Low Frequency Measurement System

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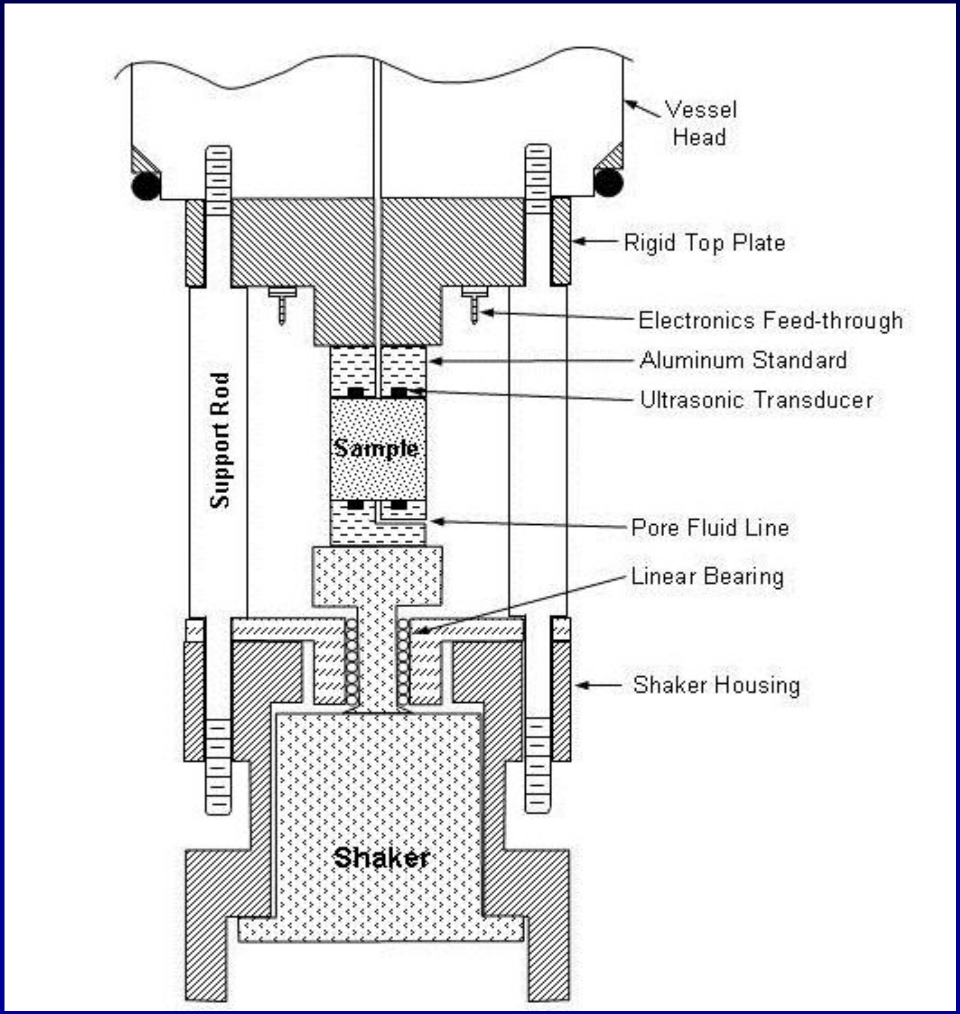
Why do we need low frequency measurement

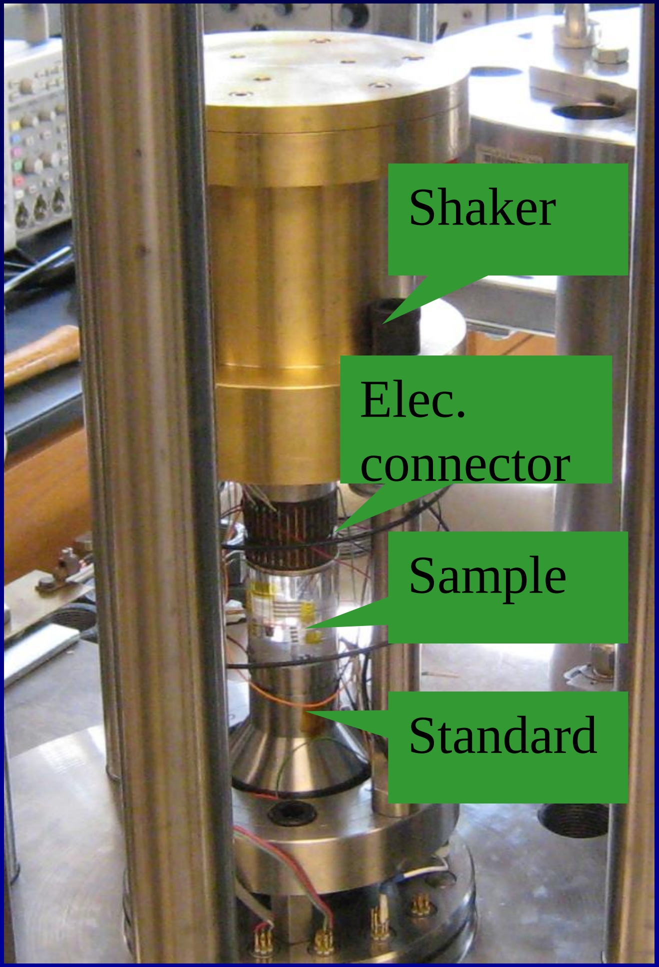
- Dispersion: integration of seismic, well-log and core data
- Attenuation: another attribute for DHI

History for lab measurement

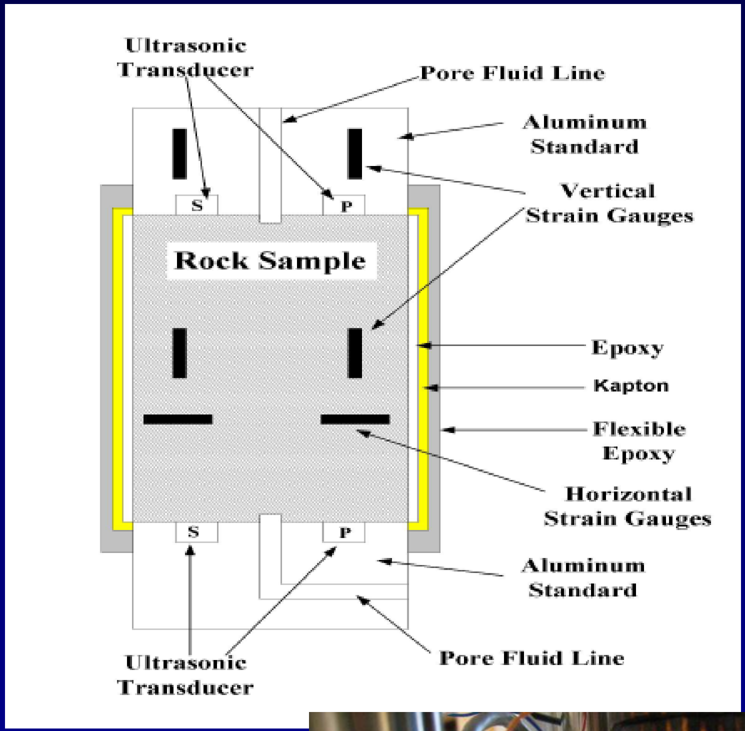
- Ultrasonic: ~MHz
- Resonant bar: >400Hz (logging)
- Force-deformation: Hz-1000Hz (seismic)

Low frequency system: principle





Low frequency system: principle



$$E = \frac{\sigma}{\varepsilon_{\perp}}$$

$$\gamma = \frac{\varepsilon_{||}}{\varepsilon_{\perp}}$$

$$\frac{1}{Q} = \tan(\theta)$$

$$V_p = \sqrt{K + \frac{4}{3}\mu \Big/ \rho}$$

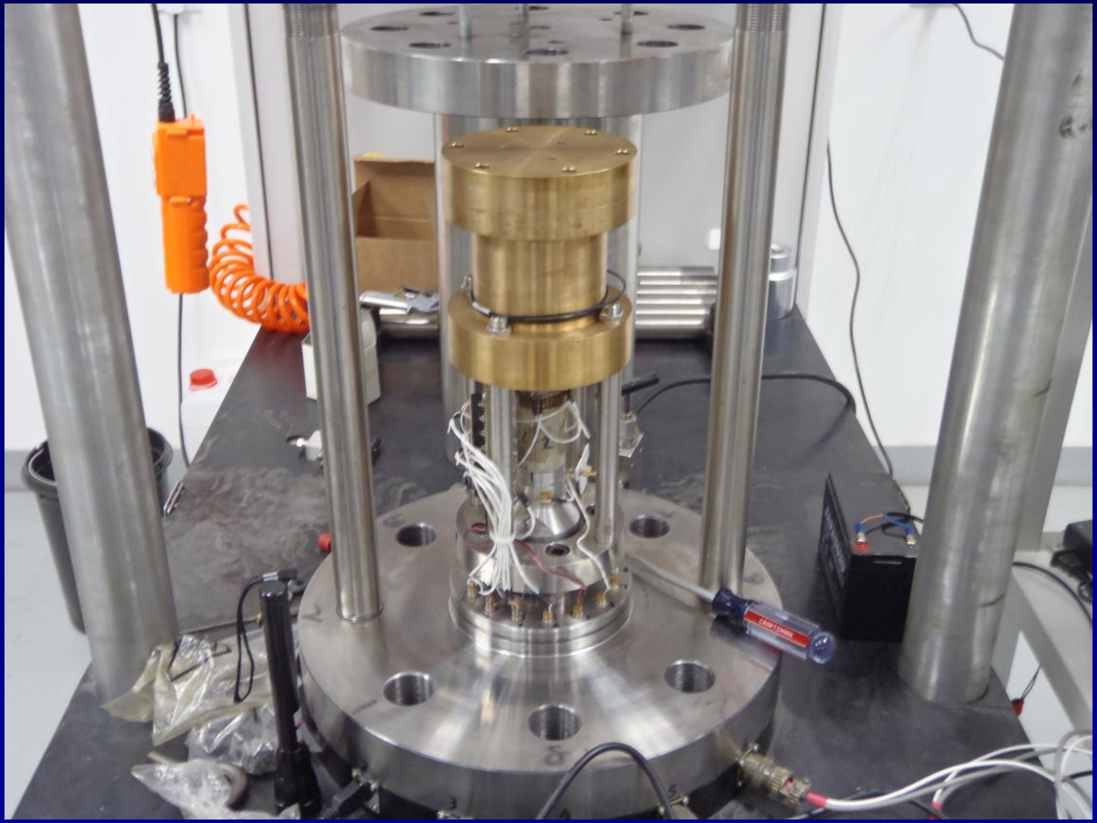
$$V_s = \sqrt{\mu \big/ \rho}$$

Engineering challenges

- Small strain $<10^{-6}$ and small output (μV)
- Results sensitive to amplitude and phase
- Special hardware and software need be developed
  - Small signal amplifier with differential input and shield driving
  - Lock-in amplifier to deal with low signal-noise ratio
  - 24 bit 16 channel NI acquisition system
- Multiple calibrations needed

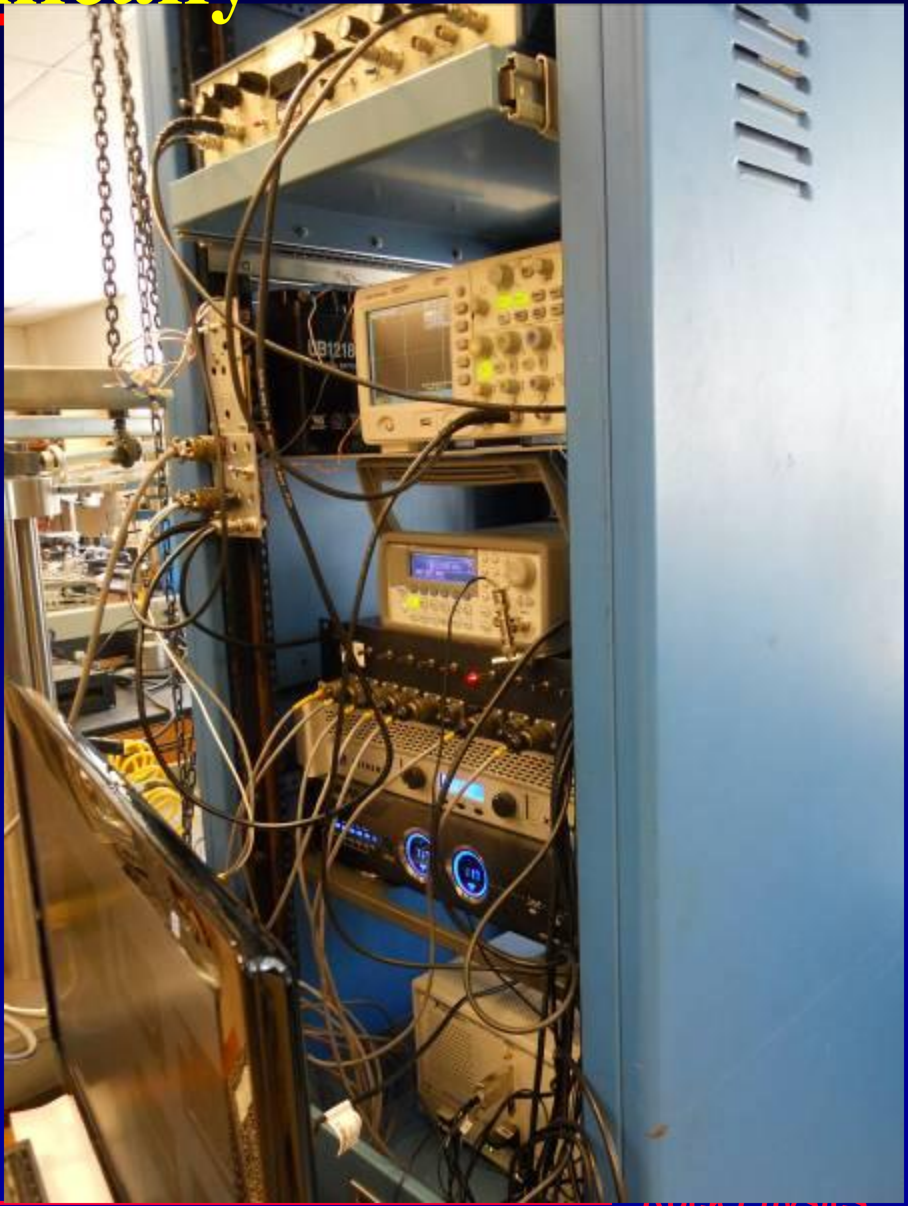
Acknowledge: CSM & Shell

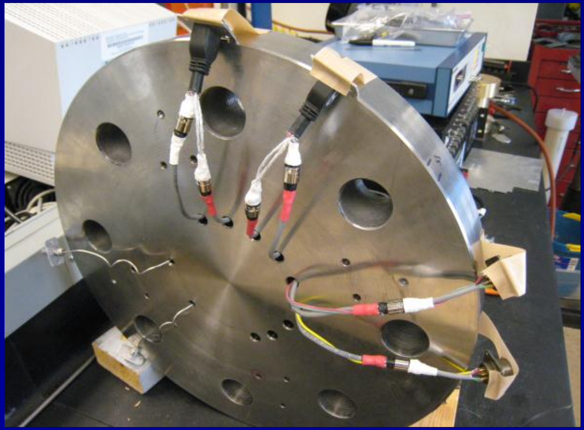
What's new: Mechanically



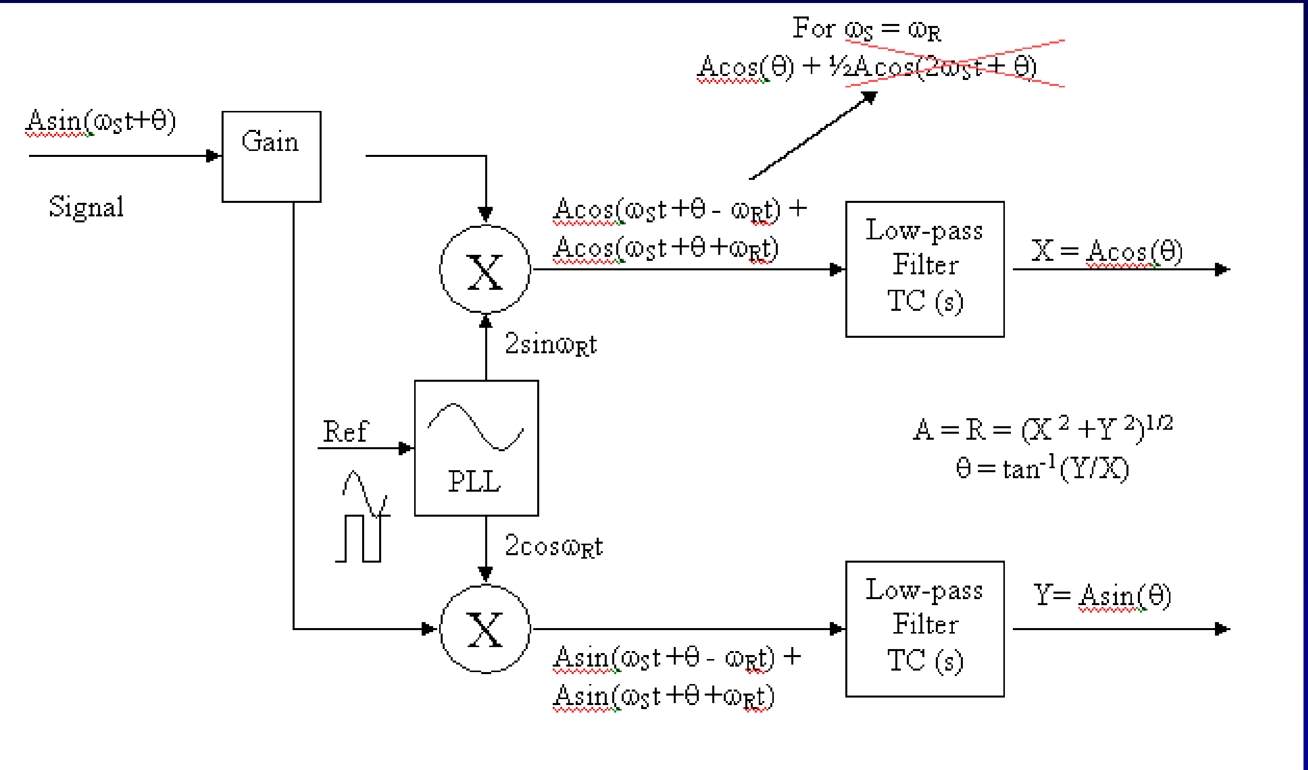
- Stationary sample assembly: more reliable
- In vessel shaker: better vibration mode

What's new: Electronically





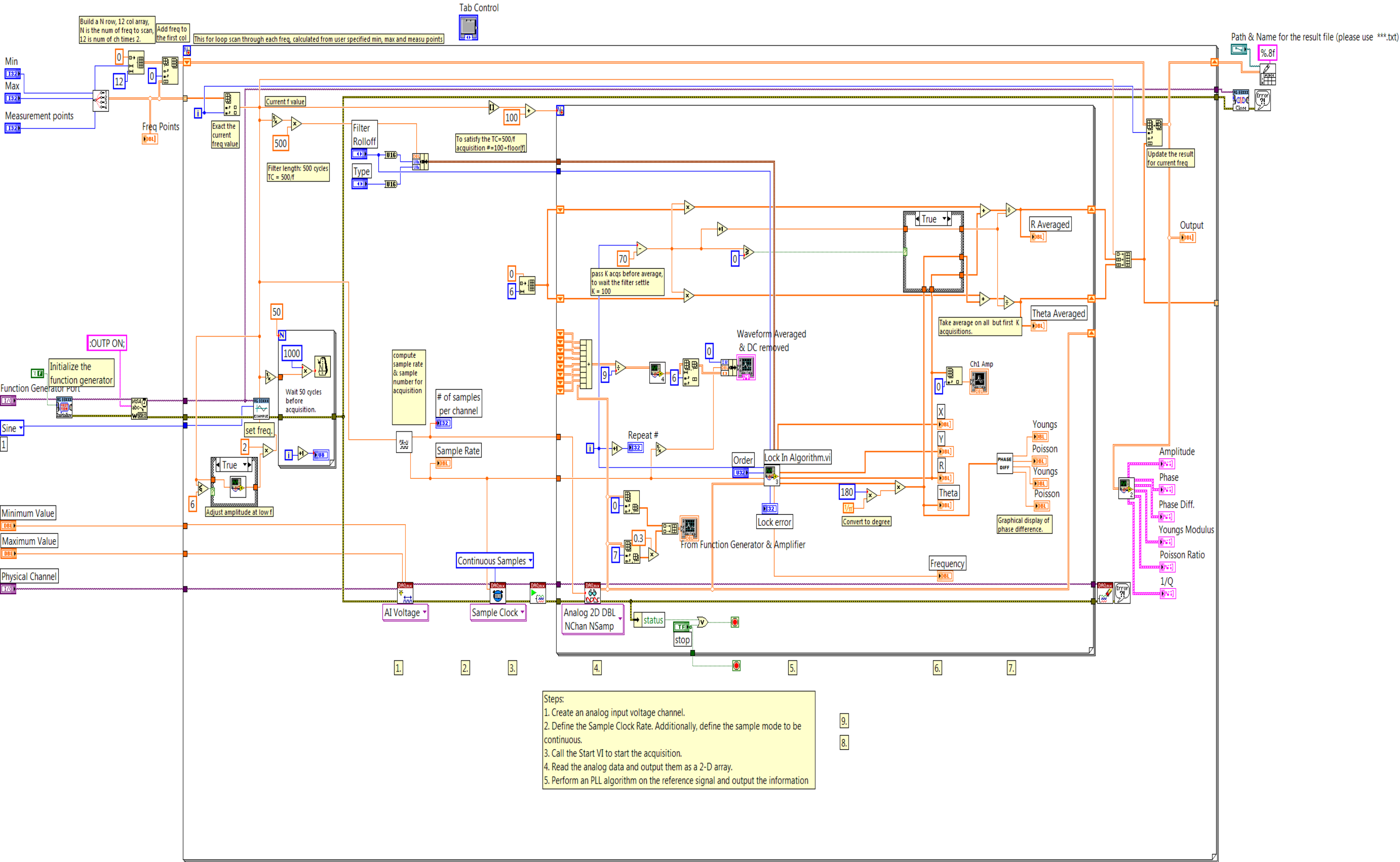
What's new: virtual lock-in amplifier



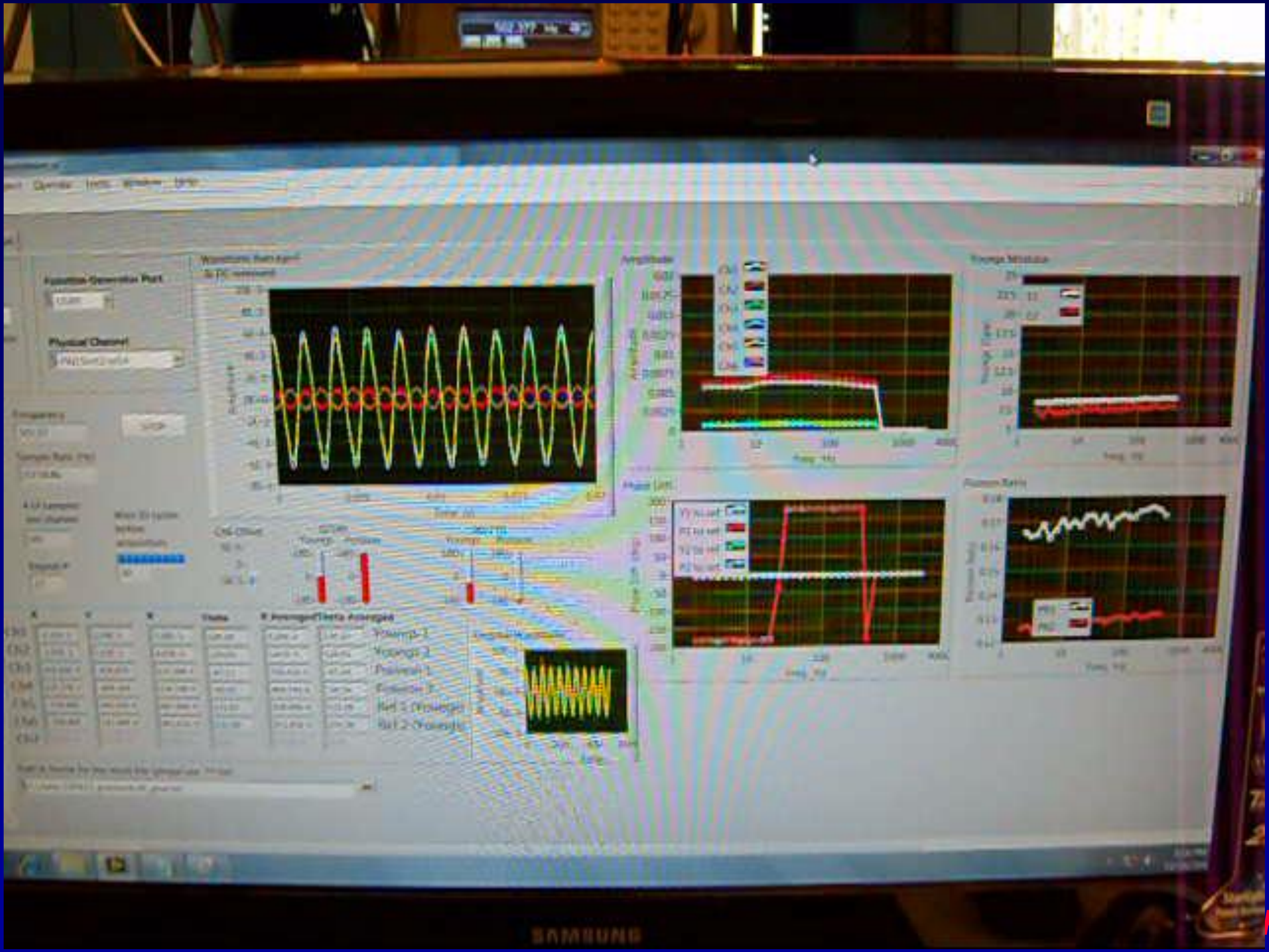
Simplified Lock-In Block Diagram

- 1st in the world
- Separate with acquisition hardware
- 16 channels, efficient & consistent
- Better integration with processing

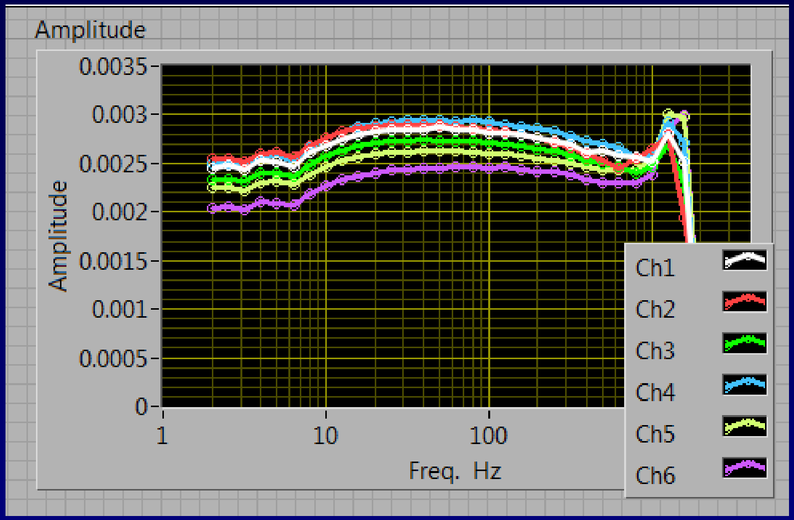
Software: acquisition, processing, automation



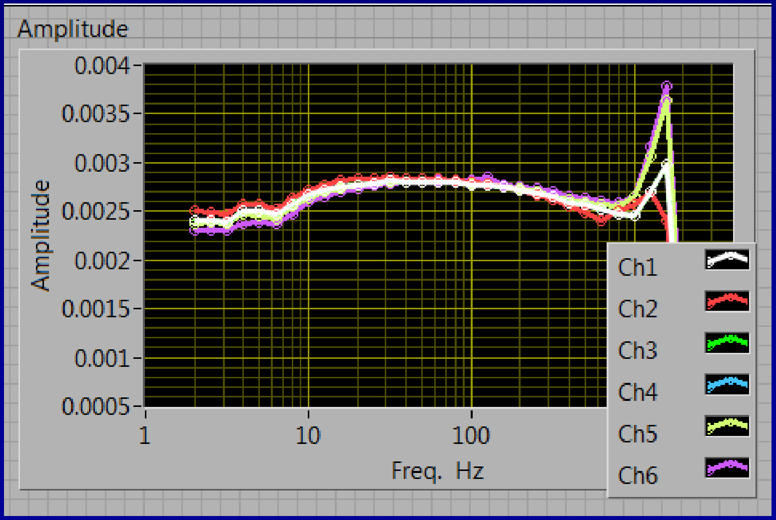
Software: acquisition, processing, automation



Calibration:

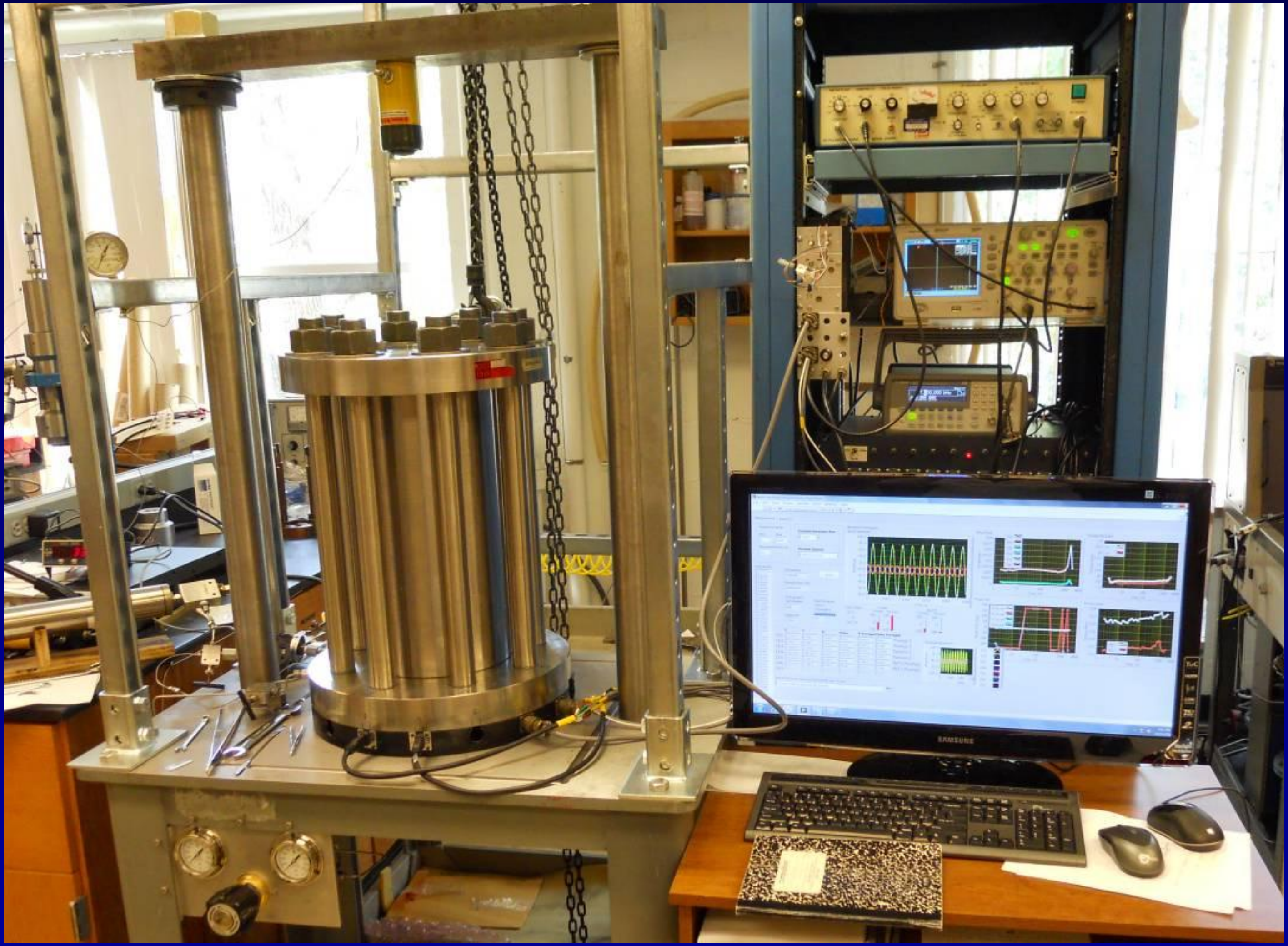


Before

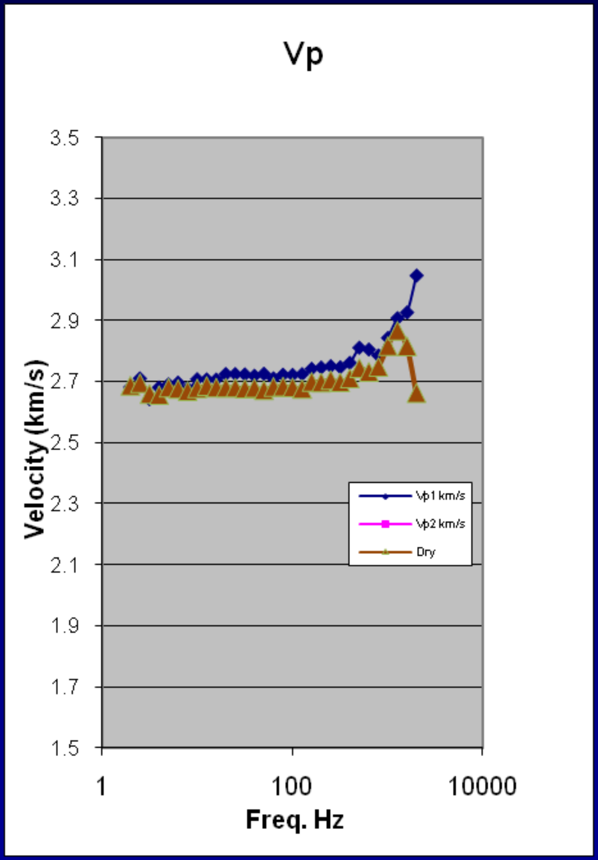


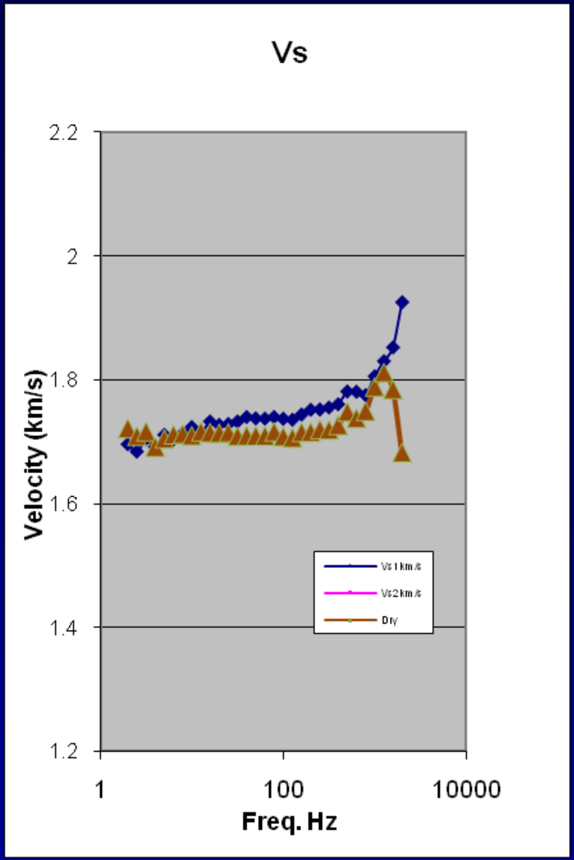
After

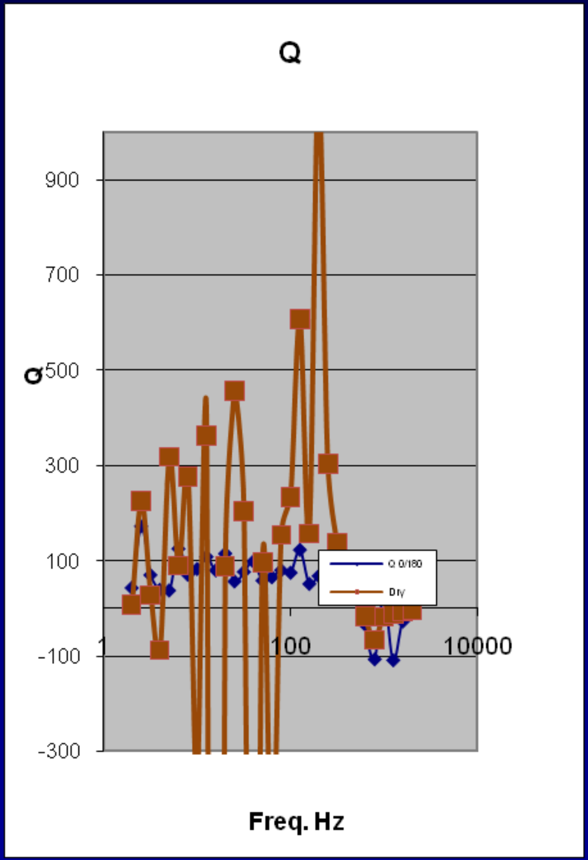
Whole system



Primary result: Dry vs. Butane saturation







THANK YOU !