Schlumberger Array Tools

KAPPA

SCHLUMBERGER ARRAY TOOLS

&

TPHL, WFL

Module #12

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FloView

Courtesy SCHLUMBERGER

Fluid entry	
Depth resolution	<1 ft
Threshold	50 B/D
Caliper measurement	
Caliper range	2 to 9 in.
Accuracy	0.25 in.
Resolution	0.1 in.
Tool operation requires fluids not in emulsion and bubbles sufficiently large compared with the size of the probe tip.	

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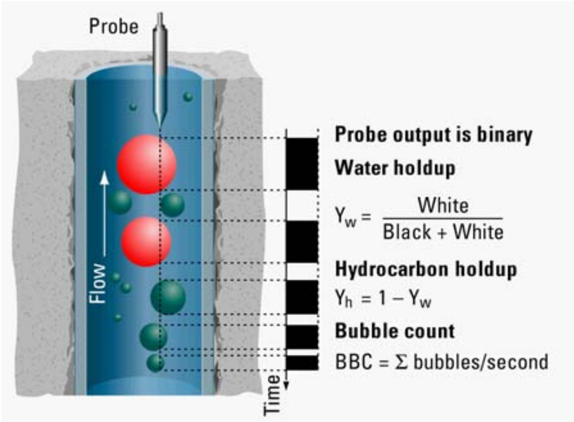
Local Probe Principle

Key assumptions

- **Distinct fluids (no emulsions)**
- **Local measurements are representative**
- **Flow not affected by presence of the tool**
- **Only differentiates between water and hydrocarbons**



Courtesy SCHLUMBERGER

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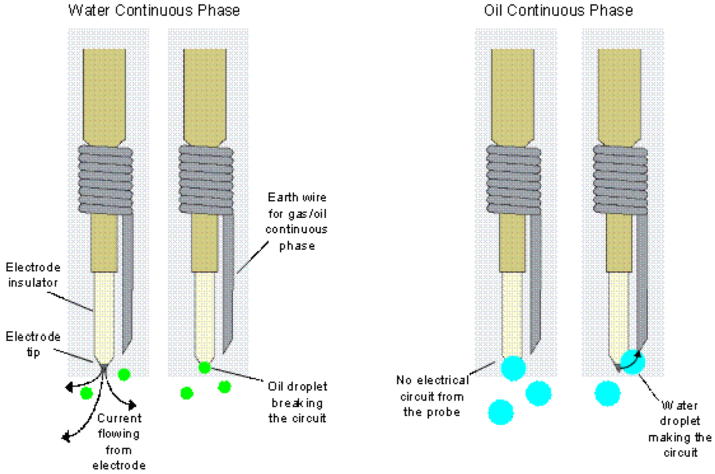
FloView operation



Operation of the FloView Water Holdup Probe

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FloView

Water continuous phase... current is emitted from the probe tip and returns to the tool body. A droplet of oil or gas on the probe tip will break the circuit and be registered.

Oil continuous phase… a droplet of water touching the probe tip will not provide an electrical circuit. Instead, the water droplet must connect the electrical probe to the earth wire. Thus a larger droplet is needed for gas or oil detection than in a water-continuous phase.

In both cases the best measurement is made with the bubbles approaching the probe from below. Fast up passes in slow-velocity wells drag the probe backward through the bubbles and deliver an inferior water holdup.

It is not unusual to disregard all water holdup probe measurements from the up passes.

In high-velocity wells the droplets of oil and water can become too small for the probes to see and the discontinuous phase is then undercounted. Empirical velocity limits have been determined.

- Oil or gas is the continuous phase: Vm < 1 m/s.
- Water continuous phase: Vm < 2 m/s.
- Horizontal wells with gravity segregation: Vm < 3 m/s.

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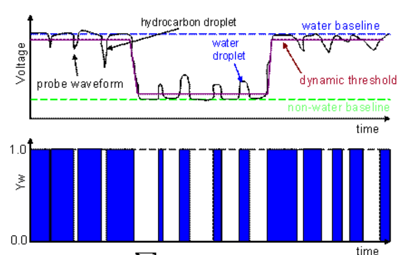
FloView Probe Processing



$$Y_w = \frac{\sum t_w}{t} \qquad bc = \frac{n_b}{t}$$

FloView Probe Waveform Processing

The signal from the FloView probe lies between two baselines, the continuous water-phase response and the continuous hydrocarbon-phase response. To capture small transient bubble readings a dynamic threshold is adjusted close to the continuous phase and then compared with the probe waveform. A binary water holdup signal results, which when averaged over time becomes the probe holdup. All the probe waveform within a 6-in depth frame is processed in this way.

The number of times the waveform crosses the threshold is counted and divided by 2 to deliver a probe bubblecount

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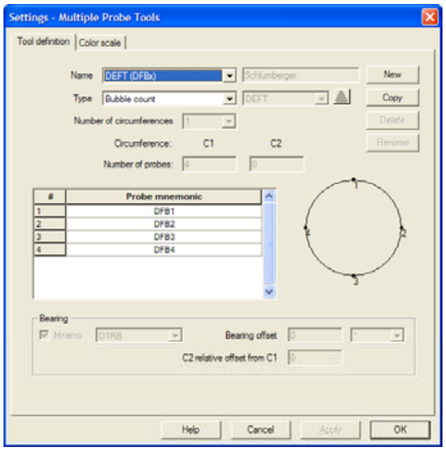
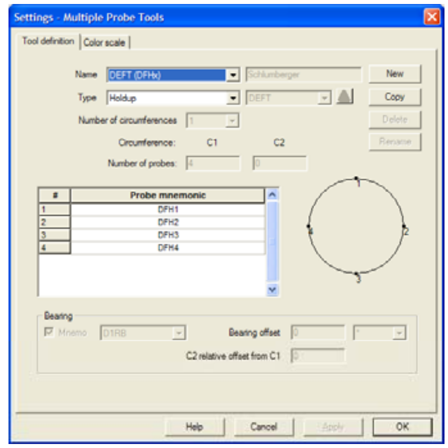
DEFT - FloView





DEFT (DFBx) Tool

PFCS (DFBx) Tool

DEFT (DFHx) Tool

PFCS (DFHx) Tool

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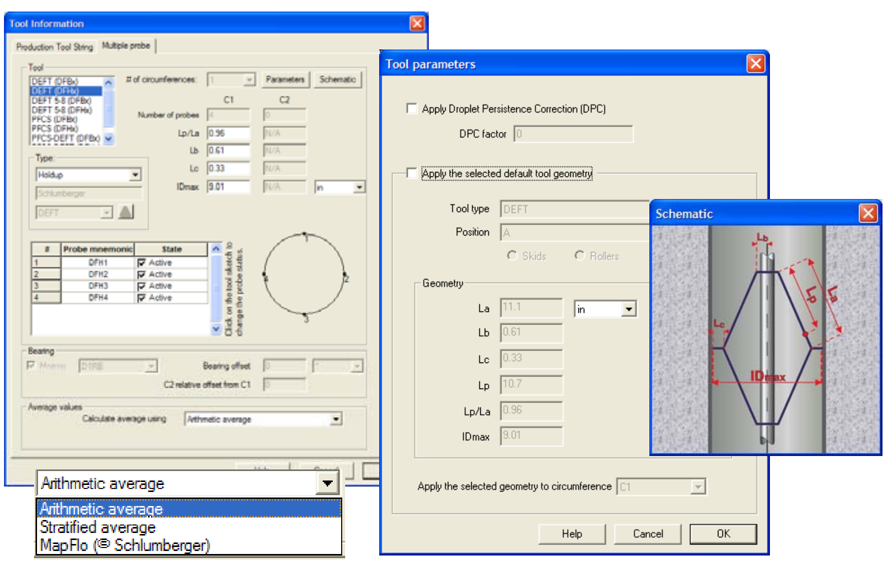
DEFT - FloView



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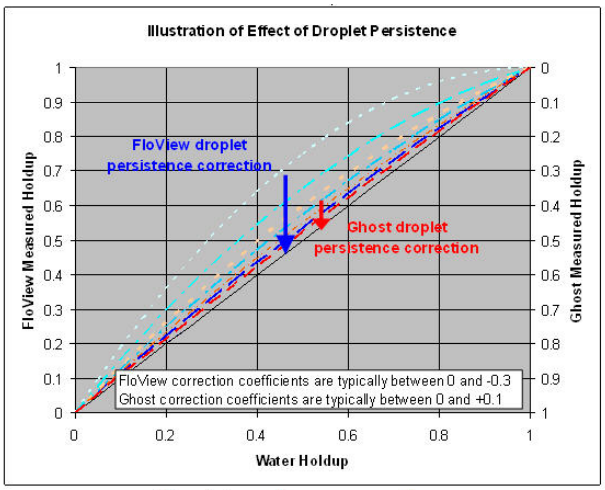
Droplet Persistence - DPC



Droplet persistence corrections

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DPC

Schlumberger FloView* and GHOST probes have been observed to over-read the water holdup. The physics of this error are not completely understood, but it appears to be triggered by water droplets clinging to the probe tips when low-density gas has insufficient energy or momentum to clean the probe tip.
The phenomenon is called “droplet persistence.”

Following some laboratory flow-loop experiments, a proprietary correction algorithm has been developed and implemented inside Emeraude.

The droplet persistence correction (DPC) can be applied in “Survey – Tool info – Multiple Probe – Parameters,” but because an iterative approach is often used to choose the correct value of DPC, it is easier to apply from “Browser – MPT processing.”

Typically the MPT raw channels are left uncorrected and only the MPT processed channels are persistence corrected as they are created; however, new values of the MPT raw channels can be generated if desired.

FloView* water holdup DPC coefficient is between 0 and –0.3

GHOST DPC coefficient is between 0 and 0.1

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QAQC & tips – DEFT/FloView

•Check for individual sensor response by making image view and cross section view of each pass.

•Make sure wellsite averages, DFHM etc are prepared correctly

•The response is valid for fluid velocity < 120 m/min

•Use the correct options in Emeraude for MPT processing: probe status (active/ignore/disable), average values (arithmetic/stratified).

•Compare to the centered capacitance/water hold up, if available.

•Used to differentiate water and hydrocarbon hold up.

•Check for the tool rotation (relative bearing data) along the logged interval.

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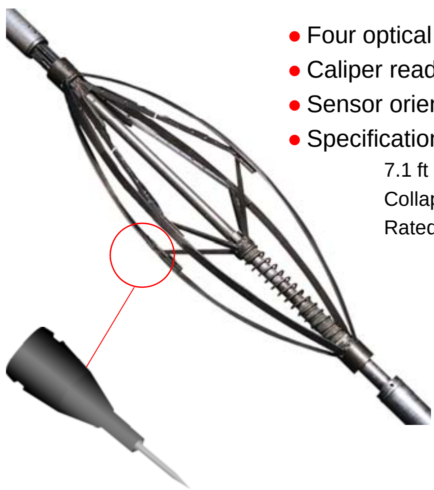
GHOST



Courtesy SCHLUMBERGER

- Four optical probes positioned on centralizing arms
- Caliper reading
- Sensor orientation with relative bearing
- Specifications:
  - 7.1 ft [2.18 m] long
  - Collapses to $1^{11}/_{16}$ -in. diameter
  - Rated to 300°F [150°C] and 15,000 psi [1035 bar]

- 0.004-in. [0.1-mm] diameter sensing area not influenced by wetting effects
- No maximum phase velocity limitation
- Gas holdup accurate to within 7%
- Bubble count accurate to within 1%

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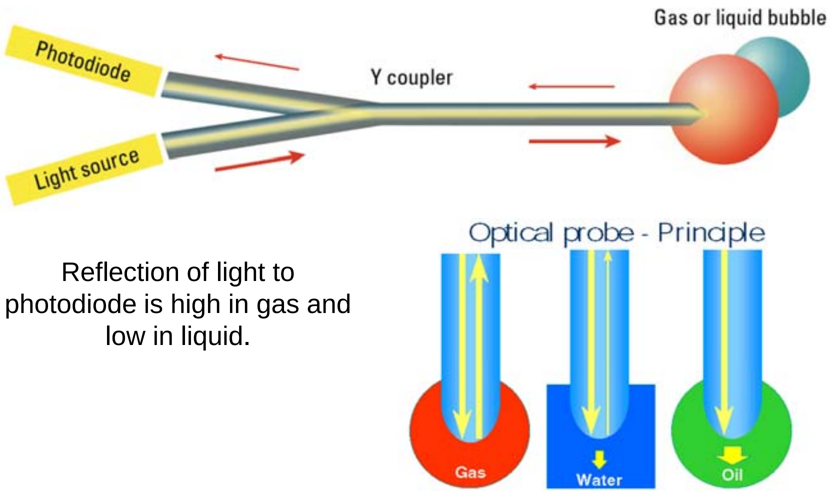
Optical Gas-Liquid Differentiation



Reflection of light to photodiode is high in gas and low in liquid.

Courtesy SCHLUMBERGER

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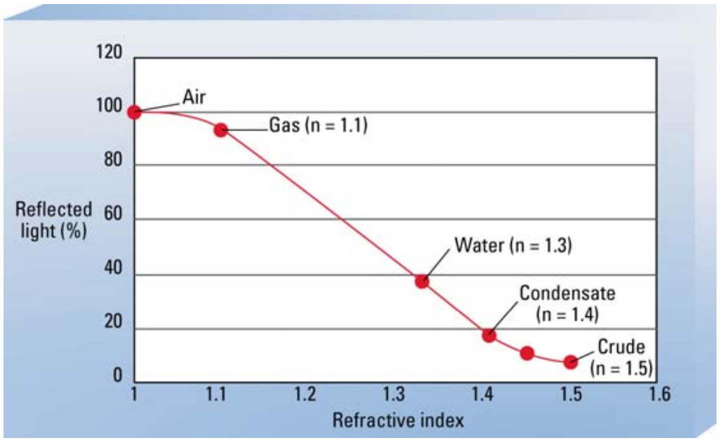
GHOST Measurement Principle

GHOST Probe Response



Reflected light depends on refractive index of medium (n).

Courtesy SCHLUMBERGER

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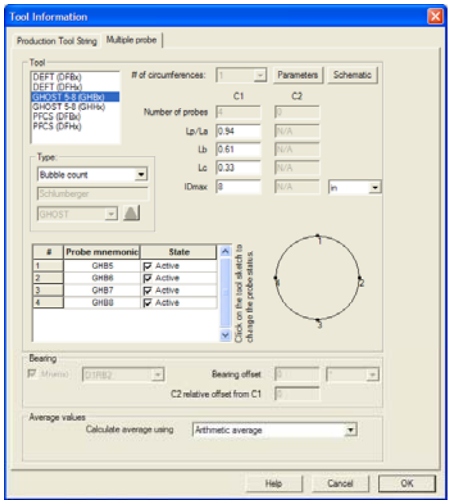
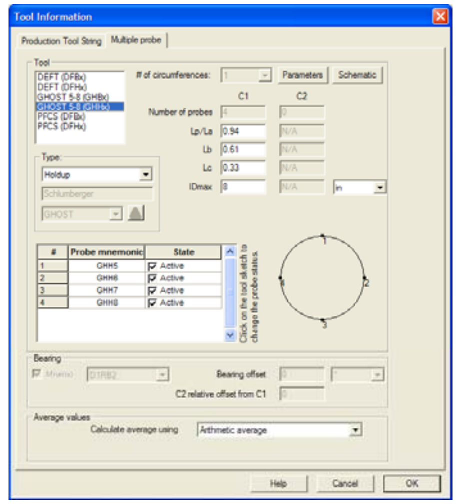
GHOST – Tool Info





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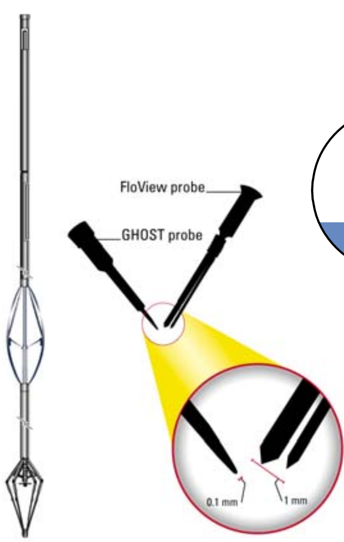
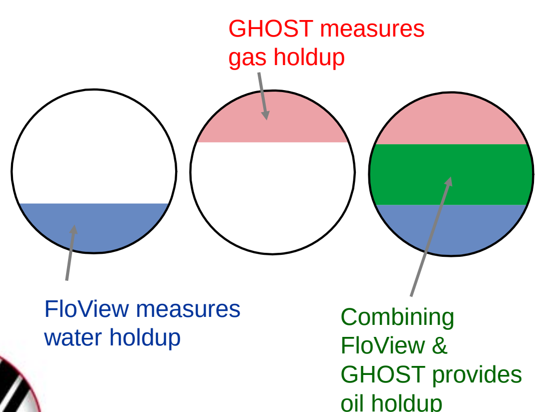
Three-Phase Holdup Measurements





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QAQC - GHOST

•Check for individual sensor response by making image view and cross section view of each pass.

•Used to differentiate gas and liquid hold up.

•Check the consistency with other hold up/density tools.

•Check for the tool rotation (relative bearing data) along the logged interval.

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Schlumberger FSI Tool

FloScan Imager Tool

5 Micro-spinners

6 GHOST gas holdup sensors

6 FLOVIEW (DEFT) water holdup sensors

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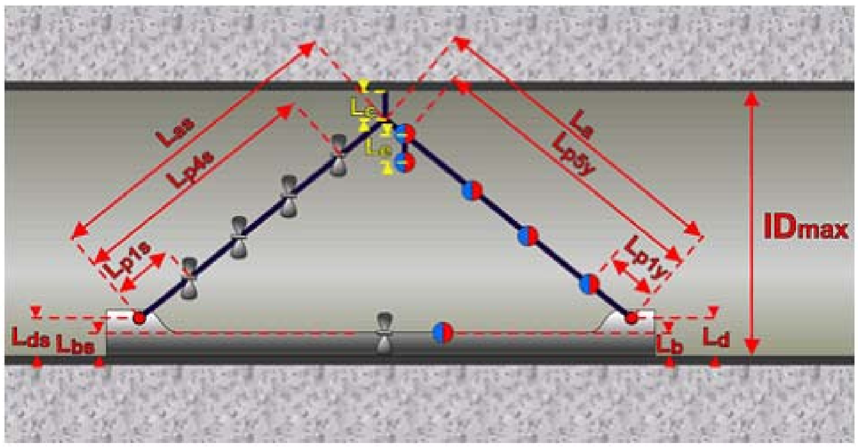
FSI – The Tool



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FSI - Interpretation

APPLICATIONS

- Multiphase PL interpretation in deviated or horizontal wells
- Identification of mixed & segregated flow regimes
- Identification of gas and fluid entries in multiphase wells
- Identification of “Apparent downflow” - recirculation

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Flow Profile Behavior

Vertical – low deviation wells

Smooth velocity and holdup profile across the pipe

Conventional centered measurements generally provide the solution.

Low – high deviation wells

Some areas of the wellbore can be monophasic, but segregation effects can create very complex flow regimes and varied profiles across the wellbore. Shear forces between fluids gives instabilities and large velocity and holdup gradients across the wellbore.

High deviation – horizontal wells

Flow regimes are generally stratified even at higher velocities. However small changes in deviation will dramatically change the velocity and holdup profiles.

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FSI Physics of measurement

- Designed for highly deviated and near horizontal wells.
- Solving flow patterns across the vertical diameter of the wellbore
- 5 mini-spinners (1” diameter)
- 6 GHOST optical probes distinguish gas from liquid
- 6 FloView electrical probes distinguish water from hydrocarbon
- Hydraulic opening and closing

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FSI – Primary Measurements

SPIF0_FSI ~ SPIF4_FSI	Filtered Rotational Velocity Spinner
DFHF0_FSI ~ DFHF5_FSI	Filtered Water Holdup
GHHF0_FSI ~ GHHF5_FSI	Filtered Gas Holdup
DFBF0_FSI ~ DFBF5_FSI	Filtered Bubble Count Electrical probes
GHBF0_FSI ~ GHBF5_FSI	Filtered Bubble Count Optical probes
CALI_FSI	Calibrated FSI caliper
RB_FSI	Relative Bearing memorized

Note: The indices start at 0 from the low side of the FSI tool

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FSI – Additional Measurements

ADDITIONAL MEASUREMENTS:

- FSI caliper
- Relative bearing
- Pressure
- Temperature
- Gamma ray CCL
- Deviation
- Compression & tension at head of the toolstring
- Combinable with other Schlumberger PS Platform tools
- RST

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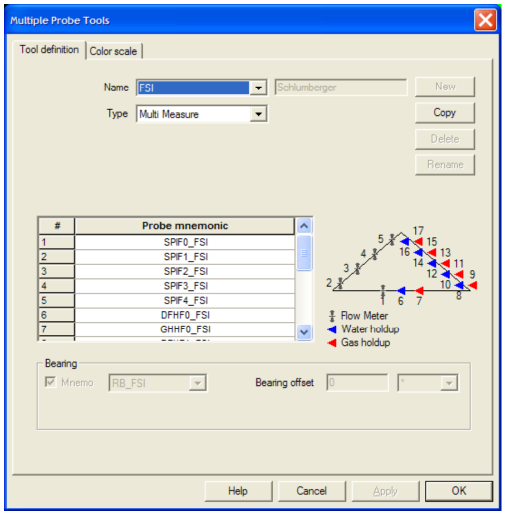
FSI – Settings



General tool configurations

"SETTINGS"

One time set up tool defaults

Handling non-standard tool mnemonic settings.

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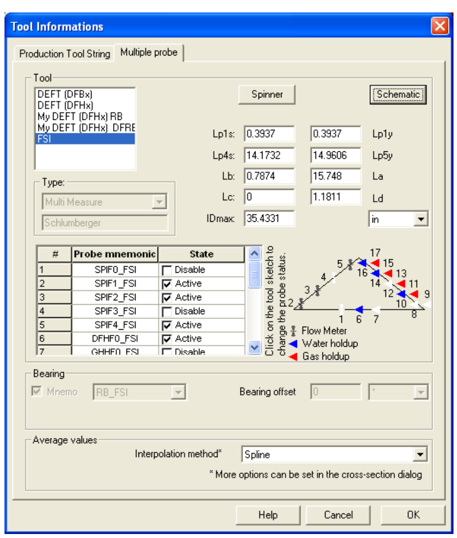
FSI – Tool info



Job specific FSI tool details

1. "SURVEY"
   "Tool info"

2. Or access via
   "Image view" – edit properties

   Gives user control for……
   data editing,
   presentation options
   and calculation options.

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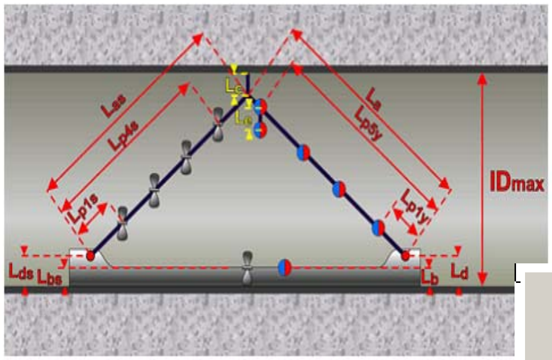
FSI – Tool geometry



Tool geometry details

Lp1s	6.48	5.4	Lp1y
Lp4s	25	27	Lp5y
Lbs	0.85	0.75	Lb
Las	27	27	La
Lds	0.88	1.12	Ld
Lc	0.6	0.5	Le

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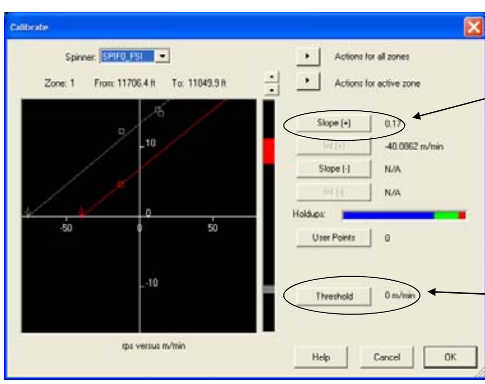
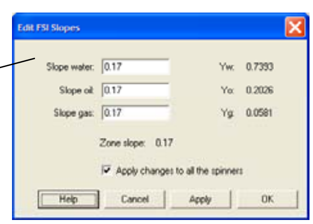
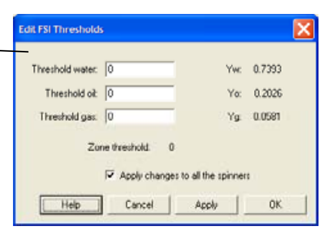
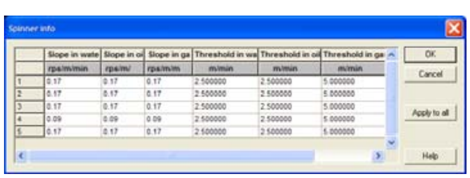
FSI - Spinner Calibration









	Slope in wate	Slope in oi	Slope in ga	Threshold in wa	Threshold in oil	Threshold in ga
	rps/m/min	rps/m/	rps/m/m	m/min	m/min	m/min
1	0.17	0.17	0.17	2.500000	2.500000	5.000000
2	0.17	0.17	0.17	2.500000	2.500000	5.000000
3	0.17	0.17	0.17	2.500000	2.500000	5.000000
4	0.09	0.09	0.09	2.500000	2.500000	5.000000
5	0.17	0.17	0.17	2.500000	2.500000	5.000000

$$Slope = Slope_w \times y_w + Slope_o \times y_o + Slope_g \times y_g$$

$$Threhsold = Threshold_w \times y_w + Threshold_o \times y_o + Threshold_g \times y_g$$

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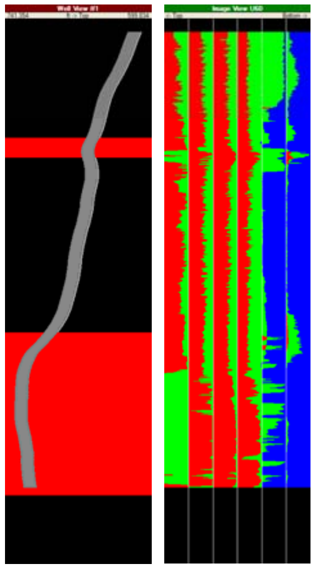
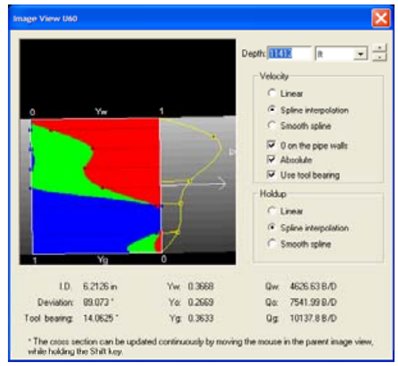
FSI – Image views





Linear: simple linear interpolation,
Spline: cubic spline though all the points with no curvature at the end points.
Smooth spline: cubic spline though the end points and one point along each intermediate segment.

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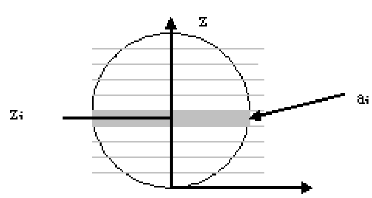
FSI - Processing

The resulting logs can also be created directly in the source pass.
They are given the following mnemonics:

Holdups: YW_FSI, YG_FSI
Velocity: VT_FSI
Rates: QW_FSI, QO_FSI, QG_FSI



$$y_p = \frac{\sum_i a_i \times y_p(z_i)}{\sum_i a_i} \qquad V_m = \frac{\sum_i a_i \times V(z_i)}{\sum_i a_i} \qquad q_p = \sum_i a_i \times y_p(z_i) \times V(z_i)$$

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FSI – Tips & Tricks

- Load only minimum required curves at import.
- If present at import, rename original Schlumberger Yw_FSI etc, if you wish to preserve them, or load to a separate survey for later comparison.
- Be organised and systematic with use of multiple surveys, image views, user views etc.
- Perform separate “conventional” spinner calibrations, one FSI spinner at a time, to evaluate for threshold and slopes in the various phases.
  (Use all available data & surveys to this end)
- When the flow is segregated, and unless in mist flow, there will be some local slippage and therefore the rates resulting from the direct FSI processing will not be adequate. In this case, one should use only the VT and holdups from the FSI.

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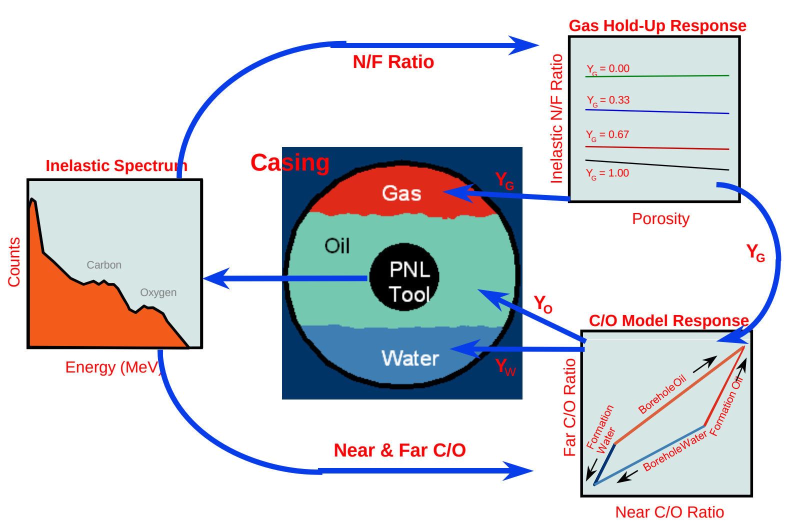
Three Phase Holdup



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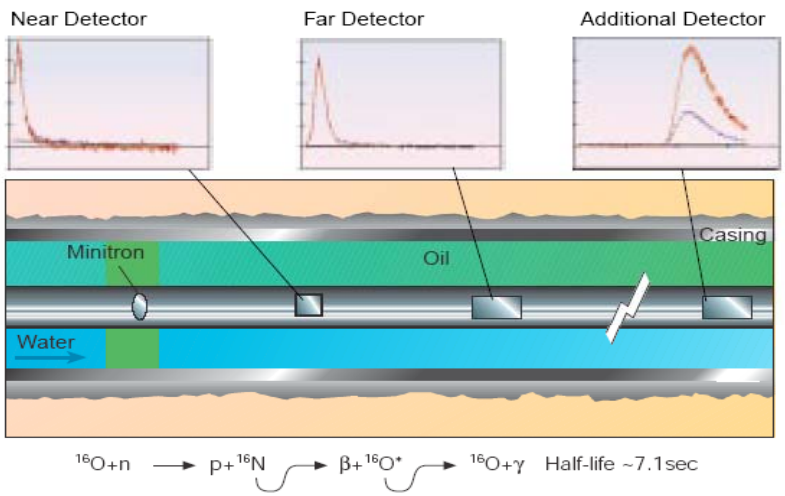
Water Flow Log



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Sondex Array Tools

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SONDEX ARRAY TOOLS

Module #13

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CAT

Temperature rating	177 degree C
Pressure rating	15,000psi
Tool body diameter	1 11/16" (43mm)
Make-up Length	55.5" (1410mm)
Weight	17.3lbs (8.1kg)
Number of fluid sensors	12
Orientation sensor	Indicates which sensor is "up"
Maximum pipe size	7" casing
Toolbus Standard	Ultrawire for memory or SRO

Courtesy SONDEX

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Sondex – Capacitance Array Tool

SONDEX - CAT

12 Probes

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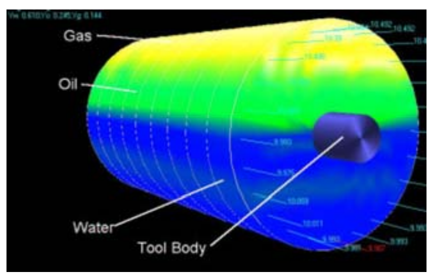
Capacitance Array Tool

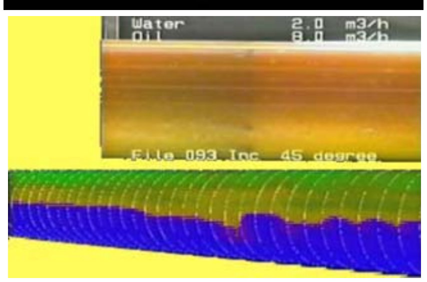
OPERATING PRINCIPLE

Oil, Gas & Water have different dielectric constants. The output frequency of a sensor changes with the dielectric constant of the fluid surrounding it. A simple calibration of the sensors enables the identification of the fluid surrounding each sensor.

APPLICATIONS

- **Phase identification in horizontal & highly deviated wells.**
- **Calculation of % of each phase present.**
- **Plotting of phase composition along the wellbore.**
- **Identification of water entry areas.**
- **Changes of wellbore fluids with time or different abstraction conditions.**





Courtesy SONDEX

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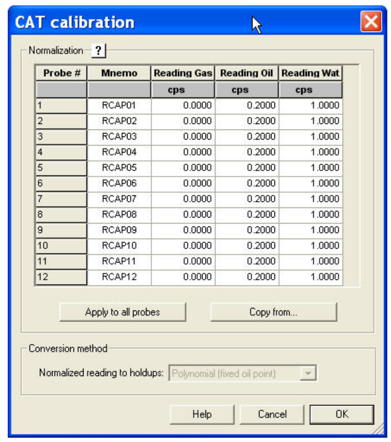
CAT

CAT: (CN1,…,CN12; RELB)

CAT-N: (NCAP01,…,NCAP12; CATROT)

CAT-R: (RCAP01,…,RCAP12; CATROT)



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RCAP & NCAP

- Raw (RCAP) or normalized (NCAP) capacitance values can be loaded.
- Raw values (RCAP)
- When raw values are used, the normalization is governed by the “Calibration” option of the Survey-Tool Info Multiple probe' dialog.
- Individual probes normalization is possible with 3 end points defined for each probe: gas phase reading, oil phase reading and water phase reading.
- The raw values from the tool are whole numbers from 0 to 255. Normalized capacitance is defined as Gas = 0.0, Oil = 0.2 and Water = 1.0
- The normalization of the raw data uses gas and oil phase readings if the raw CAT data is within the segment defined by these 2 values. Otherwise, it uses the oil and water readings.

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QAQC - CAT

•Check for individual normalisation applied on NCAP values. It is possible to re-normalise individual sensor in Emeraude (‘calibration’ option in Survey-Tool Info-Multiple probe).

•Check for individual sensor response by making image view and cross section view of each pass.

•Check for the tool rotation (relative bearing data/CATROT) along the logged interval.

•There are several options in Emeraude for MPT processing: probe status (active/ignore/disable), average values (arithmetic/stratified).

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RAT

Courtesy SONDEX

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RAT

RAT: (RATHU01,…,RATHU12, RATROT)

The RATHUxx curves are recognised by EMERAUDE as Water Holdup curves

NOTE: These RATHUxx curves are calculated from the raw RAT curves using a SONDEX software called RATUTIL

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SAT

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SAT

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SAT

SAT: (SPIN1,…,SPIN6; FLOW1,…,FLOW6, SATROT)

The FLOWx mnemos are not actual measurements but provisions to load velocity channels calculated by the Sondex acquisition software. This is optional.

It is always possible to define a user tool when different mnemos are encountered.

One can also use a distinct bearing channel with an arbitrary offset if necessary

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Baker Atlas

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BAKER ATLAS

Module #14

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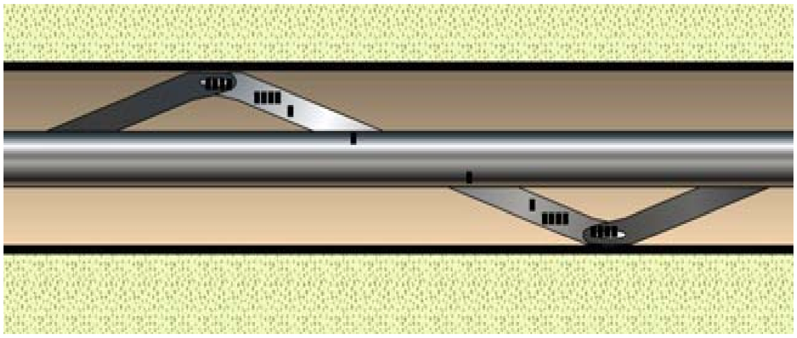
Multiple Capacitance

MCFM (MultiCapacitance Flow Meter)
Baker-Atlas



Each probe gives a local measurement of holdup
2 Calibrations ; holdup extended to 3 phase

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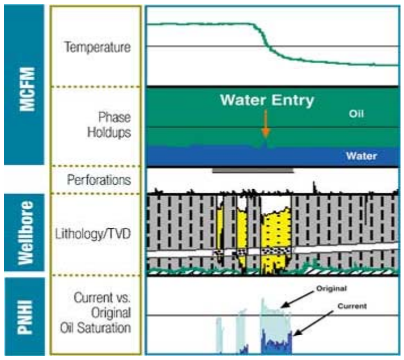
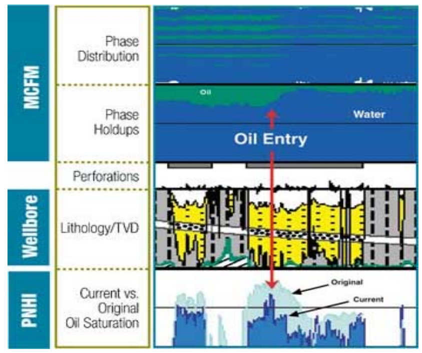
The Multi-Capacitance Flow Meter (MCFM)





A jet of water entering a horizontal wellbore through an interval, only inches in length, in the perforations is identified.

An increase in oil holdup identified with the MCFM tool correlates with an oil stringer located by the RPM-PNHI measurement in an interval that is largely depleted

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