

**SARA**  
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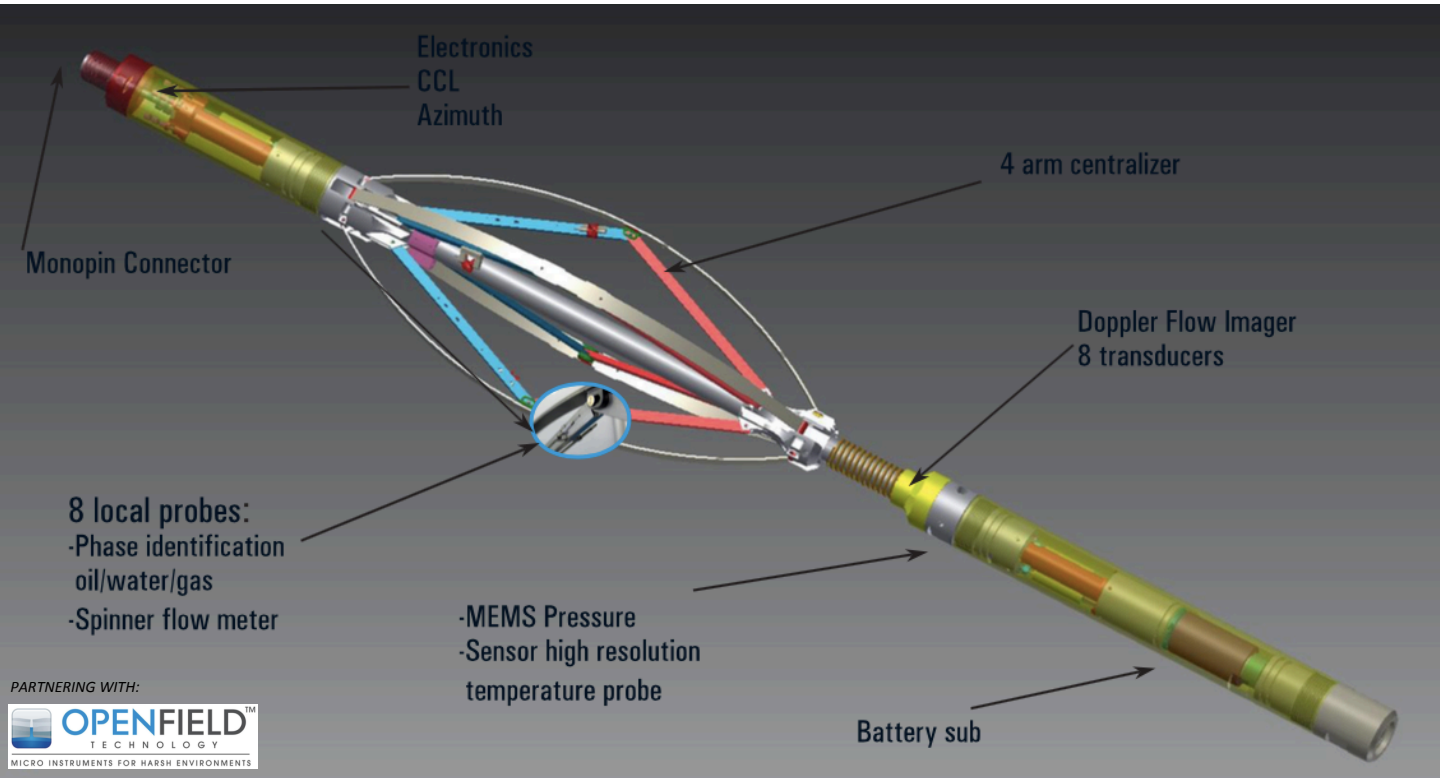
# MULTIPHASE FLOW **ARRAY** SENSING TOOL

DEVIATED AND HORIZONTAL  
WELL - SMALL TUBING  
HIGH WATERCUT - LOW  
FLOWS - LOW HOLDUPS



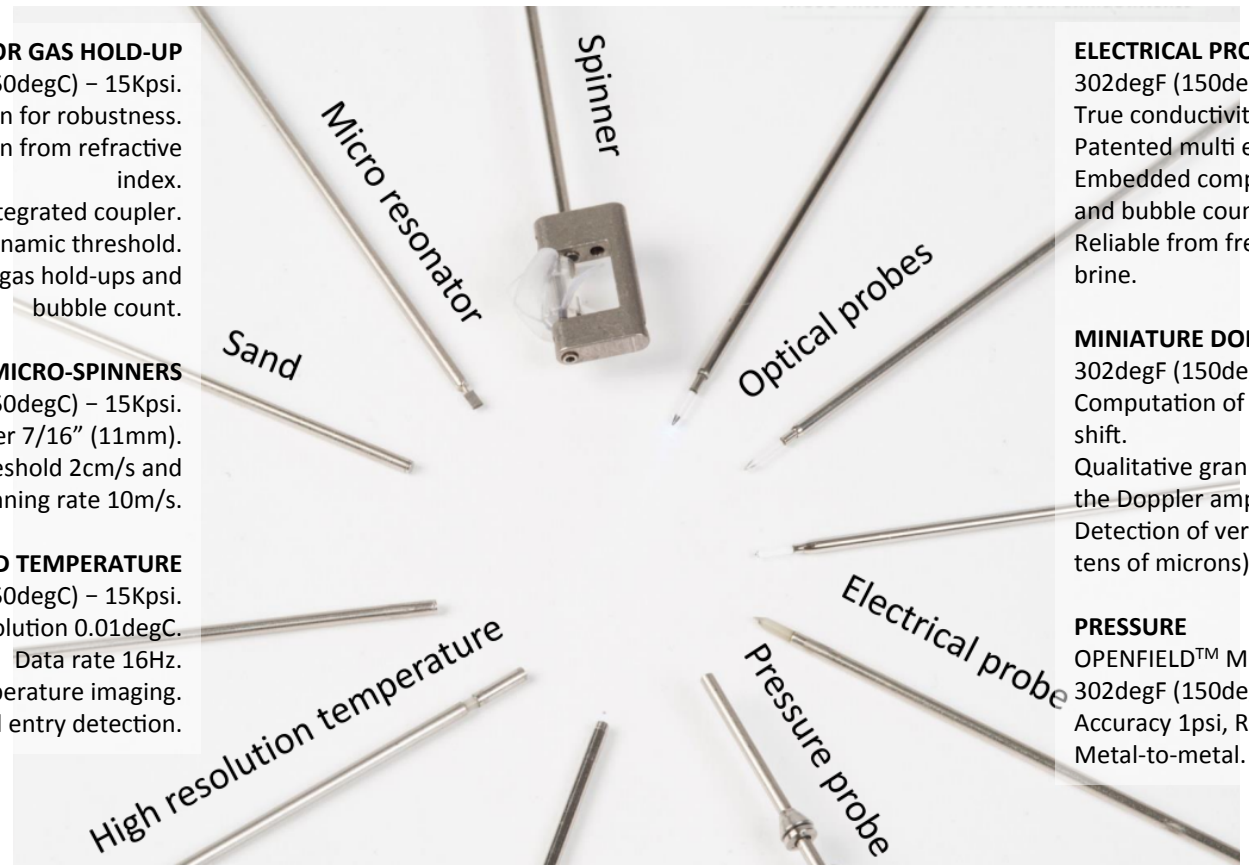
# M U L T I P H A S E F L O W A R R A Y S E N S I N G T O O L

S H O R T - C O M P A C T - L I G H T W E I G H T



# M U L T I P H A S E F L O W A R R A Y S E N S I N G T O O L

L O C A L P R O B E - V E L O C I T Y - H O L D U P



### OPTICAL PROBE FOR GAS HOLD-UP

302degF (150degC) – 15Kpsi.

Sturdy design for robustness.

Liquid/gas discrimination from refractive index.

Integrated coupler.

Dynamic threshold.

Embedded computation of gas hold-ups and bubble count.

### MICRO-SPINNERS

302degF (150degC) – 15Kpsi.

Diameter 7/16" (11mm).

Fluid velocities; min threshold 2cm/s and max spinning rate 10m/s.

### ULTRAFAST FLUID TEMPERATURE

302degF (150degC) – 15Kpsi.

Accuracy 0.1degC, Resolution 0.01degC.

Data rate 16Hz.

Enables high resolution temperature imaging.

Early fluid entry detection.

### ELECTRICAL PROBE FOR WATER HOLD-UP

302degF (150degC) – 15Kpsi.

True conductivity measurement.

Patented multi electrode technology.

Embedded computation of water hold-ups and bubble counts.

Reliable from fresh water to high salinity brine.

### MINIATURE DOPPLER TRANSDUCER

302degF (150degC) – 15Kpsi.

Computation of velocities from the Doppler shift.

Qualitative granulometry index of fluids from the Doppler amplitude.

Detection of very early fluid entries (a few tens of microns).

### PRESSURE

OPENFIELD™ MEMS Pressure sensor.

302degF (150degC) – 15Kpsi.

Accuracy 1psi, Resolution 0.01psi.

Metal-to-metal.

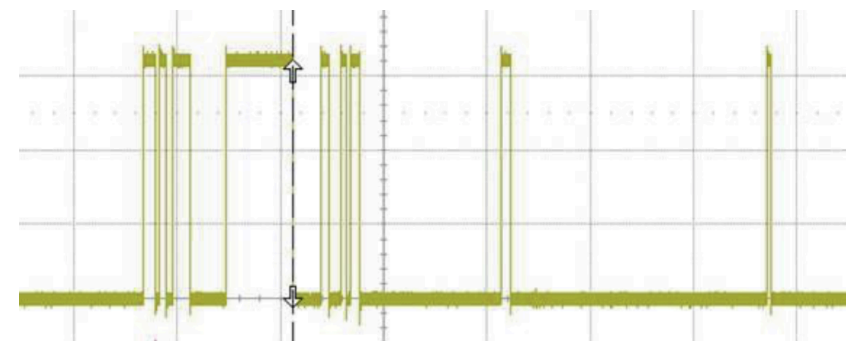
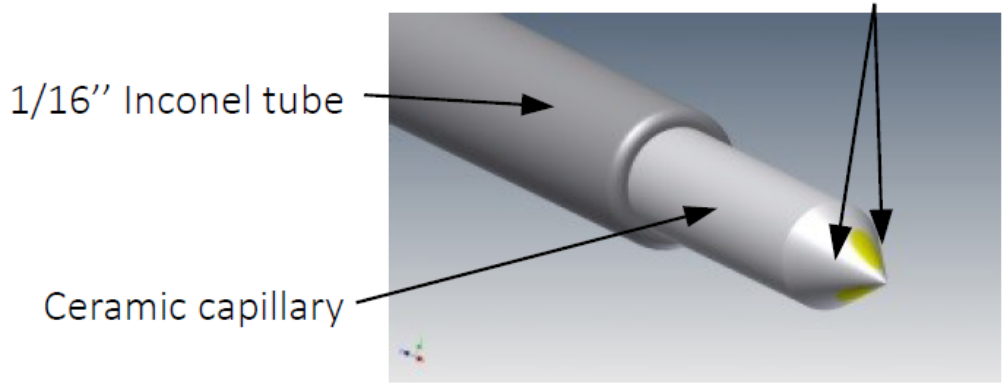
## ELECTRICAL PROBE

- Ceramic needle shape probes: minimum perturbation on the local flow.
- Sensor array close to pipe wall to capture thin layers.
- Holdups and bubble counts embedded computation. Binary output signal.
- Fast transient response.
- Conductivity detection down to fresh water.
- Direct oil detection in high water cut wells.

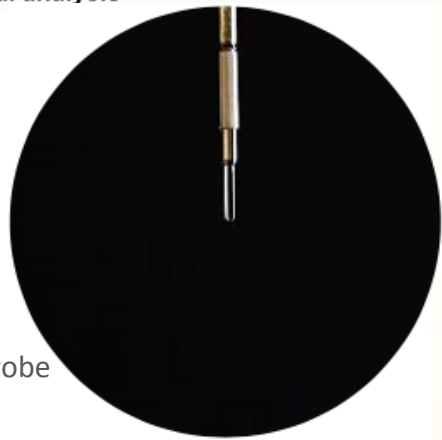
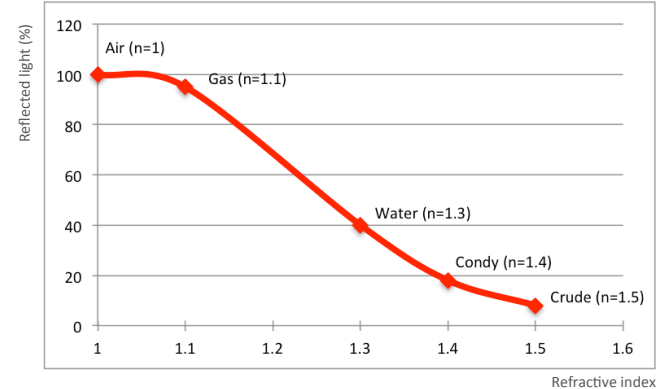
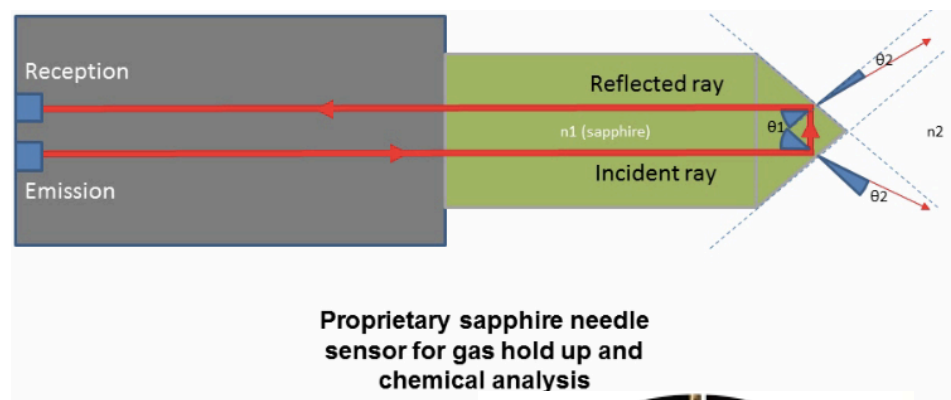
Electrical probe



Inconel Electrodes



## OPTICAL (TRI-PHASE) PROBE

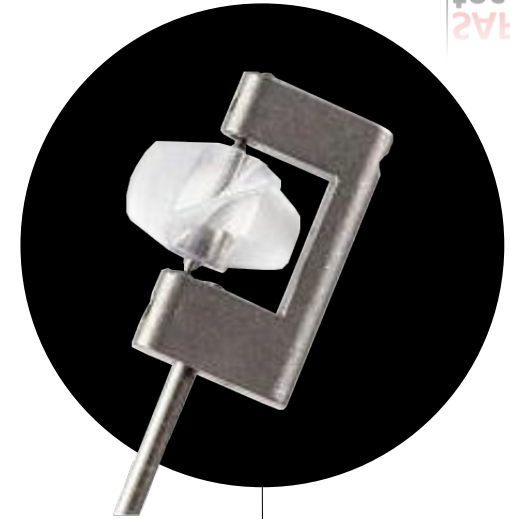


Tri-Phases Optical Probe

- Needle (Sapphire) shape probes: minimum perturbation on the local flow.
- Direct oil detection in high water cut wells.
- Ultra fast refractive index measurement for liquid/gas discrimination.
- Using Sapphire material for robustness and needle shape for self cleaning in multi-phasic conditions.
- Light emitter, photodetectors, coupler, digital output intergrated module: direct bubble counts and hold-ups computation.

## MICRO-SPINNERS

- Spinner works even bowspring is in fully closed position.
- No obstruction – spinners located at the side of arm (not behind).
- Spinner array close to pipe wall to capture fluid movement around tubing wall.
- No bearings, lighter material – good for ultra low velocities.



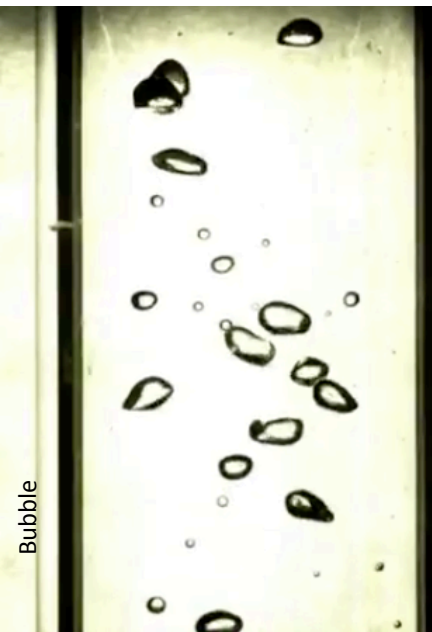
Micro-spinner

# I N N O V A T I V E M E A S U R E M E N T S

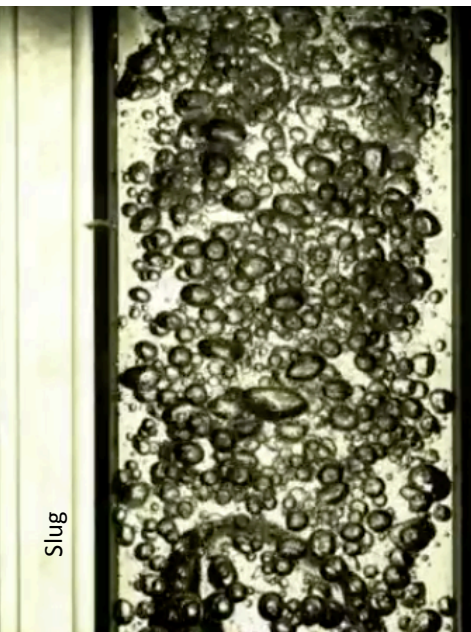
M U L T I P H A S E E N V I R O N M E N T S



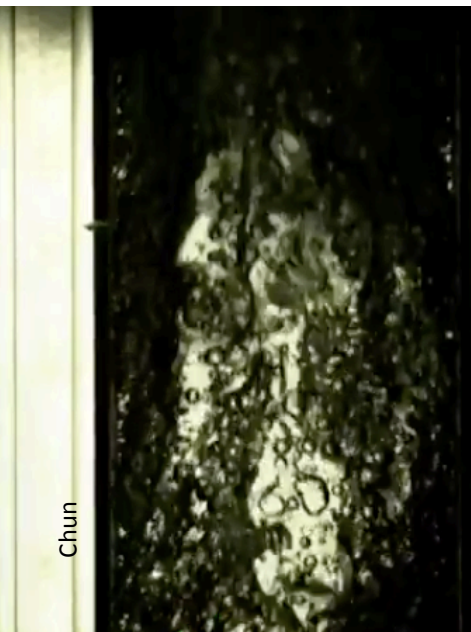
Sand production • Tri-phasic optical probe • FAST response platinum • RTD Differential pressure upcoming • Ultra high resolution MEMS pressure sensor • Doppler flow (secondary velocity measurement) • Sensor array close to pipe wall to capture thin layers • Variety of downhole fluid analysis sensors upcoming • MML (MEMS Magnetic Locator), magnetic depth correlation • Sensor configuration can be optimized for each production challenge • Water conductivity, holdups not affected by change in continuous medium • All probe measurements (fluid identification and velocities) performed at the same depth • Dual tool configuration for very high coverage, high resolution image and cross correlation interpretation.



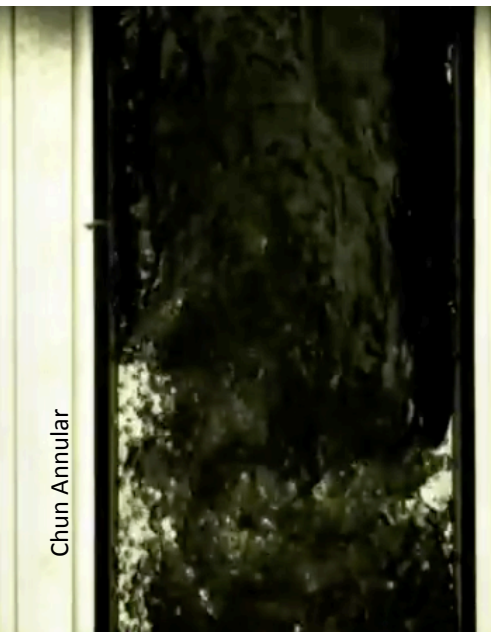
Bubble



Slug



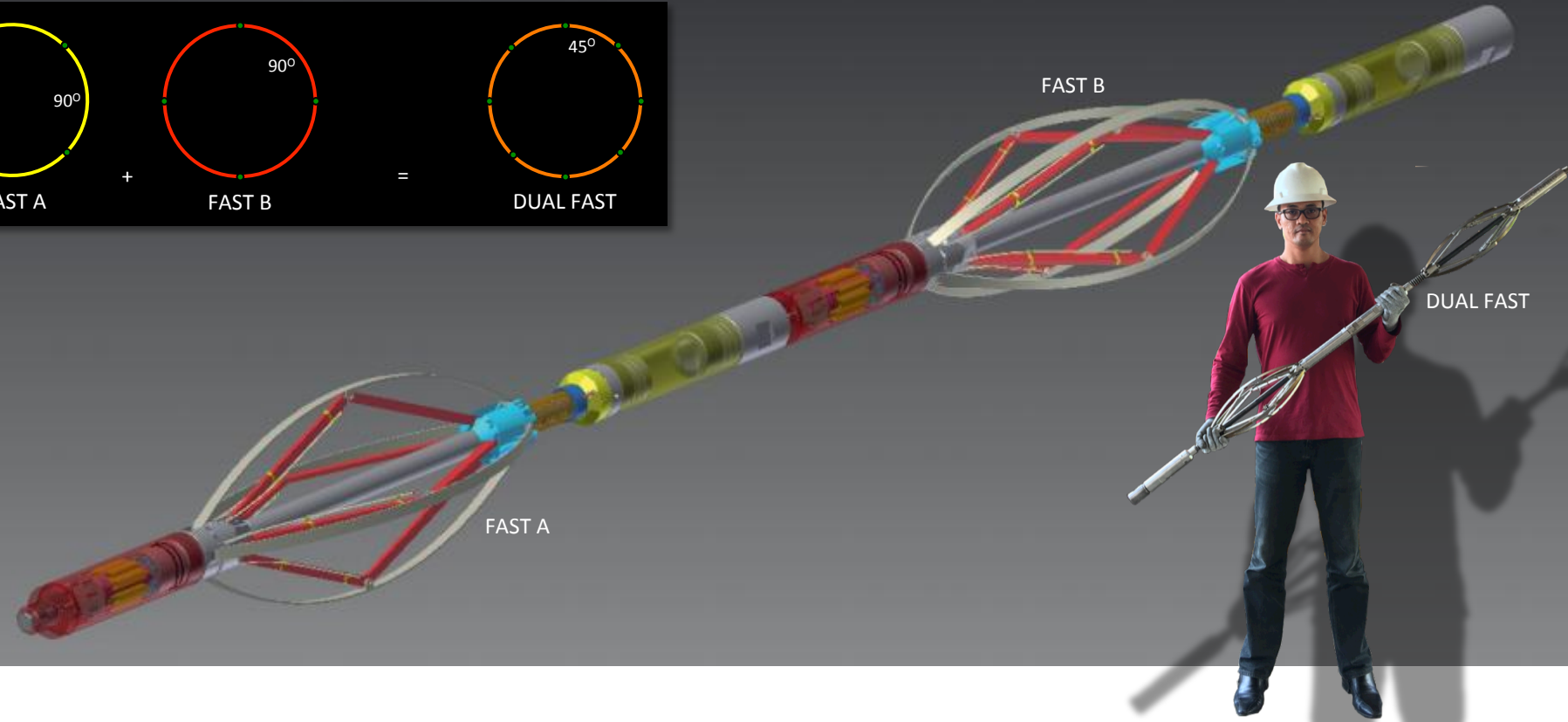
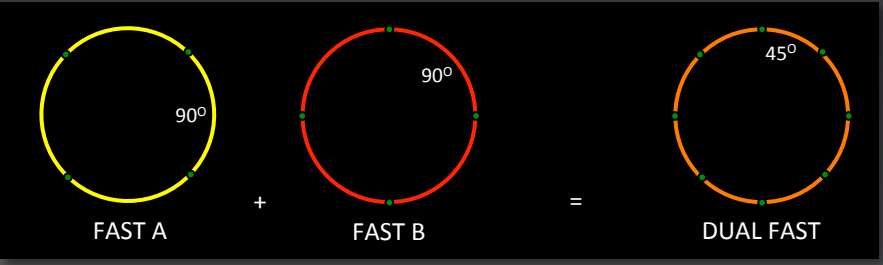
Churn



Churn Annular

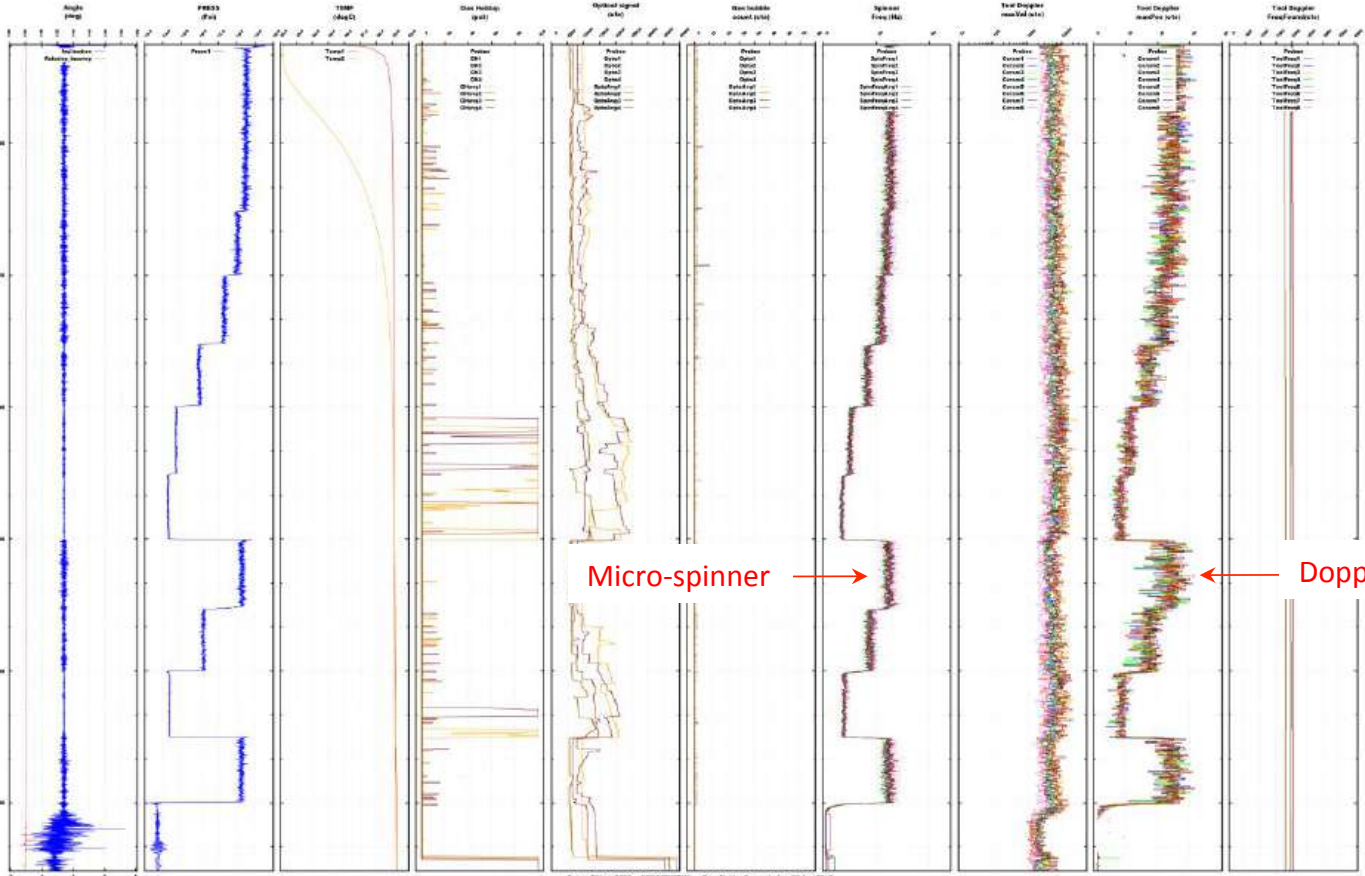
# MULTIPHASE FLOW ARRAY SENSING TOOL

DUAL CONFIGURATION FOR BETTER HIGH COVERAGE



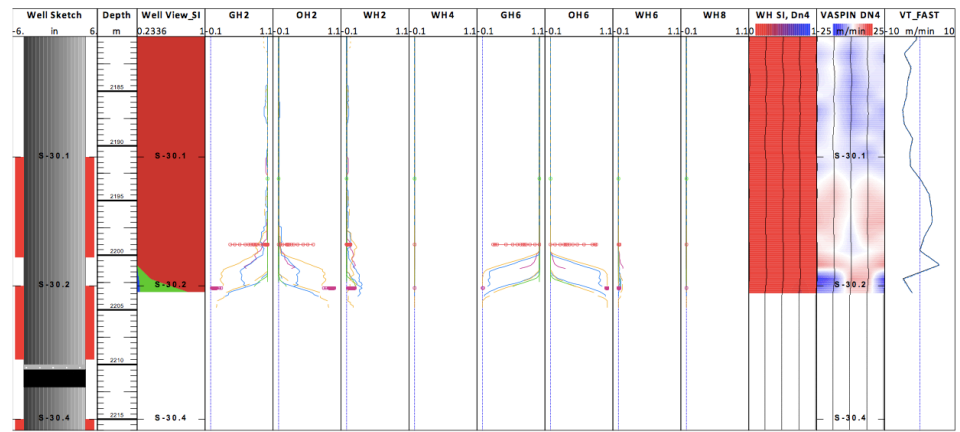
# F A S T C A S E S T U D I E S

LABORATORY - DOPPLER TEST INSIDE FLOW LOOP TUBE



- Water and air during flowtube test.
- Doppler and spinner flowrate measurement matches.

Sample FAST data with tri-phase probe..

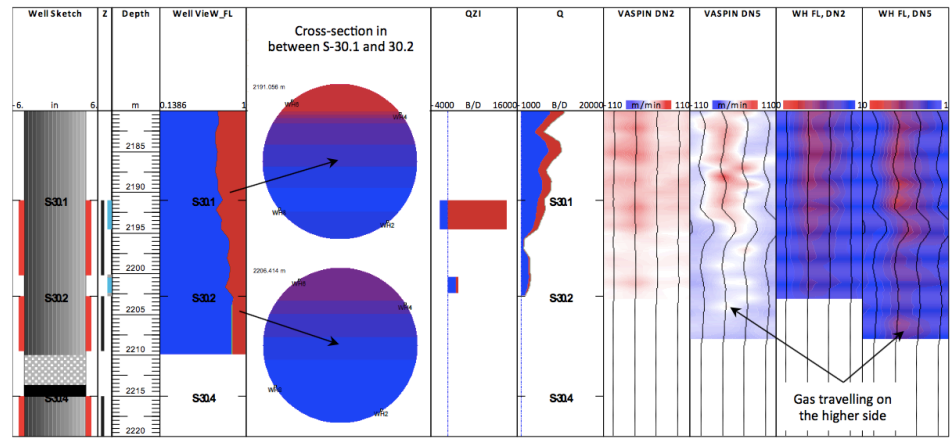


LEFT image:

- FAST with tri-phase probe data in gas well during shutin mode.
- Clear indication of liquid level can be seen to show unwanted condensate present at held-up depth.

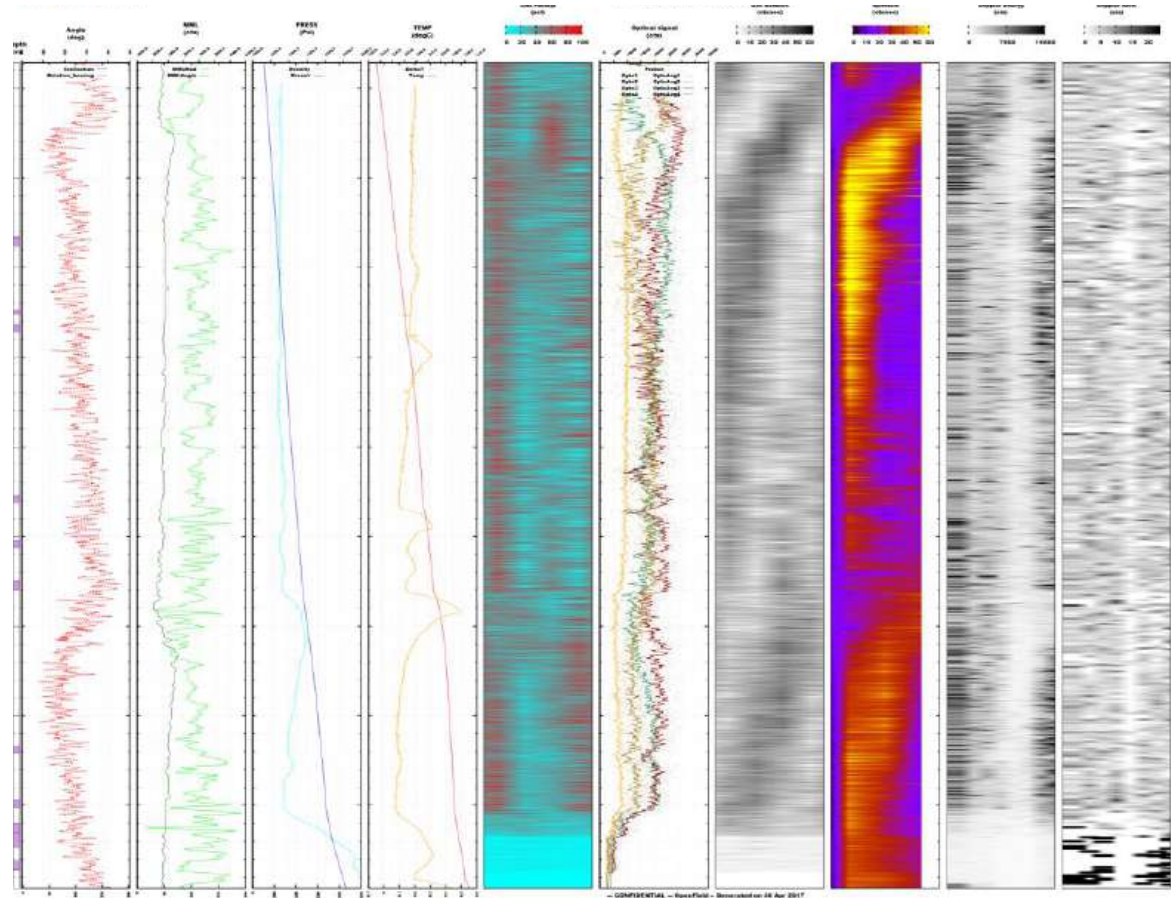
RIGHT image:

- Both micro-spinners and tri-phase probes agree each other.
- Fluid movement of light phase can be seen at the higher side of tubing.
- And heavy phase on the lower side of tubing.



# F A S T C A S E S E T U D I E S

DEVIATED - HORIZONTAL - HIGH WATERCUT - LOW FLOW



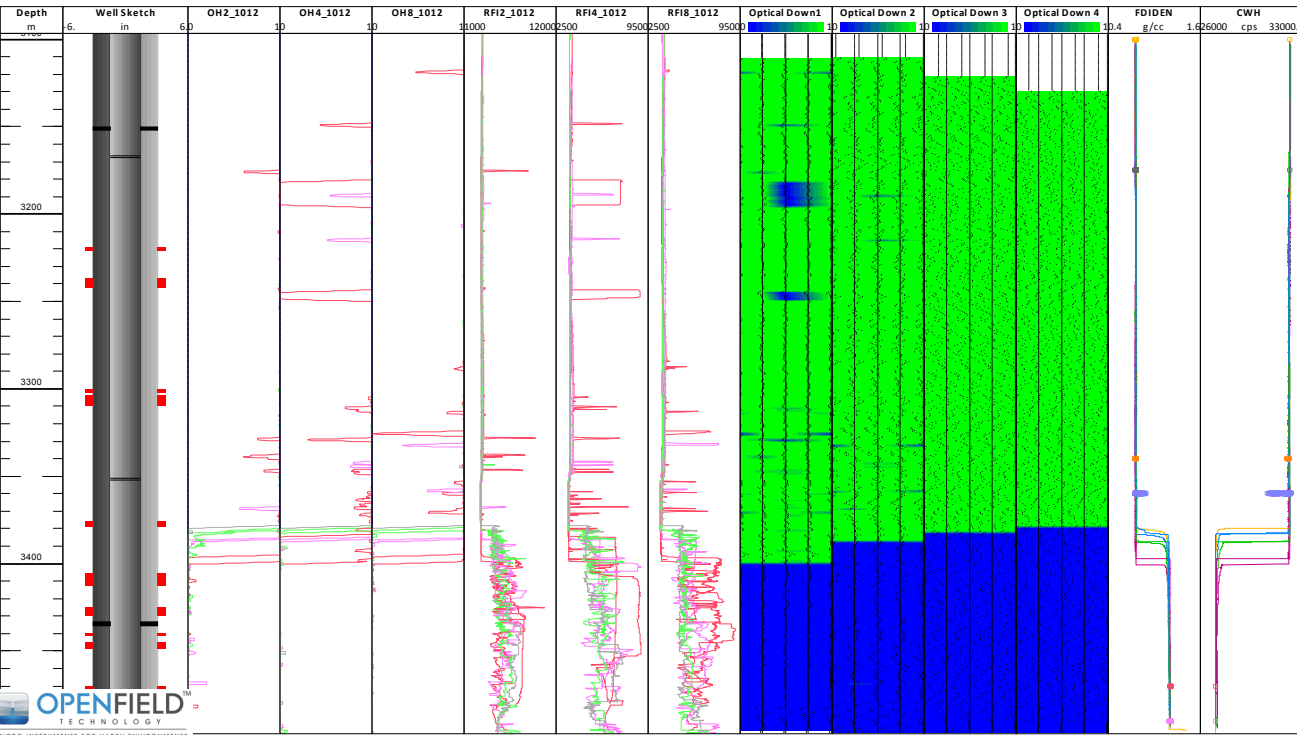
- Segregated flow.
- Rotating tool.
- Gas producing at 4100m.
- Very good agreement between spinners, doppler and optical probes.

# F A S T C A S E S T U D I E S

## DEVIATED - HORIZONTAL - HIGH WATERCUT - LOW FLOW



- Oil - water interface in a heavy oil well, where probes/tool can get coated.
- Optical probes are showing a perfect agreement with FDI density and CWH capacitance.



TUNISIA - OIL WATER HOLDUP FROM OPTICAL PROBES

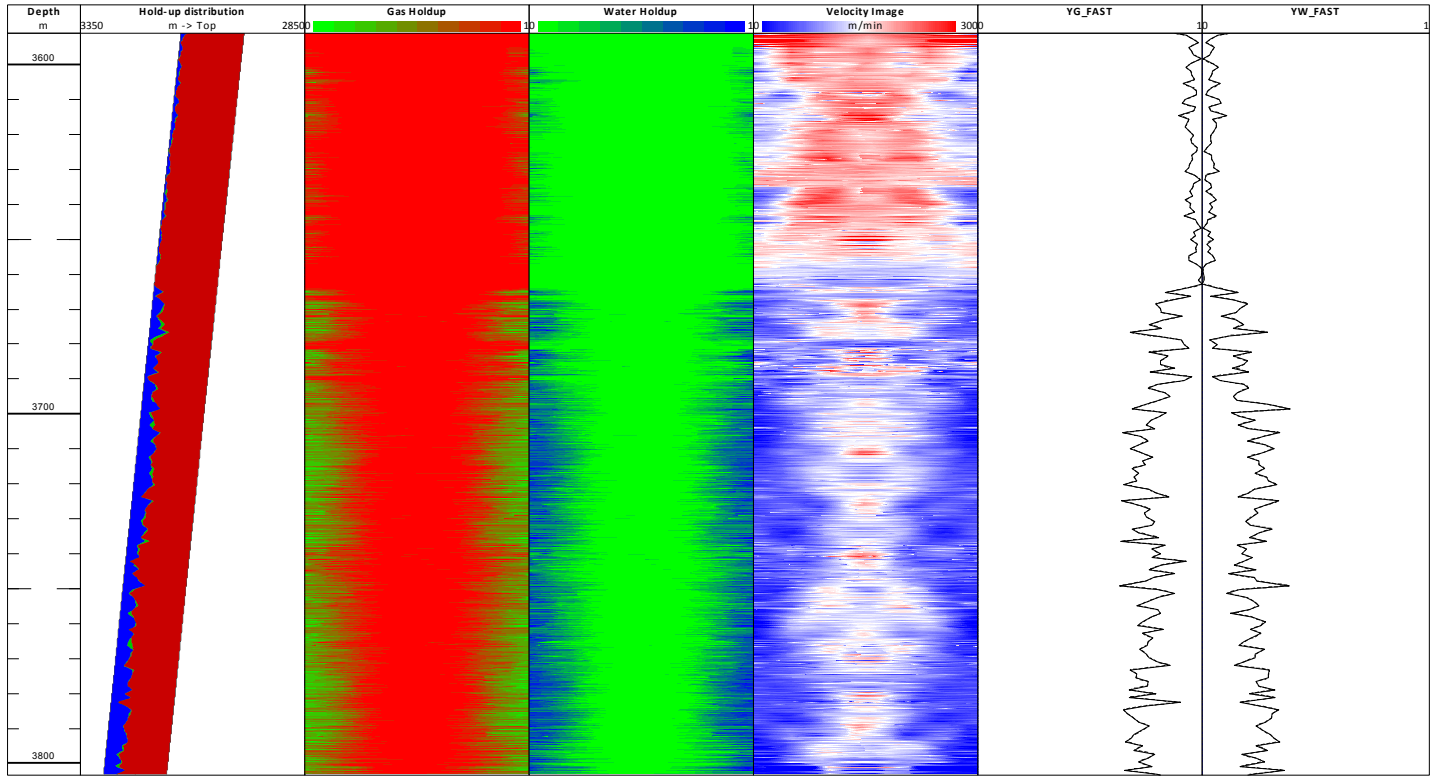


# F A S T C A S E S T U D I E S

## COMPARISON BETWEEN FAST TOOL AND FSI TOOL



- Holdups and velocity in gas well with condensate and water.



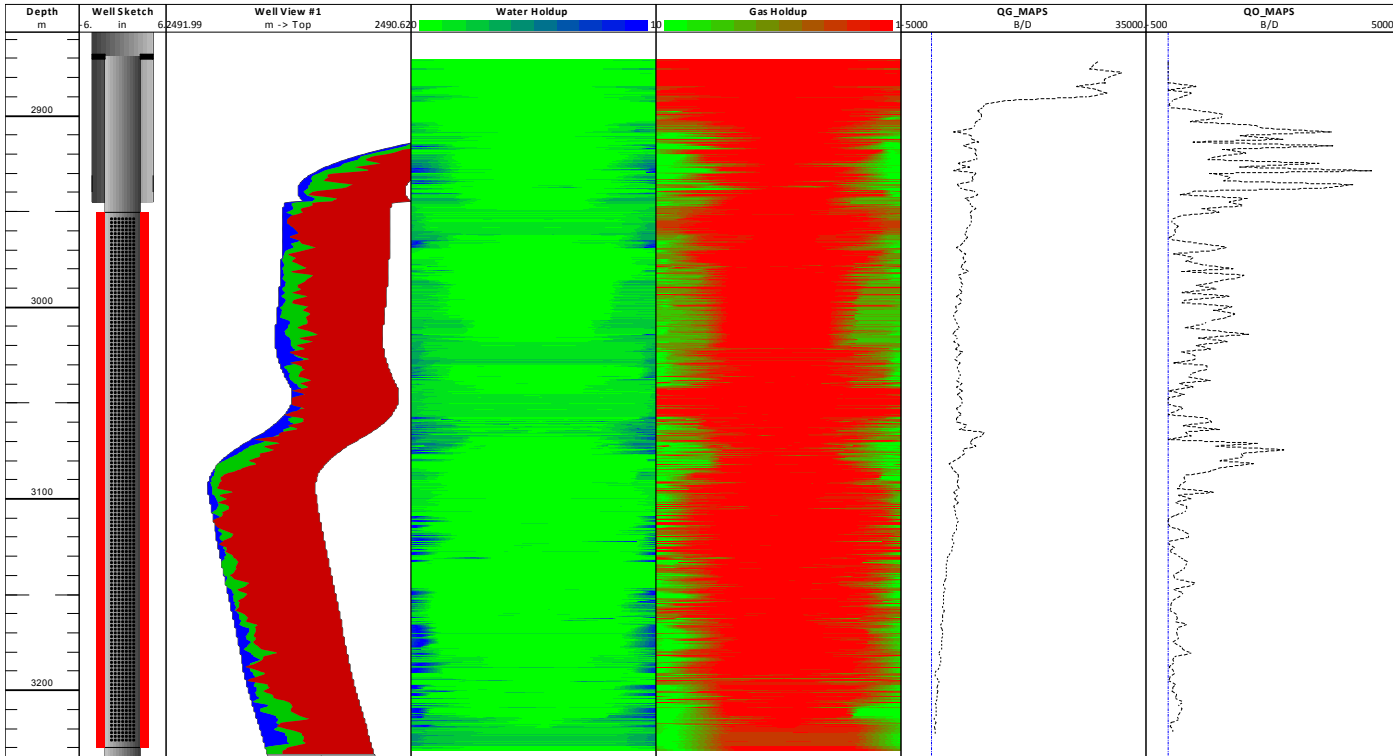
CONGO - HOLDUPS AND VELOCITY

# F A S T C A S E S E S T U D I E S

COMPARISON BETWEEN FAST TOOL AND FSI TOOL



- Multiphase rate calculation from FAST optical holdup and mini-spinners in a horizontal well.



IVC - HORIZONTAL WELL

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## FSI

- 30 ft.
- 49 kg.
- 150degC – 15000psi.
- 5 spinners and 6 fluid identification sensors located across the well section diameter.
- Max opening 6”.

## FAST

- 3 ft.
- 5 kg.
- 150degC – 15000psi.
- 8 inter-changeable sensors located around the well section perimeter, close to pipe wall.
- Max opening 7”.

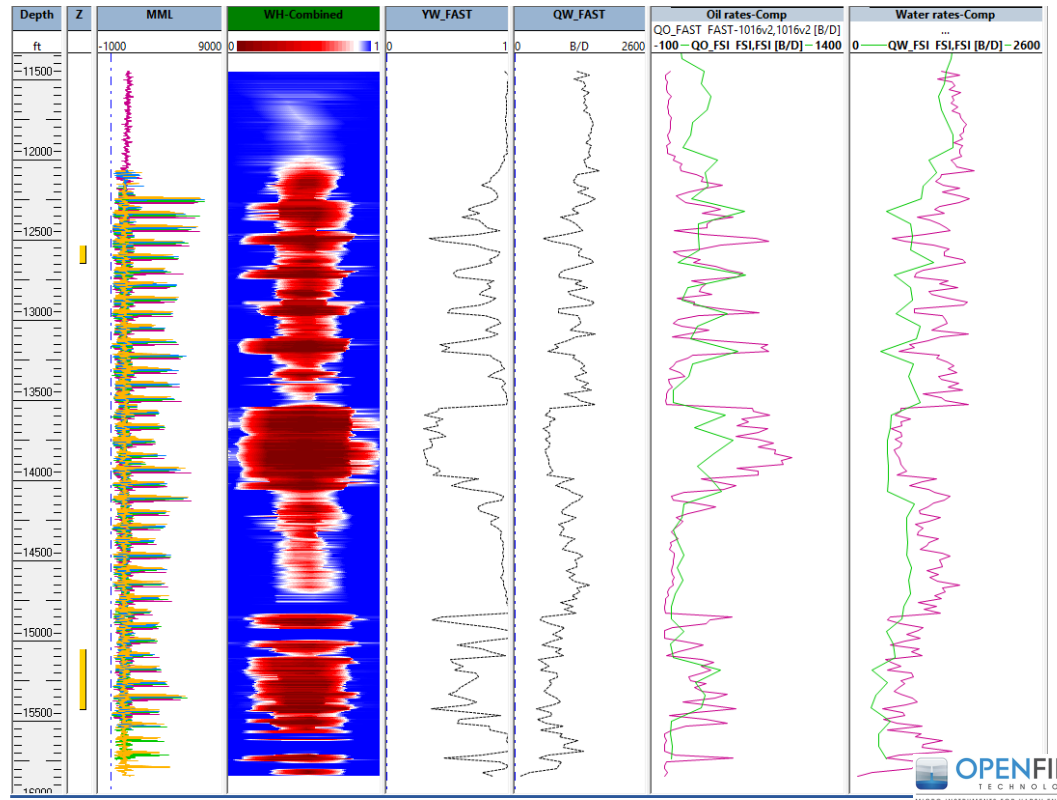
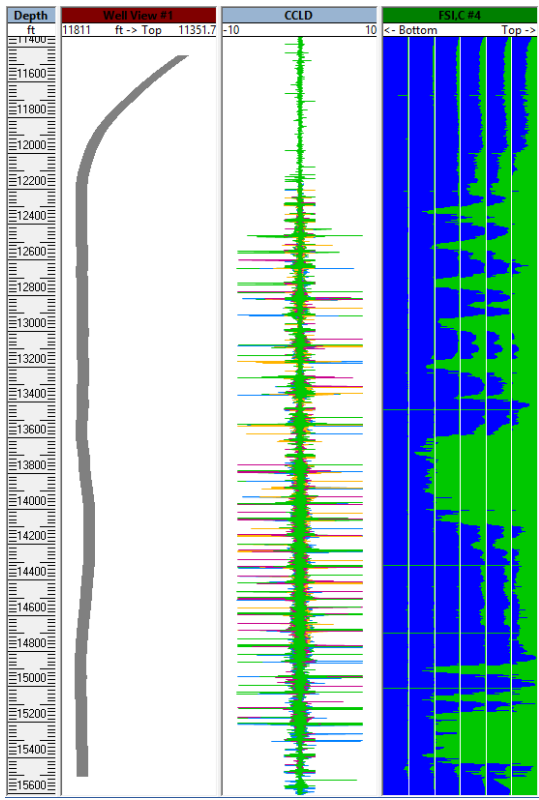


# F A S T C A S E S T U D I E S

COMPARISON BETWEEN FAST TOOL AND FSI TOOL



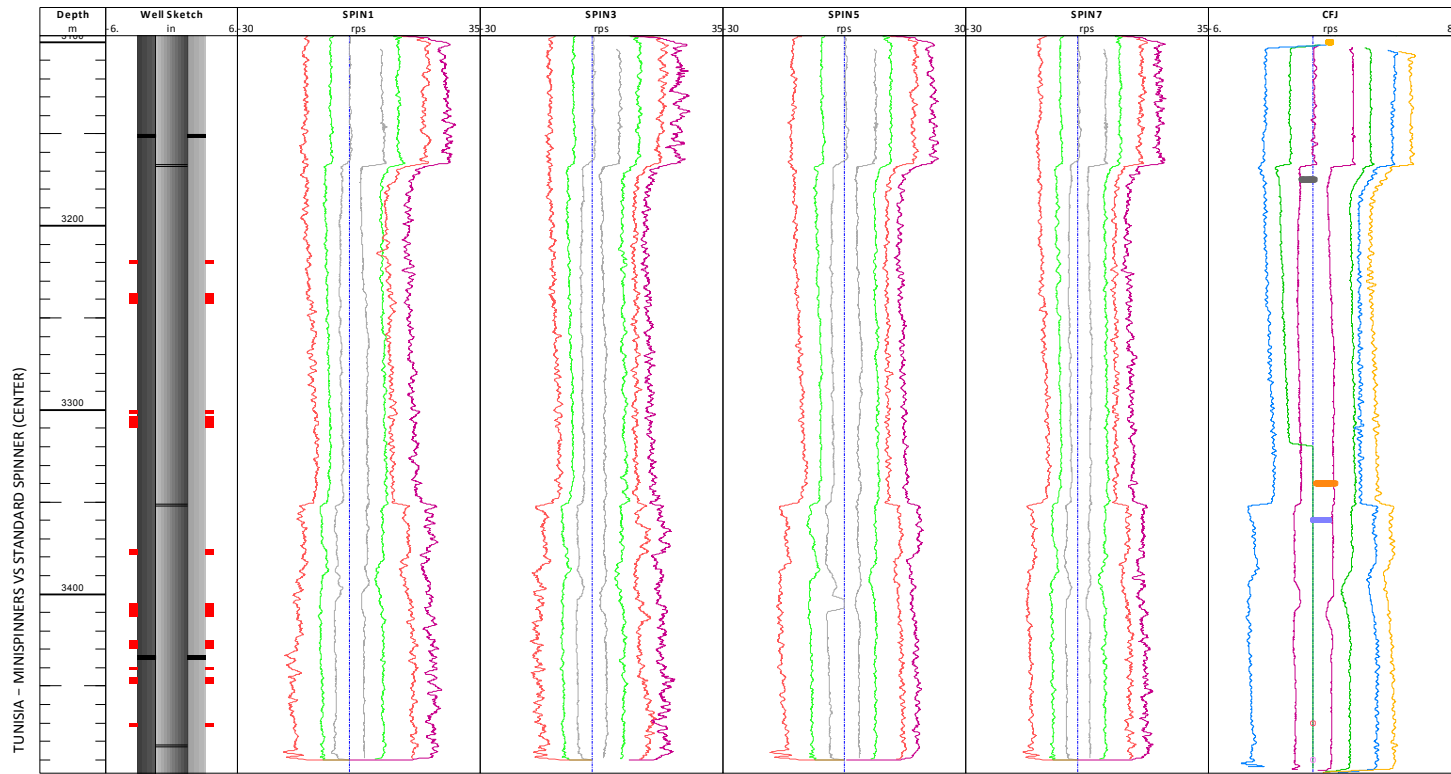
- Fair matches of oil and water rates from FAST vs FSI.



# FAST COMPARISON BETWEEN FAST AND CFJ



- FAST micro-spinners show a much larger sensitivity (~4 times higher) than the CFJ spinner.
- This is reflected in the spinner of the calibration plot.

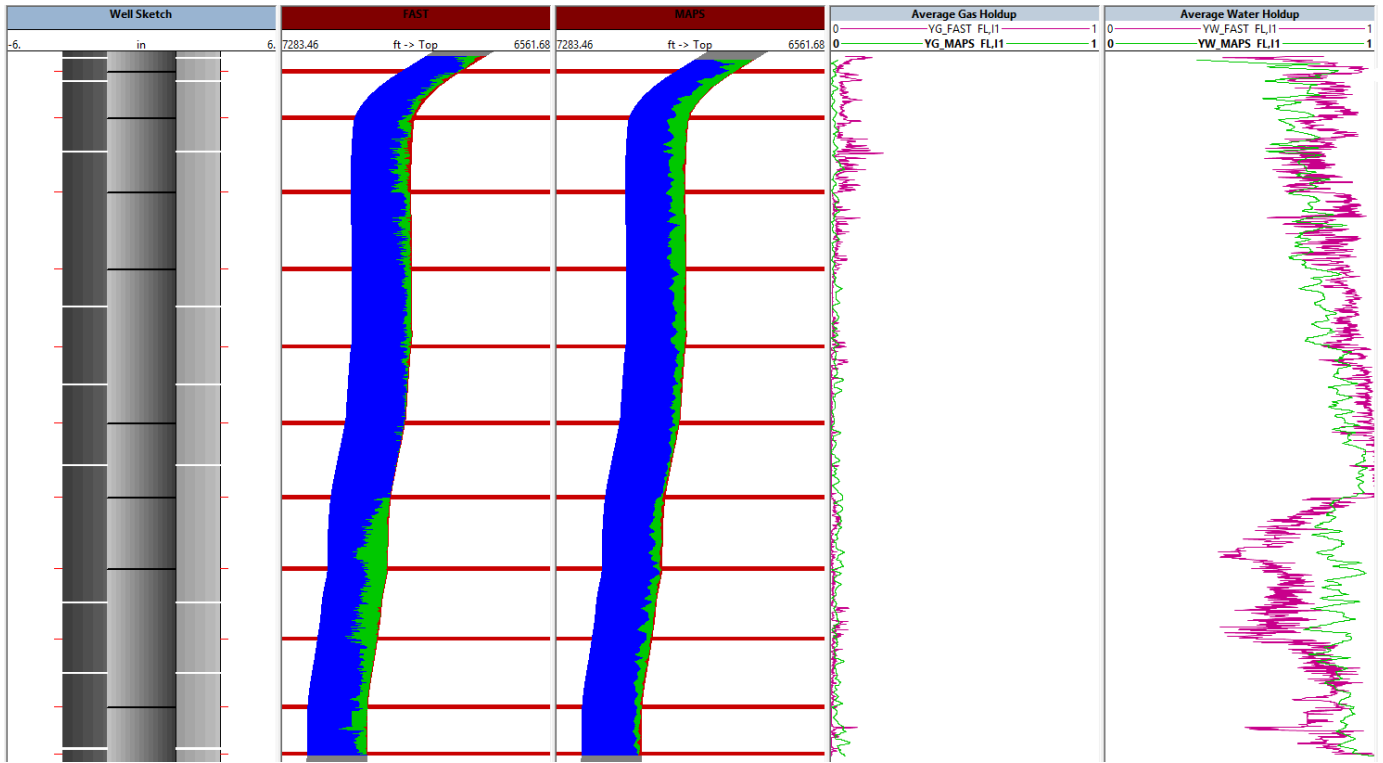


# F A S T C A S E S T U D I E S

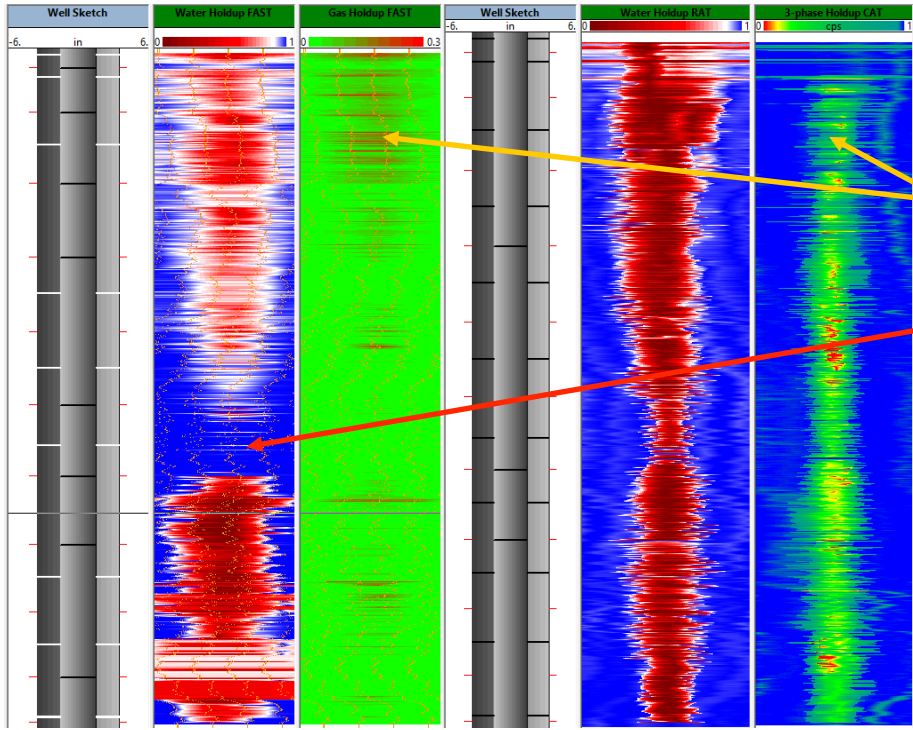
COMPARISON BETWEEN FAST AND SONDEX GEMAPS



- Comparison of the average holdup computation using 4 optical FAST probes, vs. 12 CAT capacitance and 12 RAT resistance.
- Good agreement between both tools, with FAST being less than 1/3 of the length of CAT-RAT combined.



### FAST HOLD-UP COMPARISON WITH MAPS



4 FAST optical probes vs. 12 RAT and 12 CAT probes.

FAST is able to distinguish the gas from the oil, in sections where CAT struggles.

FAST underestimates the hydrocarbon hold-up in one section due to the limited coverage of the cross section of the pipe. This can be solved by adding a second FAST with an angular offset.

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