

Field Device to Measure Viscosity, Density, and Other Slurry Properties in Drilled Shafts



GRIP 2015

Gray Mullins, Ph.D., P.E..

Problem Statement

- ◆ Drilled excavation requires slurry that falls within a set of parameters regarding density, viscosity, pH and sand content; typically, each slurry property is tested using a unique, separate test method.
- ◆ Slurry properties are measured every 2 hours for the first 8 hours and 4 hours thereafter.
- ◆ A downhole device to measure all properties real time may improve data quality and expedite construction.

Research Approach

- ◆ Task 1 Literature Review
- ◆ Task 2 Component Development
- ◆ Task 3 Laboratory Trials
- ◆ Task 4 Field Testing
- ◆ Task 5 Draft Final and Final Report

Research Approach

- ◆ Task 1 Literature Review – Current Practices
- ◆ Task 2 Component Development
- ◆ Task 3 Laboratory Trials
- ◆ Task 4 Field Testing
- ◆ Task 5 Draft Final and Final Report

FDOT Standard Specifications for Road and Bridge Construction Section 455-15.8

Mineral slurries

Item to be measured	Range of Results at 68°F	Test Method
Density	64 to 73 lb/ft ³ (in fresh water environment) 66 to 75 lb/ft ³ (in salt water environment)	Mud density balance: FM 8-RP13B-1
Viscosity	30 to 50 seconds	Marsh Cone Method: FM 8-RP13B-2
pH	8 to 11	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	4% or less	FM 8-RP13B-3

Polymer slurries

Mixed Polymer Slurry Properties		
Item to be measured	Range of Results at 68°F	Test Method
Density	62 to 64 lb/ft ³ (fresh water) 64 to 66 lb/ft ³ (salt water)	Mud density balance: FM 8-RP13B-1
Viscosity	Range Published By The Manufacturer for Materials Excavated	Marsh Cone Method: FM 8-RP13B-2
pH	Range Published By The Manufacturer for Materials Excavated	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	0.5% or less	FM 8-RP13B-3

Density

Standard mud balance



Viscosity

Viscometer Measurements

Newtonian fluids

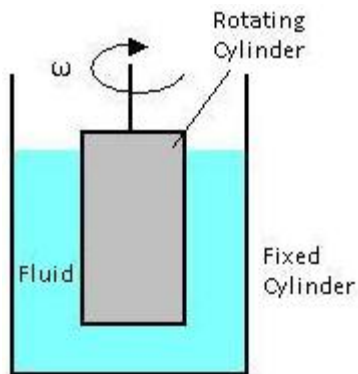
-Viscosity

Shear-thinning fluids

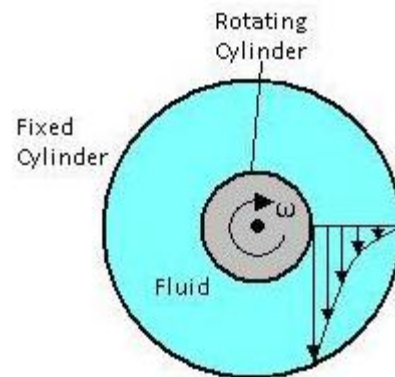
-Apparent viscosity

-Gel strength

-Yield point



Side view



View from above



Viscosity

Marsh Funnel Measurements

- ◆ Time required for 1qt of fluid to flow from the orifice of a standardized funnel.
- ◆ Reported units is seconds



Sand Content

Sand content is obtained by filling the measuring cylinder with drilling mud and then washing out the slurry through a #200 sieve screen, leaving behind the sediments.

NOTE: Volumetric Sand Content



Research Approach

- ◆ Task 1 Literature Review – Concepts
- ◆ Task 2 Component Development
- ◆ Task 3 Laboratory Trials
- ◆ Task 4 Field Testing
- ◆ Task 5 Draft Final and Final Report

Measuring Viscosity

Shear Stress v. Shear Rate

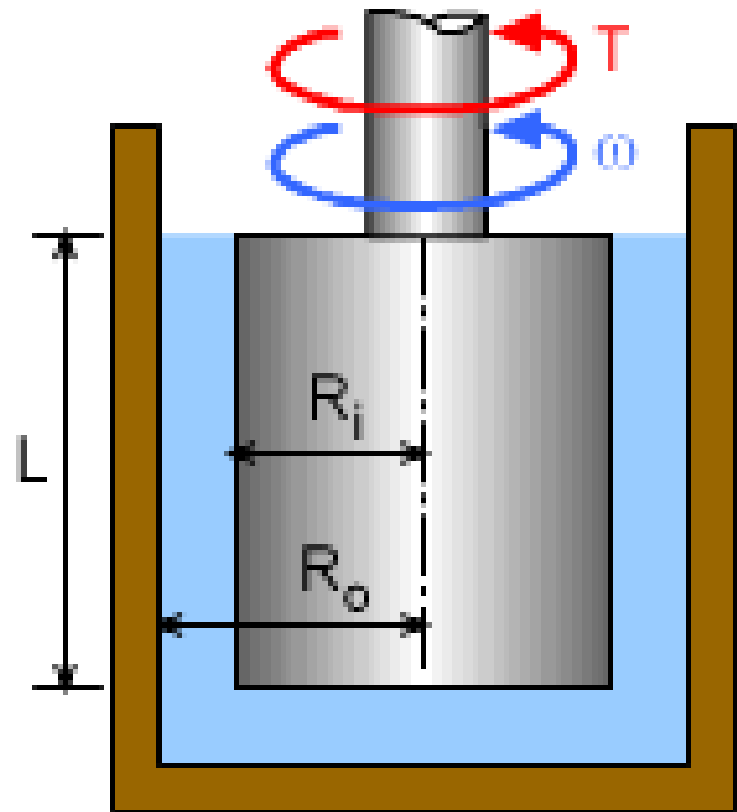
Torque v. Rotation Rate

Examples

Bob & Cup

Cone & Disc

Parallel Plates



Measuring Viscosity

Shear Stress v. Shear Rate

Pressure v. Flow Rate

Examples

Marsh Funnel

Efflux Cup

Capillary Viscometer

Float Viscometer

Variable Area Viscometer



Measuring Viscosity

Shear Stress v. Shear Rate

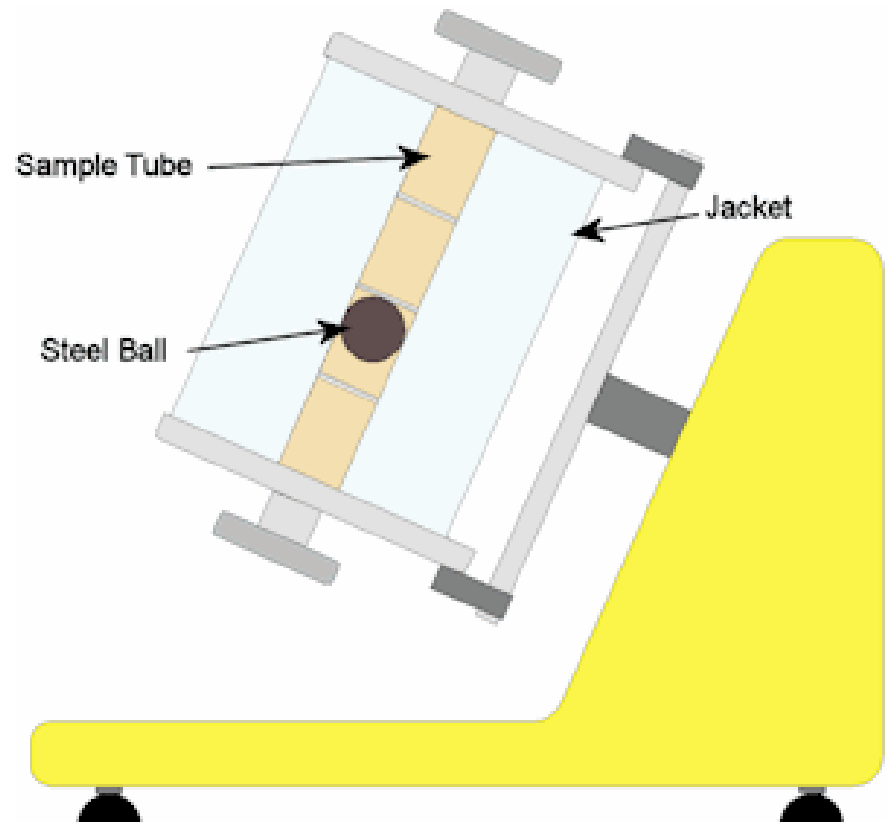
Force v. Velocity

Examples

Falling Ball

Falling Piston

Rolling Ball



Measuring Viscosity

Shear Stress v. Shear Rate

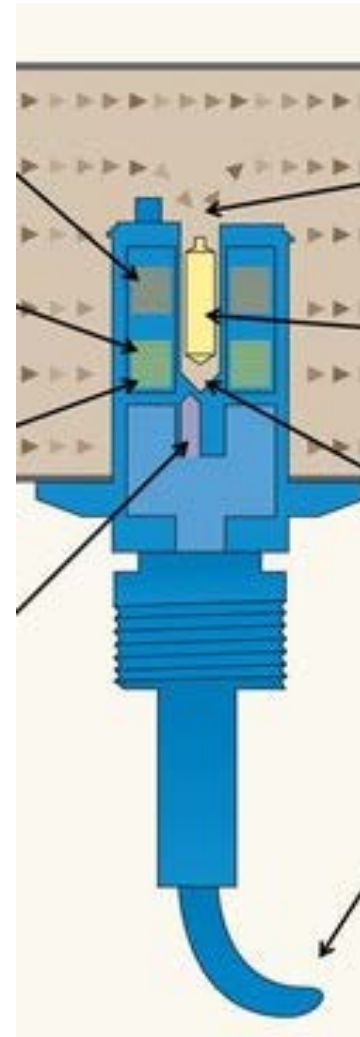
Vibration v. Damping

Examples

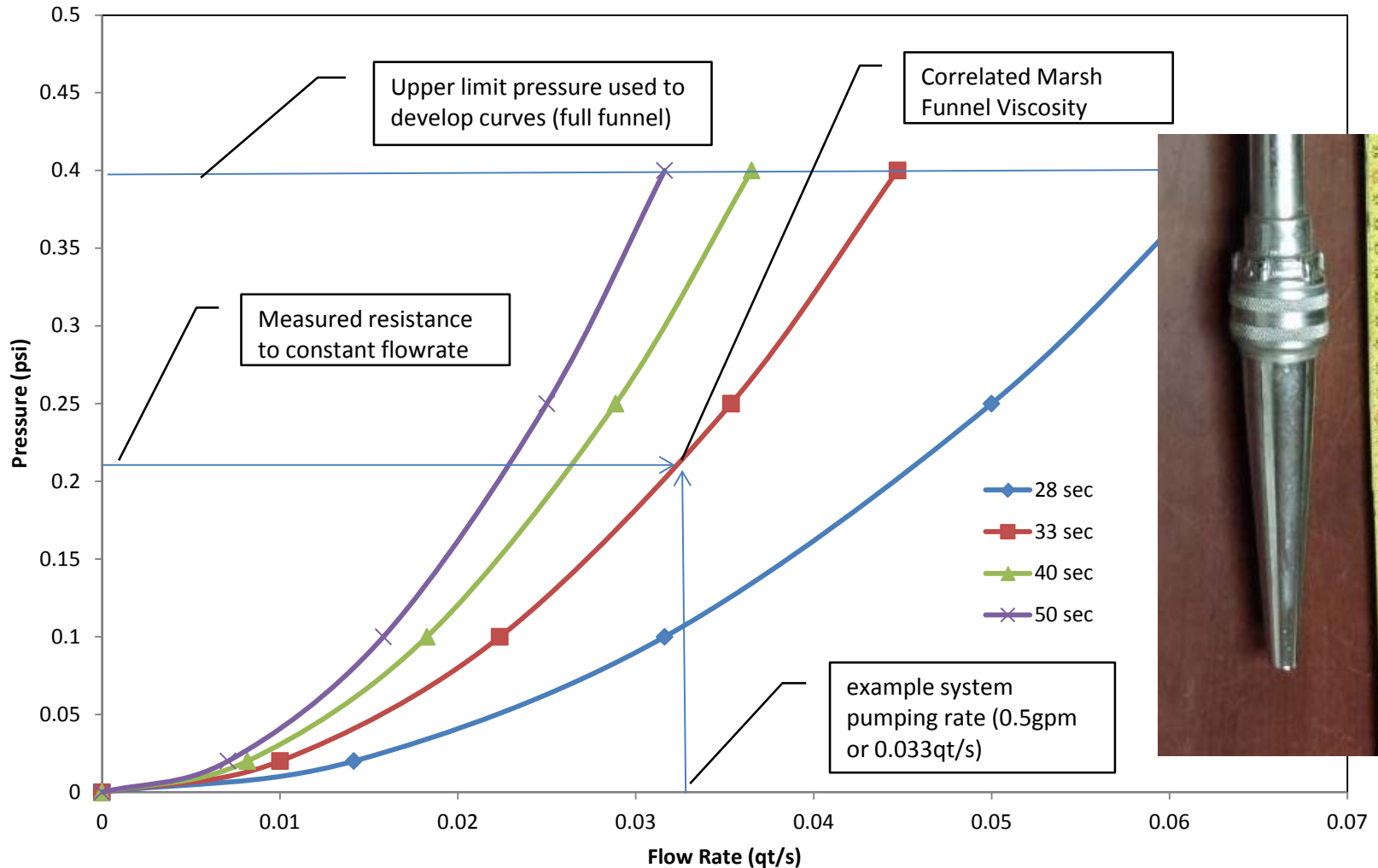
Vibrating Reed

Oscillating Piston

Oscillating Disc



Pressure vs. Flow Rate (GRIP 2014)



Research Approach

- ◆ Task 1 Literature Review – OTS Components
- ◆ Task 2 Component Development
- ◆ Task 3 Laboratory Trials
- ◆ Task 4 Field Testing
- ◆ Task 5 Draft Final and Final Report

OTS Components



www.omega.com

Pressure Transducer

- Pressure transducers report pressure by converting strain from a strain gauge into pressure.
- Can be used for P v. Q viscosity as well determining density from hydrostatic pressure



www.omega.com

Submersible pH electrode

OTS Components



www.coleparmer.com

Ultrasonic Flow Meter

- Ultrasonic flow meters work by relating the change in frequency of a reflected sound wave to the rate of flow.
- Designed for water containing particulate matter.



www.omega.com

Variable area flow meter

- Measures force exerted on spring as fluid flow around a piston or disc.
- Measured force is a function of flow rate and viscosity.

OTS Components



www.omega.com

Electromagnetic Flow Meter

- An electromagnetic flow meter measures the voltage generated by the flow of a conductive fluid through a magnetic field.
- This type of flow meter may be used to gain insight on sand content due to the reduction of electrical conductivity of a slurry specimen with sand.



www.hw-well.com/Portable%20Sandmaster.htm

Sand Concentration Measurement Device

- Current sand concentration testing devices use flow rate, a laser and particle counting software to compute sand concentration.

Current Slurry Testing Equipment



Mud balance with case

- Used to determine density



Marsh funnel and cup

- Used to determine viscosity

Research Approach

- ◆ Task 1 Literature Review
- ◆ **Task 2 Component Development**
- ◆ Task 3 Laboratory Trials
- ◆ Task 4 Field Testing
- ◆ Task 5 Draft Final and Final Report

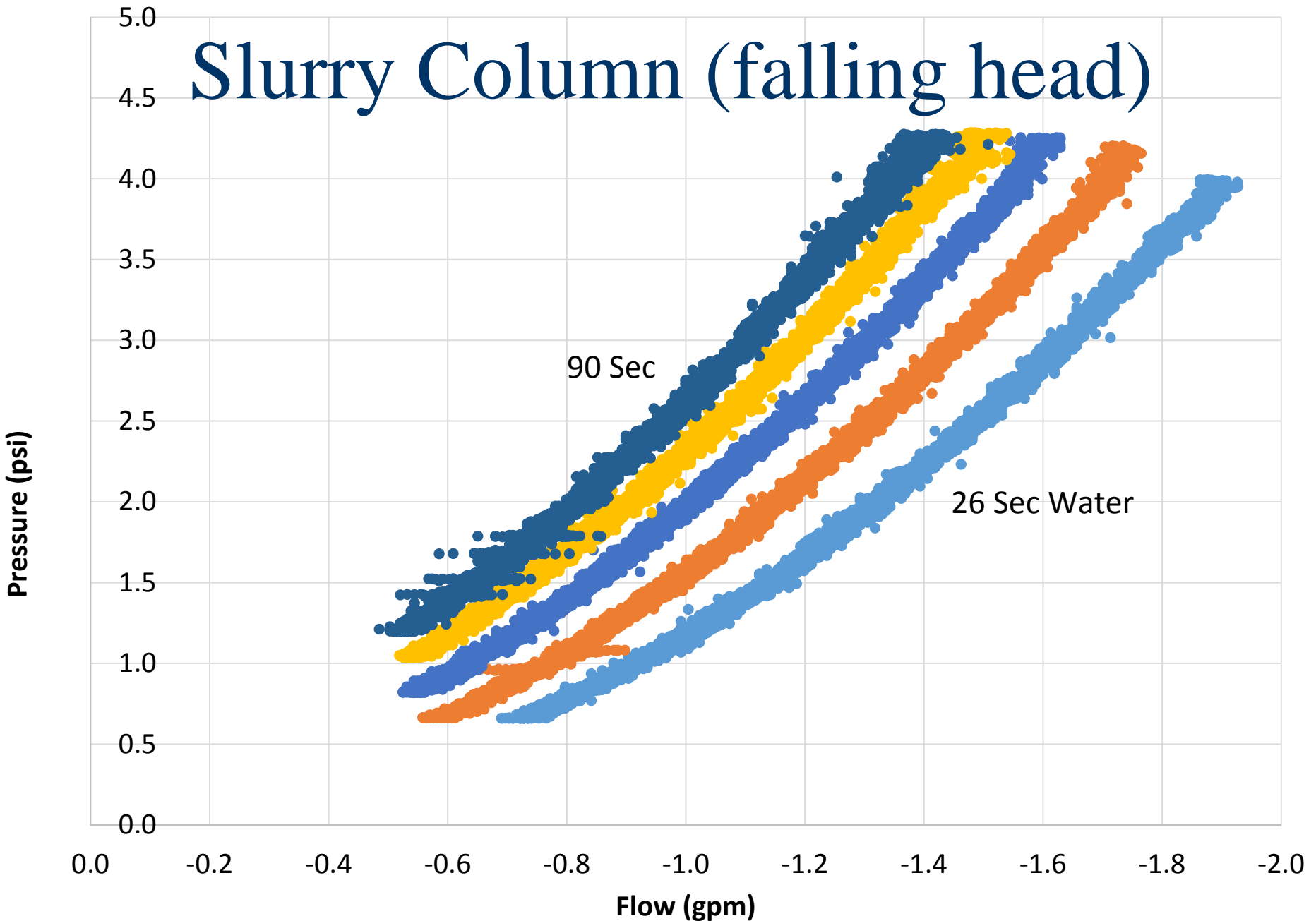
Slurry Column Tests



Slurry Column Tests

- ◆ Bentonite slurry viscosity
 - ranged from 26 (water) to 90 sec/qt
- ◆ Flow rates (12ft falling head)
 - 0 to 2gpm
- ◆ Density
 - 64 to 71 pcf
- ◆ Sand contents
 - 0.25 to 10% by volume

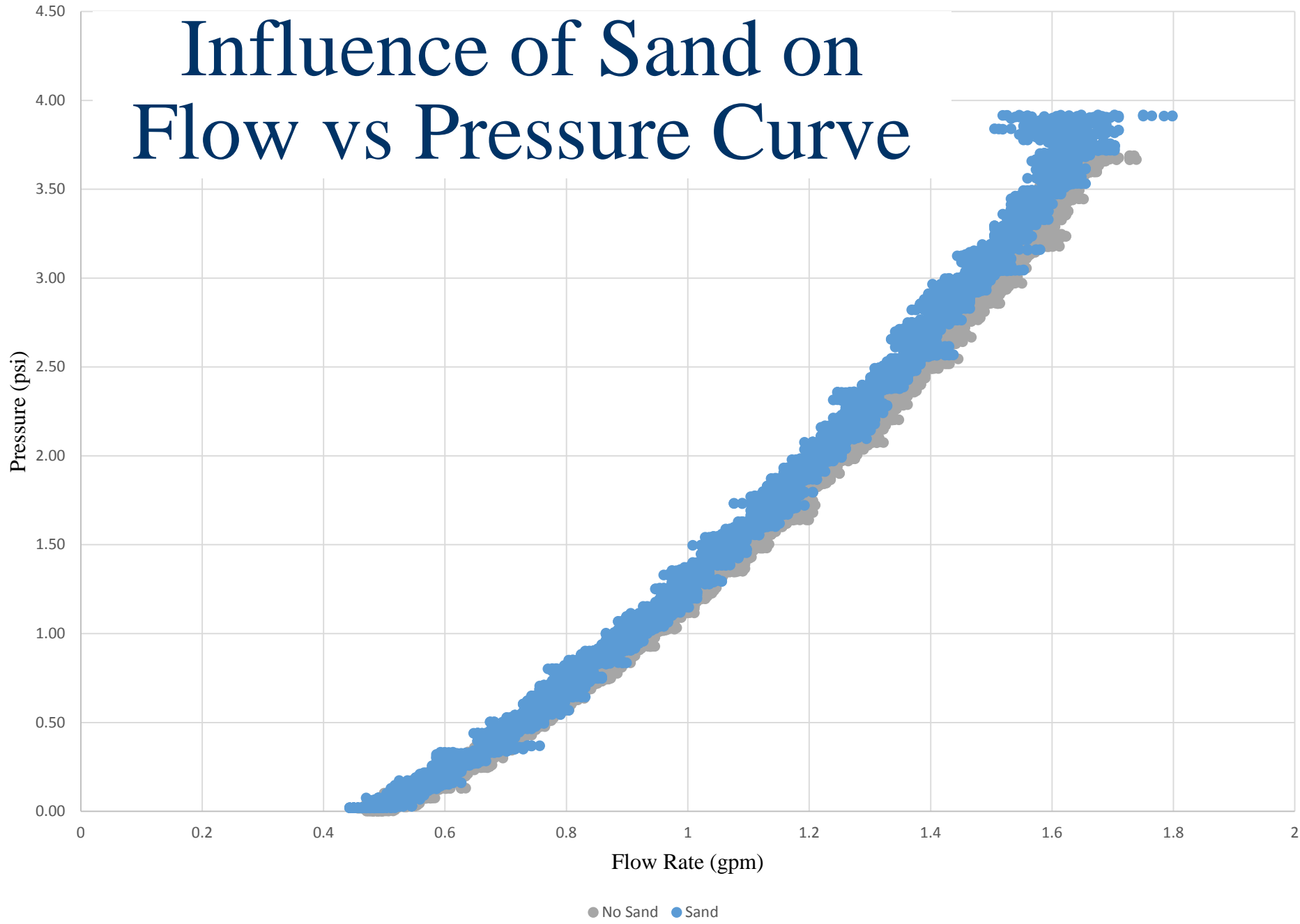
Slurry Column (falling head)



3/16" ID Orifice

40 Second Marsh Funnel

Influence of Sand on Flow vs Pressure Curve



Test Batch Summary

Batch	Average Marsh Funnel Test (sec)	Average Sand Content (%)	Density (lb/ft ³)
No Sand	40.03	.25	64.81
Sand	39.3	6.58	68.24

Use density measurements to determine gravimetric sand content

Pressurized Flow Tests

Flow
Meter



Pressure
Transducer



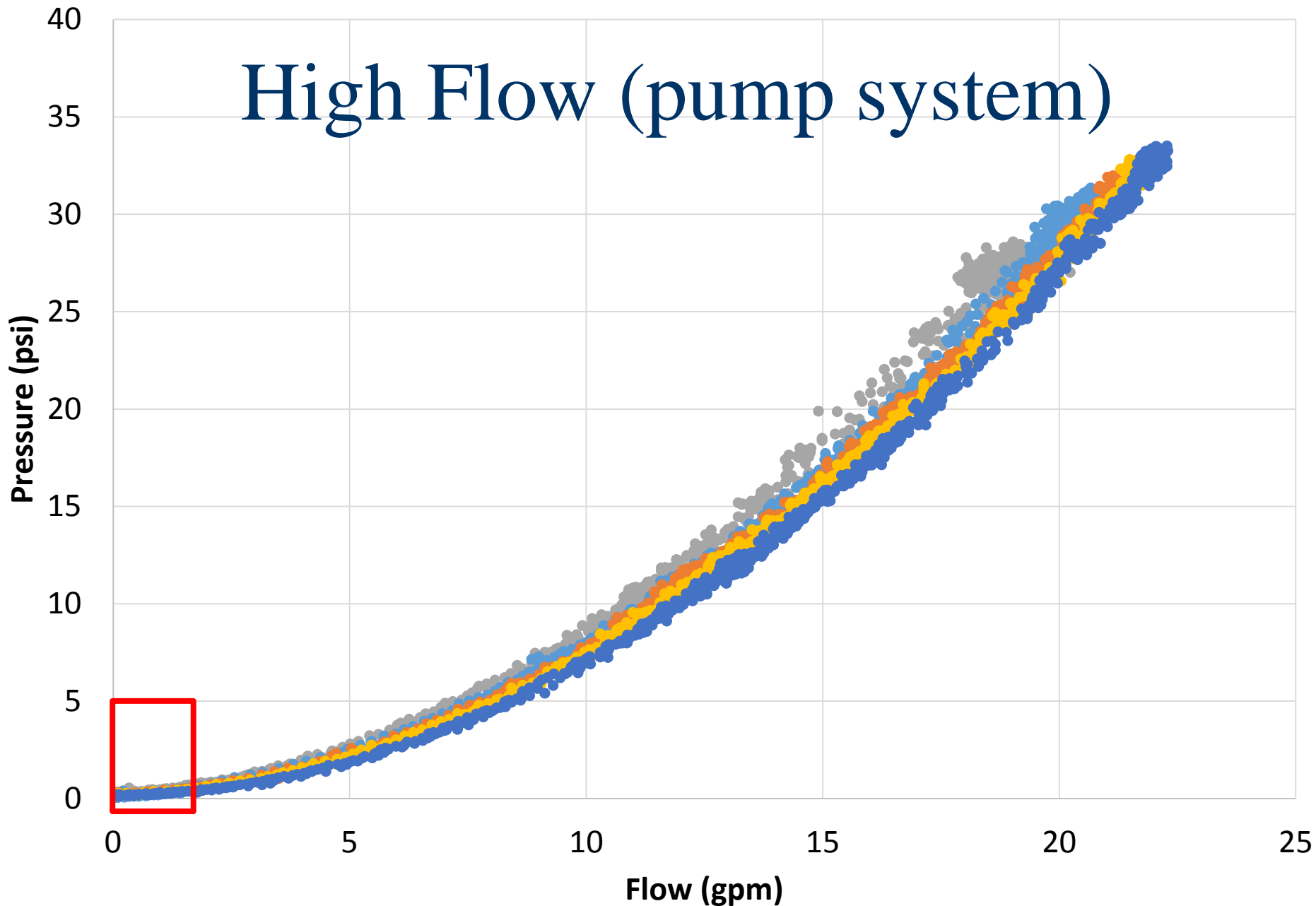
Nozzle



High Flow / Pressurized

- ◆ Bentonite slurry viscosity
 - ranged from 30 to 140 sec/qt
- ◆ Flow rates (pumped)
 - 0 to 23gpm
- ◆ Density
 - 64 to 66 pcf
- ◆ Sand contents
 - 0.25% pure bentonite only

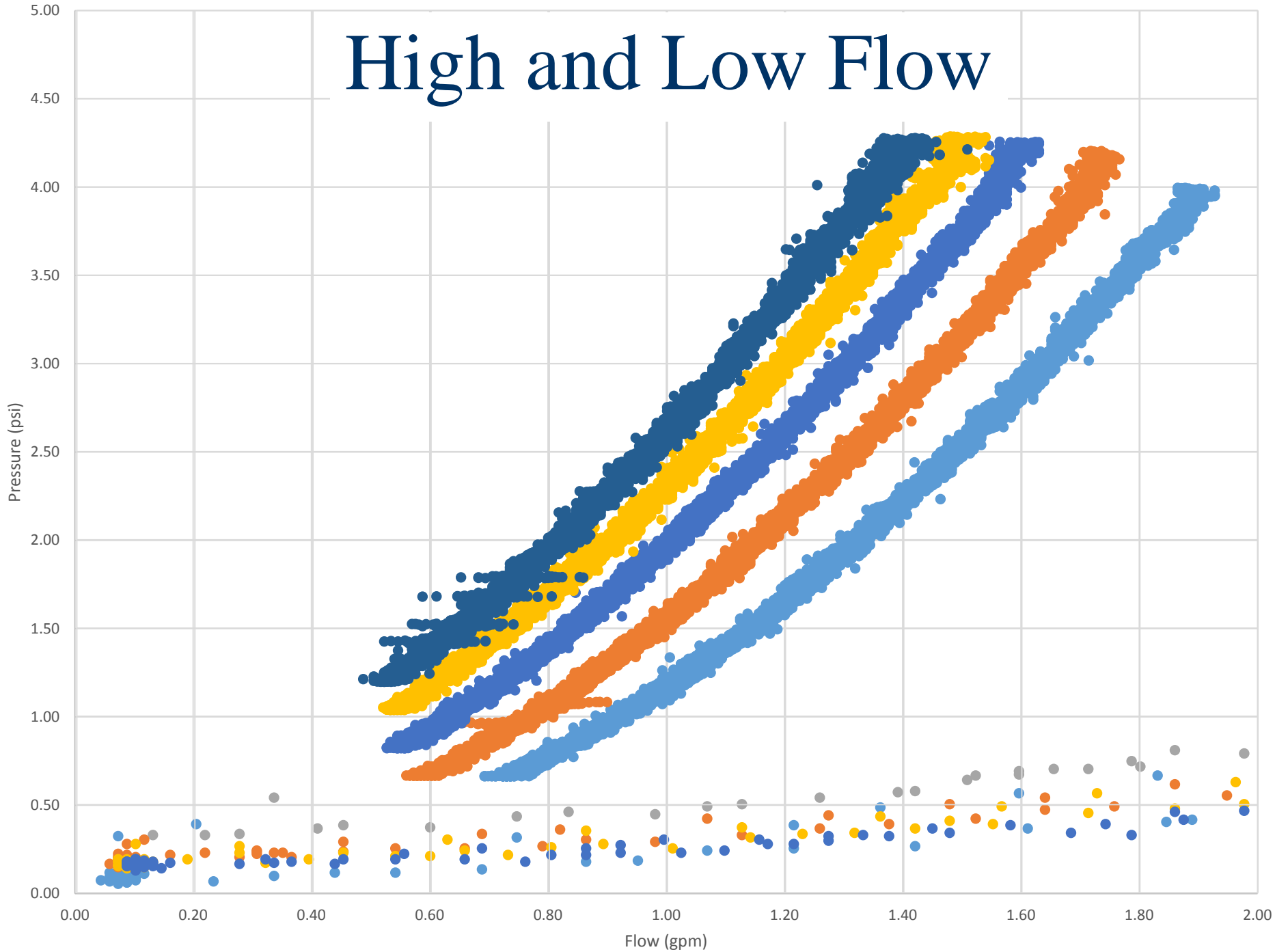
High Flow (pump system)



3/8" ID Nozzle

● 143s ● 59s ● 46s ● 40s ● 31s

High and Low Flow





Select System Orifice



- ◆ Small orifice is affected most by changes in viscosity
- ◆ Large orifice less affected by debris
- ◆ Selection of system orifice based on balancing positive benefits

Instrumentation Options

- ◆ Magnetic flux flowmeters best for all conductive fluids (especially with suspended solids)
- ◆ Open face pressure transducers single source or differential will be used
- ◆ Density device should be similarly unaffected by slurry

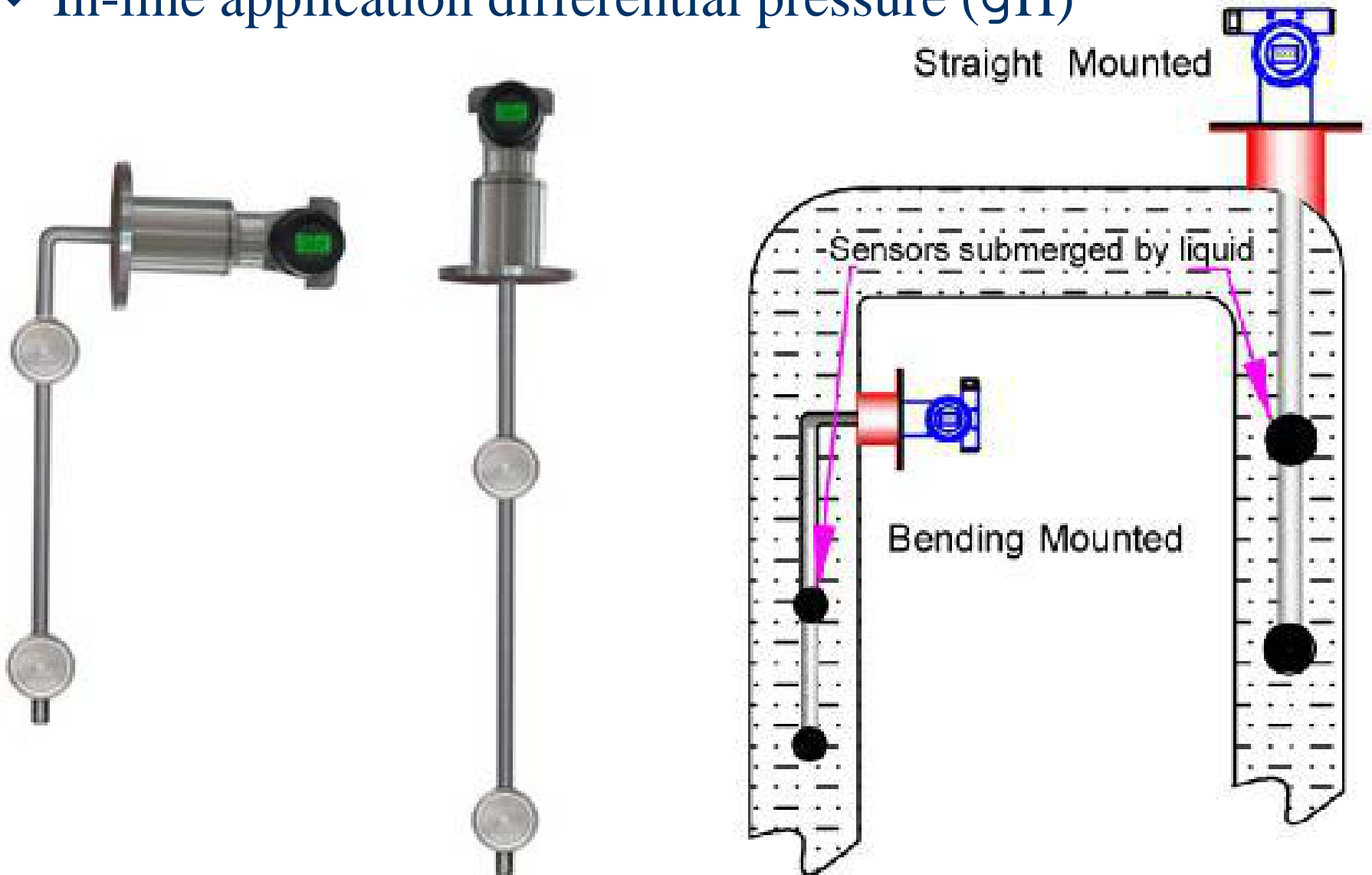
Density

- ◆ Liquid Density Monitor (Archimedes Principle)
- ◆ Drop in application

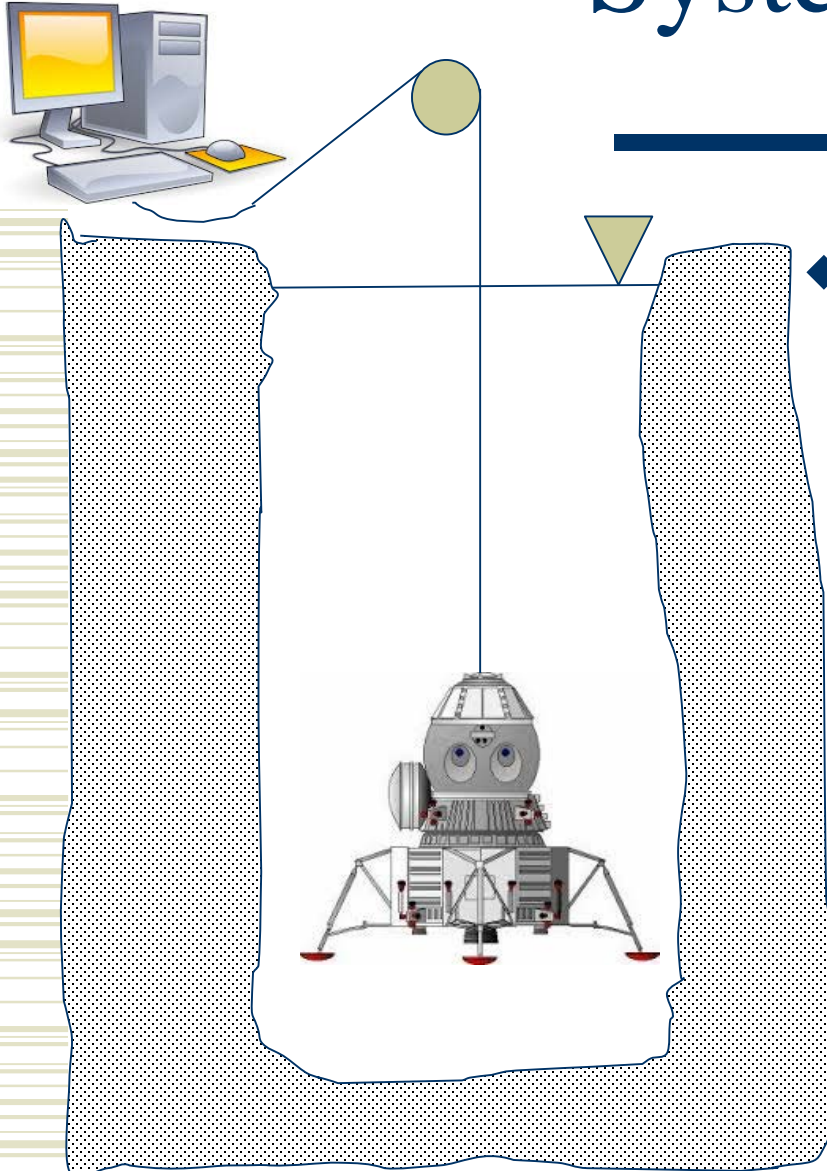


Density

- ◆ In-line application differential pressure (gH)



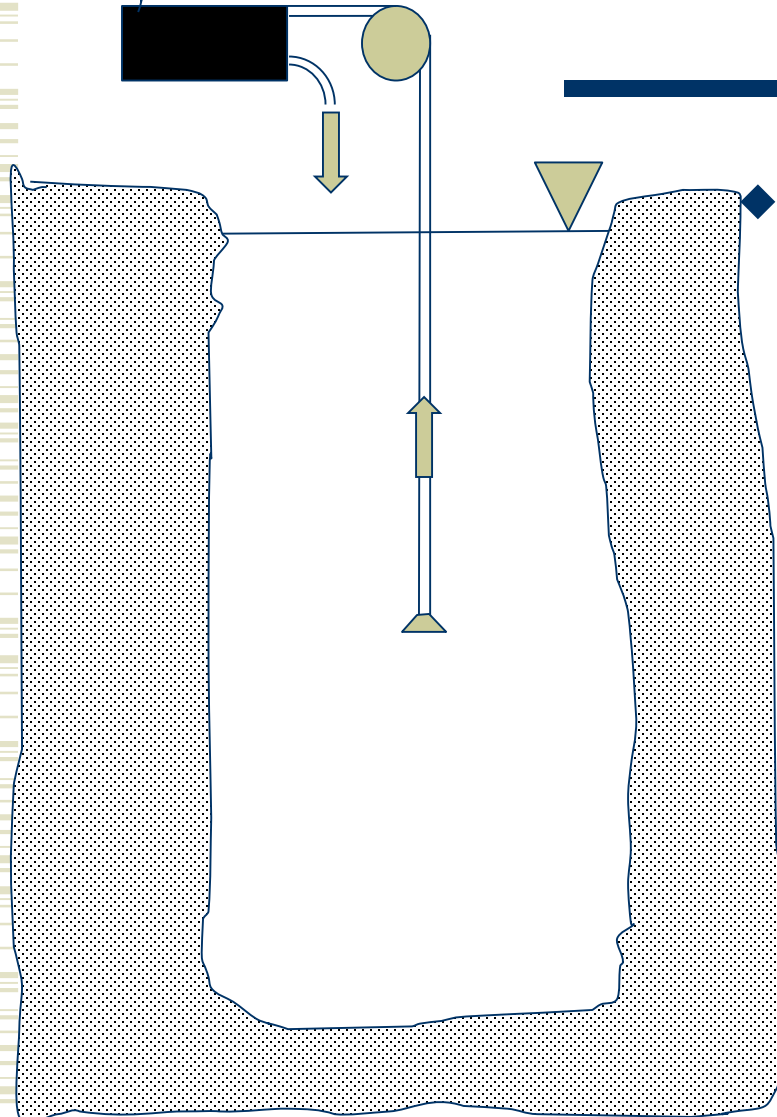
System Concepts



- ◆ Downhole self contained “dive bell”
 - Pressure
 - Flow
 - Density
 - Tethered to air, hydraulic or electric power along with signal leads
 - Depth measured topside



System Concepts



◆ All topside measurements

- Pickup hose
- Measure hose depth
- Track flow from a given depth through topside systems.
- Correlate sample to measurements based on hose position and time in hose / flow

Questions?

