Density and Holdup Tools

KAPPA

DENSITY AND
HOLDUP TOOLS

Module #8

Density and Holdup Tools

The velocity measurement will give the total flowrate.
The objective of the density and holdup tools is to determine the mixture holdups and ultimately determine the relative proportions of the phases present in the total flowrate at any level.

Fluid Density

Gradiomanometer

Nuclear fluid density tool

Tuned density tool

Hold - up

Capacitance / Impedance tools

Imaging Tools

- bubble count tool – water-hydrocarbon hold up
- optical device – gas-liquid hold up
- Capacitance style probes

Density and Holdup Tools

The hold up or fluid density is essential when dealing with anything other than single phase flow

The measurement gives answers to:

- What fluids are coming from which perforations
- Direct in-situ measurement of mixture fluid density
- Measurement of individual phase densities for use in constraining Emeraude PVT (eg. Density readings during shut in)
- Fluid contact information
- Identify regions suitable for spinner calibration

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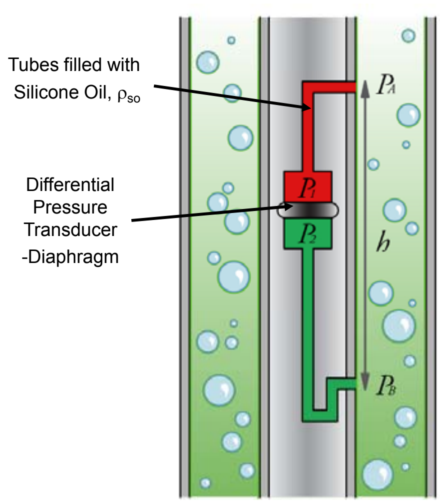
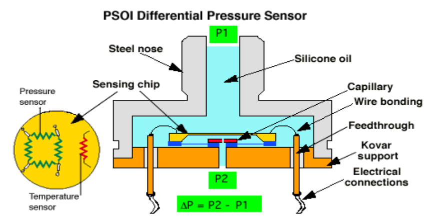
Gradiomanometer



The tool measures the difference in pressure between either side of a sensing chip,

(It is a single sensor).

The single differential pressure sensor gives the density.



Courtesy Schlumberger

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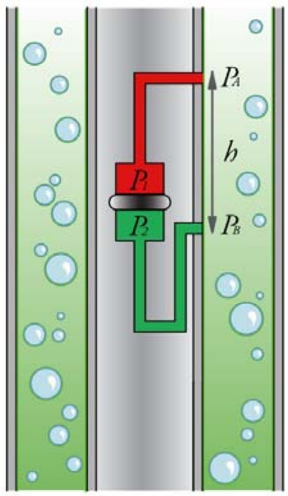
Gradiomanometer



P_2 - P_1

↓ **(tool specific) silicon oil**

P_B - P_A

↓ **(friction, deviation)**

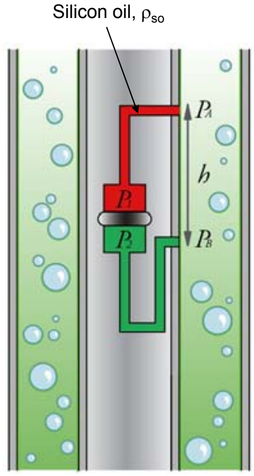
Density

The measurement is affected by its environment.

- Deviation effect

- Friction induced pressure drop

Gradio: Vertical



$$P_2 = P_B$$

$$P_1 = P_A + \rho_{so} gh$$

$$P_2 - P_1 = [P_B - P_A] - \rho_{so} gh$$

$$P_2 - P_1 = \rho_{fluid}\, gh + \left[\frac{dP}{dZ}\right]_{fric} + \left[\frac{dP}{dZ}\right]_{acc} - \rho_{so} gh$$

$$\Rightarrow \rho_{fluid} = \frac{[P_2 - P_1] - \left[\frac{dP}{dZ}\right]_{fric} - \left[\frac{dP}{dZ}\right]_{acc}}{gh} + \rho_{so}$$

If/when friction/acceleration are not significant

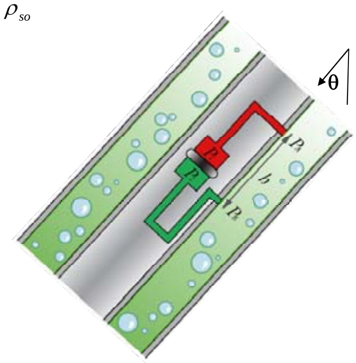
$$\rho_{fluid} = \frac{[P_2 - P_1]}{gh} + \rho_{so}$$

Gradio: Deviated

$$P_2 - P_1 = \rho_{fluid}\, gh\cos(\theta) + \left[\frac{dP}{dZ}\right]_{fric} + \left[\frac{dP}{dZ}\right]_{acc} - \rho_{so}\, gh\cos(\theta)$$

$$\Rightarrow \rho_{fluid} = \frac{[P_2 - P_1] - \left[\frac{dP}{dZ}\right]_{fric} - \left[\frac{dP}{dZ}\right]_{acc}}{gh\cos(\theta)} + \rho_{so}$$

$$\rho_{fluid} = \frac{[P_2 - P_1]}{gh\cos(\theta)} + \rho_{so}$$



NOTE: Schlumberger gradio specifics

WFDE already corrected for deviation with internal deviation measurement

UWFD not corrected for deviation

MWFD pseudo density from pressure

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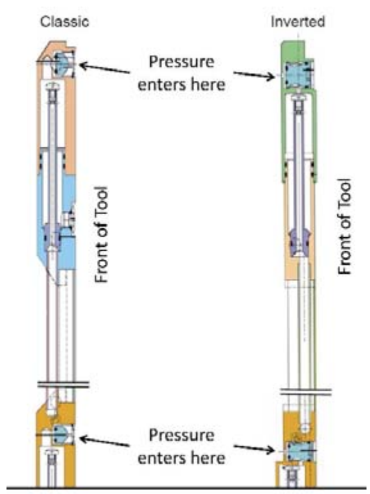
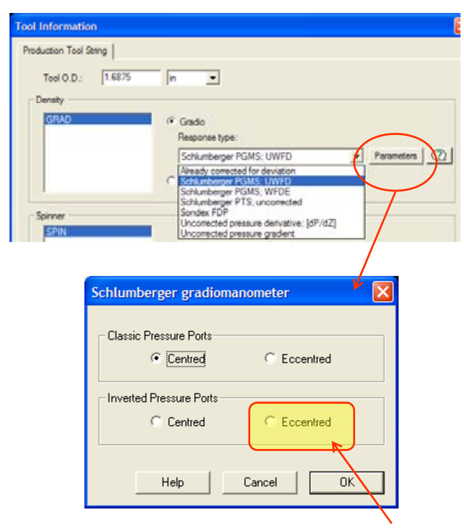
Gradio - Schlumberger



Courtesy Schlumberger



Recommended

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Gradiomanometer

Density channel function of pressure gradient and deviation

Tool response = f(dP/dZ, Dev)

dP/dZ comprises several components

$$dP/dZ = [dP/dZ]_h + [dP/dZ]_{pf} + [dP/dZ]_{tf} + [dP/dZ]_a$$

[dP/dZ]h = Density.Visc.(cos Dev) hydrostatic head

[dP/dZ]pf = friction along the pipe

[dP/dZ]tf = friction due to the tool presence, *Not for pseudo density*

[dP/dZ]a = acceleration, seldom significant (mist, gas)

Gradiomanometer: Friction

FRICTION:
The general expression of the friction gradient is:

$$\frac{dP}{dZ} = \frac{f\rho V^2}{8} \times \frac{S}{A}$$

where:
f **is the Moody friction factor,**
f **is proportional to the Reynolds number and Relative roughness**
S is the surface in contact with the fluid, A is the area opened to flow
r **is the density**
V is the speed of the fluid relative to the considered surface.

The friction corrected density is only computed after the rates have been calculated

Therefore an iterative solution method is required, since we need to know the velocity to calculate the friction, which in turn will allow us to calculate the velocity.

Friction terms

$$\frac{dP}{dZ_{friction}} = \frac{dP}{dZ_{pipe}} + \frac{dP}{dZ_{tool}} = \frac{f_p \rho V^2}{2} \times \frac{D}{(D^2 - d^2)} + \frac{f_t \rho V_t^2}{2} \times \frac{d}{(D^2 - d^2)}$$

where:

f **: friction factor, function of the appropriate Re number and roughness**
S: the surface in contact with the fluid
A: area opened to flow
ρ**: density**
V: the speed of the fluid relative to the considered surface.

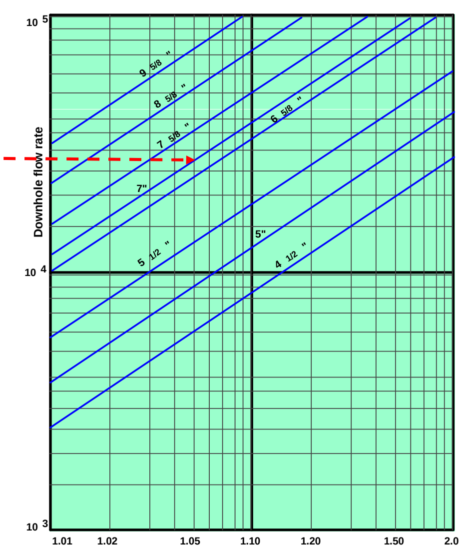
The density appearing in the above equations depends on the flow regime. For instance in annular flow, a liquid film is in contact with the pipe and only the liquid density is considered.

Friction Correction

7" casing

45,000bbl/d (7150m3/d)

Corrected gradio = 5%



Courtesy of Schlumberger

Friction Correction also depends on individual tool characteristics, particularly:

- position of sensing ports
- tool orientation and position
- fluid velocity

Roughness

Relative roughness = $\frac{\text{Absolute roughness}}{\text{Pipe ID}}$

NOTE.. The absolute roughness is a physical measurement of the dimensions of the defects on the metal surface.

Relative roughness coefficient in scaled pipe?

Any suggestions?

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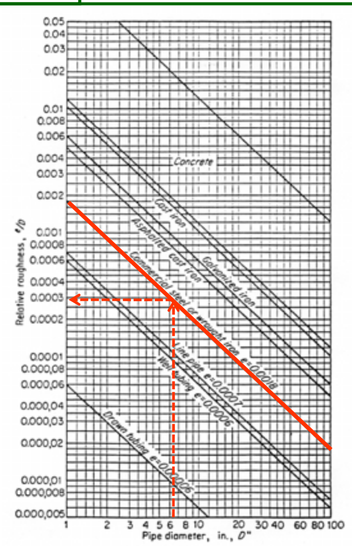
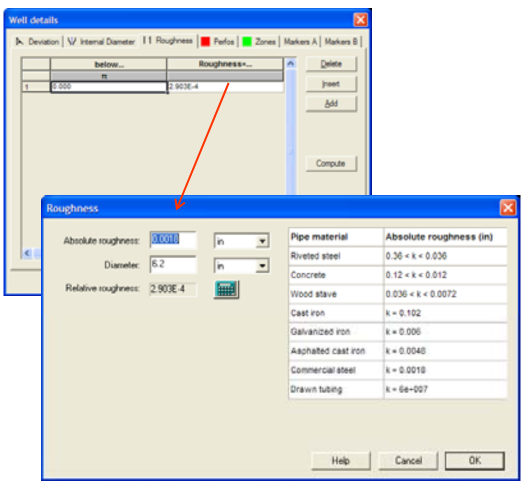
Relative Roughness





Moody, L. F. (1944), "Friction factors for pipe flow", *Transactions of the ASME* **66** (8): 671–684

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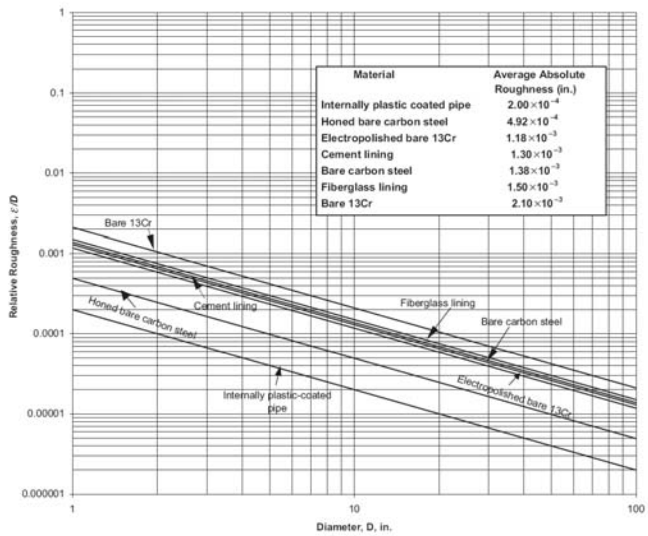
Relative Roughness

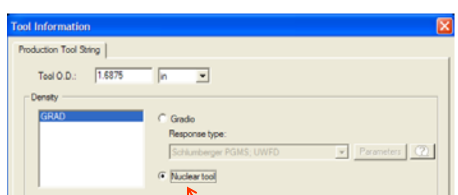


Farshad & Rieke SPE 79123

Sondex - FDR

Nuclear/Radioactive Density Tool

Courtesy: Sondex



- No deviation correction
- No friction correction

Nuclear Density Tool

Courtesy: Weatherford

Nuclear Density

The big advantage of the nuclear fluid density tool is that the density measurement is not affected by wellbore deviation, or by friction effects

However, since the tool relies on radioactive decay, the readings are subject to statistical variations

It should also be noted that the measured quantity is the average density of the flowing mixture; thus, it is subject to the same holdup effects as the gradiomanometer

DISADVANTAGE.. It is a nuclear tool with a source.

Tuning Fork Density (TFD)

Scientific Drilling TFD

The Tuning Fork Density (TFD) tool is designed to measure the density of fluid (gas to liquid) at the fork. The fork is contained in a protective cage.

The TFD sensor operates by measuring the effect of the fluid on a resonant fork. As the density of the fluid changes, the resonant frequency of the tuning fork also changes. The resonant frequency is measured and presented in grams/cc.

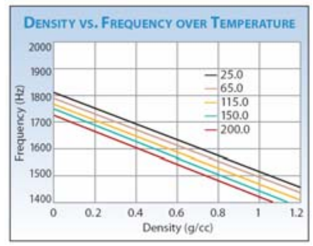
The tool is not affected by friction or deviation.

It should be defined at "TOOL INFO" as a nuclear tool in order the EMERAUDE handles it appropriately.

Acoustic Density (Spartek)	
Sensor	Vibrating Element
Range	0 - 2 g/cc
Resolution	0.01 g/cc
Accuracy	0.03 g/cc

Technical Specifications

Tool Type	Standard 1.38" TFD-A	Flasked 1.44" TFD-B
Length	38.0"	115.0"
O.D.	1.375"	1.44"
Maximum Pressure	15k psi	15k psi
Maximum Temperature	347°F (175°C)	428°F (220°C)
Sensor Range Resolution Accuracy	0.0 g/cc to 1.2 g/cc .001 g/cc .003g/cc	



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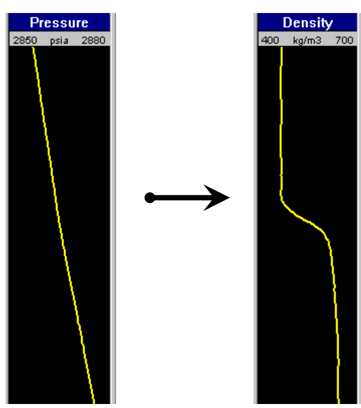
Pseudo-density



dp/dZ calculated from p vs Z

Needs:
- correction for pipe friction
- correction for deviation

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Density

- The density measurement give an instant picture of the fluids in the well
- The slowest pass is best, as there are less effects on the curve.
- Fix the "produced water", "oil" and "gas" values, for possible constraint of the PVT density values.
- Look for changes which will indicate entries of different fluids.
- The sump may give confusing readings, and is unlikely to represent the density any of the produced fluids

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Density Tool Specs

	NANGAL Tuned Density	SONDEX Nuclear	LEE SPECIALITIES Gradio	SCHLUMBERGER Gradio
Accuracy	**+/- 0.001g/cc**	**+/- 0.03 g/cc**	**+/- 0.03g/cc**	**+/- 0.04g/cc**
Resolution	**0.00001g/cc**	**0.01g/cc**	**0.001g/cc**	**0.002g/cc**

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QA/QC: Density

DENSITY – (GRADIO)

- Select the right density mnemonic used, for the correct calculation of the matched/simulated/calculated gradio, e.g. WFDE, UWFD, MWFD
- Ensure to input casing roughness and well angle.
- Compare with dP/dZ
- Identify jetting effects and eliminate from calculation zones
- Identify areas of possible friction effect

DENSITY – (NUCLEAR)

- Check the validity of the tool reading with the PVT correlation in a known single phase zone.
- Check the consistency with capacitance, dP/dZ or gradiomanometer
- Check for repeatability and consider statistical error in radioactive readings