SLAC-PUB-95-6867

# VIBRATION STUDIES OF THE STANFORD LINEAR ACCELERATOR†

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## ABSTRACT

Vibration measurements of the linear accelerator structures in the SLC linac show a 1 micron rms vertical motion. This motion reduces to 0.2 micron rms motion when the cooling water to the accelerator structures is turned off. The quadrupoles have 250 nanometer rms vertical motion with the accelerator structure cooling water on and 60 nanometer motion with it off. These results together with measurements of the correlations as a function of frequency between the motions of various components are presented.

## I. INTRODUCTION

During the 1994/95 colliding beam run of the SLC, the measured jitter in the vertical beam position indicated it had a significant impact on the luminosity [1]. Diagnosing the sources of jitter became a priority issue. The possibility of vertical movement of quadrupole magnets or even accelerator structures affecting the beam was considered, and efforts toward modeling and measuring potential sources [2] of beam jitter in the linac ensued. This paper primarily describes measurements of quadrupole and accelerator structure motion in the linac under various conditions and the conclusions reached.

## II. SETUP

The system used for most measurements combined Mark L4-C geophones, and a SLAC built integrator and amplifier, with a mobile LabView® data acquisition and analysis system.

The geophone is essentially a mass suspended on a spring that induces a signal on a coil which is proportional to velocity of the ground motion for frequencies above the geophone natural frequency (~1 Hz). The signal is integrated, amplified, then digitized at 4 kilohertz on a quad channel board and analyzed using LabView® on a PC. The combined system as configured for these measurements has good resolution from 2 to 100 Hz. Electrical noise in the geophone measurements was determined to be several orders of magnitude below the measurement data.

Cross checks of the geophones were made using a Hewlett Packard HP3560A Dynamic Signal Analyzer with a PCB Piezotronics model 393B31 accelerometer and an optical linear encoder (Heidenhain model MT60K) with 50nm resolution. They agreed at the 10% level.

## III. MEASUREMENTS

Vertical motion of accelerator structures was measured at 1 micron rms, and thought not to be a problem for SLC beams. Quadrupole vertical motion was about 250 nanometers rms, enough to be a problem [2]. Correlation between the motions of two quadrupoles separated by 12 meters was high in the 8-14 Hz range (see figure 1) but not elsewhere in the spectrum.

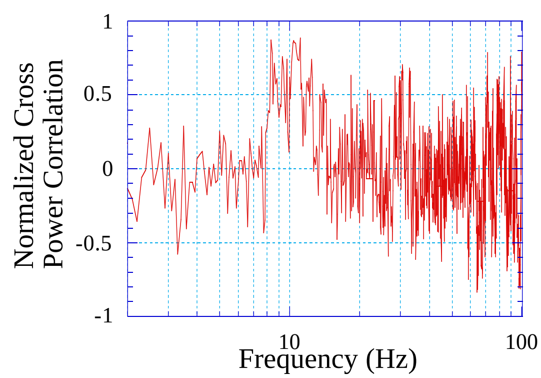


*Figure 1. Spectrum of normalized cross power correlation of vertical motion of two quadrupoles.*

Turning off water to the quadrupoles themselves had little affect, but turning off the water to the adjacent accelerator structures lowered vibration of the quadrupoles from about 250 nanometers rms to about 60 nanometers rms (see figure 2). Thus most of the quadrupole motion is due to the vibrations that are caused by the cooling water. Much of the motion is at 59 Hz (see figure 2 bottom plot) which can be seen in the jitter of the beam orbits [3]. The 59 Hz motion is believed to be due to the accelerator water pump impeller rotating at 59 Hz. The quadrupole motion in the 8-14 Hz

Work supported by Department of Energy contract DE–AC03–76SF00515.

†Supported by D.O.E. contract DE-AC03-76SF00515.

range, however, was not reduced dramatically with the water off (see figure 2).

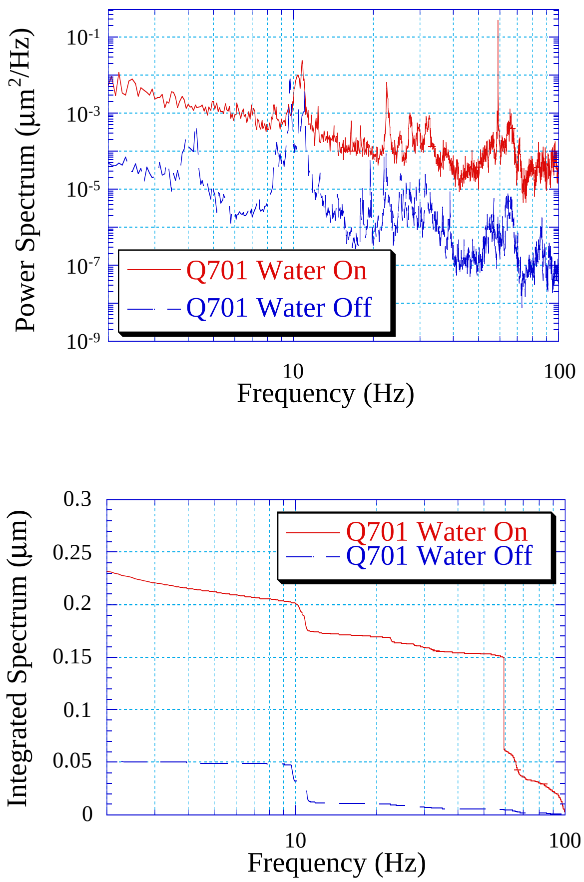


*Figure 2. Quadrupole motion spectrum (top) and integrated spectrum (bottom) with accelerator cooling water on and off.*

Not all quadrupoles exhibit the same behavior. Figure 3 shows some examples of the integrated spectrum. Note that the fraction of 8-14 Hz motion and 59 Hz motion differs. Oscillations at 28-30 Hz dominate the spectrum of quadrupoles that have upright supports (the so called matching quadrupoles, see Q901 in figure 3) even with the water off. These quadrupoles also have a spike at 59 Hz that disappears when the accelerator water is turned off.

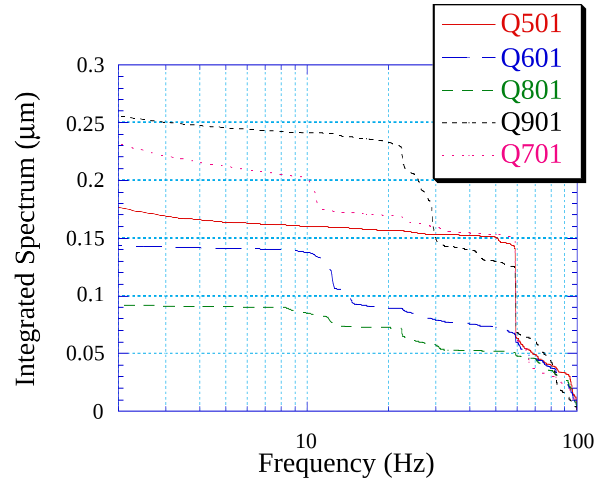


*Figure 3. Integrated vertical motion of five quadrupoles with the accelerator water on.*

Much of the quadrupole motion is related to the design of its support. The centroid of the quadrupole is offset along the beam direction (Z) which allows the quadrupole to vibrate in an arc in the ZY plane (see figure 4). Clamping the quadrupoles to the adjacent structure reduced the 10-14 Hz motion significantly.

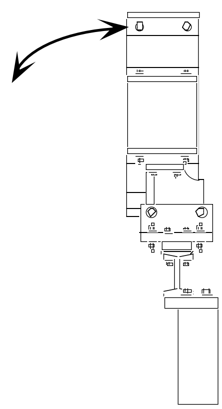

*Figure 4. Side view of standard quadrupole with arrows showing direction of movement.*

Quadrupoles in different sectors are affected by different accelerator water circuits. Those sampled in sector 12 did not show as large a 59 Hz problem as seen in sectors 14 and 15.

To study the difference, the pipe vibration near the pump was measured in sector 14. The 59 Hz motion was observed. Also, a pressure transducer was used to measure the time variation of the pressure at sector 12 and 14. The pump rotates at 59 Hz, and pump impellers have five vanes which create a large contribution at 295 Hz. Figure 5 shows the integrated spectra of the pressure variations.

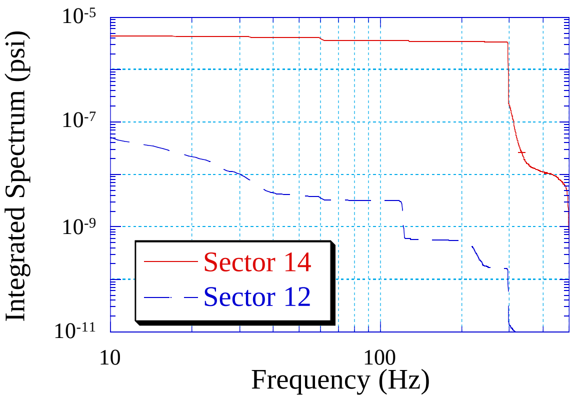


*Figure 5. Integrated water pressure variations from two accelerator water systems.*

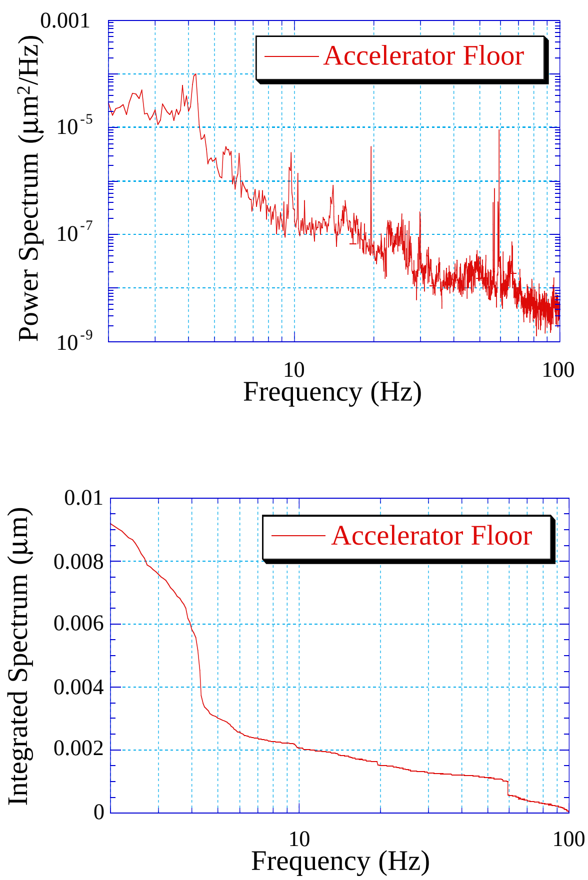


*Figure 6. Spectrum and integral of vertical motion on the floor of the accelerator tunnel (about 35' below ground [4]).*

Finally, measurements of the accelerator floor motion were made. Figure 6 shows an example. Integrated values (>2 Hz) between 9 and 35 nanometers were observed on different days.

## IV. SUMMARY AND CONCLUSIONS

The largest contributor to quadrupole vertical vibration in the SLC is due to the motion of the accelerator cooling water. Much of this motion is at 59 Hz. The 59 Hz is transmitted from the pump by modulating the water pressure. Pump impeller quality may be the cause.

Compounding the problem is a ~10 Hz resonant quadrupole support structure. Its effect was reduced by adding wedge supports. Other types of quadrupoles need similar fixes.

## V. REFERENCES


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