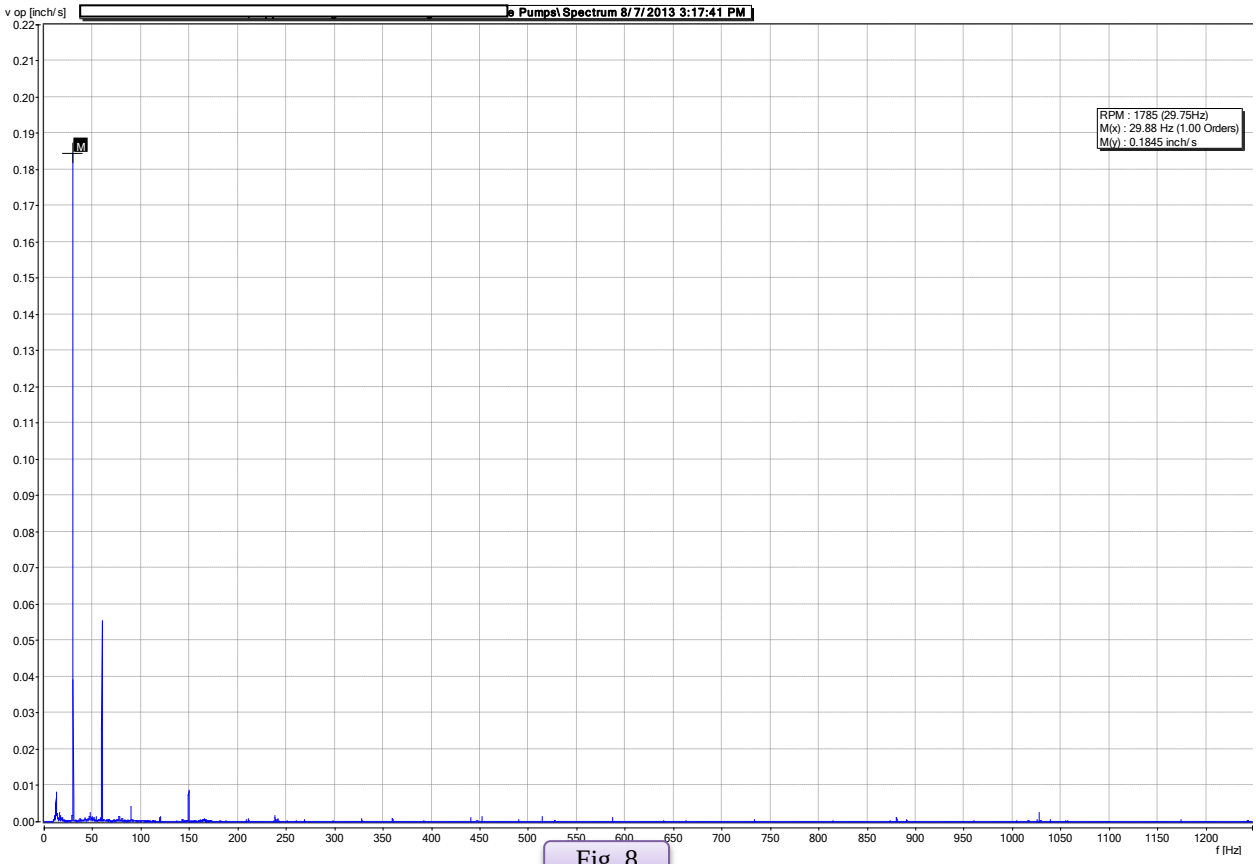

Fig. 8

Recommendation for Condensate Pumps:

Incorporate the use of the Hydraulic Institute Chart which has allowable overall vibration levels for vertical pumps. The standard was written and developed by pump manufacturers specifically for these types of vertical machines. Employ the use of TA alarm band setups within the software so that trending and alarming can occur based on the overall vibration levels and other fault indicating bands.

To insure the vibration data collected during walk around vibration surveys can be compared between the pumps, it is recommended that the data collection location be the same for each unit. Each unit should have data collected on at least 3 points.

a) Motor, Upper Bearing (radial in-line with pump discharge)
b) Motor, Upper Bearing (radial 90^0 to pump discharge)
c) Motor, Lower Bearing (axial)

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Observations on the Condition Monitoring efforts at Top Power Generation and recommendations supporting long term reliability and profitability:

The desire to identify and alleviate defects before they become or induce failures is commendable and critical to being the lowest cost provider in any industry. Ludeca is honored to be Top Power's partner in this effort.

Ludeca recommends that further training for the reliability focused employees be considered. We observe 2 critical areas that are sub-optimal:

1. Lubrication
   a. The employees that lubricate the equipment should be trained and certified.
      i. There are thousands of bearings at Top Power and there will be diminished to no profitability if these bearings fail prematurely. Each bearing depends on mere *microns* of oil film to operate reliability. When that employee is alone in the field preparing to pump grease into a bearing, it is imperative that they have the training to know they must avoid pumping dirt in (requires proper care and cleaning of grease gun head) with the grease, and maybe even more importantly, they should have the pride and integrity to strive for excellence while unsupervised. The knowledge that the company has invested in them and the effect that has on the employee cannot be over-estimated. Ludeca does not do lubrication training, so this recommendation can be understood to come solely from a desire to see our customers succeed at the highest level.
2. Vibration Analysis
   a. The vibration analyst should be further trained and dedicated to the task.
      i. He should be given the necessary training to competently maintain the vibration database in the proper state. The analysis and reporting that Top Power requires to maintain reliability depends a great deal on this individual and a lack of focus because of being pulled off on other jobs, as well as insufficient training is threatening future reliability.

Data Collection and Analysis Intervals:
For some process equipment quarterly data collection may be acceptable. However, for most of the major equipment at Top Power, quarterly intervals are wholly inadequate to give early enough warning to reliably prevent many catastrophic failures. The data collection and analysis intervals should be based upon the equipment criticality, failure modes, rapidity of fault progression and necessary time for planning and scheduling repair work.

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Information on the importance of Precision Balance:

Balancing tolerances for machines have been available for some time and they are based on the rotors weight and its operating speed. There are several balance tolerances in current use and some of these tolerances allow for more residual unbalance to be left in the rotating assemblies. One of the most widely published and used standards is the ANSI S2.19-1975 which was first published by the ISO in 1940.

Other balance standards include MIL-STD-167-1 which was developed by the military primarily for slow speed machines, but can be used for machine speeds above 1000 rpm. Probably the most restrictive balancing tolerance in terms of the allowable remaining residual unbalance which can be left in a rotating assembly is the American Petroleum Institute (API) standard. Sometimes when using the API standard (4W/N) the tolerance is considered excessive and unnecessary, but ultimately the end user must make a choice. The smaller the amount of residual unbalance which is left on a rotating assembly when it leaves the balance stand, the less centrifugal force it produces at operating speed and the less force the bearings/machine assembly have to absorb. This means it will have lower vibration levels and will run longer and smoother, but most importantly it will actually use less energy and cost less to maintain.