Research Summary

MEASURING MASS OF GAS IN-PLACE IN CORES

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Outline

- Objective
- Background
- Materials & Equipment
- Methodology & Results
  - Measure Spring Constant (k)
  - Determine Added Mass Coefficient (α)
  - Validate Pore gas Mass (m_p)
- Conclusion
- Future work

Objective

- Measure mass of gas in-place in cores (not crushed)
  - Develop a method that determines mass by measuring the frequency of oscillation
  - Test the method on Berea sandstone cores
  - Verify that mass of pore gas can be measured using the oscillation method
- Measure Original Gas in-Place (OGIP) in other tighter rocks

Background

Hookian Spring

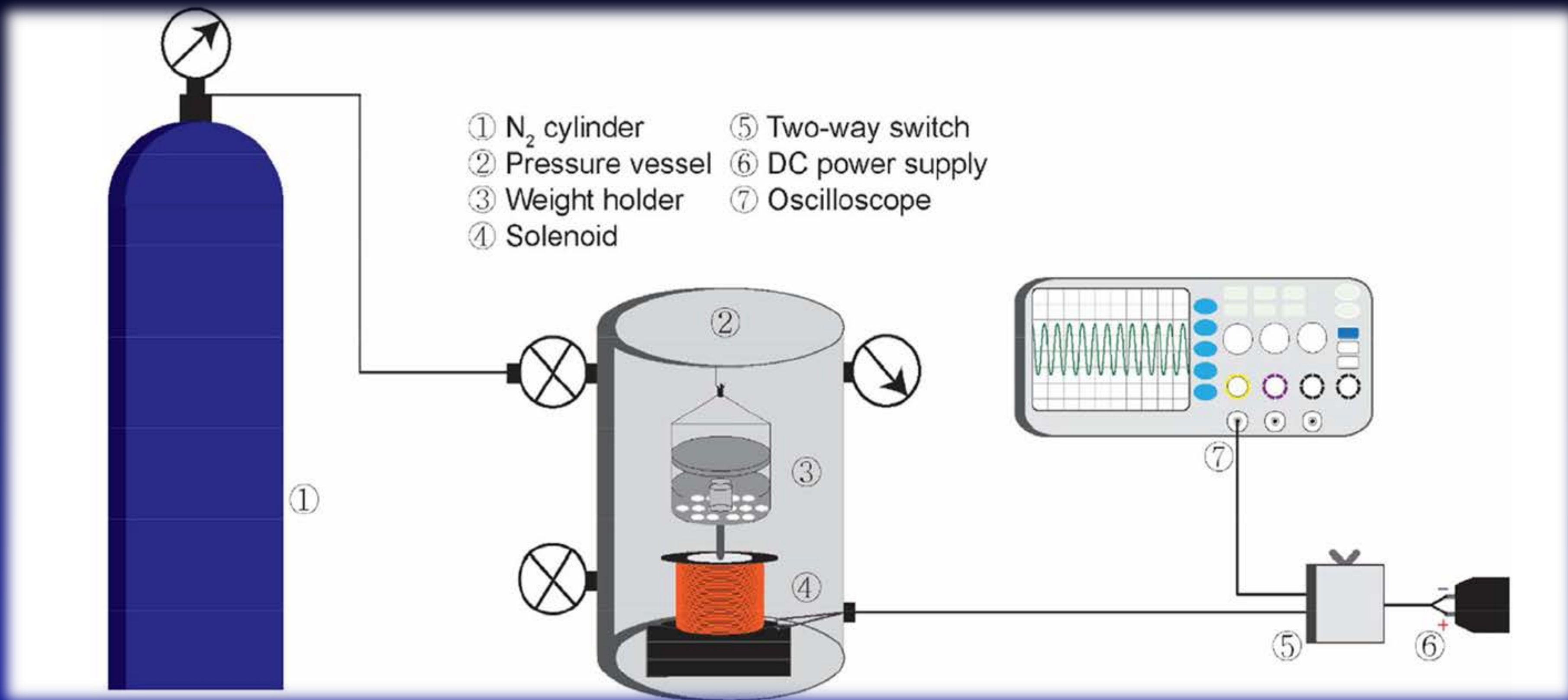
$$m = \frac{k}{4\pi^2 f^2}$$

m = Effective mass (g)

f = Frequency from Oscillation (Hz)

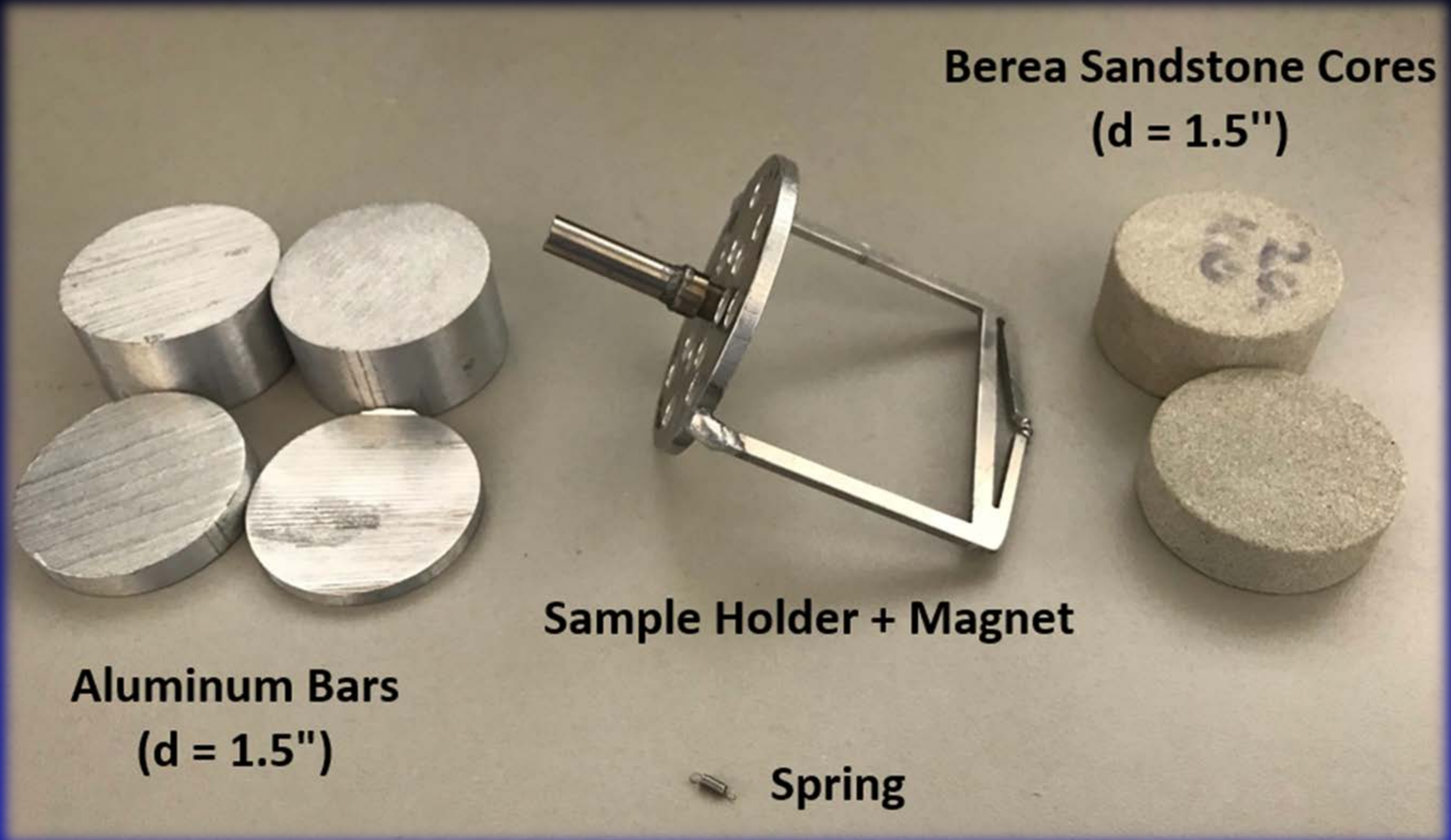
k = Spring constant (N/mm)

Materials & Equipment



Larson, Cho, Yin (2017)

Materials & Equipment



Methodology & Results

$$\Delta m = m - m_0 - m_a - m_p$$

Δm	=	Mass attributed to gas condensation and adsorption (g)
m	=	Effective Mass from Oscillation (g)
m_0	=	Mass of sample at ambient condition (g)
m_a	=	Added Mass due to co-acceleration of gas external to the sample (g)
m_p	=	Mass due to co-acceleration of gas inside pores of the sample (g)

Methodology & Results

$$\Delta m = m - m_0 - m_a - m_p$$

$$m = \frac{k}{4\pi^2 f^2}$$

m = Effective mass from Oscillation (g)
f = Frequency from Oscillation (Hz)
k = Spring constant (N/mm)

$$m_a = \alpha P$$

α = Added mass coefficient (g/psi)
P = Pressure (psi)

$$m_p = \emptyset V * \rho$$

φV = Pore volume (cc)
ρ = Fluid density (g/cc)

Methodology & Results

Step 1: Measure Spring Constant (k)

Mass, m_0 (g)	Spring Constant, k (N/mm)
10.971	0.14597
22.114	0.14610
33.085	0.14601
59.292	0.14591

*** Every k shown in Table above is an average of 10-15 measurements**

Spring Constant (k) = 0.14600 N/mm

Methodology & Results

Step 2: Determine Added Mass Coefficient (α)

- Using non-porous medium (Aluminium Bar)

$$\cancel{\Delta m} = m - m_0 - m_a - \cancel{m_p}$$

$$m = m_0 + m_a$$

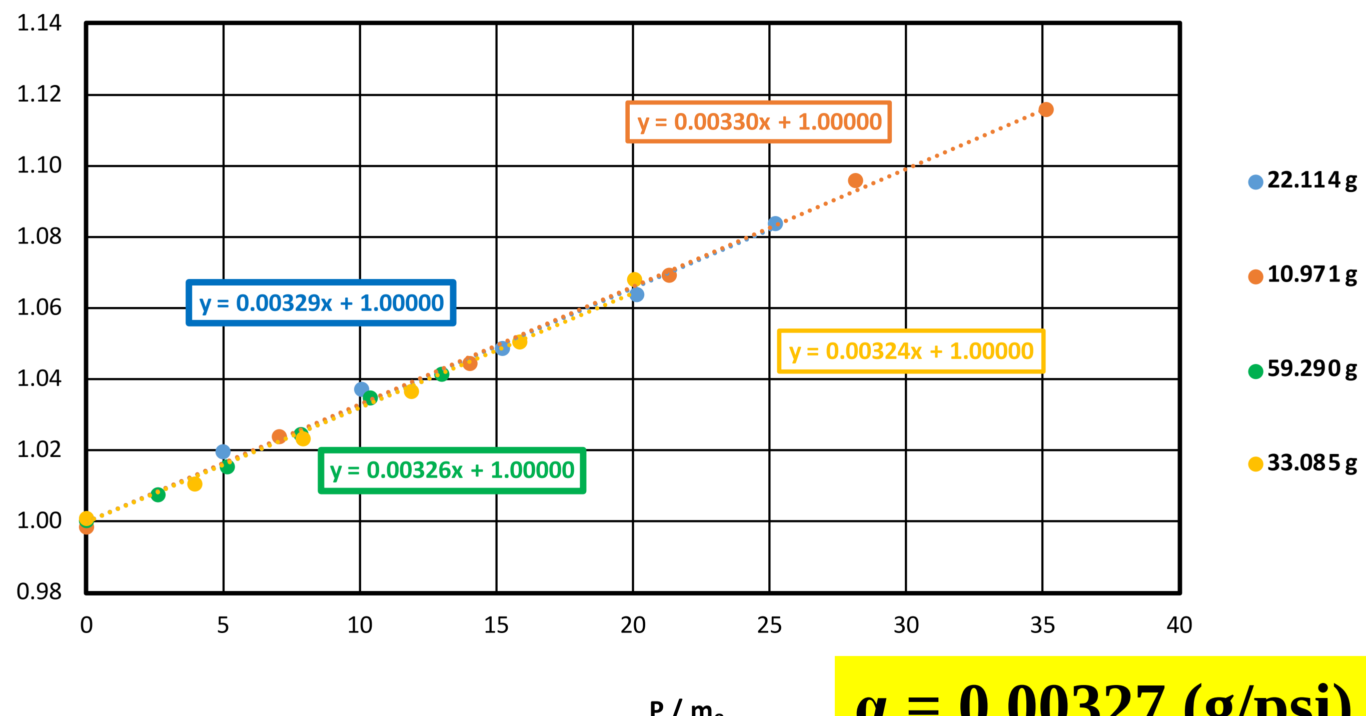
$$\frac{k}{4\pi^2 f^2} = m_0 + \alpha P$$

$$\boxed{\frac{k}{4\pi^2 f^2 m_0} = 1 + \alpha \frac{P}{m_0}}$$

$$\alpha = slope\ of\ the\ plot\ \frac{k}{4\pi^2 f^2 m_0}\ vs\ \frac{P}{m_o}$$

Methodology & Results

Step 2: Determine Added Mass Coefficient (α)



α = 0.00327 (g/psi)

*** Every point in Figure above represents an average of 10-15 measurements**

Methodology & Results

<u>Step 3</u>: Verify that Pore Gas Mass (m_p) can be calculated using Oscillation Method

- Measure Pore Gas from Oscillation Method using porous medium (Berea Sandstone)

$$\cancel{\Delta m} = m - m_0 - m_a - m_p \qquad m_p = m - m_0 - m_a$$

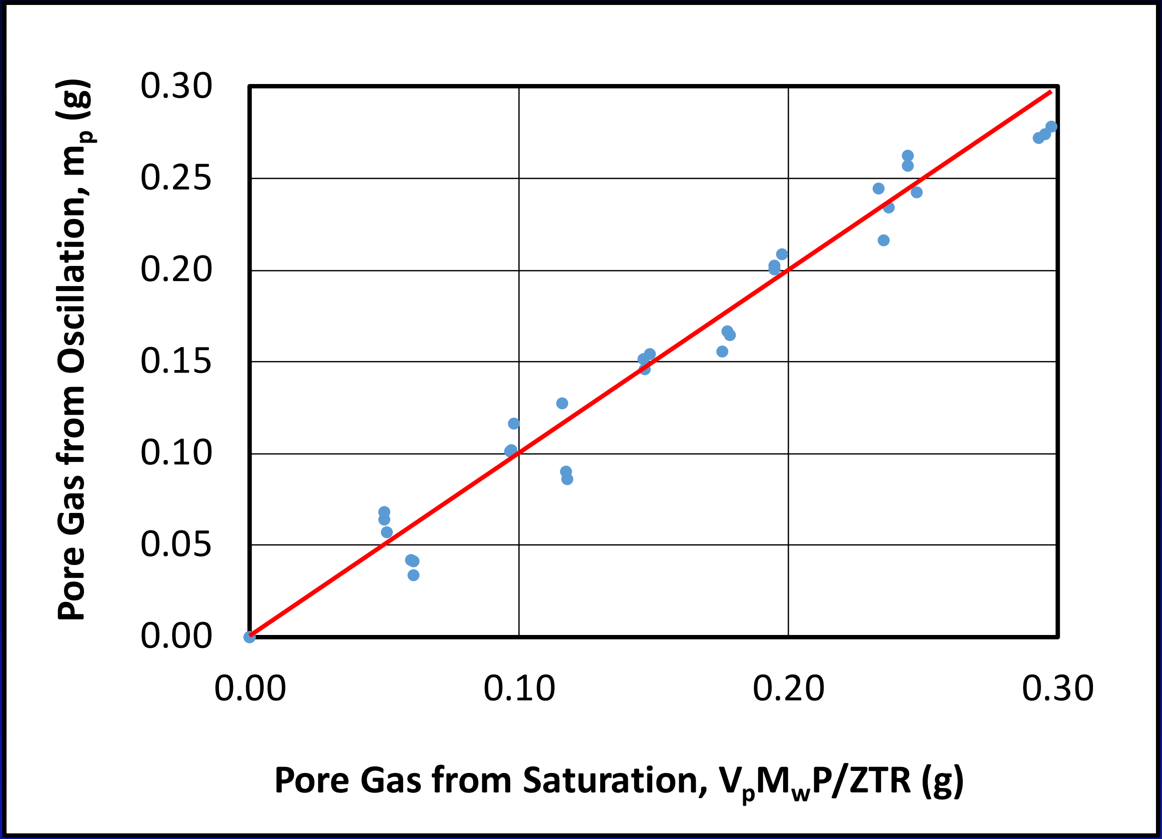
- Measure Pore Gas from Water Saturation method

$$m_{p_{Saturation}} = \left(\frac{m_{saturated} - m_{dry}}{\rho_{water}}\right) * \rho_{N_2}$$

- Compare Pore Gas Masses (m_p) measured from two methods

Methodology & Results

Step 3: Verify that Pore Gas Mass (m_p) can be calculated using Oscillation Method



$$m_p = \emptyset V * \rho$$

φV = Pore volume (cc)

ρ = Fluid density (g/cc)

Conclusion

$$\Delta m = m - m_0 - m_a - m_p$$

$$\Delta m = \left(\frac{\boldsymbol{k}}{\boldsymbol{4\pi^2 f^2}}\right) - m_0 - (\boldsymbol{\alpha P}) - (\boldsymbol{\emptyset V} * \boldsymbol{\rho})$$

m_0 = Mass of sample at ambient condition (g)

f = Frequency from Oscillation (Hz)

k = Spring constant (N/mm)

α = Added mass coefficient (g/psi)

P = Pressure (psi)

φV = Pore volume (cc)

ρ = Fluid density (g/cc)

Future Work

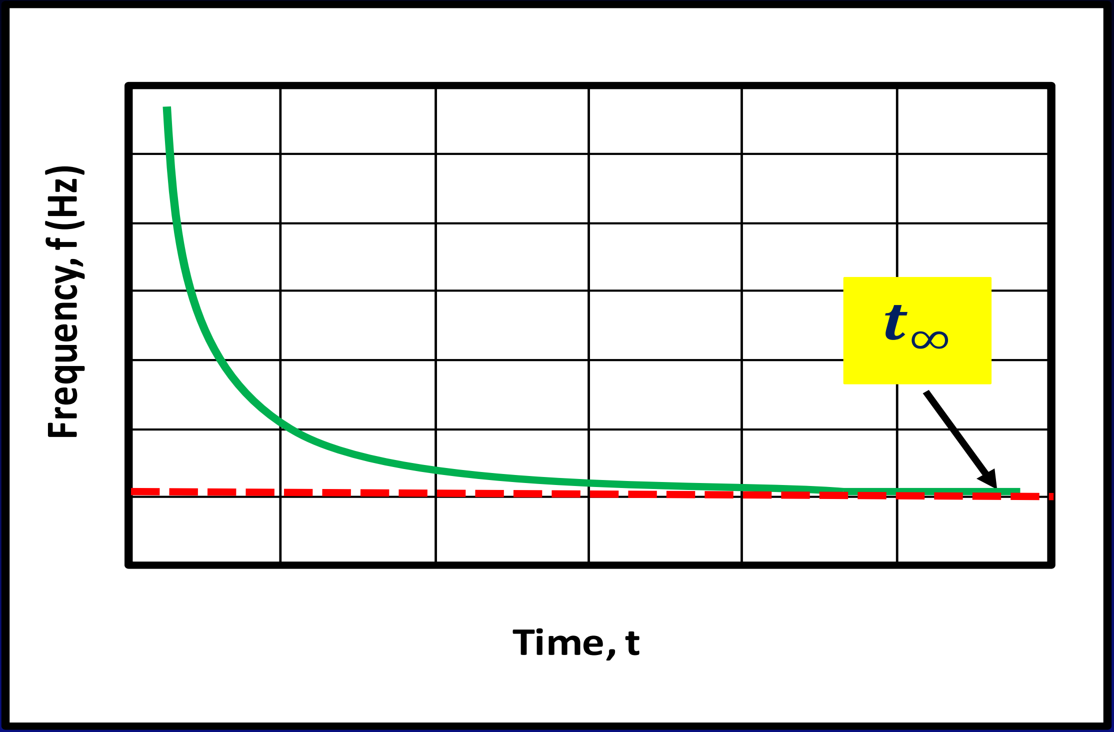
Apply This Method on Whole Unconventional Core

- To test if this method is also applicable on tighter cores
- To estimate Original Gas in-Place (OGIP)

$$OGIP = \Delta m + m_P = \left(\frac{k}{4\pi^2 f_\infty^2}\right) - m_o - m_a$$

$$* \; f_\infty = \; Frequency\ from\ Oscillation\ at\ t = \infty$$

Future Work



$$m = \frac{k}{4\pi^2 f^2} \qquad f \propto \frac{1}{m}$$

Take measurement at long time (t_∞)

$$\left(\frac{k}{4\pi^2 f_\infty^2}\right) - m_o - m_a$$

OGIP

Due to transient flow, gas is slowly diffusing in the core. Hence, the mass (m) slowly increases while frequency (f) slowly decreases.

Q&A