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

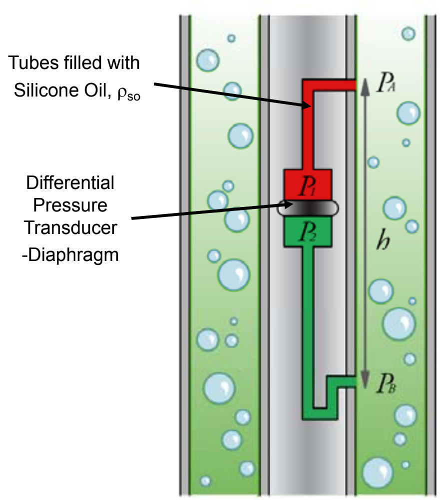
Density and Holdup Tools

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

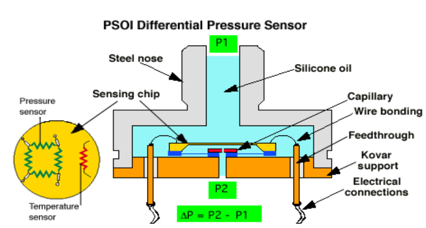
Gradiomanometer



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

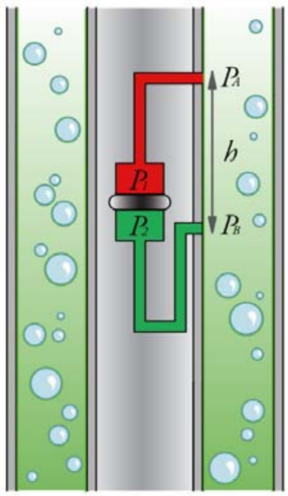
(It is a single sensor).

The single differential pressure sensor gives the density.



Courtesy Schlumberger

Gradiomanometer



$P_2 - P_1$

↓ **(tool specific)** **silicon oil**

$P_B - P_A$

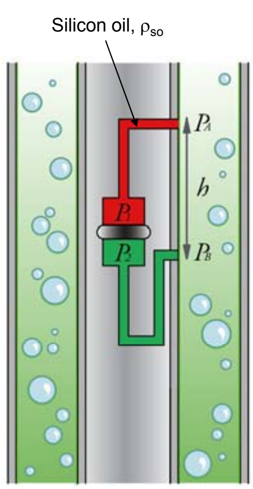
↓ **(friction, deviation)**

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

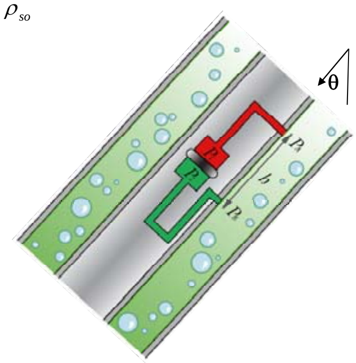
$$\rho_{fluid} = \frac{[P_2 - P_1]}{gh} + \rho_{so}$$

Gradio: Deviated

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

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

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



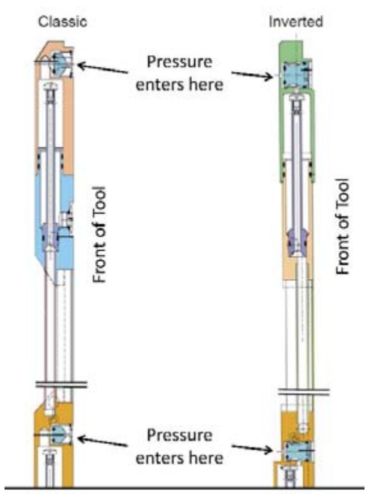
NOTE: Schlumberger gradio specifics

WFDE already corrected for deviation with internal deviation measurement

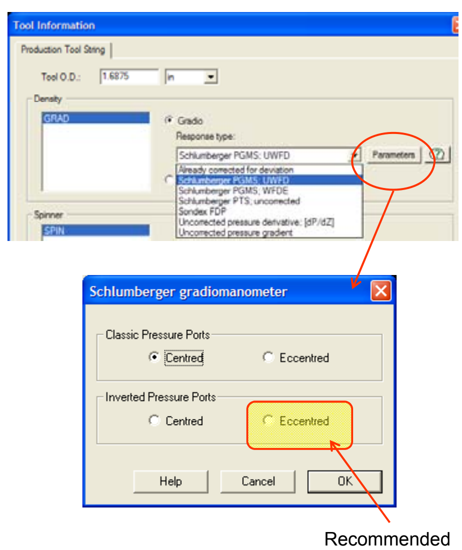
UWFD not corrected for deviation

MWFD pseudo density from pressure

Gradio - Schlumberger



Courtesy Schlumberger



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)

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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.

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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.

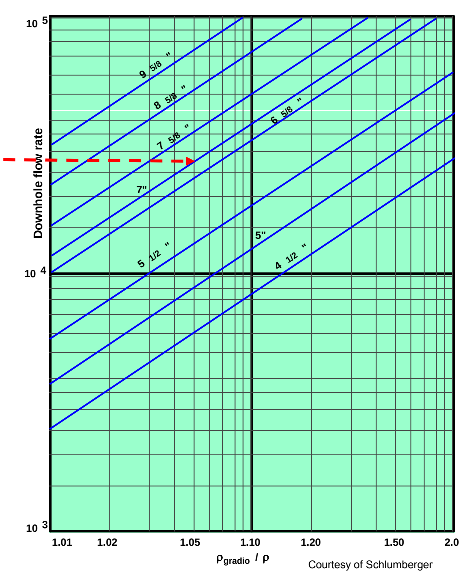
The density appearing in the above equations depends on the flow regime. For instance in annular flow, a liquid film is in contact with the pipe and only the liquid density is considered.

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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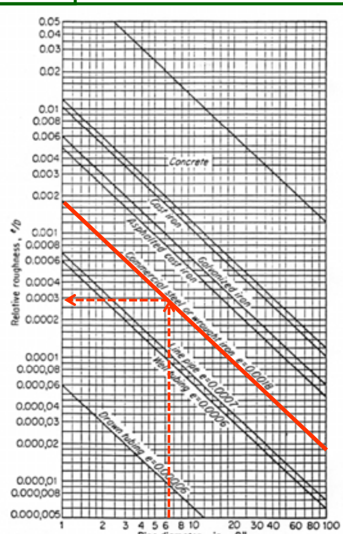
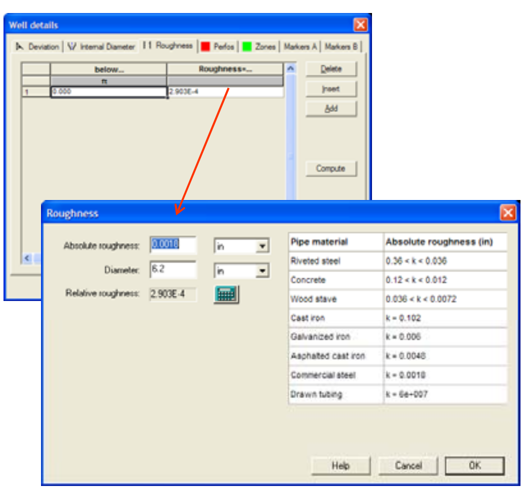
Relative Roughness





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

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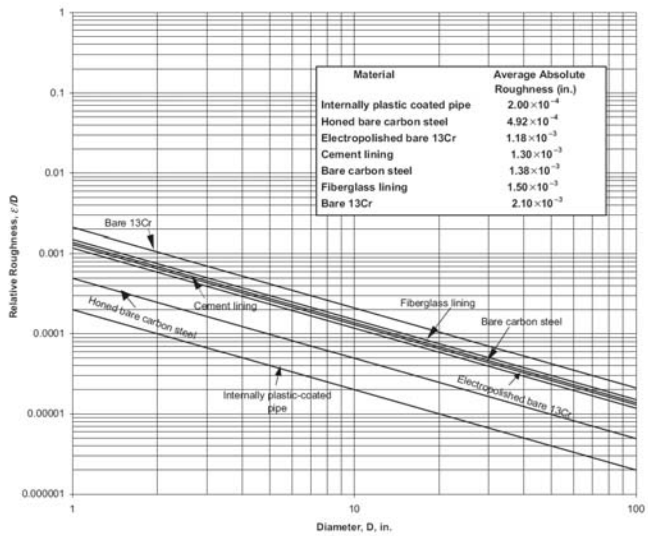
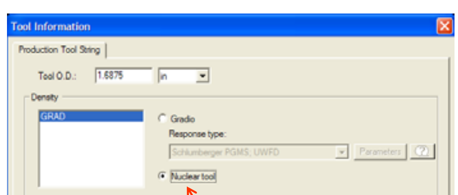
Relative Roughness



Farshad & Rieke SPE 79123

Sondex - FDR

Nuclear/Radioactive Density Tool



- No deviation correction
- No friction correction

Courtesy: Sondex

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.

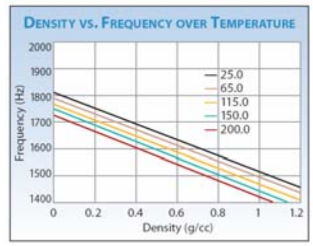
The TFD sensor operates by measuring the effect of the fluid on a resonant fork. As the density of the fluid changes, the resonant frequency of the tuning fork also changes. The resonant frequency is measured and presented in grams/cc.

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.

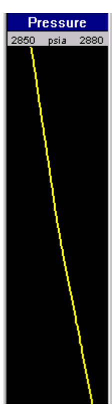
TECHNICAL SPECIFICATIONS

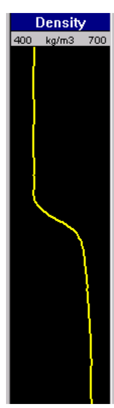
Tool Type	Standard 1.38" TFD-A	Flasked 1.44" TFD-B
Length	38.0"	115.0"
O.D.	1.375"	1.44"
Maximum Pressure	15k psi	15k psi
Maximum Temperature	347°F (175°C)	428°F (220°C)
Sensor Range Resolution Accuracy	0.0 g/cc to 1.2 g/cc .001 g/cc .003g/cc	



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

Pseudo-density





dp/dZ calculated from p vs Z

Needs:
- correction for pipe friction
- correction for deviation

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

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**

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

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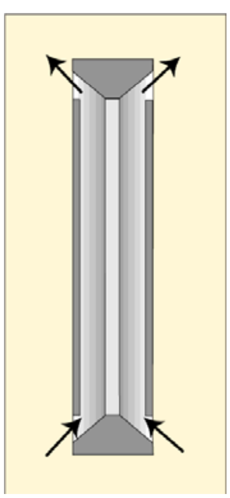
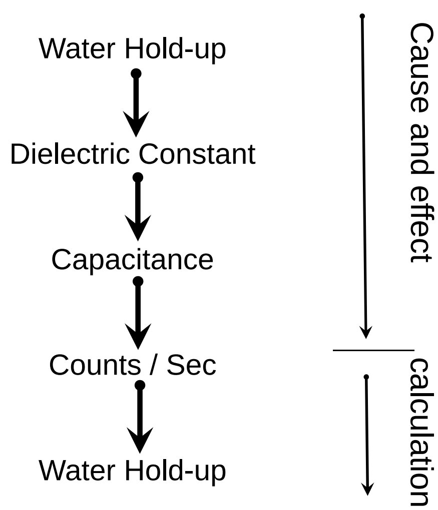
CAPACITANCE

Module #9

Capacitance Tools





Capacitance Tool

Courtesy: Weatherford

Measurement chamber

Courtesy: Spartek

Capacitance

This group of widely-used tools depend for their operation on the difference between the dielectric constant of water (78) and that of oil or gas (4).

A simple way to find the dielectric constant of a fluid is to use The fluid as the dielectric between the plates of a capacitor

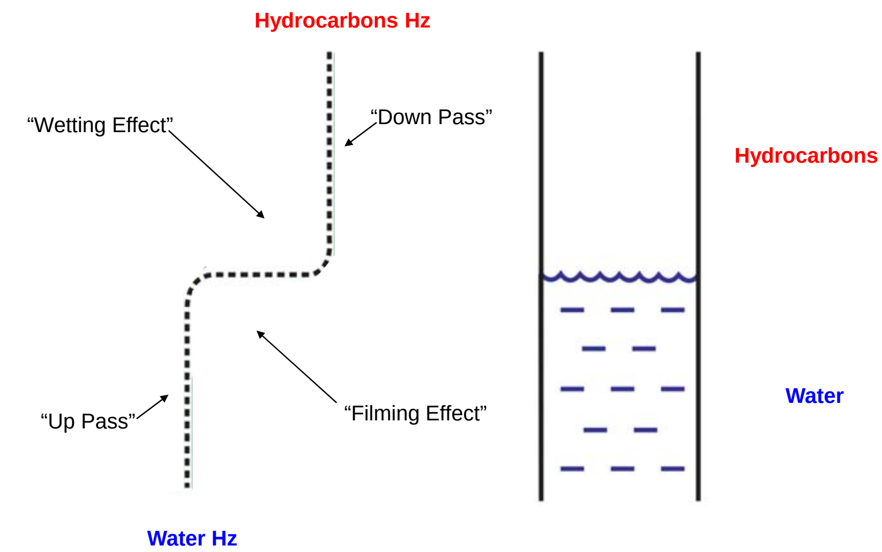
The capacitance may be found by classical methods such as including it in an RC network and finding the resonant frequency

Hence the tools generally output frequency… counts /sec

Needs calibration (surface check, and downhole in-situ calibration)
Before job (in air, water, and possibly a liquid hydrocarbon.. diesel)
During job (in water and hydrocarbon from shut-in pass data)

NOTE: "Wetting" and "Filming" effects

Filming & Wetting



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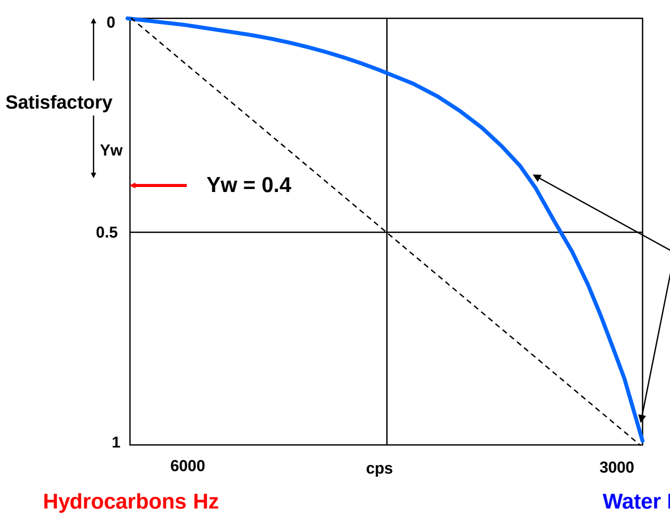
Capacitance: Limits



This class of tools works well as long as oil is the continuous phase

In practice they become unreliable if the water cut is above 30% - 40% The tool goes into "conductive" mode when the water becomes the dominant phase in the mixture.

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Capacitance Calibration

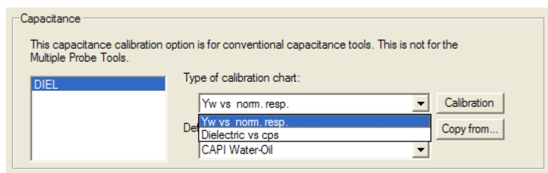
Calibration: convert cps to water holdup

Yw = f(Normalized response)

Normalized response (Recommended) $= \dfrac{100\%HC - Response}{100\%HC - 100\%H_2O}$

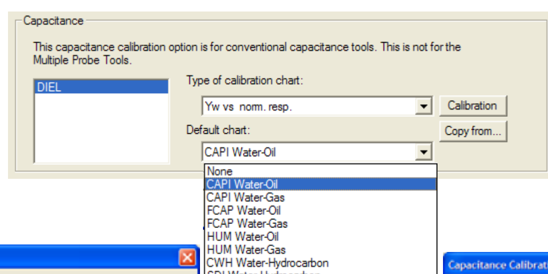
Diel = f(Resp) $Y_w = \dfrac{Diel - Diel(100\%HC)}{Diel(100\%H_2O) - Diel(100\%HC)}$

Survey
- Tool Information

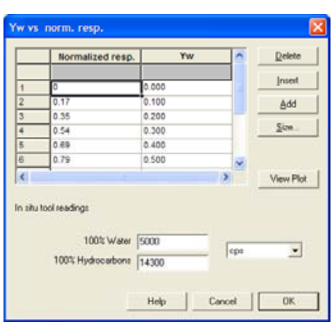


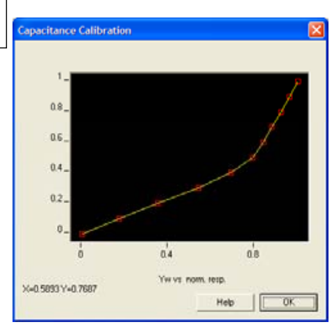
Capacitance Calibration

SURVEY
- TOOL INFO



CAPI – Sondex
FCAP – Atlas
HUM – Schlumberger
CWH – New Sondex
SDI – Scientific Drilling





Capacitance Tool Specs

	SONDEX	SPARTEK	SCHLUMBERGER
Accuracy	**+/- 3% Water Holdup**	**2% (0-30%WC) 5% (30-60%WC)**	**N/A**
Resolution	**1% (0-45%) Water Cut**	**0.1%**	**N/A**

QA/QC: Capacitance

- -Check range of frequencies against surface tool checks
- -Repeatability of passes
- -Identify wetting (up passes) & filming (down passes) at water hydrocarbon contacts.
- -Select water and hydrocarbon end frequencies
- -Do not define as a reference channel in Emeraude, unless it is going to be used in the numerical analysis.
- -Normally use slow down passes for interpretation

Gas Holdup Tool

The Sondex Gas Hold Up Tool was originally developed by Halliburton to provide a reliable, cross wellbore means of measuring gas volume fraction in any flow regime and at any deviation.

The tool response is said to be representative of the entire cross section of the well bore within the casing and is almost completely independent of salinity, water cut and oil/water densities.

APPLICATIONS

Multi-phase Production Profiling
Fluid Identification
Bubble Point Determination
Gas Entry Detection

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Gas Holdup Tool

Courtesy: Sondex

Mode	Memory or SRP	
Measurement Range	0-100% gas holdup	
Pipe Size	2.9 – 9.9 inch	
Accuracy	± 3%	
Resolution	1%	
Vertical Resolution	2.5 in	64 mm
Source	Cobalt 57 – 3mCi	Cobalt 57 – 111 MBq
Pressure Rating	15,000 psi	103 MPa
Temperature Rating	350 DegF	177 DegC
Make-up Length	27 in	686 mm
Tool Body Diameter	1 11/16 in	43 mm
Weight	10 lb	4.5 kg

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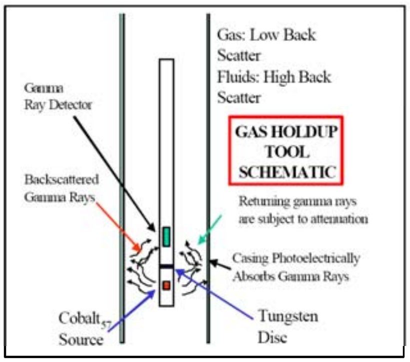
GHT Tool Design



3 Millicurie Cobalt 57 gamma ray source
Low energy gamma rays of 122 keV and 136 keV
Tungsten shield between source and detector

Courtesy SONDEX

The choice of source energy level is such that the tool measures only the fluid in the wellbore and not the formation.

The measurement discriminates on the amount of back scatter.

Gas has low electron density and has low back scatter.

Water has a high electron density and displays more back scatter.

Oil has a lower electron density than water, but due to compensating effects from the absorption in the oil, the difference between the oil and water response is about 5%

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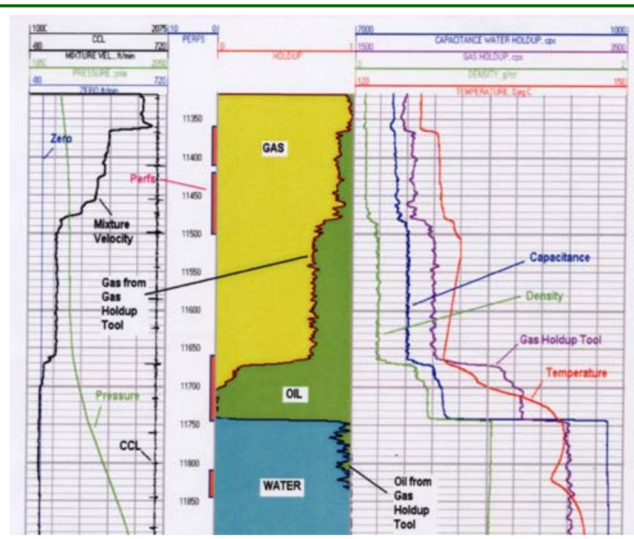
Gas Holdup Tool Example



Courtesy SONDEX

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Gas Holdup Tool

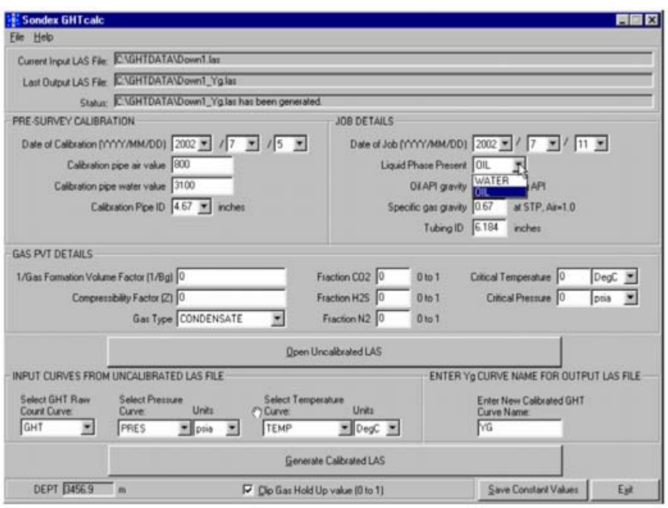
Advantages:

- Gives an across wellbore measurement - virtually insensitive to stratification.
- Not influenced by the formation behind casing.
- Works at all well deviations (including horizontal).
- Unaffected by fluid velocity
- Response to hold-up is approximately linear.
- Virtually unaffected by salinity changes.

Disadvantages:

- Uses a radioactive source.
- Must be run centralised.
- Raw counts have to be corrected for changes in fluid properties with pressure and temperature variations.
- The tool is affected by pipe ID. Raw counts have to be corrected for changes in pipe ID
- Affected by presence of radioactive scale.

GHT - Field Inputs



FIELD INPUTS

Calibration
Pipe ID
Pressure
Temperature
PVT properties

NOTE:
EMERAUDE accepts the GHT Yg curve as a direct Yg input.

Courtesy SONDEX

QA/QC: Gas Holdup Tool

- **Check values in a known environment and fluid type.**
- **Verify response correct with regards other sensors eg. Density**
- **Remember that Yg delivered from the WARRIOR acquisition logging system is a calculated curve, depending on wellsite inputs of a number of parameters, including ID, Pressure, Temperature, & PVT properties.**