Bellows Vibrations in the 3.9 GHz Cryomodule

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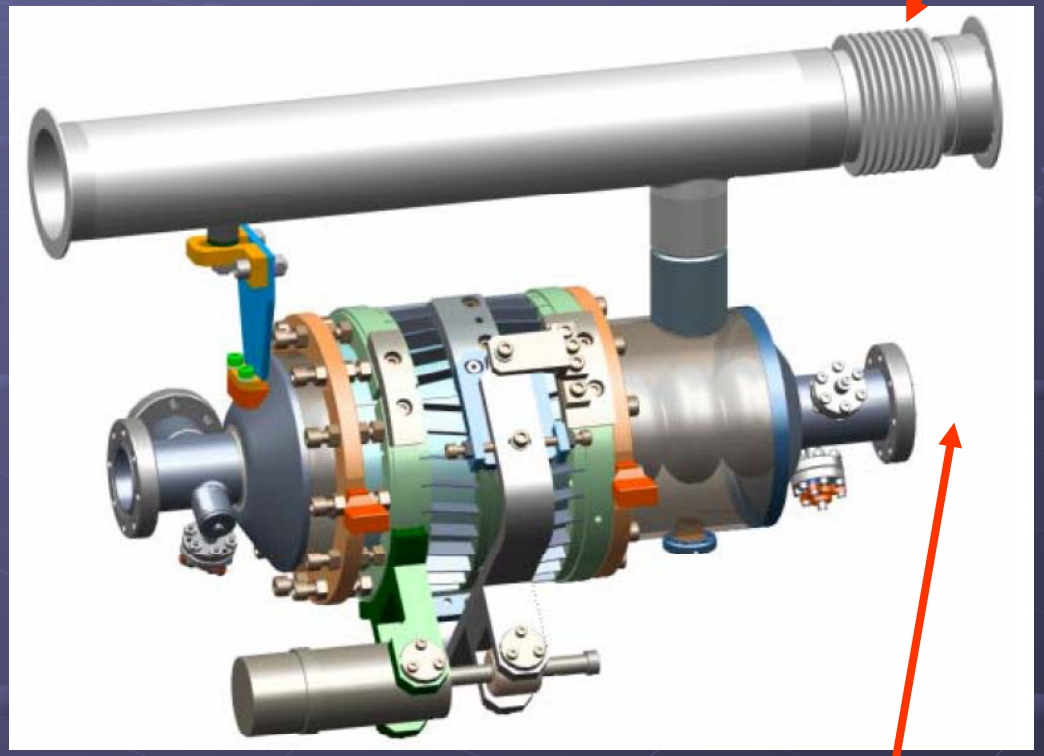
3.9 GHz Cryomodule Bellows

- Concern that bellows may be damaged by shock or vibration during transportation
- Two types
- 3 of each type in cryomodule



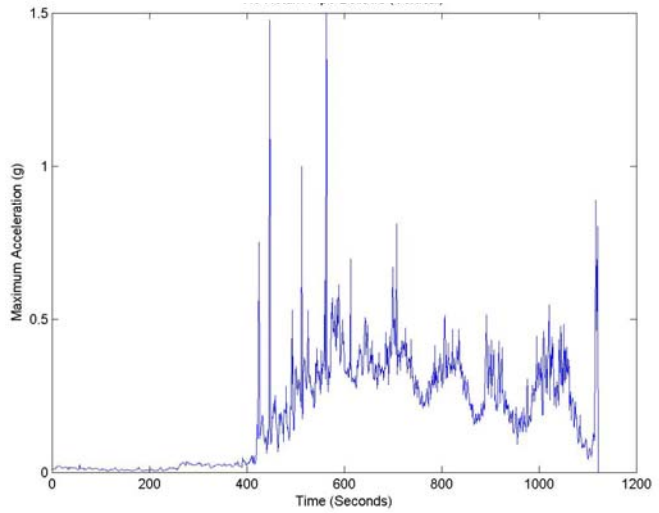
On Site Road Test

- Slow Speed <=40 MPH of Fermilab Site
- Pipe bellows instrumented with Endevco 27A12 Accelerometer
  - 1gram
  - 10 g/Volt
  - 0.2Hz to 12 KHz
- Bellows switched to intra-cavity bellows halfway through the test
  - Limited by short notice and available electronics

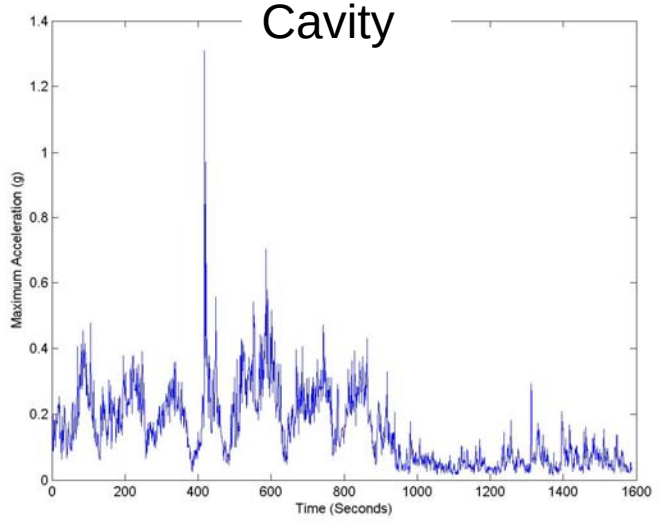
On-Site Road Test Maximum Acceleration

- Maximum vertical acceleration <1.5 g for both bellows

Pipe

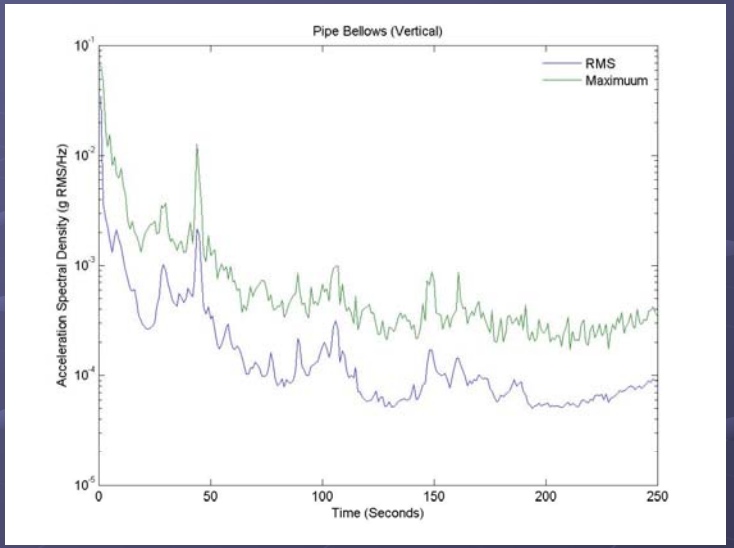


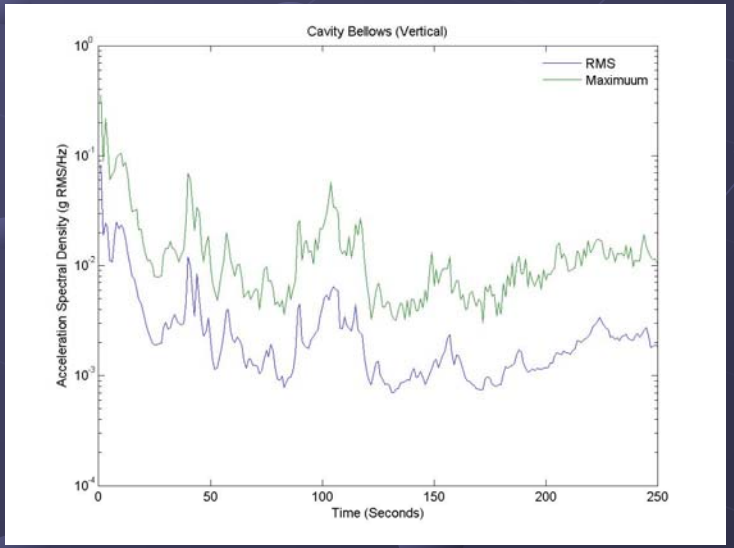
Cavity



On Site Road Test

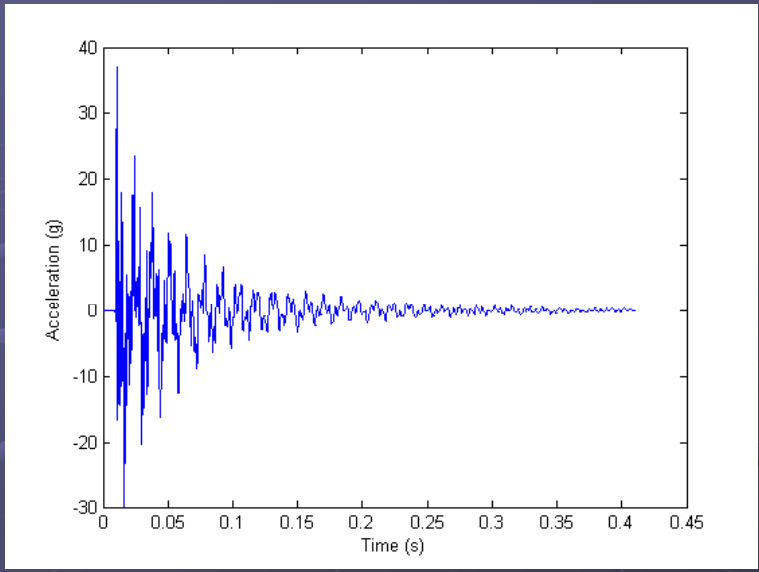
- Power Spectrum for both bellow shows resonance near 45 Hz
- Two types of bellows are different
- Implies both being driven by a common source

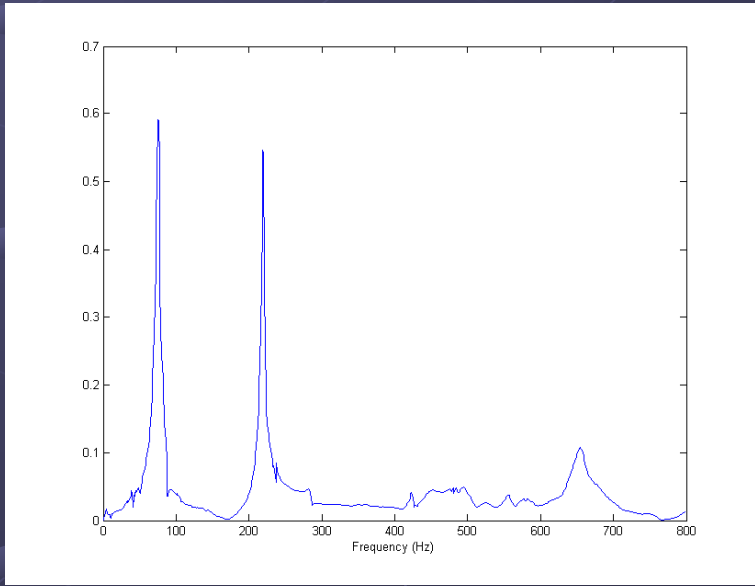




Tap Tests

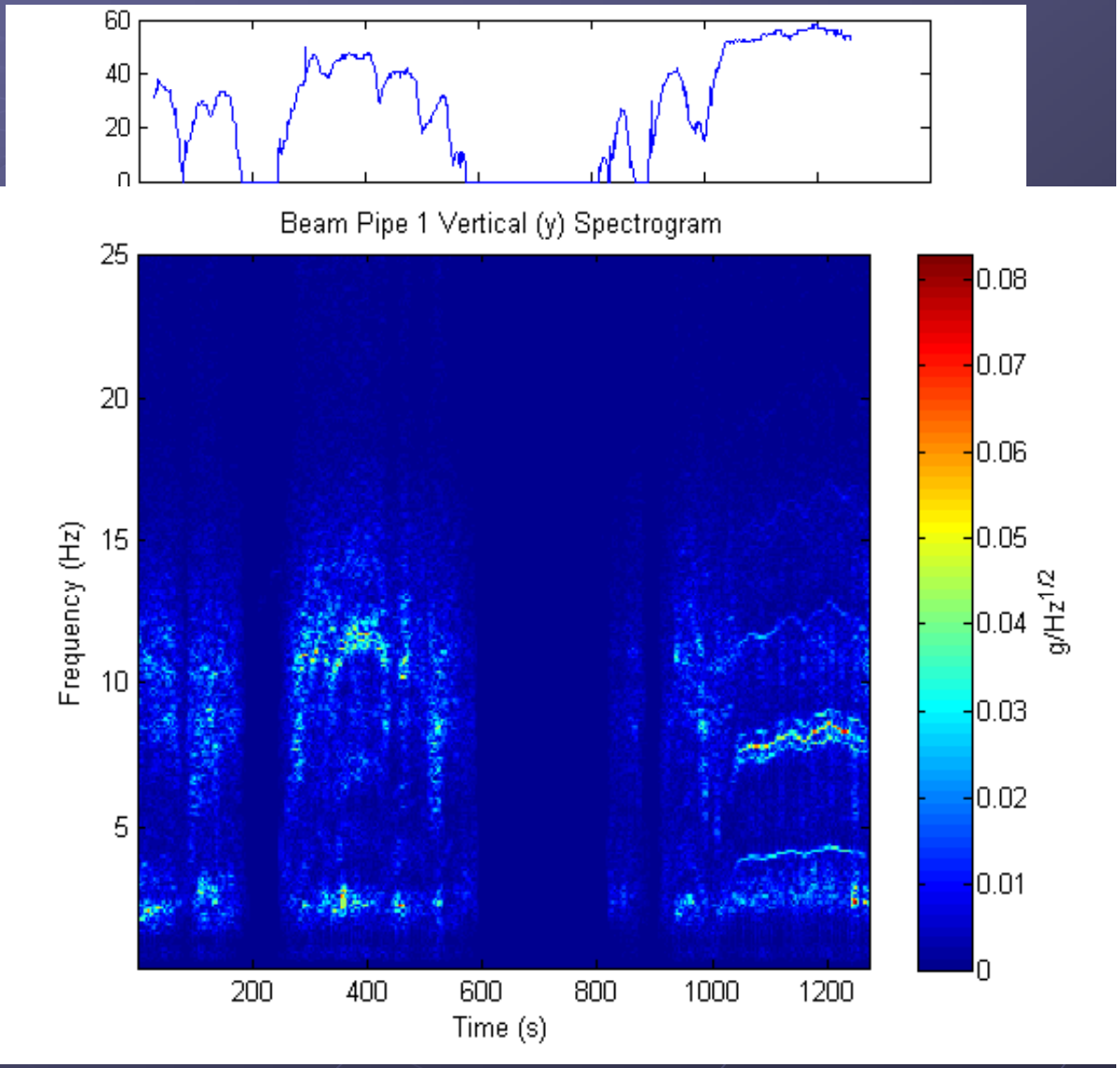
- Measure transient response of bellows to tapping on the cryomodule
- Prominent resonances at 74 Hz and 218 Hz not at 45 Hz





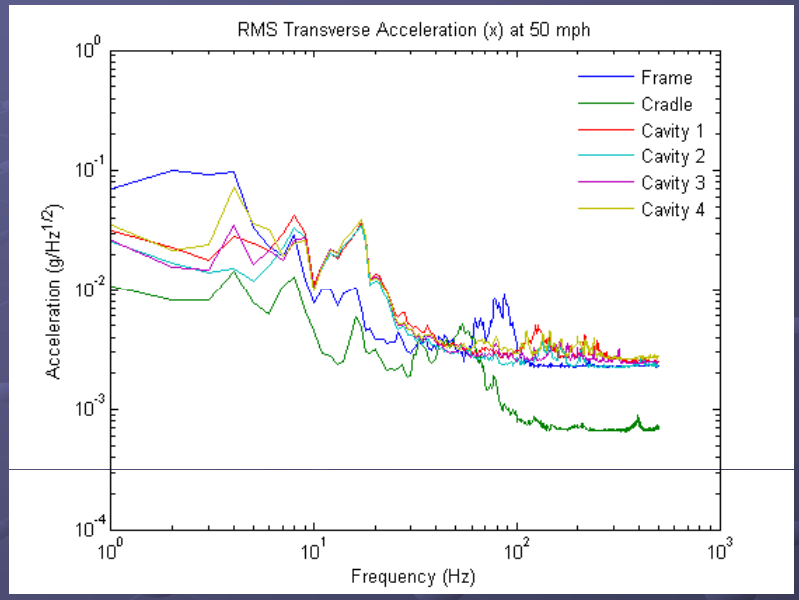
Off-Site Road Test

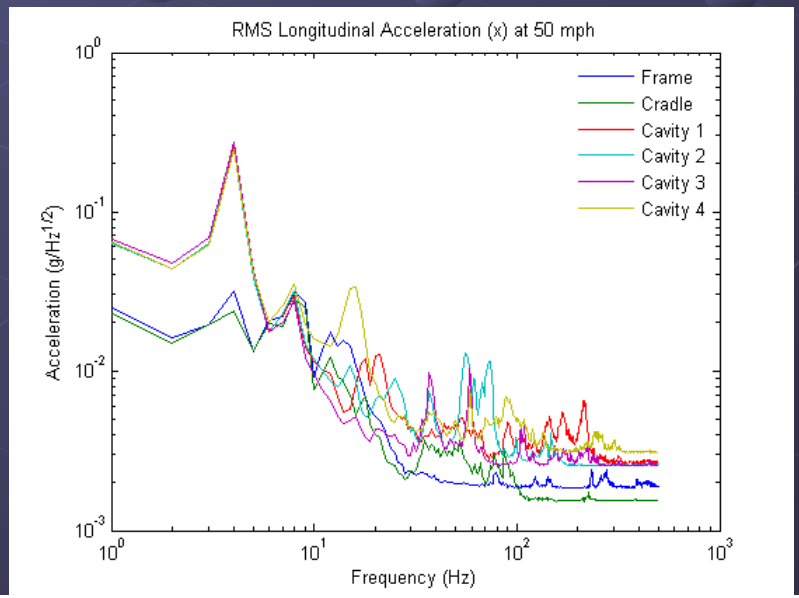
- Flange near intra-cavity bellows instrumented with GS 14-L9 geophone
- Vibration spectrum of the pipe dominated by narrow low-frequency lines correlated with speed of the truck
- Truck drive train is most likely source



Acceleration PSD

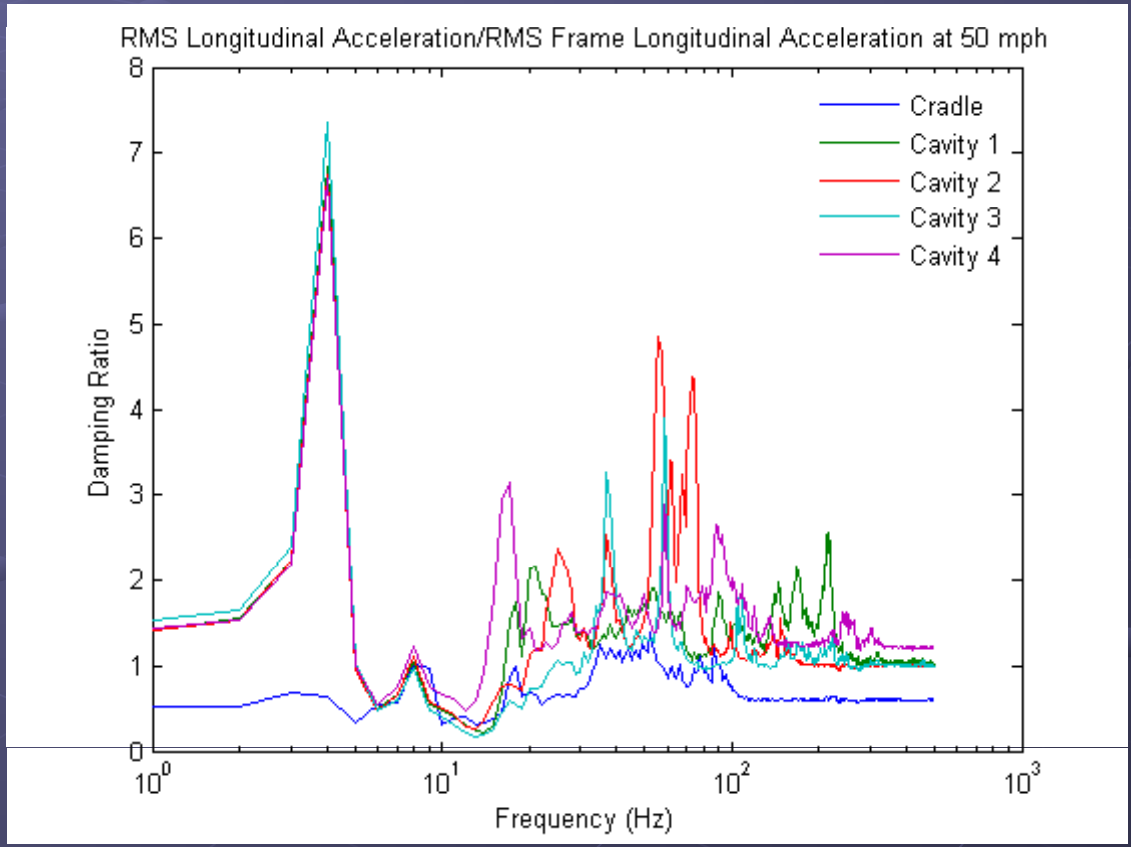
- Acceleration PSD dominated by low frequencies





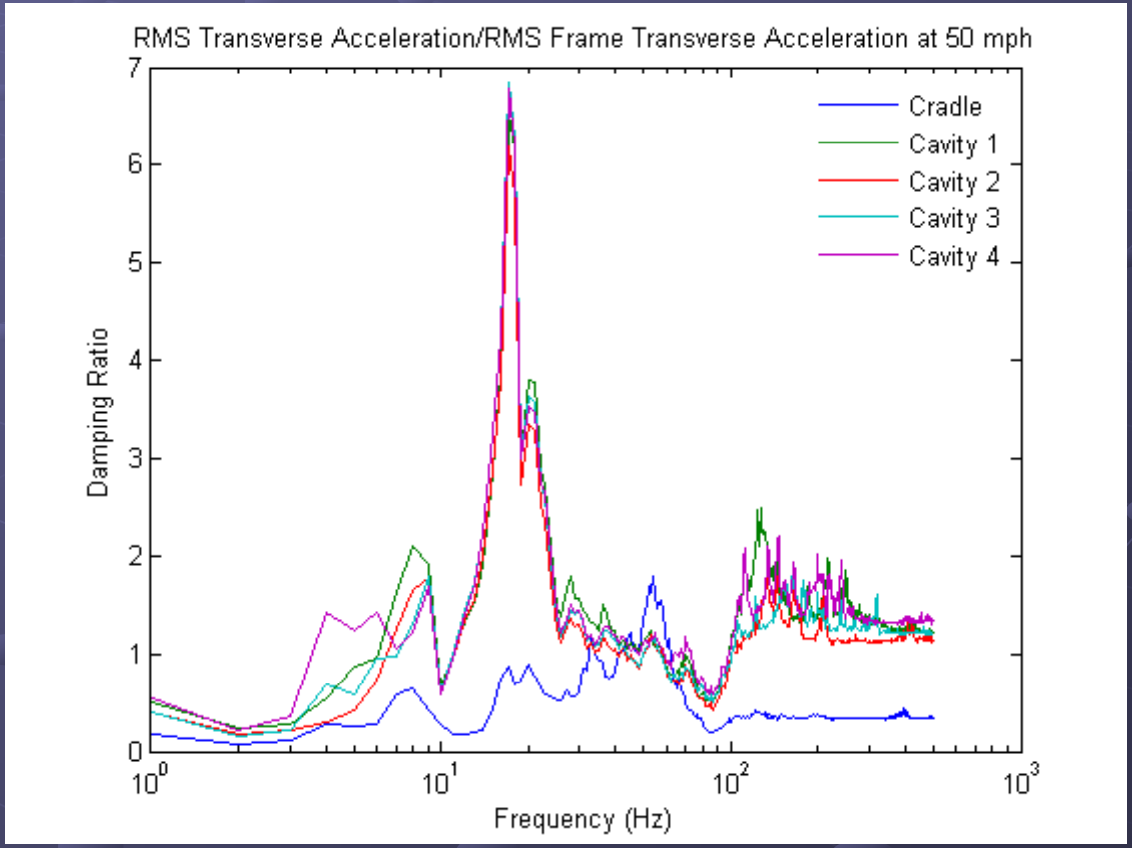
Longitudinal Damping Ratio

- Cradle vibrates less than the frame
- Cavities vibrate more than the cradle



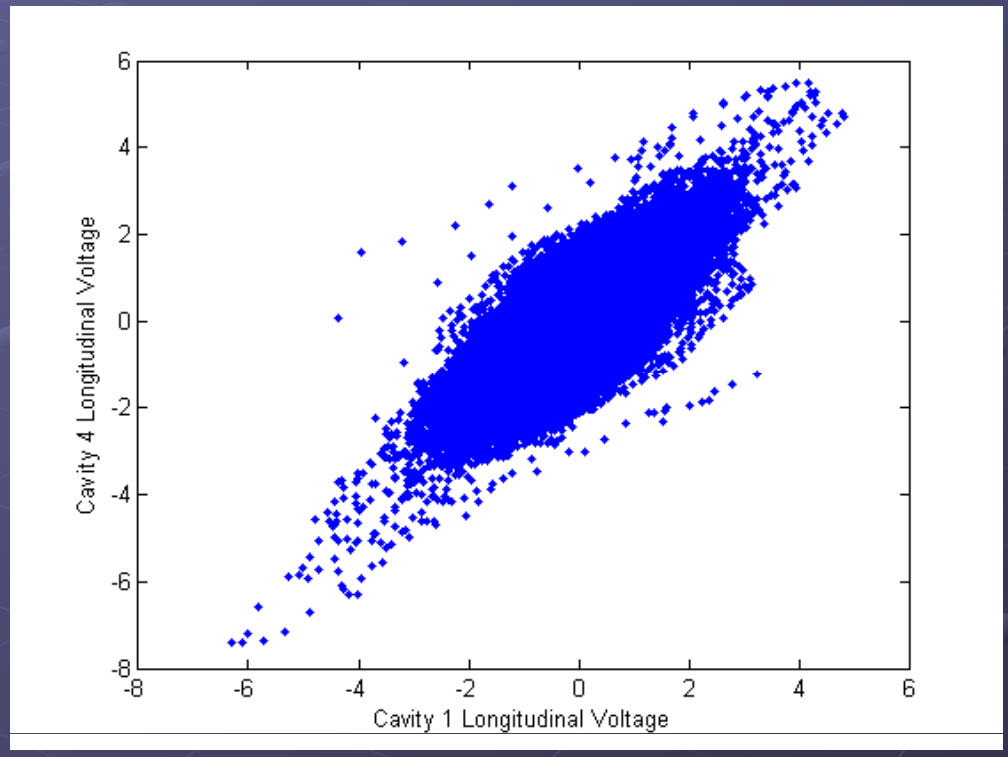
Transverse Damping Ratio

- Similar behavior in transverse direction



Correlation Between Cavities

- Longitudinal and transverse motion of the cavities is highly correlated
- Vertical motion is likely to be correlated in the same way but not possible to verify using current data sets



Summary

- During on-site road tests
  - Maximum acceleration less than 1.5 g
  - Both bellows being driven by common source at 45 Hz
- During both road tests, vibration was dominated by low frequency, speed-dependent vibrations from the truck drive train
- Cradle effectively damps high frequency vibrations from the bed
- Cavities vibrate more than the cradle
- Cavities vibrate coherently

Conclusions

- The vibrations of the bellows are most likely part of coherent vibrations of the entire cold-mass rather than differential motion of the bellows with respect to the pipe or flange
- Damping the bellows is not likely to help by itself
- Lowering the resonant frequency of the damping system to reduce the low frequency, speed-related vibration from the truck could help
- Reducing the Q of the cold-mass could help

Further Work

- During next road test, instrument one pipe and one flange next to the bellows with XYZ geophones to confirm that these components vibrate coherently with the cavities in all three axes
- When the cold-mass is removed from the vessel, measure the differential vibration of the bellows in all three axes with respect to XYZ geophones on the pipe and the flange using tap tests