LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory

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CIT / LASTI
PUMP STATION PERFORMANCE
DATA

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1 Introduction

This document describes measurement data comparing the screw pump vs gear pump, and pressure ripple with other variables such as bladder pressure in the accumulators, temperature, viscosity, coupling spider material and alignment etc, as well as notes on significant features and some tentative conclusions.

2 Experimental Apparatus

2.1 Basic Setup used for all measurements unless otherwise noted:

The Basic Setup used for all measurements unless otherwise noted is as follows:

Graphs were made with the Stanford Research Analyzer.

The sensors are in 5 locations (See Figure 1) as shown on the drawing enclosed.

The sensors were checked and found to be reading correctly, (Ref. 1 volt = 300 PSI)

Settings are shown or called out on the graphs, most were made at 200 fft lines and 0-100 Hz. The number of averages was 4.

The 800fft line setting shows more detailed structure, and overall lower PSI floor, the time of acquisition is 3 minutes @800 vs 20 seconds with the 200fft line setting.

Ref Motor Controller Hz. Setting vs Motor RPM

60 Hz. = 1752 RPM

50 Hz = 1460 rpm]

The heavy dashed horizontal line [▬ ▬ ▬] appearing on the graphs represents the goal for the maximum pressure peak @$10^{-}3$ PSI/Hz

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SENSOR LOCATIONS 1 THRU 5 June 27, 2002

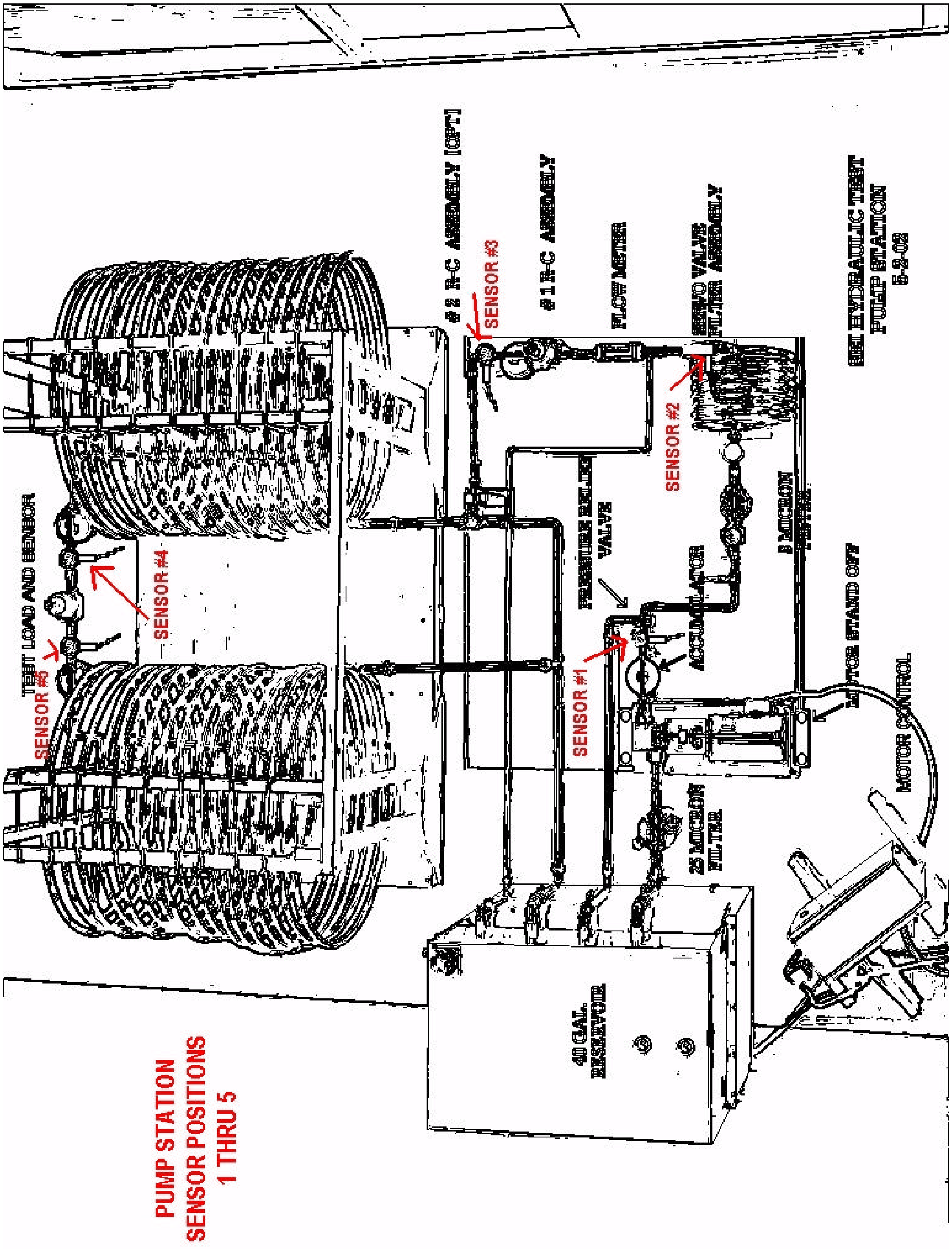

Figure1 General Layout and Locations of Sensors 1 thru 5

3 Experimental Results

3.1 Sensor Noise Floor

The sensor noise is well below the goal for the system maximum pressure peaks of the system.

Measurements were made with the following conditions:

In Figure 2, showing all 5 sensors

Only the controller on and the pump motor not running.

100 psi Static Pressure in system / ~0-100Hz.

Pump Motor Off /Motor Controller Running @60 Hz

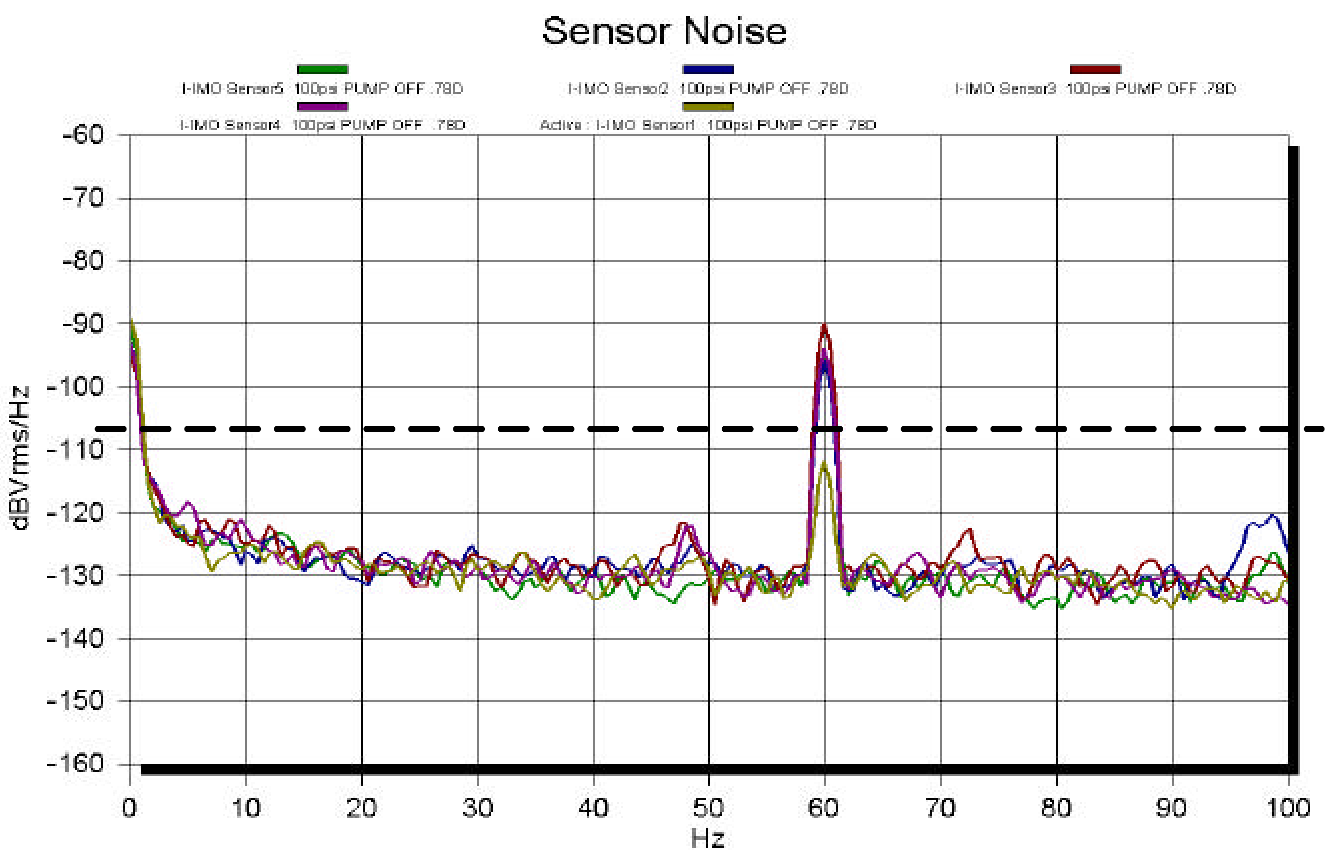

Figure 2 Pressure Sensor Noise with controller on motor not running

3.2 Sensor noise with the controller plus motor running and no pump.

The controller 50 Hz, and the background 60 Hz line frequency showing.

Measurements were made with the following conditions:

In Figure 3

The controller on and the motor running alone / no pump, @50Hz. [800 fft-fine resolution]

100 psi Static Pressure in system ref. Sensor 1 & 3 / ~0-100Hz.

Motor Controller set @50 Hz (1460 RPM)

Note the peaks at the motor speed and background 60Hz.

Reference line [▬ ▬ ▬] at the goal of 10^{-3} PSI/Hz

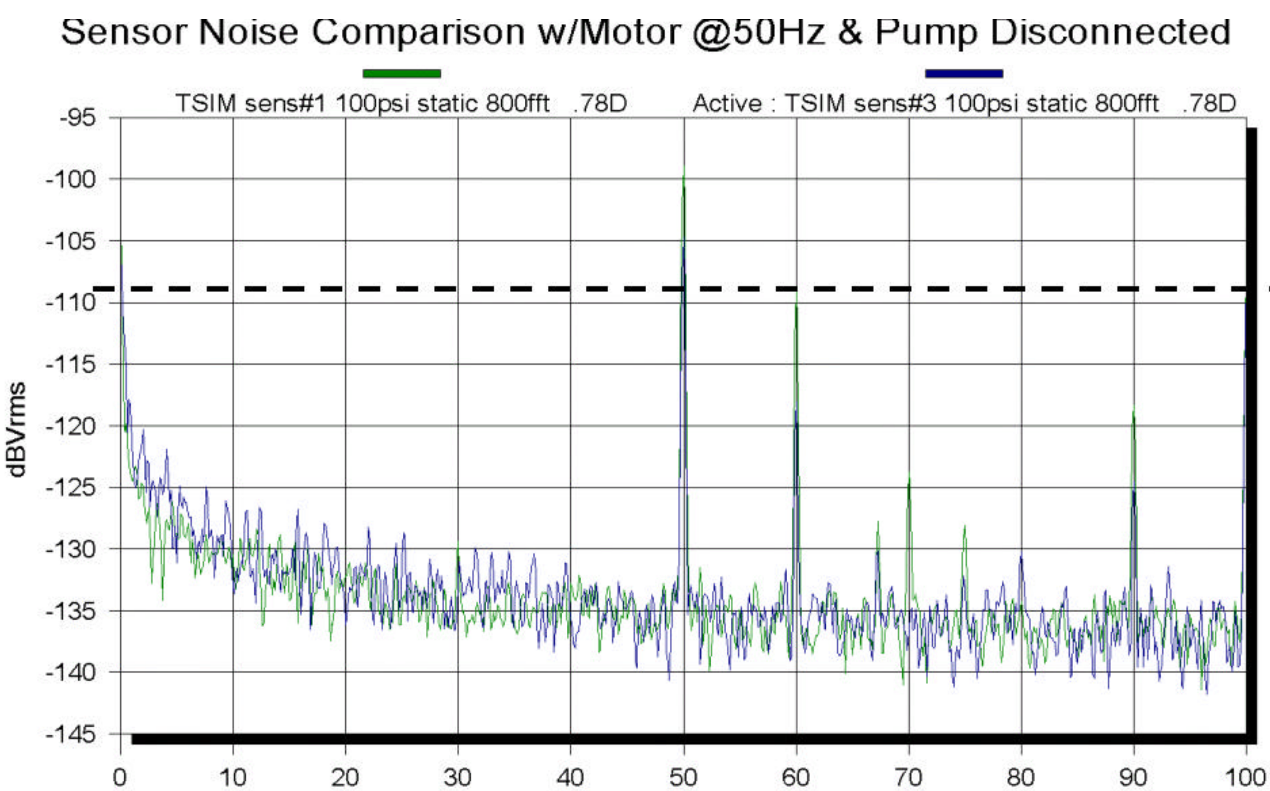

Figure 3 Sensor Noise with the Controller and Motor running [no pump]

3.3 The relative Pressure Noise comparison of the Screw pump and Gear pump.

Overall the screw pump seems to have lower pressure peaks than the Gear Pump.

Measurements were made with the following conditions:

Comparison of Gear Pump and Screw Pump at Sensor #3 This sensor location is just after the R/C assembly, and before the 180' tubing run. [See Fig 1.]

Note: **Screw** Pump [GREEN] runs at 50 Hz vs 60 Hz for the **Gear** Pump [BLUE]

Reference line [– – – –] at the goal of 10^{-}3 PSI/Hz

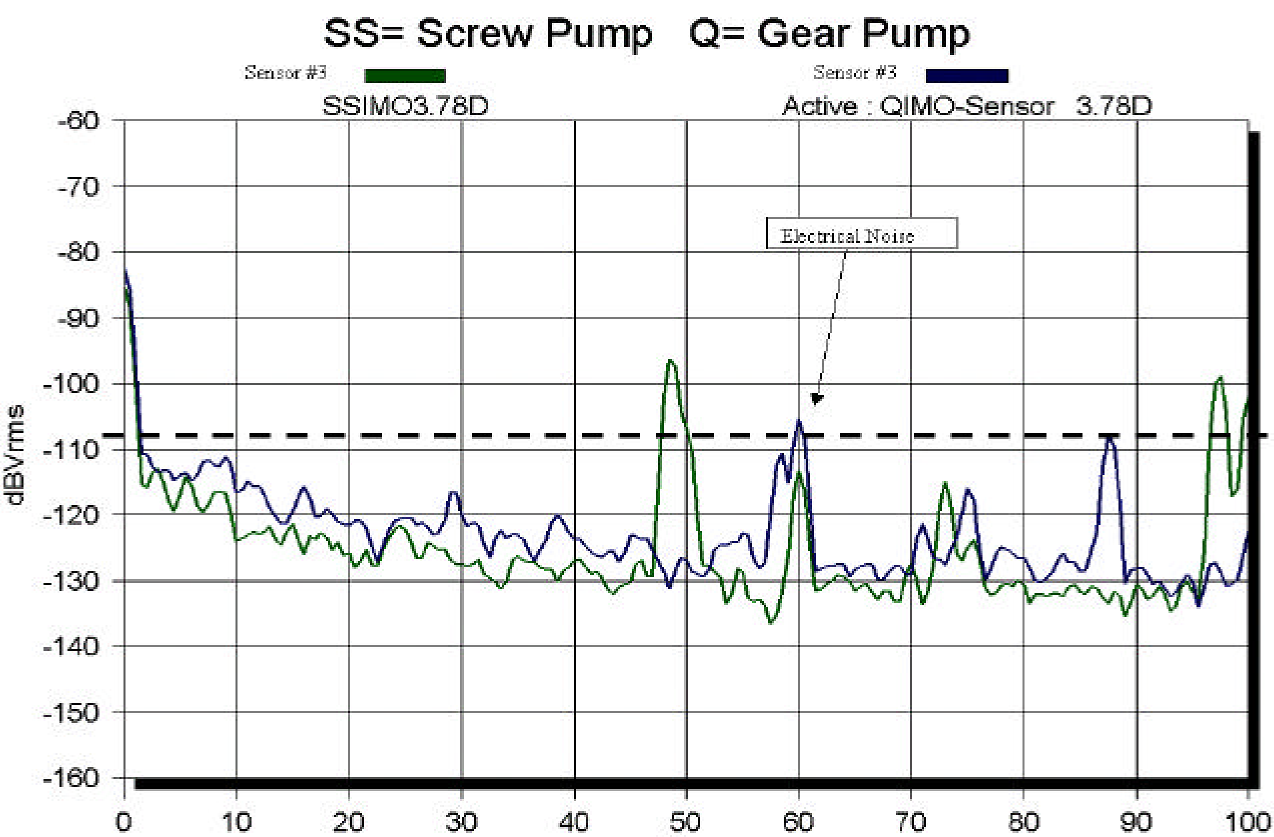

Figure 4 Comparing the Screw and Gear Pump at Sensor #3

The measurements show pressure noise peaks after the long 180' run of tubing, that don't show in Fig 4 before the tube run.

Measurements were made with the following conditions:

Comparison of Gear Pump and Screw Pump pressure as measured at the #4 Sensor location. This is at the end of the 180' tubing run [ref. see Fig.1]

Note: **Screw** Pump [GREEN] runs at 50 Hz vs 60 Hz for the **Gear** Pump [BLUE]

Reference line [— — —] at the goal of 10-3 PSI/Hz

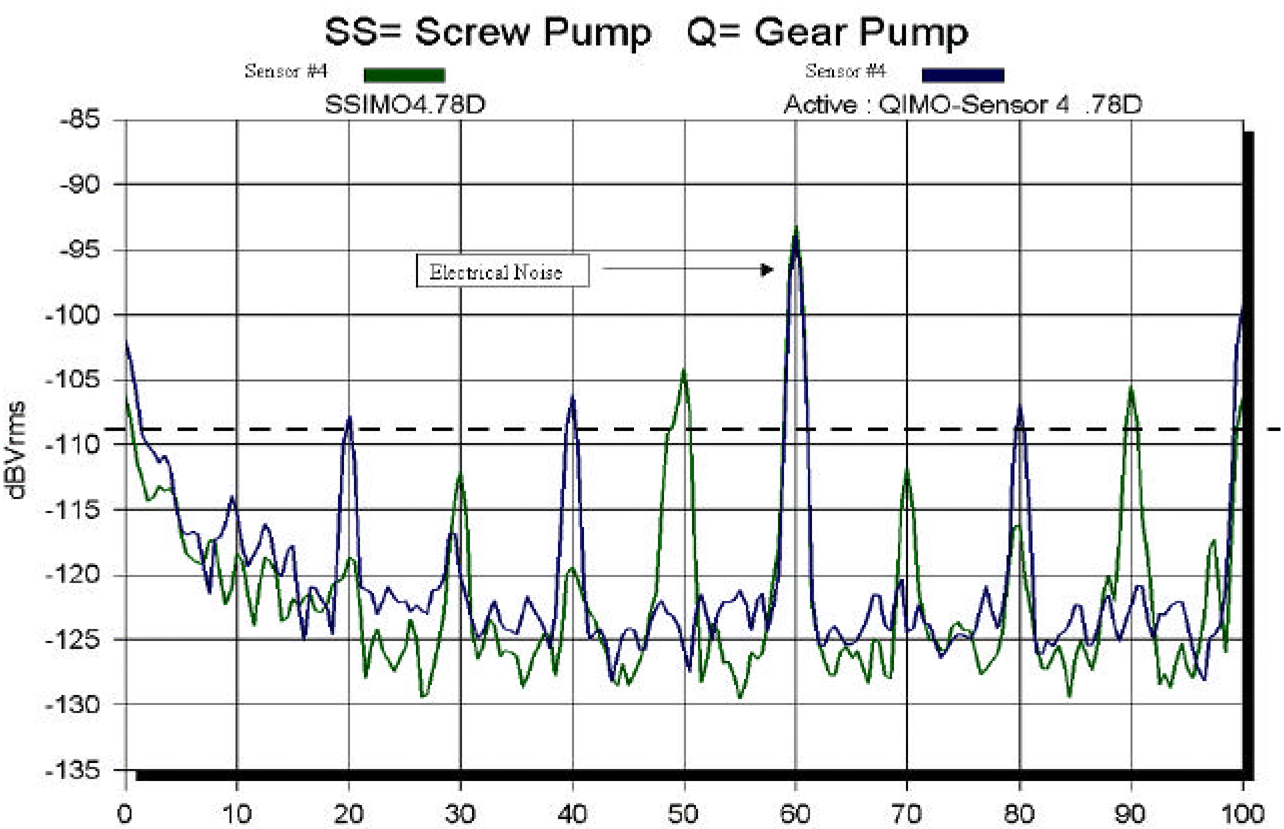

Figure 5 Comparing the Screw and Gear Pump at Sensor #4

3.4 Expanded lower frequency range ref. @ ~ 0-6.25 Hz, this is the same data as in Fig. 4

This shows Screw Pump has lower pressure ripple than Gear Pump in lower frequency range.

Measurements were made with the following conditions:

Comparison of Gear Pump and Screw Pump at sensor #3 from ~0-6.25 Hz. This sensor location is just after the R/C assembly.

Green is the gear pump

Blue is the screw pump

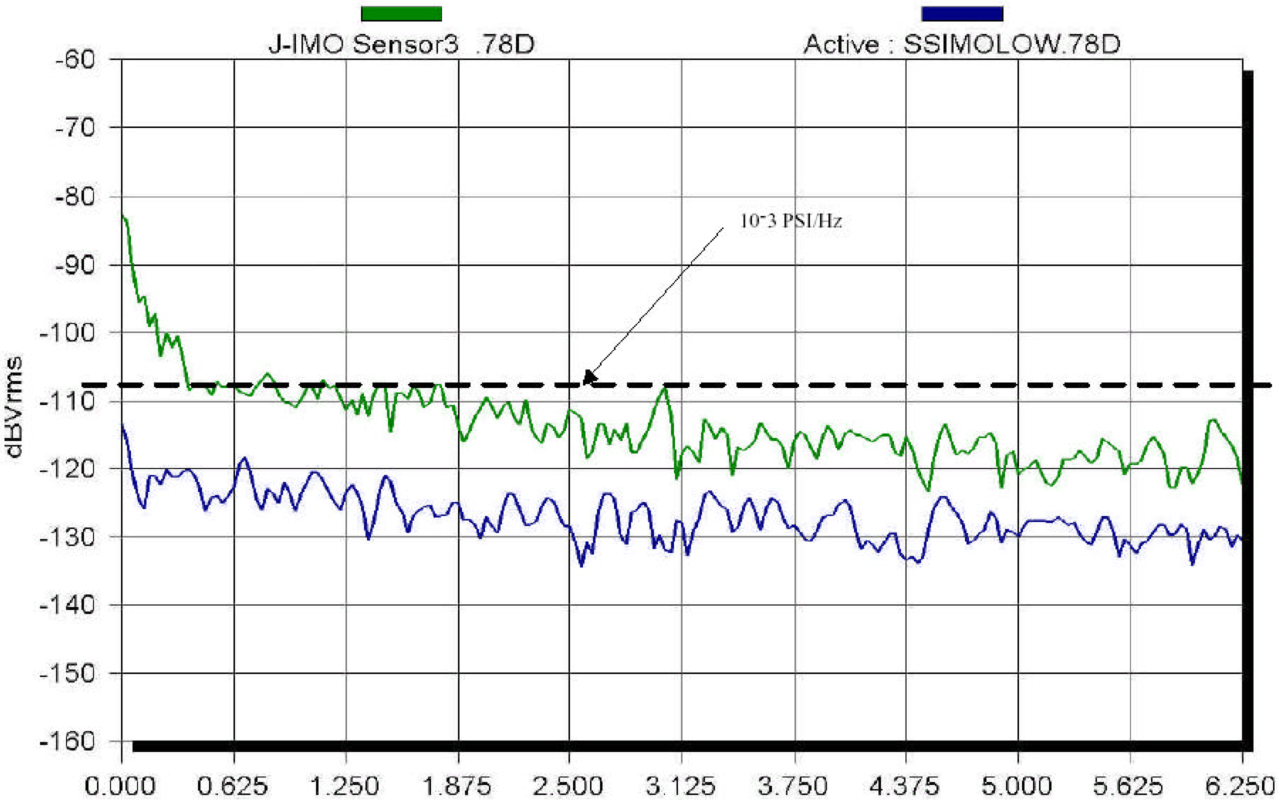

Figure 6 Gear Pump and Screw Pump at sensor #3 from ~0-6.25 Hz

3.5 Screw Pump Pressure Noise Performance

Comparison of Screw Pump shows pressure readings at sensors 3, 4 and 5

Measurements were made with the following conditions:

The motor is running at 50 Hz [1460 rpm] scale ~0-100Hz range, t

Ref. Sensor 3 is at the RC assembly, sensor 4 is before Test Load and at the end of the 180‘ tubing run, and sensor 5 just after the test load. Ref. the Test Load is similar to an RC assembly and seems to reduce the ripple at that point.

Look at Fig. 11 which separates the peak at 50 Hz. into two peaks one electrical and one from the pump pulse.

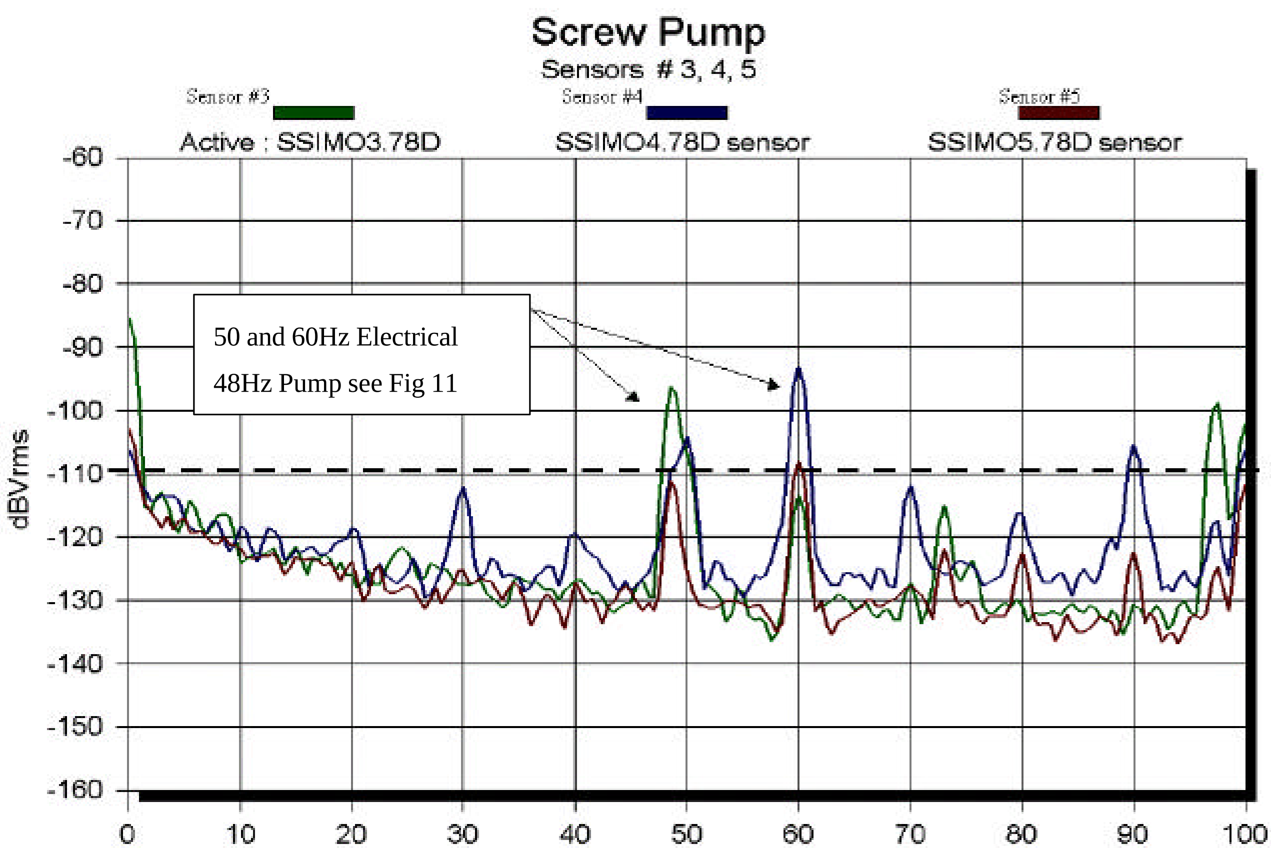

Figure 7 Screw Pump Pressure Noise Performance

3.6 Pump Mounting Style Comparison

This graph shows that separating the pump from the motor reduced the peaks.

Measurements were made with the following conditions:

Comparison of single unit Motor Pump Mount, with the Motor Separated Foot Mounted Pump.

Gear Pump, measurements taken at sensor 3 location

Blue Pump Mounted to Motor Adaptor Mount

Green Pump Mounted Separate, on Angle Foot Mount

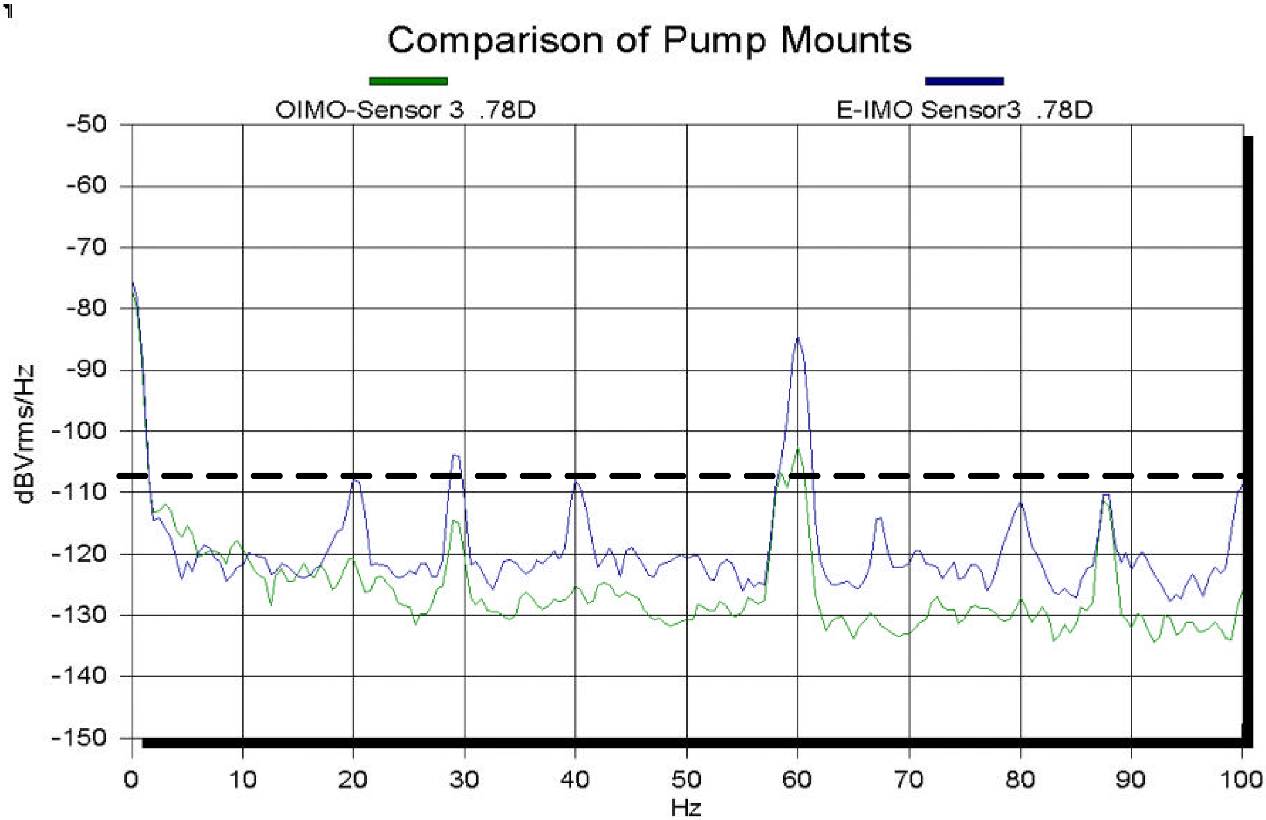

Figure 8 Pump Mounting Style Comparison

3.7 Coupling Spider Material Comparison

Measurements were made with the following conditions:

Gear Pump @ 1752 rpm taken at Sensor 2 location [see fig. 1]

Compares the Coupling Spider Materials:

Buna-n [**Green**] material,

Urethane [**Blue]** material

It appears peaks are slightly lower with Buna-n material, this is a softer material.

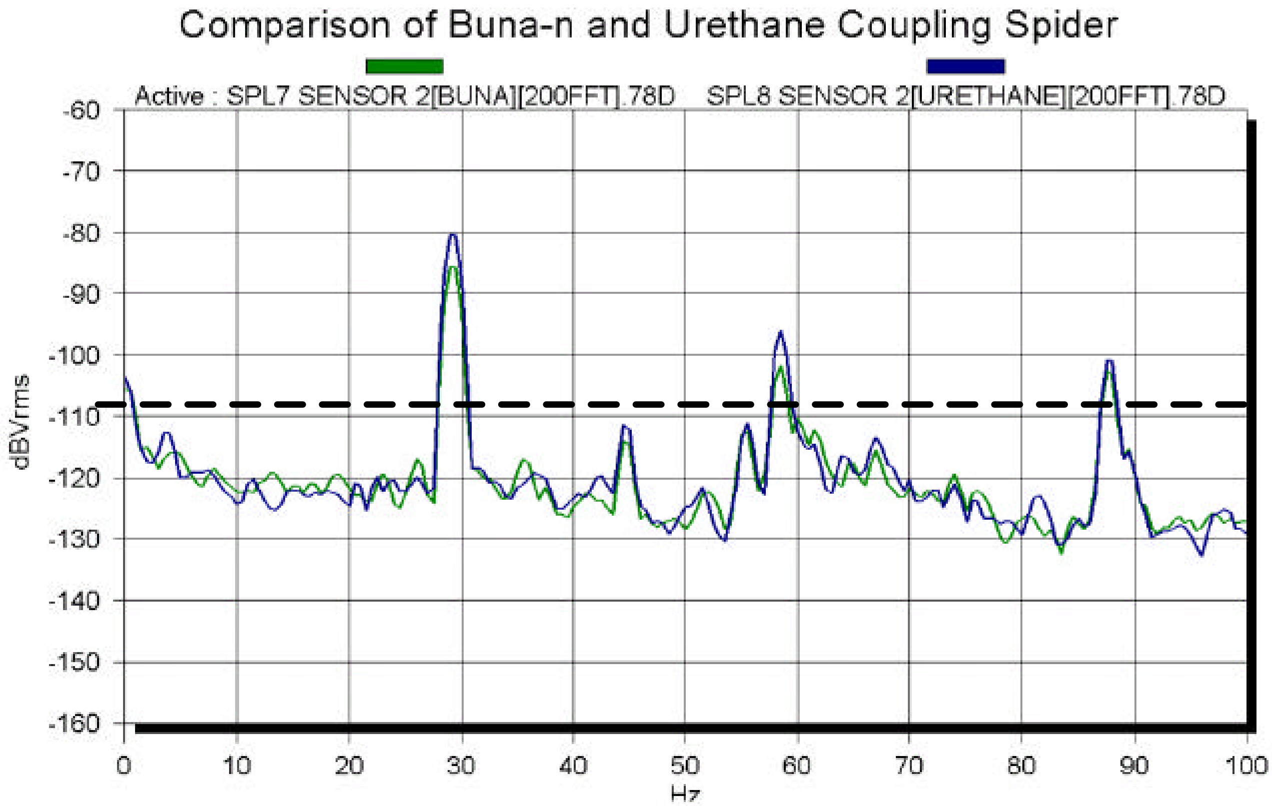

Figure 9 Coupling Spider Material Comparison

3.8 Effect of Coupling Alignment on Pressure Peaks

Comparison of 5 alignment settings of the coupling. [Motor/Pump Alignment] These were setups starting from scratch doing a manual alignment each time. This graph shows no change in the pressure peaks due to any variable change in the 5 different setups.

Measurements were made with the following conditions:

At sensor location 2 with the Screw Pump running @50Hz [1460 RPM] , ~0-100Hz range. Various Alignments, Angular and Axial spacing of coupling.

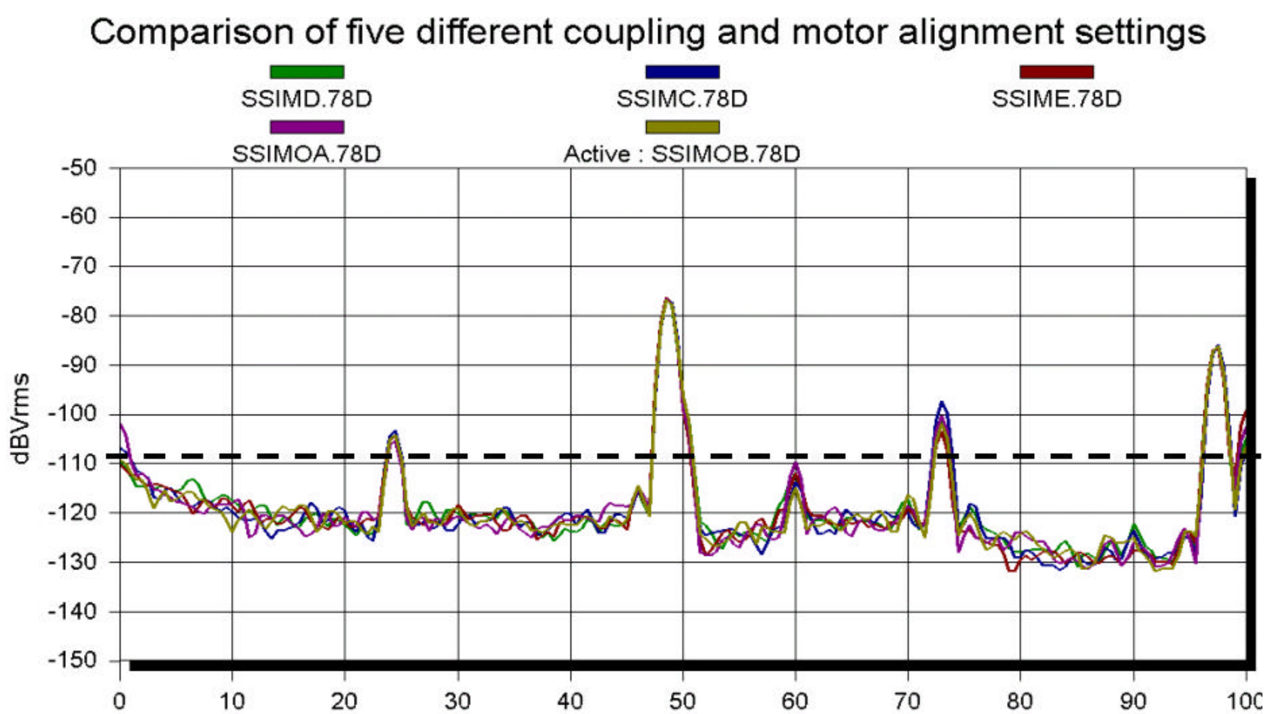

Figure 10 Effect of Coupling Alignment on Pressure Peaks

3.9 Analyzer Setting Change from 200 to 800 fft

This is a setting on the analyzer that shows higher resolution in the graph.

This separated the peak at 50 Hz. into two peaks, one electrical and one 2x pump rotation speed.

Measurements were made with the following conditions:

Comparison of the readout of identical tests at sensors 1 and 3, with the analyzer setting at 200 and 800 fft setting. The 800fft line setting shows more detail and overall lower floor, the time of acquisition is 3 minutes vs 20 seconds with the 200fft line setting.

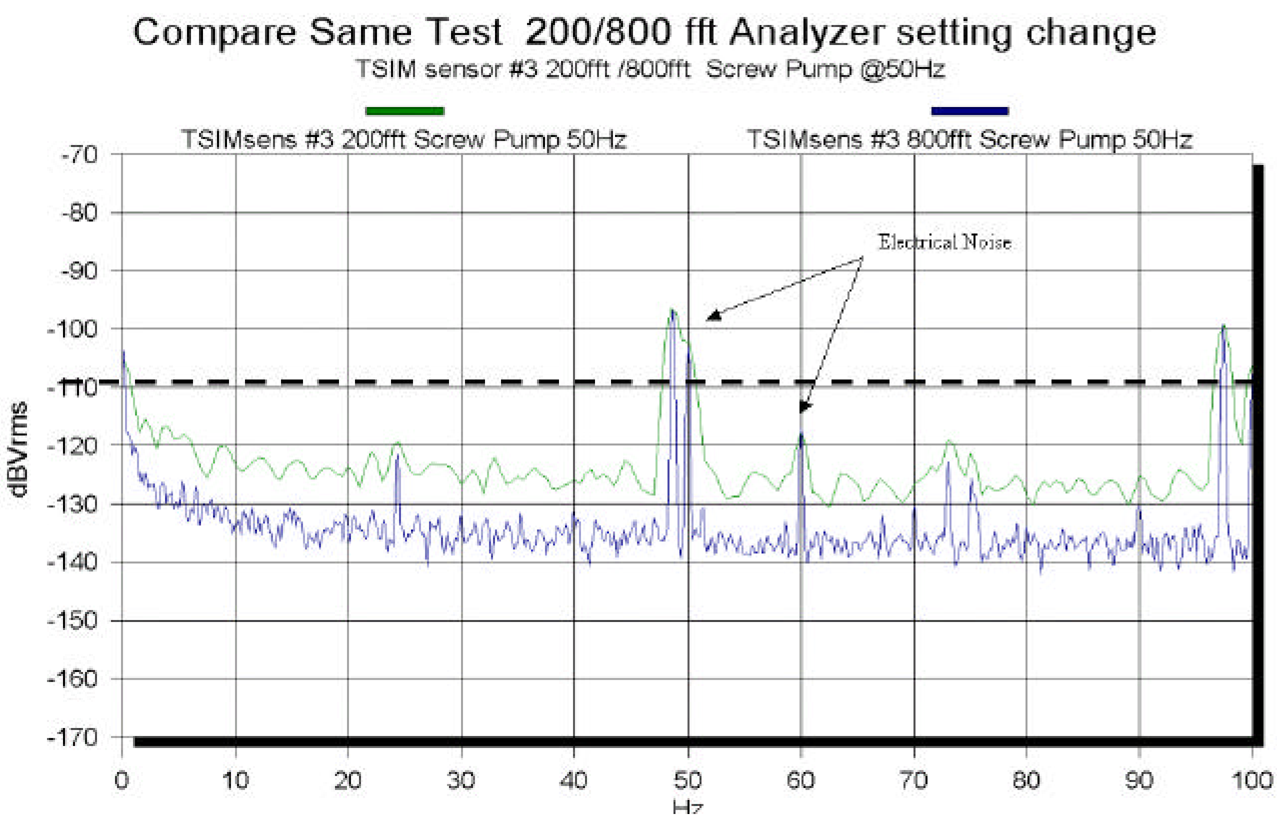

Figure 11 Analyzer Setting Change from 200 to 800 fft

3.10 Effect of a 10 Degree F Oil Temp Change on Pressure Peaks

The 10 F temp change had little affect on the pressure peaks shown in the graph.

Measurements were made with the following conditions:

Compares sensor 3 readings at three different times, one with a 10 F temperature change

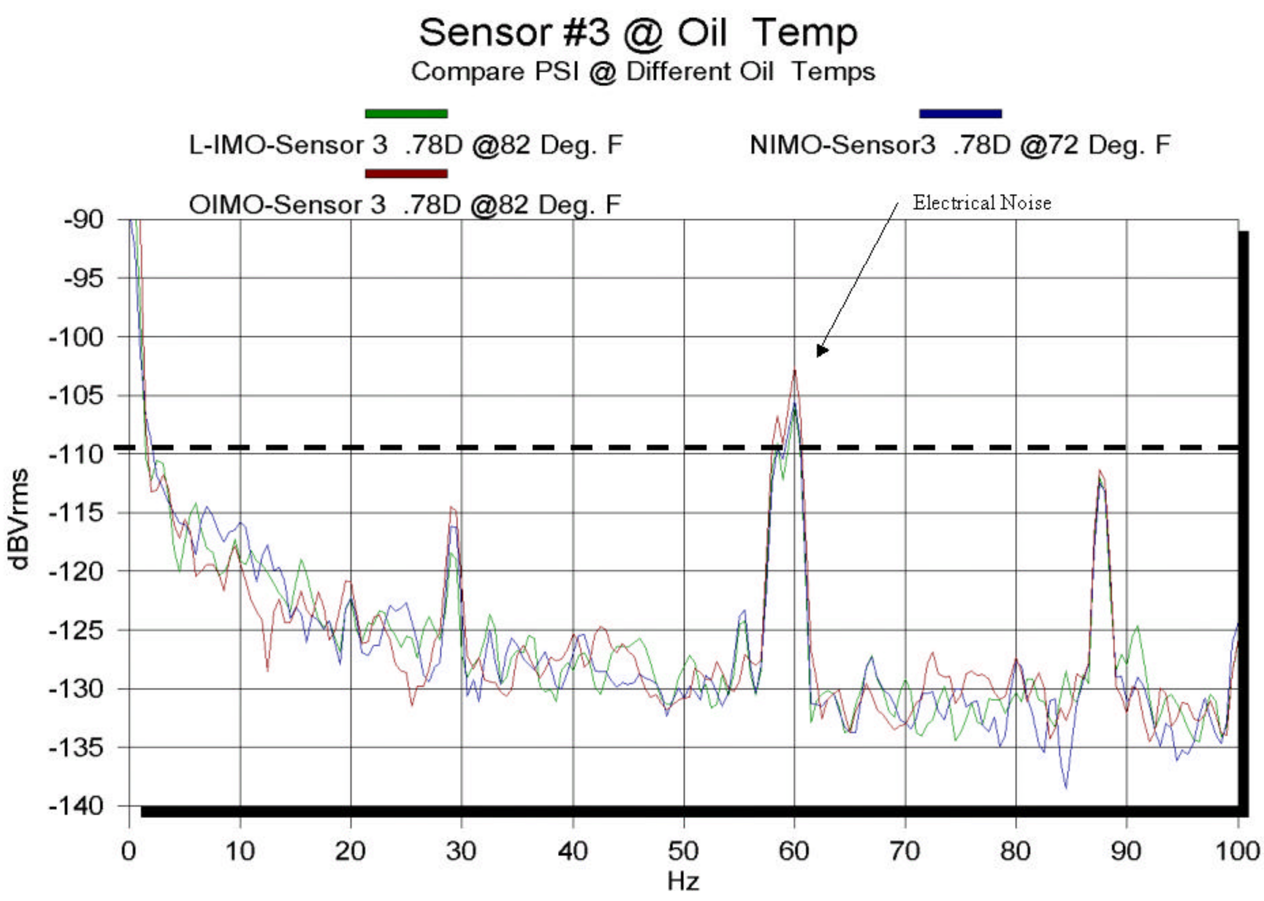

Figure 12 Effect of a 10 Degree F Oil Temp Change on Pressure Peak

3.11 Accumulator Bladder Pressure Changes and their Effect on Fluid Pressure Peaks.

Pressures in the accumulator had little affect in a range of .5 to .9 line pressure

Note when the pressure in the accumulator exceeds the line pressure the large peaks appear,

Measurements were made with the following conditions:

Taken at Sensor 3 located just after the R/C assembly [see fig. 1]

With a line pressure approx 74 psi

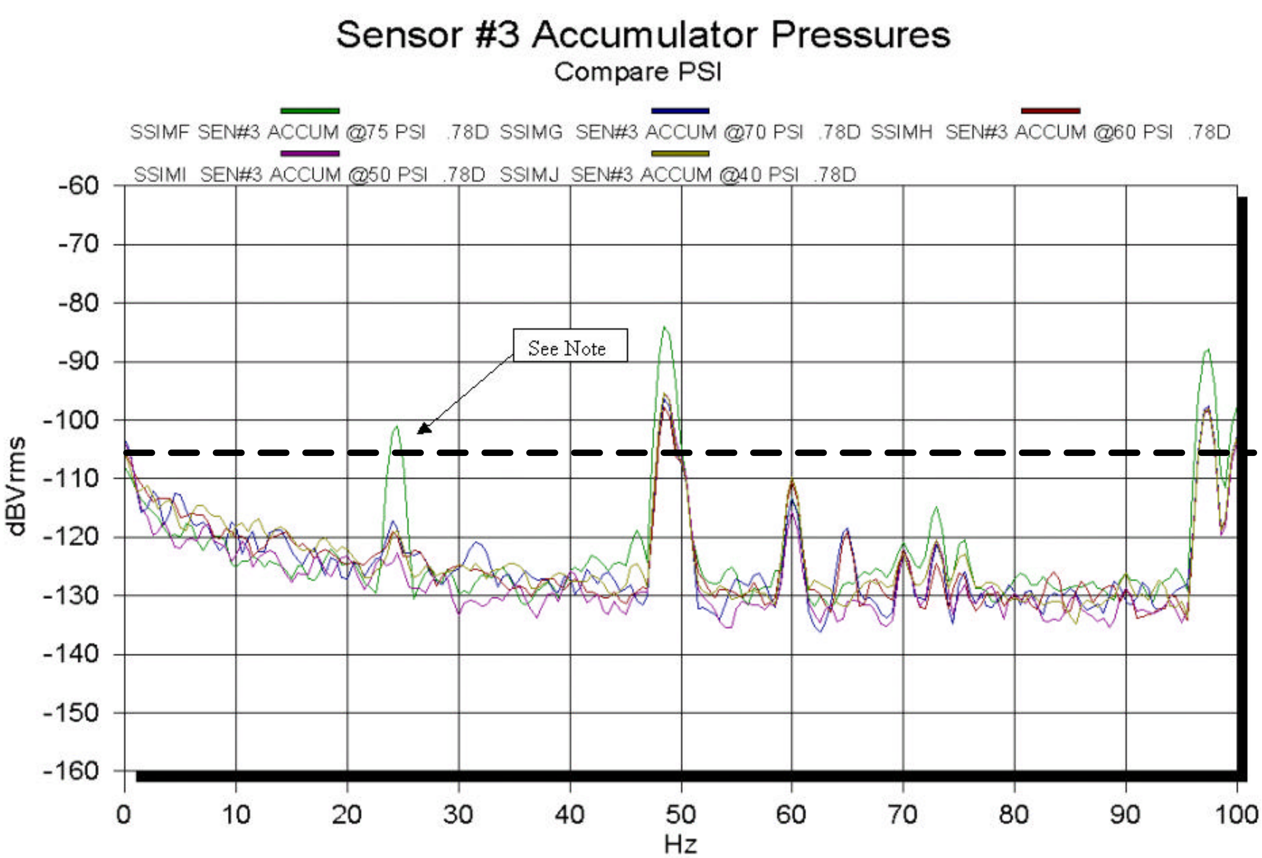

Figure 13 Effect of Accumulator Bladder Pressure vs. Fluid pressure peaks

3.12 Direct and Reduced Motor Speed Pulley Drive

Minus the chatter caused by the eccentric pulley drive and the seam on the v-belt, there is a real fluid pressure peak at around 48.6 Hz. [2x pump rotation speed]

Measurements were made with the following conditions:

Shows at sensor 3, the pump properties at a constant 1460 RPM direct drive vs a Reduced Motor Speed.

This setup used an overdrive pulley which lowered the motor controller speed to 34.6 Hz to separate electrical peaks form pump pressure peaks

Direct drive is green

Pulley drive is blue

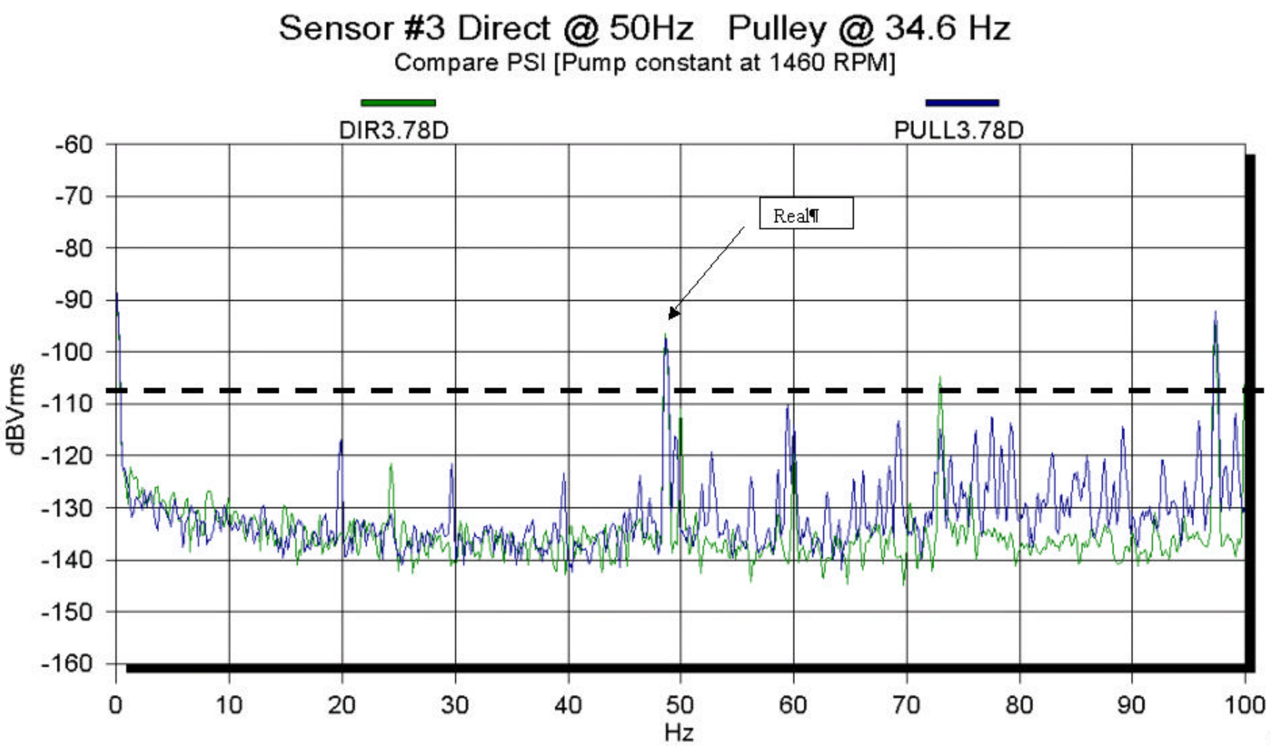

Figure 14 Direct and Reduced Motor Speed Pulley Drive

4 Appendix

Ref.

Conversion from the analyzer output Volt data to PSI, Notes.

transducer - 300 PSI / V

200 lines

plots are in dBV $/\sqrt{Hz}$

convert X $dBV/\sqrt{Hz}$ into Y $V/\sqrt{Hz}$

example $-115\ dBV/\sqrt{Hz}$

$-115/20 = -5.75$

1/. divide X by 20 = A

2/. the voltage is then 10^{A}.

voltage $= 10^{-5.75}$

$= 1.78 \times 10^{-6}$ V

3/. the pressure is then 300 PSI/V x voltage

pressure $= \frac{300\ PSI}{V} \cdot 1.78 \times 10^{-6}\ V$

$= 533 \times 10^{-6}$ PSI

$= 0.533 \times 10^{-3}$ PSI

for a plot of 0 - 100 Hz with 200 lines ⇒ measurement BW = 0.5 Hz

to convert to $V/\sqrt{Hz}$, divide all by $\sqrt{BW}$

so in this case

pressure $= \frac{1.78 \times 10^{-6}\ V}{0.707 \sqrt{Hz}} \times \frac{300\ PSI}{V}$

$= 0.755 \times 10^{-3}\ PSI/\sqrt{Hz}$

Conclusion

$-115\ dBV = 0.755 \times 10^{-3}\ PSI/\sqrt{Hz}$

to convert to V/Hz, divide by BW

pressure $= \frac{1.78 \times 10^{-6}\ V}{0.5\ Hz} \times \frac{300\ PSI}{V}$

$= 1.06 \times 10^{-3}$ PSI/Hz

$10^{-3}\ PSI/Hz$

conversion to V

$$\frac{10^{-3}\ PSI}{Hz} \times \frac{1\ V}{300\ PSI} = 3.33\times10^{-6}\ \frac{V}{Hz}$$

convert to dB

$$20\log_{10}(V) = 20\log_{10}(3.33\times10^{-6})$$

$$= 20\left[-6 + \log_{10} 3.33\right]$$

$$\boxed{= -109.6\ dBV/Hz}$$

$$-110 + 49.5 = -50.5$$

$$10^{-(50.5/20)} = 9.48\times10^{-4}$$

$$\sim 10^{-3}$$

Acrobat Document

ref page 1

Acrobat Document

ref page 2

5 Descriptions of Other Test Sets

For completeness a number of other test sets were performed:

All the tests usually were taken with readings at all 5 sensors, and the parameters of each of the setups are documented.

The temperature and the pressures at the analog gages these changed throughout the day due to the viscosity change with temperature.

Mounting the motor on a soft and hard mount

Mounting the pump on a soft and hard mount

Using a slight pressure in the fluid supply to the pump to eliminate any pump work to ‘pull’ the fluid in.

Damping the tubing in the 180’ run and at other places to determine the affect on the pressure peaks.

The information was used in designing a site version of the pump staton.

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