General

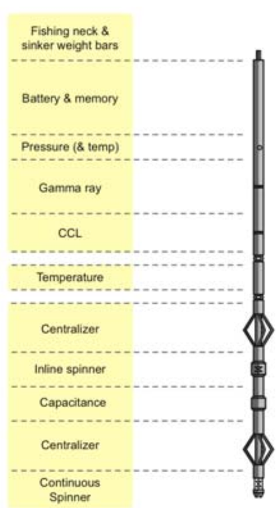
KAPPA

PRODUCTION LOGGING
TOOLS

Module #4 TOOLS GENERAL

04

Typical PL Toolstring



No.	Tool Length (meters)	Outside Diameter (inches)
1	0.4670	1 11/16
2	0.476	1 11/16
3	0.306	1 11/16
4	0.675	1 11/16
5	0.468	1 11/16
6	0.171	1 11/16
7	0.316	1 11/16
8	0.171	1 11/16
9	0.613	1 11/16
10	0.440	2 1/8
11	0.664	2 1/8
12	0.613	1 11/16
13	0.557	2 1/8

Sondex MPLT string

04

Adapters

Courtesy: **Sondex**

Swivel Joint

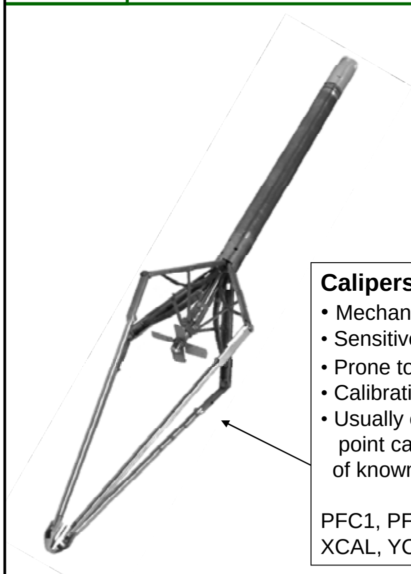
Knuckle Joint

Adapters

Bullnose

04

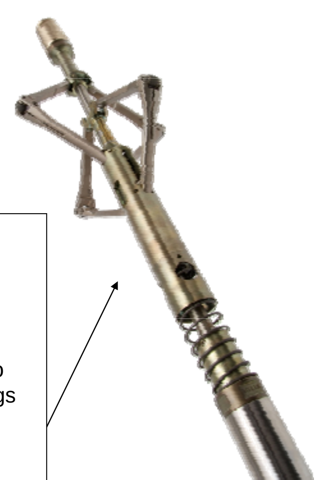
Calipers



Calipers

- Mechanical devices
- Sensitive readings
- Prone to sticking
- Calibration can shift
- Usually calibrated with a two point calibration using 2 rings of known diameters.

PFC1, PFC2 - Schlumberger
XCAL, YCAL - Sondex



04

Tool Summary Auxiliary Measurements

Basic Measurements

- Caliper – measures diameter of the wellbore
- Deviation – realtime measurement of deviation at the tool
- Head tension – tension or compression at the logging tool head
- Cable tension – tension in the logging cable at surface

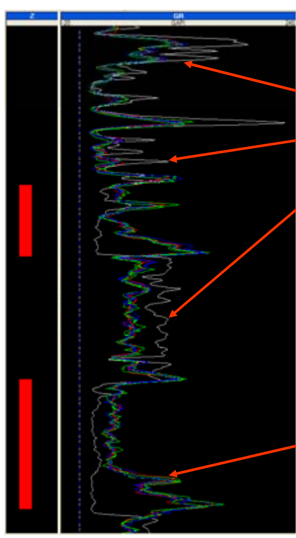
Depth control

- Gamma Ray – counts GR's with an unfocussed detector
- Casing Collar Locator – responds to changes in metal thickness

Other

- Pulsed Neutron – Oxygen Activation
- Noise log
- Tracer

Open hole GR



White Open hole GR is higher
than the PL GR curves
Normal response for calibrated GR

Coloured PL GR curves are higher
than the white Open hole GR
Probably due to there being radioactive
scale deposits in front of the perfs.
(Indicative of water production)

Tool Connections

Telemetry errors

Tool communication problems

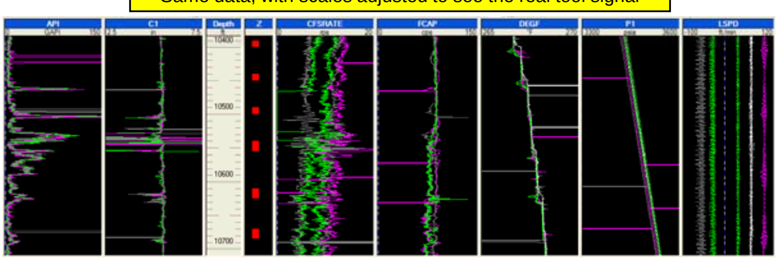
Spikes on data

04

Signal vs Noise

Note: Track scales indicating noise spikes on top of data

Same data, with scales adjusted to see the real tool signal



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Tools Summary

Flowmeters	- Fluid Velocity
Density	- Fluid mixture or hold up
Capacitance	- Water holdup
Pressure	- Pressure profiles & Pseudo-density & SIP
Temperature	- Variations from the gradient (flow analysis) Input to pressure measurement (gauge calibration)
Press &Temp	- Needed to compute fluid properties - PVT

04

Tool Summary Main Measurements

Single phase profiles

- Temperature (for PVT)
- Pressure (for PVT)
- Spinner/flowmeter
- Caliper

Multi-phase profiles

- Density, Gradiomanometer
- Capacitance
- Gas holdup
- Imaging/probe/array tools
- Direct velocity measurements

04

QA/QC: Caliper

- Check for repeatability
- Try to identify perforation position – sometimes slight swelling/enlargement of casing at perfs
- Verify tool calibration – in known completion ID
- Compare caliper readings with relative bearing where available – is casing really ovalised?
- Always present all calipers C1, C2 & C1C2 on same scale for comparison purposes
- Check changes in caliper against changes in spinner response
- Make sure a caliper is inside the interpretation node, or in the General Well Data in EMERAUDE

QA/QC: CCL

- Check for repeatability
- Confirm CCL against wellsketch, completion diagram, tubing shoe, pipe tally, packers, reference CCL log, etc
- See if perfs show on CCL
- Stuck tool - Use CCL background noise to see if tool is moving downhole (analog signal)
- Adjust the scale to show sensitivity
- Does not respond in non-magnetic tubulars
- Sensitivity will depend on casing size, centralizing of the tool and logging speed.

QA/QC: Gamma Ray

- Check for repeatability between passes
- It is the first level of lithology indicator.
- Check for dynamic range of GR .. normally 0-120API +/-
- Verify that perforation depths agree with the GR log
- Often use the first slow UP pass for correlation with OHGR
- Check depth control with open hole GR reference.. Adjust depths if necessary
- Compare PL GR vs Open hole GR
- Above normal GR could be due to deposits of radioactive salts/sulphates – check caliper for buildups on ID – possible indicator of water production
- Low values of PL GR compared with OH GR could be due to extra hardware between tool and formation

QA/QC: Gamma Ray (contd)

- GR will show sensitivity with change of metal thickness.. eg multiple tubulars, inside packer sealbore.
- Look for RA pip tags – Repeatable spikes of very high API
- Try to confirm perforation zones have some “agreement” with the GR log
- Slow passes should show better definition/resolution
- Do not correlate on peaks - Correlate on large “shoulders” of GR contrast
- Tool sensitivity could be affected by a cracked measure crystal.
- High temperatures could affect the performance of the detector

FLOWMETERS

KAPPA

TOOLS

Module #5 Flowmeters

Flowmeters

Flowmeters measure fluid movement…..
Hence they are used to detect flow phenomena, for example:

- Where is the flow coming from?
- Are all perforations flowing?
- Is there crossflow?
- Are there any leaks?

Flowmeters

Courtesy - SONDEX

One of the simplest but most important tools in the PL string

Measures: RPS

But we need:
- FLUID VELOCITY
- RATE

Fullbore Inline/Continuous Diverter/Basket

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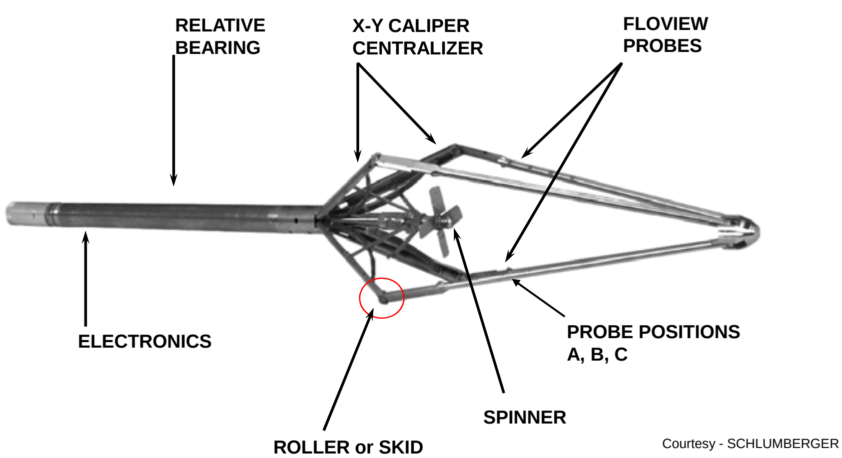
Schlumberger PFCS



Courtesy - SCHLUMBERGER

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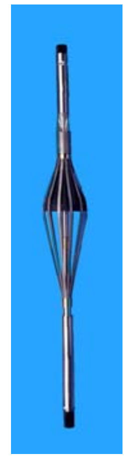
Flowmeter Types





Fullbore Spinner 3-arm | **Fullbore Spinner 6-arm** | **Continuous Spinner** | **Continuous Spinner Jewelled** | **In-line Spinner** | **Diverter Flowmeter**

Courtesy - SONDEX

More Spinners





Courtesy - SONDEX

Sondex Flowmeters

Courtesy - SONDEX

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Weatherford: Spinner & Temperature

Courtesy - WEATHERFORD

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Flowmeter Types

In line Flowmeters
- Small spinner
- Good for high flowrates/velocities – low sensitivity
- Can log in restricted diameters – tubing, scaled up wells, etc

Full bore Flowmeters
- Maximum spinner blade size
- Best for wide range of flowrates – good sensitivity
- Possible problem in injectors, blades collapse with flow from above

Petal Basket
- Stationary measurement only
- Good for low flowrates
- Typically < 2000bbl/d (320m3/d)
- Will probably affect the flow regime

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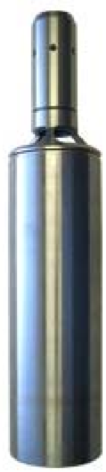
Mono-bore completion Flowmeter

Used in monobore completions in "Shallow-Gas" wells in Canada



Courtesy: SPARTEK

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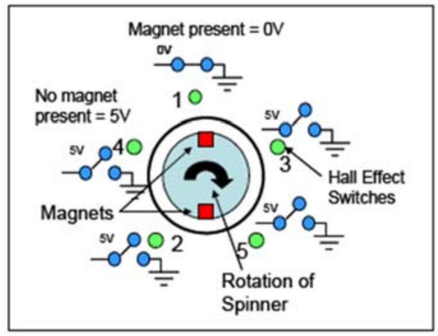
HALL effect

- The spinner action rotates the magnets, which pass the powered Hall effect switches
- Magnet present – switch is closed
- No magnet – switch is open
- The switches are opened and closed giving 10 pulses per revolution
- By counting the switchrate, and the order of closing, the direction of rotation and the RPS are measured



Courtesy - SONDEX

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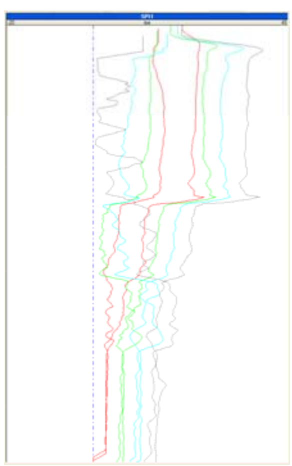
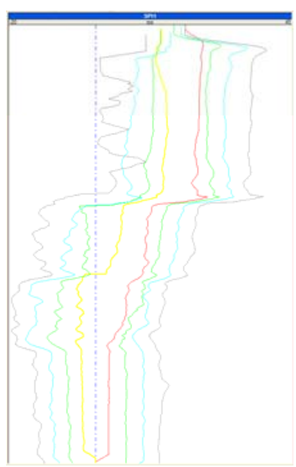
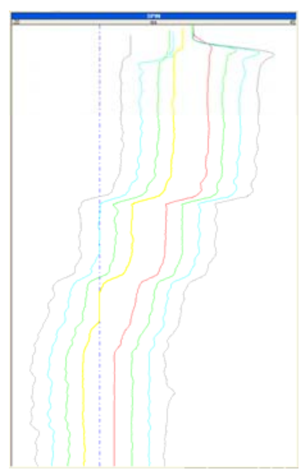
Spinner Reversal



Unsigned
Inline spinner



Reversed unsigned
Inline spinner



Signed (normal)
Fullbore spinner

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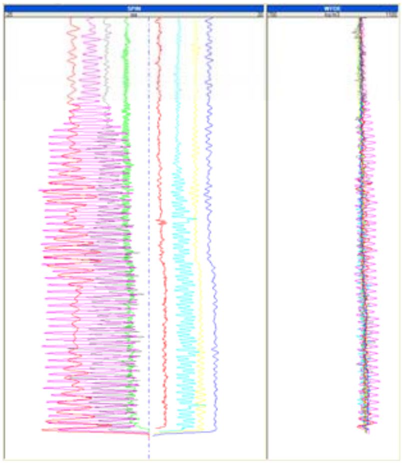
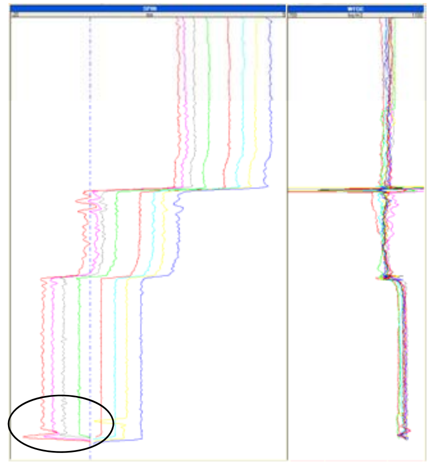
Yo yo - Stick & slip





Well shut in – “stick & slip” motion entire logging interval

Well flowing – no “stick & slip” “yo-yo” effect at start of up passes

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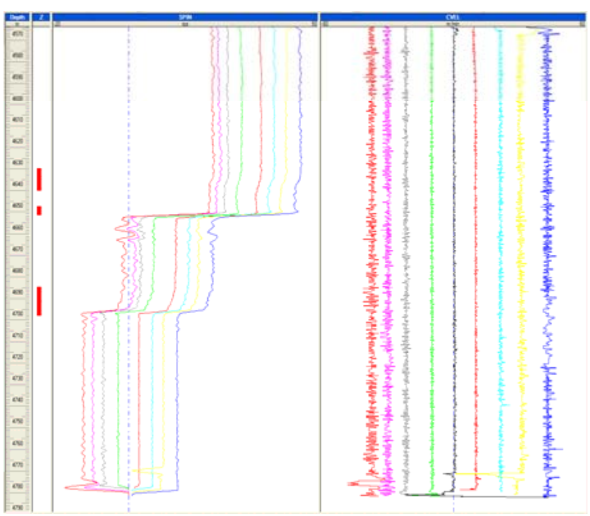
Typical Flowmeter Log



- Several passes have been made at different speeds.
- Producing well
- Signed spinner
- How long did it take to record all these passes?
- Was the well stable throughout this period?
- Did the tool condition remain the same throughout this survey period?

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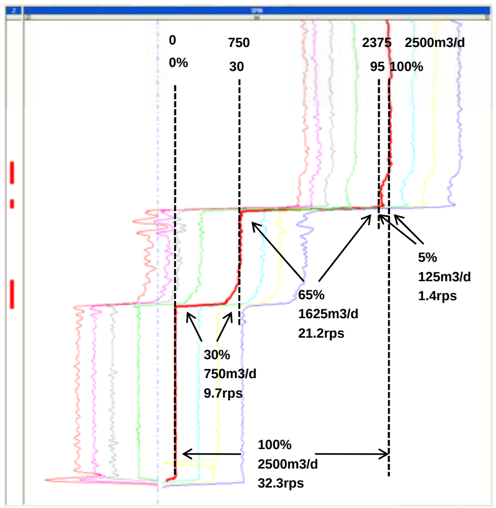
Simple Spinner Interpretation

- Maximum spinner response is normalized to surface flowrate
- Zero flow area spinner response is normalized to zero flow
- Can work in simple single-phase flow e.g. water injector monophasic producer
- Does not work in multiphase flow, or in changing fluid properties (viscosity)



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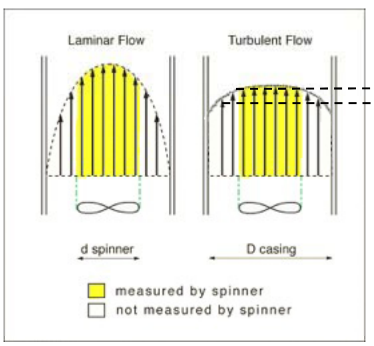
Flow in Pipes



VAPP – velocity as seen by the spinner

Vm – average mixture velocity in the pipe area needed for rate calculation

$$V_m = VPCF \cdot Vapp$$

The velocity profile correction factor, VPCF, was historically taken as 0.83

The velocity profile correction factor actually depends on Reynolds number

$$N_{re} = Area.Velocity.Density/Viscosity$$

The spinner, centered in the borehole, sees only the middle part of this flow since the blade does not cover the full casing diameter

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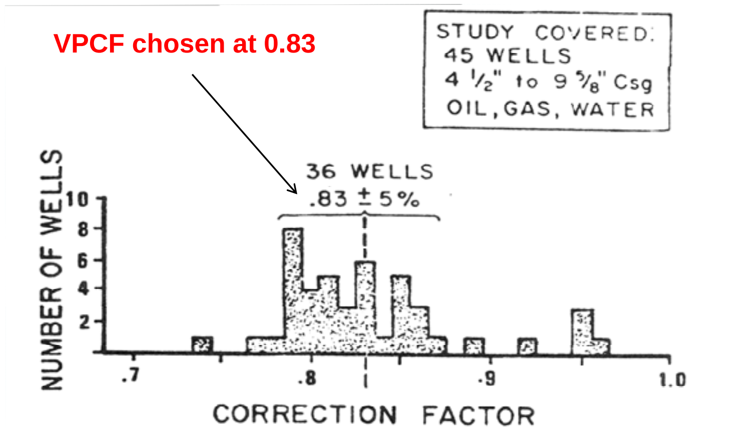
VPCF Experimental Basis

Courtesy: **Schlumberger**



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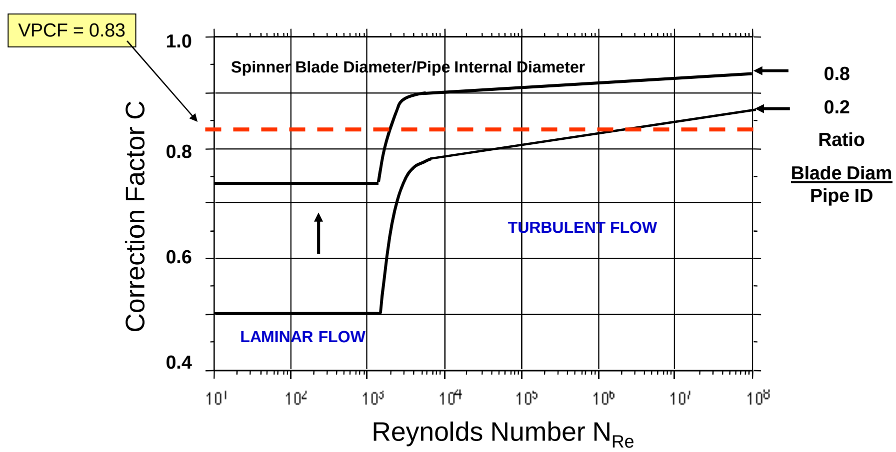
Flowmeters: Velocity Correction



The correction depends on whether there is laminar or turbulent flow, which is determined by the Reynolds number.

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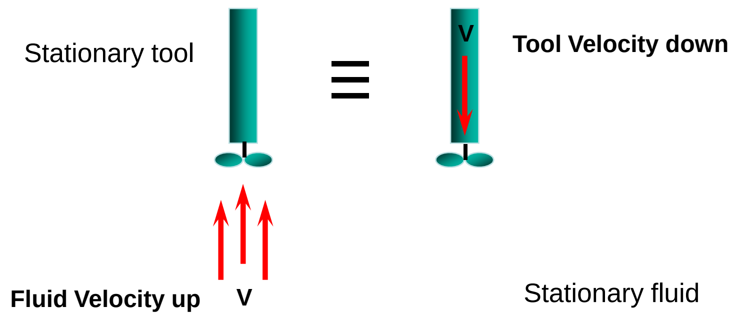
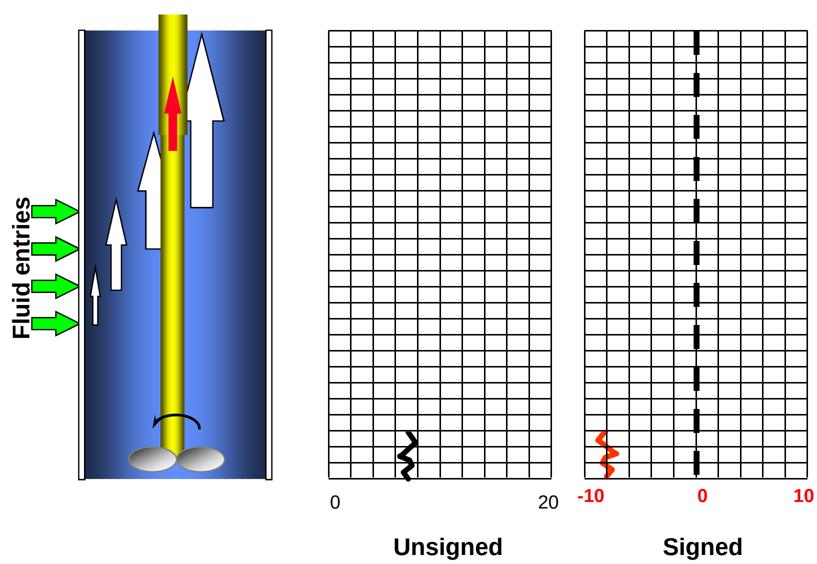
Spinner Response

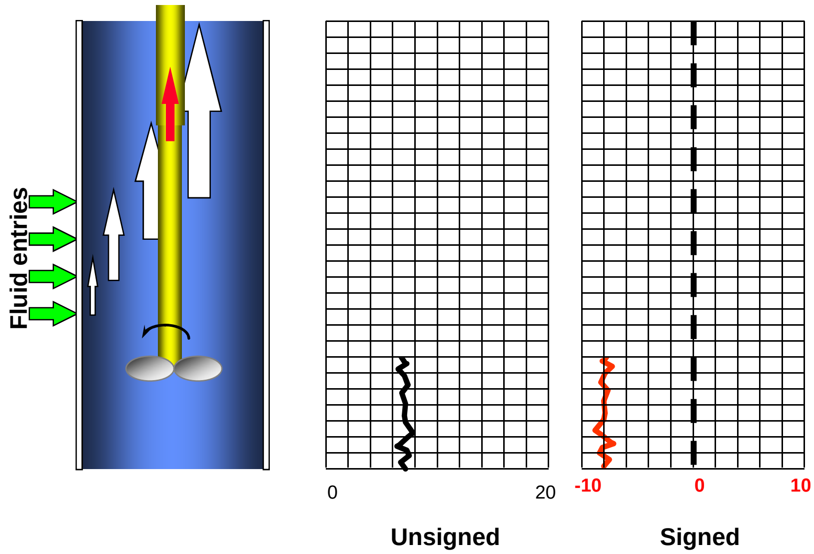
The flowmeter measurement relies on
relative **fluid - tool velocity**



Non-directional vs Directional Spinner Response



Non-directional vs Directional Spinner Response



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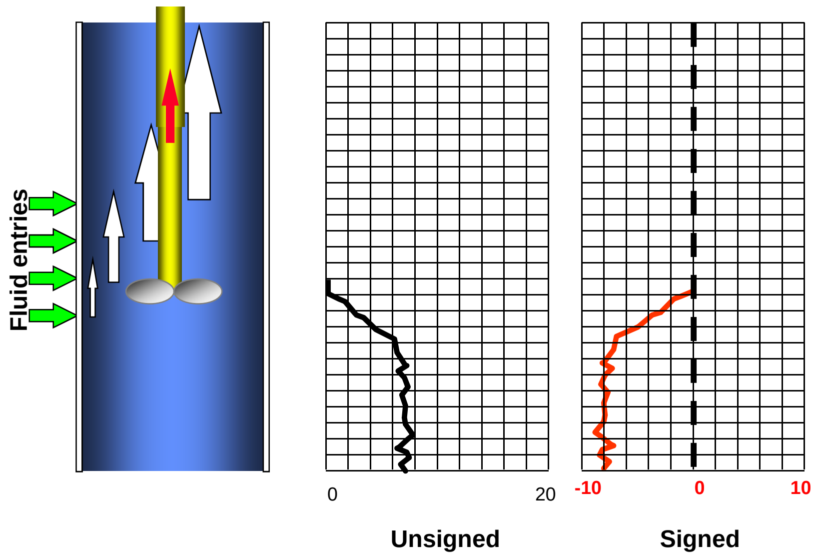
Non-directional vs Directional Spinner Response



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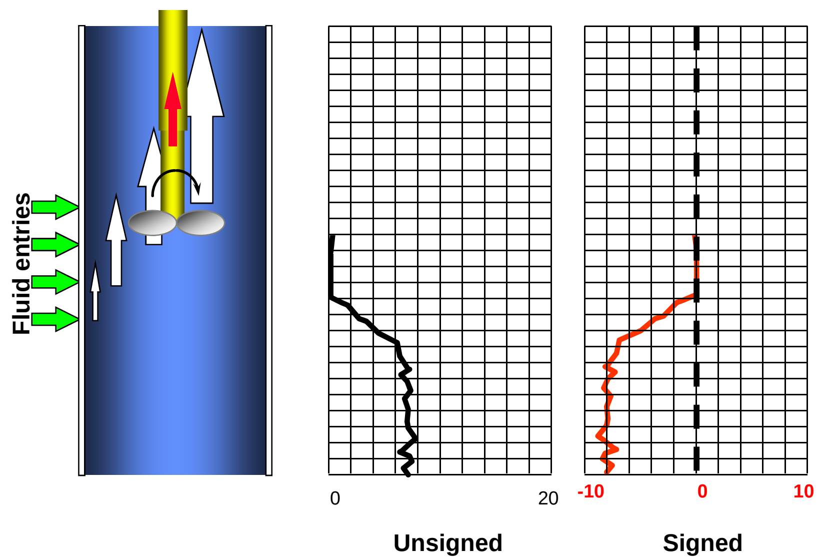
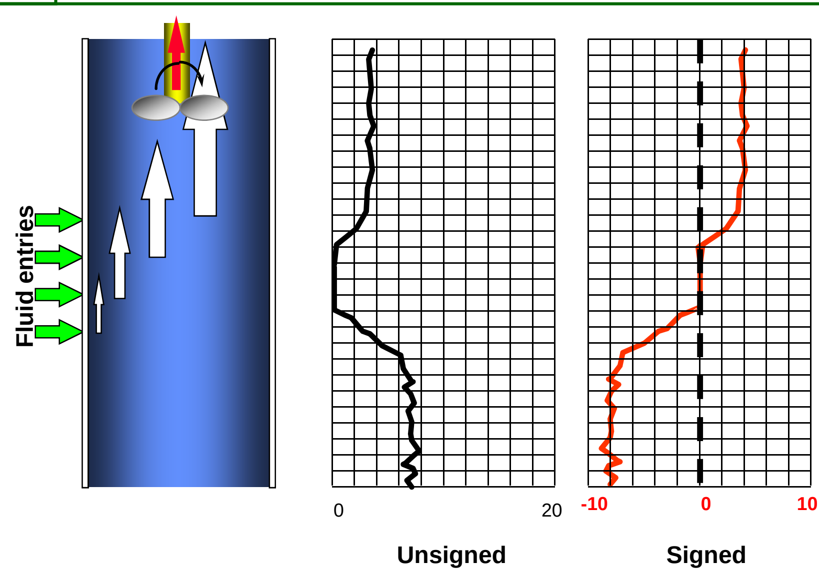
Non-directional vs Directional Spinner Response



Non-directional vs Directional Spinner Response



Spinner Reversal

- Spinner reversal (change of direction of rotation) occurs when the relative velocity between the tool to the wellbore fluid changes from positive to negative
- Typically occurs on the UP passes at the first fluid entry (Be careful with injectors!!)
- It can be difficult to see the reversal if the spinner never actually goes to zero rps. Averaging of spinner data, and filtering during acquisition can make it difficult to identify reversals.
- A spinner calibration plot will quickly indicate the occurrence of a spinner reversal.

Calibration of Spinners

- The tool measures RPS as the fluid moves past the impeller
- The actual RPS are also dependent on the logging speed, direction of the tool and the pitch of the spinner.
- The response slope, or sensitivity, is in RPS per ft/min
- The threshold velocity is the relative flow velocity required to start the spinner rotating
- In a typical producing well the spinner reads higher running into the well (against the flow) than running out (with the flow) at the same speed.
- To find the actual fluid velocity the spinner must be calibrated at downhole conditions – **IN-SITU CALIBRATION**

IN THE PHASE OF INTEREST!!!

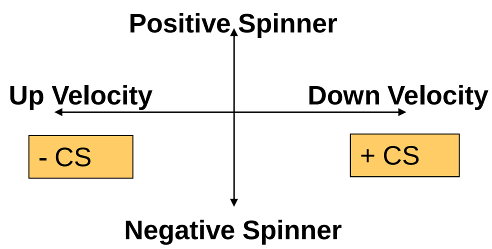
Kappa Conventions

POSITIVE cable velocity when tool is logging DOWN

POSITIVE spinner rps when the relative flow is from below the spinner

NEGATIVE cable velocity when tool is logging UP

NEGATIVE spinner rps when the relative flow is from above the spinner



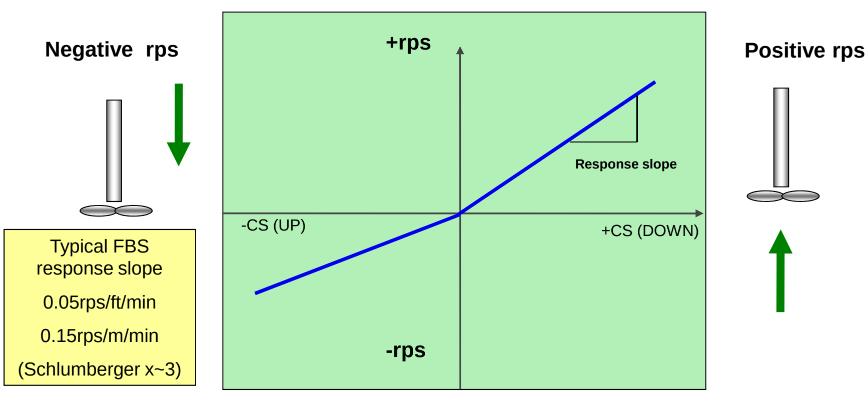
Ideal response: Zero Flow

$$rps = a \times V_{fs}$$

rps: frequency of rotation

V_{fs}: fluid velocity, relative to spinner

a: pitch coefficient, function of tool geometry



Real response: Zero Flow

$$rps = aV_{fs} - \frac{b}{\rho V_{fs}} - c\sqrt{\frac{\mu}{\rho V_{fs}}}$$

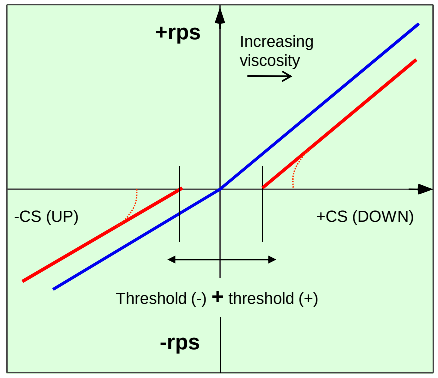
a: pitch coefficient (geometrical)

b: bearing friction coefficient

c: fluid friction coefficient

ρ: fluid density

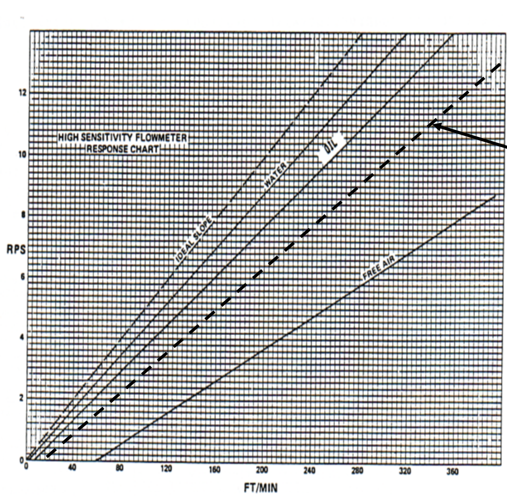
μ: fluid viscosity



Typical threshold Fullbore –(good condition)
Liquid 3-6 ft/min (1-2m/min)
Gas 10-20 ft/min (3-6m/min)
Inline spinners considerably higher thresholds

Effect of fluid type

RPS



Possible slope for gas under compression at downhole press & temp

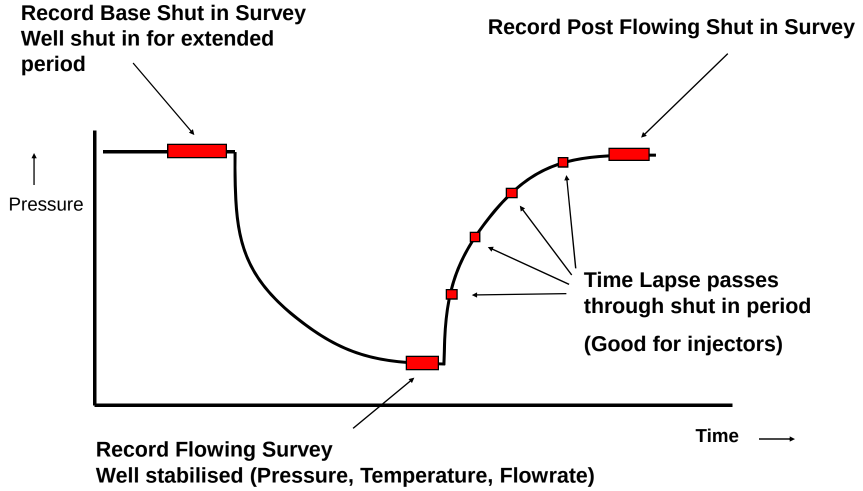
NOTE:

Slope AND threshold change with fluid type

(and possibly rate!)

Increase in threshold from liquids to gas.

When to Calibrate?



*Note: Various constraints may limit the recording or extent of some of the surveys above.

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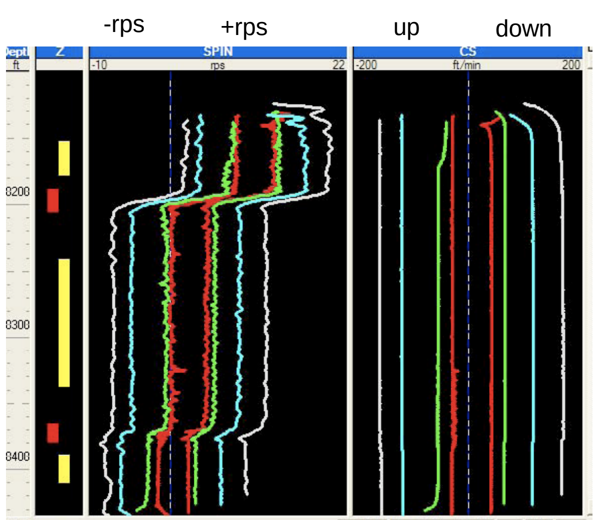
Flowmeter Calibration



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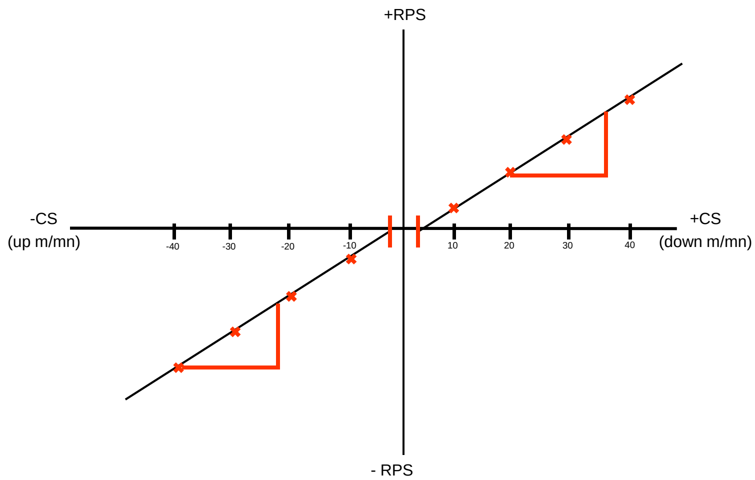
Calibration Crossplot



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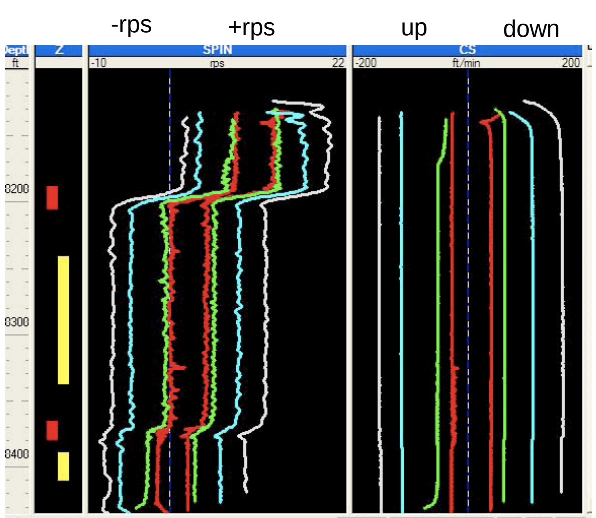
Flowmeter Calibration



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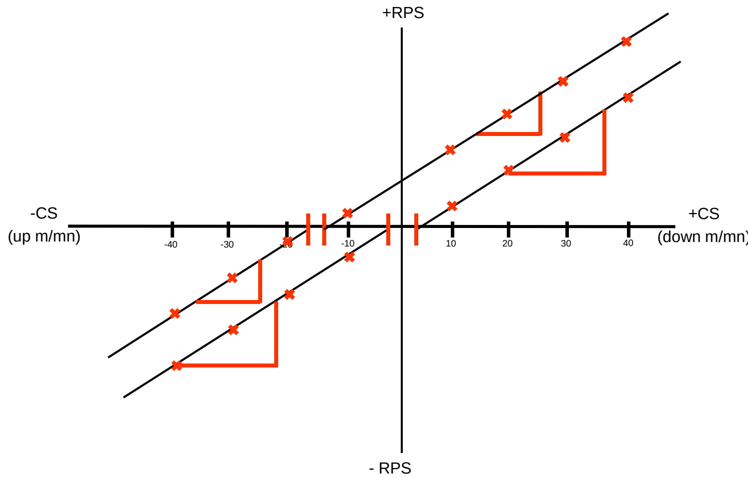
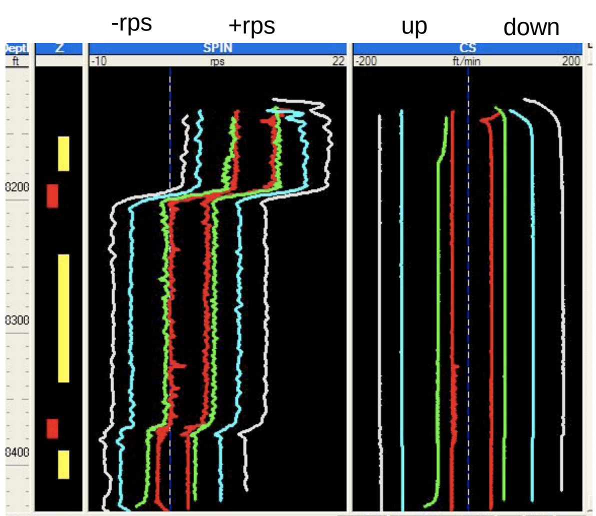
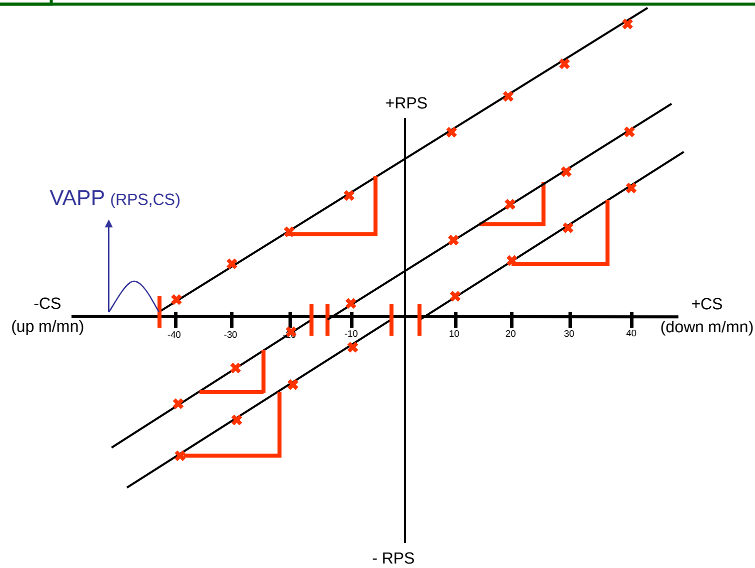
Calibration Crossplot



Flowmeter Calibration



Calibration Crossplot



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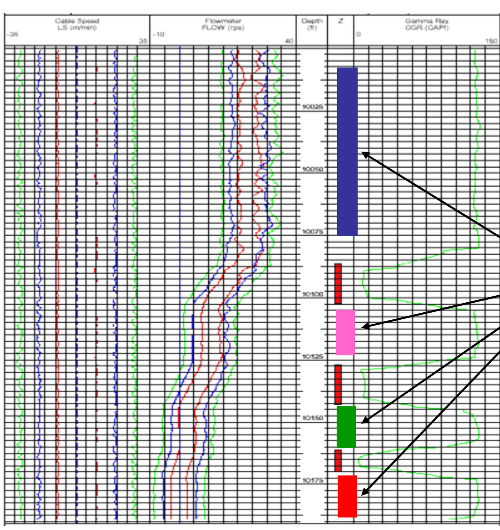
Spinner Calibration Data



1. Steady spinner
2. Steady Cable speed
3. Constant fluid type
   (In your phase or phases of interest)

Calibration Intervals

4. Confirm no change in tool condition during survey period

5. Well conditions must be stable during the survey period

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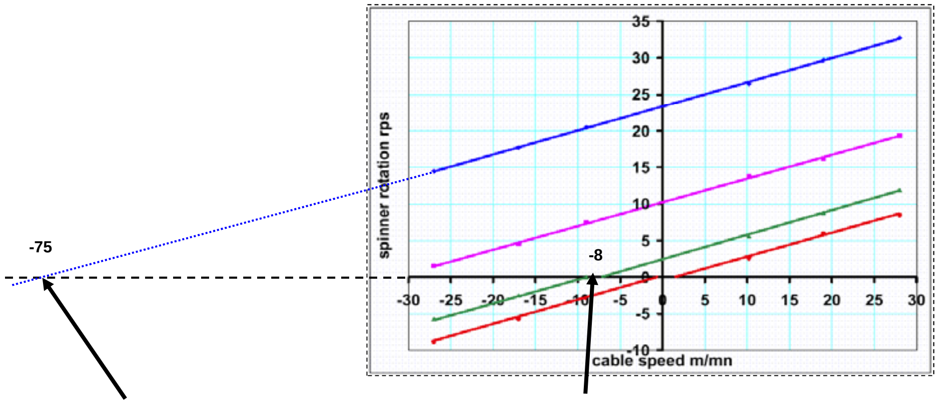
Importance of Threshold



75 +2 = 77 m/min (liquid threshold)
75 +6 = 81 m/min (gas threshold)
Small error in threshold – small VAPP error
5% difference in the VAPP

8 +2 = 10 m/min (liquid threshold)
8 +6 = 14 m/min (gas threshold)
Small error in threshold – large VAPP error
30% difference in the VAPP

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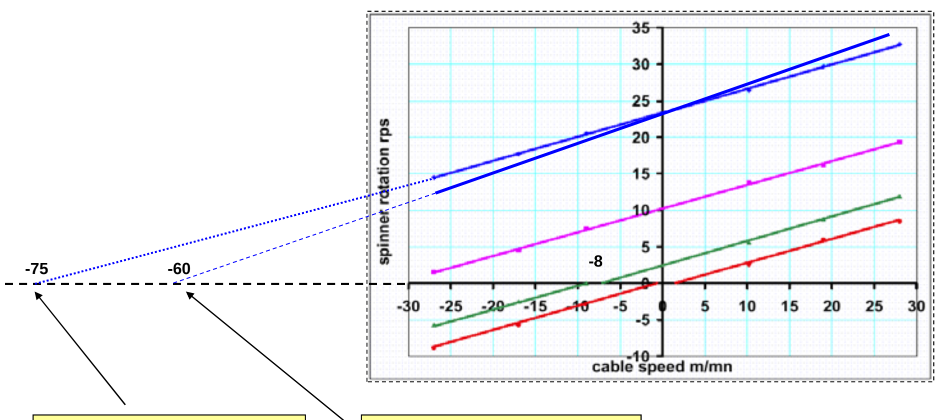
Importance of Slope



VAPP = 75 + 2 = 77m/min

VAPP = 60 + 2 = 62m/min

A small change in the slope, in a high velocity region,
will have a large resultant effect on the VAPP for that region.

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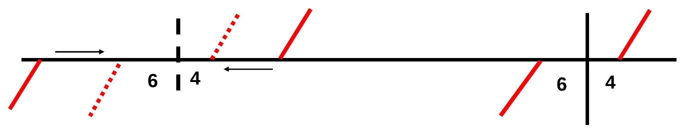
Emeraude Calibration Modes

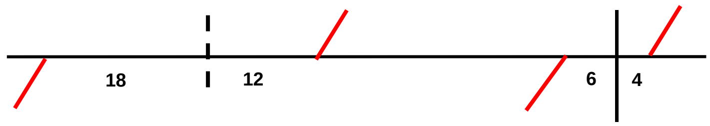
Mode 1

Unique value of (+) and (-) threshold



Mode 2

Unique ratio T (-)/(Int (-) - Int (+))

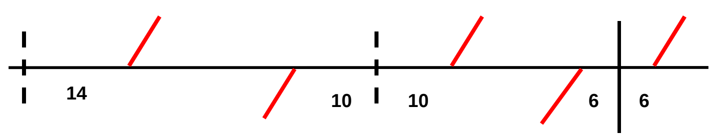


Manufacturer Default Ratio = 0.583

Emeraude Calibration Modes

Mode 3

Multiple and independent, slopes and thresholds – "user defined"

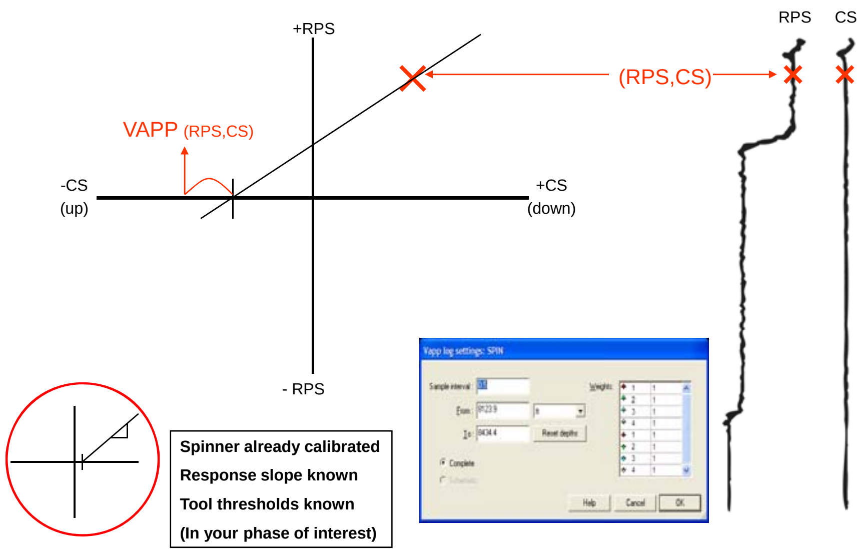


Full flow zone

Intermediate flow zone

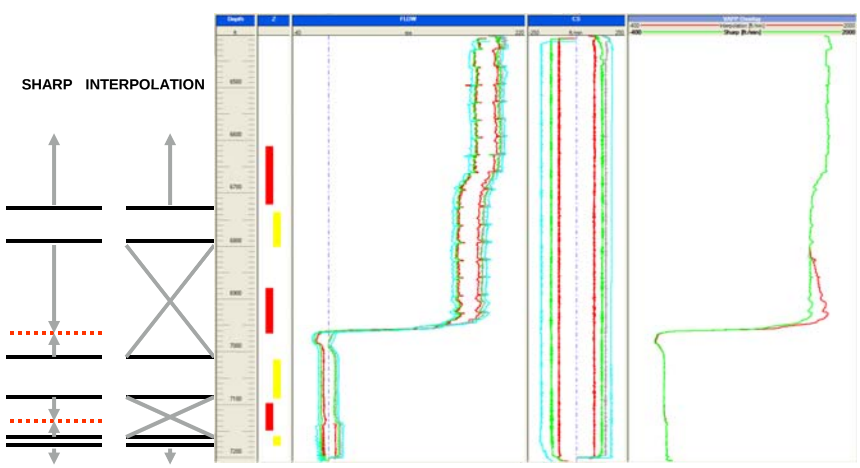
Zero flow zone

Calculating VAPP

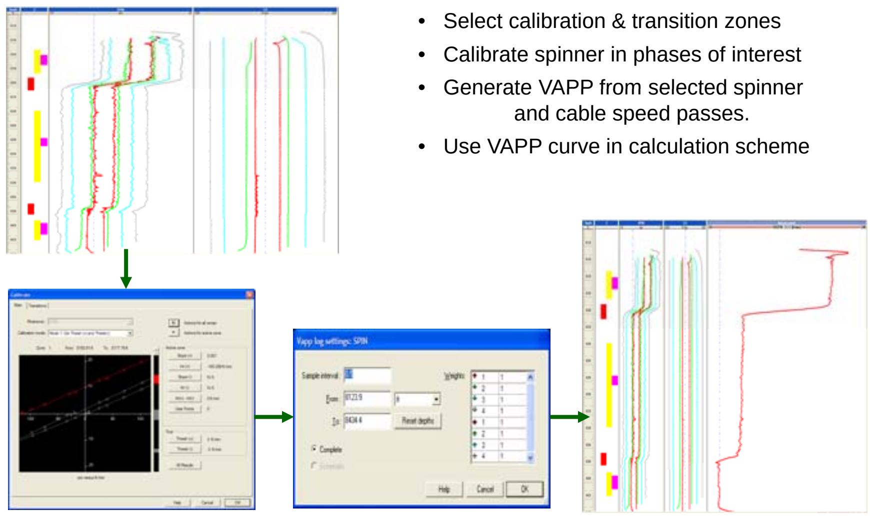


Spinner already calibrated
Response slope known
Tool thresholds known
(In your phase of interest)

Transitions



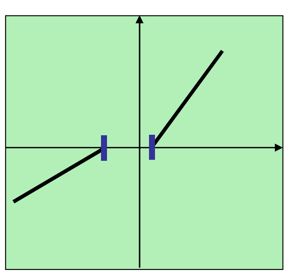
Spinner to VAPP summary



- Select calibration & transition zones
- Calibrate spinner in phases of interest
- Generate VAPP from selected spinner and cable speed passes.
- Use VAPP curve in calculation scheme

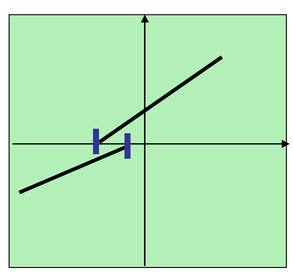
Anomalies

Different slopes & thresholds



It is normal that both the positive and negative thresholds and slopes are assymetrical due to assymetry between the upper and lower surfaces of the blade.

Overlapping intercepts



Overlapping intercepts can often be found in deviated wells, where the oil is flowing faster on the high side of the hole.

During logging the spinner trajectory can be in the oil when logging down, and the slower water when logging up.

Spinner Tool Specs

	READ	SPARTEK	SLB	SONDEX	
	Inline & Fullbore	Fullbore Folding Flowmeter		Caged Full-bore	Continuous Spinner
Accuracy	+/- 0.3%	+/- 2%		+/- 2 ft/min	+/- 7-10 ft/min
Resolution	0.1 rps	0.125 rps	2 ft/min	0.1 RPS	0.1 RPS

Spinner resolution

Question: How many RPS can I expect for 1000bpd in 7” 26# casing?
7” 26# casing ID = 6.276”

Velocity to Flow rate Conversion Chart gives:-
1000bpd = 18.2fpm

DESCRIPTION				FLUID VELOCITY FOR FLOW RATE OF:											
Nom OD	Wt	Int Diameter		1,000 B/D			10 cu m/hr			100 cu m/D			1,000 cu ft/D		
in. mm	lb/ft	in	mm	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min
	23.00	6.366	161.7	5.40	9.0	17.6	8.16	13.6	26.8	3.39	5.60	11.10	0.958	1.596	3.142
7"	26.00	6.276	159.4	5.52	9.2	18.2	8.34	13.6	27.4	3.47	5.80	11.40	0.985	1.642	3.233
(177.8)	29.00	6.184	157.1	5.70	9.5	18.7	8.64	14.4	28.4	3.51	6.00	11.80	1.015	1.691	3.329
	32.00	6.094	154.8	5.88	9.8	19.3	8.88	14.8	29.1	3.69	6.20	12.10	1.045	1.745	3.429

Therefore 1000bpd **= 18.2 x Your Spinner slope (0.05rps/fpm)**

Therefore **1000bpd = 0.91rps (~1.0rps)**
Therefore **100bpd = 0.1rps**

Spinner Resolution

Question: What is the smallest rate entry I can detect on my spinner?

e.g. I can detect 0.1rps on my spinner, what rate is that equivalent to?
Using the information on the previous slides,…

Nom OD	Wt	Int Diameter		1,000 B/D			10 cu m/hr			100 cu m/D			1,000 cu ft/D		
in. mm	lb/ft	in	mm	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min	m/min	cm/sec	ft/min

0.1rps ~ 65bpd (downhole)   5 1/2" casing (1000bpd = 29.2fpm)

5 1/2" (139.7)	13.00	5.044	128.1	8.64	14.4	28.1	12.96	21.6	42.5	5.39	8.90	17.70	1.525	2.542	5.044
	14.00	5.012	127.3	8.70	14.5	28.5	13.08	21.8	42.9	5.44	9.10	17.80	1.545	2.575	5.069
	15.50	4.950	125.7	8.94	14.9	29.2	13.44	22.4	44.1	5.59	9.30	18.30	1.584	2.640	5.196
	17.00	4.892	124.3	9.12	15.2	29.9	13.74	22.9	45.1	5.72	9.50	18.70	1.622	2.703	5.320
	20.00	4.778	121.4	9.60	16.0	31.3	14.40	24.0	47.3	5.99	9.90	19.70	1.700	2.833	5.577
	23.00	4.670	118.6	10.02	16.7	32.8	15.12	25.2	49.6	6.26	10.50	20.60	1.780	2.966	5.838

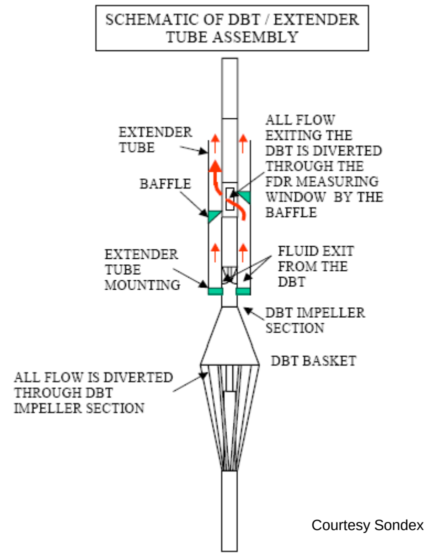
0.1rps ~ 10bpd (downhole)   2 7/8" tubing (1000bpd = 140fpm)

2 7/8" (73.0)	6.40	2.441	52.00	36.78	61.3	120	55.28	92.1	181.4	22.9	38.31	75.5	6.51	10.9	21.97
	8.60	2.259	57.38	42.90	71.5	140	64.48	107.5	211.5	26.8	44.72	87.9	7.60	12.7	24.95

Diverter Flowmeter

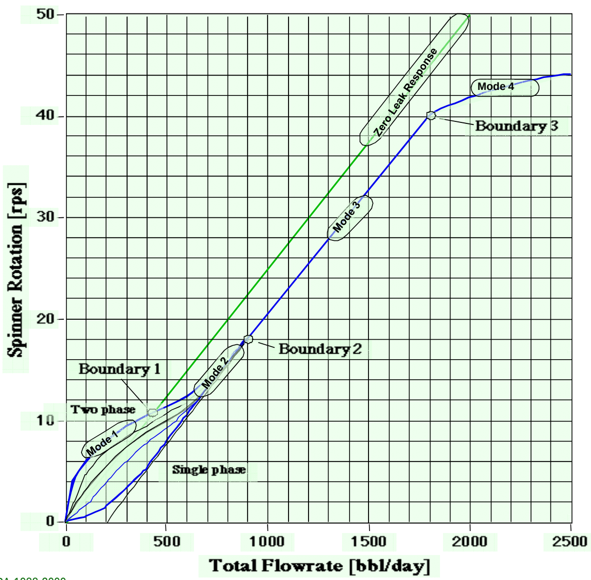
- Low Flowrate Tools or Diverter Flowmeters expand their effective diameter below tubing, to divert the flow through an orifice containing a small diameter spinner, thereby increasing the fluid velocity to a measurable level.
- Good fluid sampling characteristics because the majority of the fluids must go through the spinner section.
- These devices are not rugged enough to withstand the mechanical forces of being dragged up and down in passes, and consequently require stationary data acquisition.
- SONDEX tools come with a "Extender tube", mounted above the spinner assembly, allowing for a RA density measurement while the fluid is still contained in the restricted diameter.

Sondex Diverter Flowmeter



Courtesy Sondex

Petal Basket

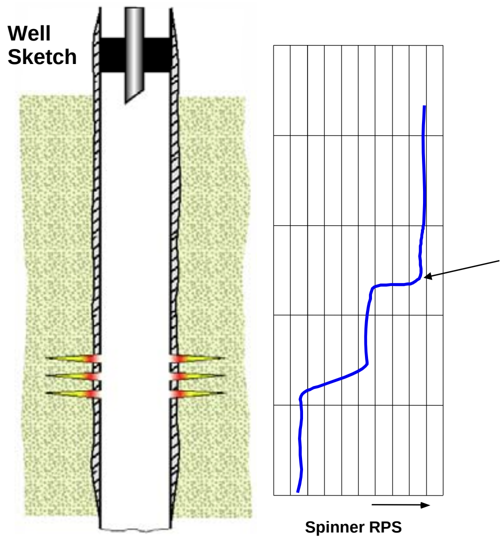


Tool calibration chart, or equations, supplied by manufacturer

e.g. RATE

= (RPS * 75.2 + 25) / 6.2898

Factors Affecting Spinner Response



What happens here?

1….?
2….?
3….?
4….?

Possible Explanations

1. Leak
2. Squeeze perforations
3. Casing weight change
4. Rate change at wellhead
5. Change of cable speed
6. Fluid interface
7. Collapsed casing
8. Scale buildup in completion
9. Metal loss from tubulars
10. Spinner damaged – tool condition
11. Specified completion incorrect
12. Bubble point PVT change
13. Failed electronics
14. Deviation change

QA/QC: Spinner

- Check for consistency/repeatability between the passes.
- Check for anomalies, i.e. the erratic/oscillatory response, uneven response among the passes, by comparing to other sensors.
- Check for possibility of apparent down flow.
- Use the raw data /unfiltered for calculation (better vertical resolution).
- Compare the velocity calculated from different spinner tools, if available.
- Watch out for turbulence / jetting effect on spinner data.
- Verify tool response on X-plot in a stable or zero flow area
- Identify valid data at beginning and ends of the passes
- Validate spinner changes caused by fluctuations of cable speeds
- Fullbore spinners can collapse in unknown restrictions

QAQC Cable speed

- See if the various cable speeds are smooth.. if not check on spinner later.
- Mechanically geared logging units usually give smoother cable speeds
- Hydraulic driven units often, but not always, have more unstable cable speeds, sometimes surging or drifting
- Remember cable speed is recorded at surface
- When using Schlumberger data, use SCVL mnemonic if available.
- Check sign of cable speed to see which is up and down passes.. but not critical. (Emeraude sets the sign of the CS during import)
- Cable speed could be affected if the cable “jumps out or off” the measure wheels
- Edit and filter if necessary to meet the following uses of Cable speed in Emeraude.

1. Spinner calibration for slope and threshold in your phase, or phases of interest.
2. VAPP calculation at every depth sample
3. Tool friction component calculation when handling Gradio tool data

Pressure & Temperature

KAPPA

TOOLS

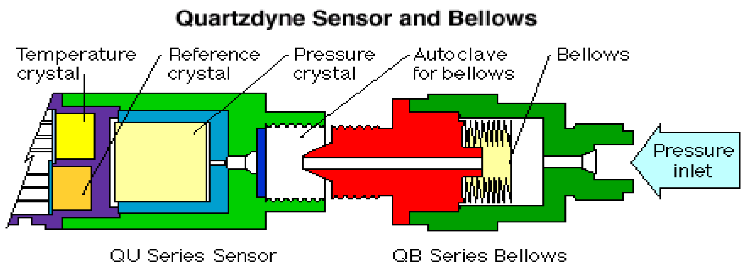
Module #6
Pressure & Temperature

Pressure

STRAIN GAUGE SENSOR
QUARTZ GAUGE SENSOR

- **The pressure measurement is a continuous profile of the pressure in the wellbore.**
- **The major reason to measure the pressure is to be able to accurately predict the PVT properties of the fluids.**
- **The curve also reflects changes in the borehole fluid composition (density). It is possible to drive a density measurement from the pressure.**
  (derivative with respect to depth, dP/dZ)
- **Use the pressure in SIP analysis technique**

Quartz sensor



- Uses 3 crystals
- Resolution 0.01 psi

Courtesy Quartzdyne

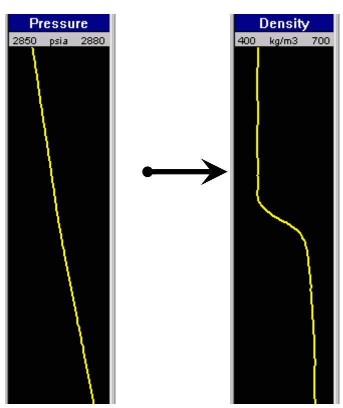
The well Pressure distorts the crystal, changing the oscillator resonant frequency.

This is reduced by the reference crystal frequency.

Master Calibration coefficients required for absolute accuracy

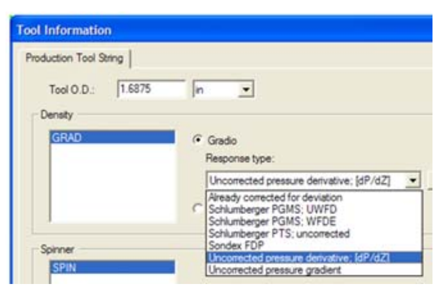
NOTE: Internal Temperature Data required for thermal corrections.

Pseudo-density



A dP/dZ created from the pressure within EMERAUDE will be handled automatically

An Schlumberger dP/dZ such as "MWFD" from Schlumberger must be defined accordingly during "Tool Info"



A dP/dZ pseudo density needs:
- **correction for pipe friction**
- **correction for deviation**

Pressure Tools

	SONDEX Quartz	SPARTEK 15,000psi	SCHLUMBERGER Strain	SCHLUMBERGER Quartz
Accuracy	+/- 2 psi	0.024% FS	+/- 6psi	+/- 1 psi +/- 0.01% fs
Resolution	0.01psi	0.003% FS	0.1psi	0.01psi

Comparison of Quartz Pressure Sensors

	Introduction Year	Sensor size (OD x OAL)	Pressure Range (PSI)	Temperature Range (C)	Accuracy	Resolution (psi)	Transient Response	Temperature Compensation	Isolation Method	1993 Price (US$)
HEWLETT PACKARD 2813D/E	1970	1.0"x3.4"	11,000	177	(1 PSI +0.01% READING)	0.001	POOR	NO	BUFFER TUBE	27,700 21,600*
HALLIBURTON HMR	1988	0.72"x1.9"	16,000	180	(1 PSI +0.01% READING)	<0.01	EXCELLENT	YES	BUFFER TUBE	NFS
SCHLUMBERGER CQG	1992	1.0"x1.5"	15,000	175	(1 PSI +0.01% READING)	0.004	EXCELLENT	YES	BUFFER TUBE	NFS
PAROSCIENTIFIC/ WELLTEST	1983	0.12"x0.6"†	15,000	177	<0.01%F.S.‡	<0.01	FAIR TO GOOD	YES	BOURDON & BUFFER TUBE	6,800
QUARTZDYNE QU16K-B	1991	0.58"x0.6"	16,000	177	0.02%F.S.	<0.006	VERY GOOD	YES	BELLOWS	7,900
QUARTZDYNE TMC16K-B	1993	0.58"x1.2"	16,000	177	0.02%F.S.	<0.006	EXCELLENT	YES	BELLOWS	10,795

*1992 PRICE--HP STOPPED PRODUCTION 3/93; NFS=NOT FOR SALE; N/A=NOT APPLICABLE
†WIDTH AND LENGTH OF SENSOR
‡NOT SPECIFIED; ESTIMATED FROM OTHER SPECIFICATIONS

From *"QUARTZ PRESSURE TRANSDUCER TECHNOLOGIES"*, ROGER W. WARD & ROBERT B. WIGGINS , QUARTZDYNE, INC.

QA/QC - Pressure

- Look for repeatability between passes to see if the well is stable or not.
- Make dP/dZ pseudo densities and compare with actual densities, in order to check validity of pressure data.
- Confirm correct wellsite gauge calibration was used if absolute pressures are in doubt.
- Use draw line option in Emeraude to check pressure gradients through the log.
- Ensure Pressure data is sufficient quality and accuracy for input to PVT in EMERAUDE.
- Ensure rate & pressure data is stable enough and accurate enough for SIP purpose.
- If SIP analysis is to be performed, then pressure data must be of sufficient absolute accuracy

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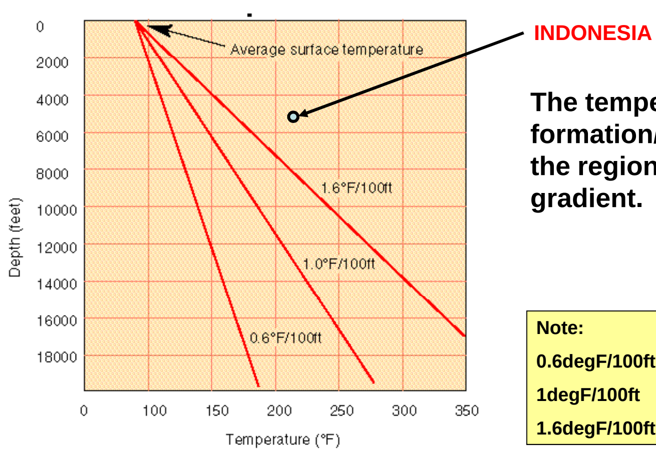
Temperature



The temperature of a formation/well follows the regional geothermal gradient.

Note:
0.6degF/100ft = 0.81degC/100m
1degF/100ft = 1.35degC/100m
1.6degF/100ft = 2.15degC/100m

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Temperature sensor

Temperature sensor

Courtesy SPARTEK

Uses of Temperature

- Evaluate production profile
- Identify deepest production or injection
- Distribution of injected fluids
- Understanding Frac job
- Understanding Acid job
- Identifying casing and tubing leaks
- Locating gas entries
- Look for channeling behind casing
- Lost circulation zones
- Isolating cement tops
- Input to EMERAUDE for PVT module

Temperature

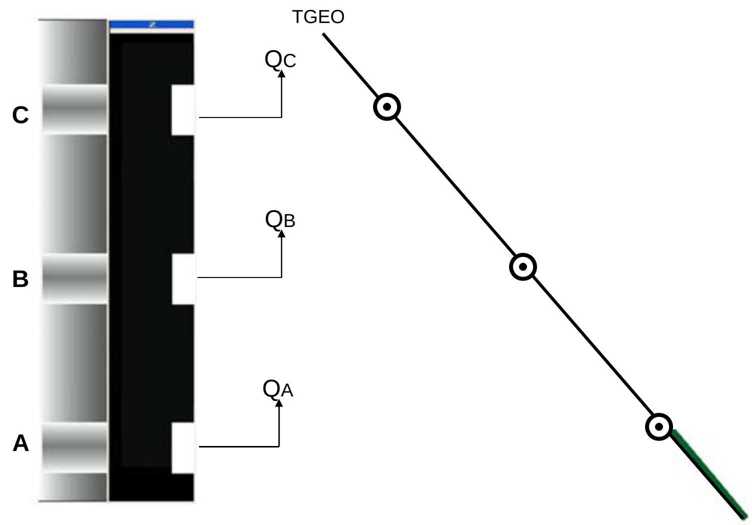
- Temperature is one of the most useful “auxiliary” measurements made in production logging.
- Combined with pressure it helps compute the PVT parameters.
- In addition it will detect very small fluid entries:
  - ➔ The derivative of temperature wrt depth (dT/dZ) can be used to clarify fluid entries in complex environments.
- It is the only tool in the string that “sees” behind casing, hence it can be used to detect channeling.

Interpreting Temperature

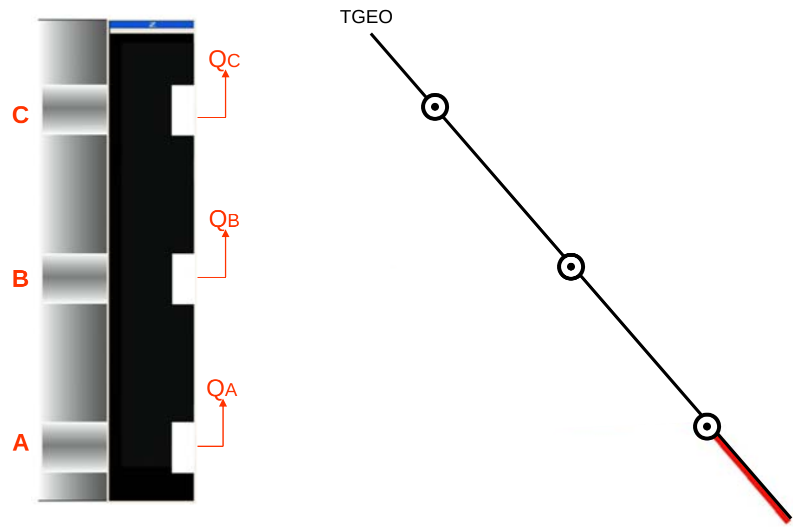
- The interpretation of temperature logs relies on patterns.
- The change in temperature with respect to the geothermal gradient has to be noted.
- Heating means a fluid is flowing from deeper to shallower, or entry of a warmer fluid into the mixture.
- Cooling means the opposite, or entry of a cooler fluid

  (or a gas entry….)
- The temperature is more sensitive to small flows than the flowmeters.
- Time-Lapse measurements are useful… e.g. comparing shut in and flowing temperature profiles

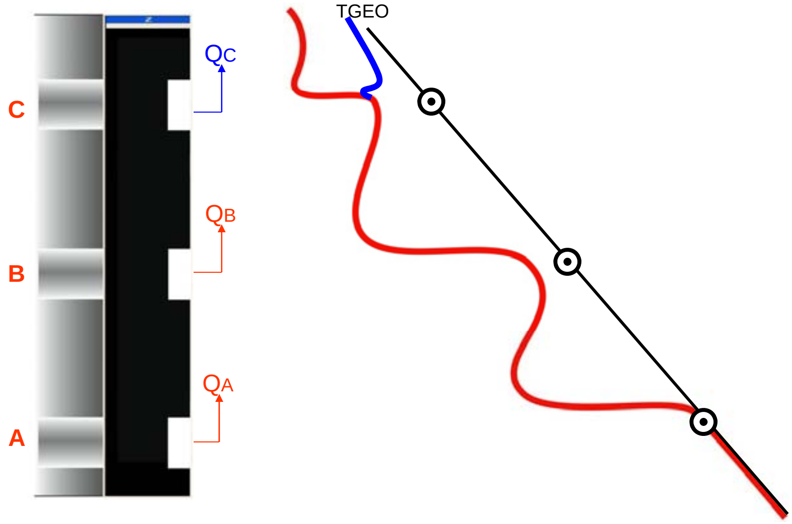
Liquid Production



Gas Production



Gas and Water Production



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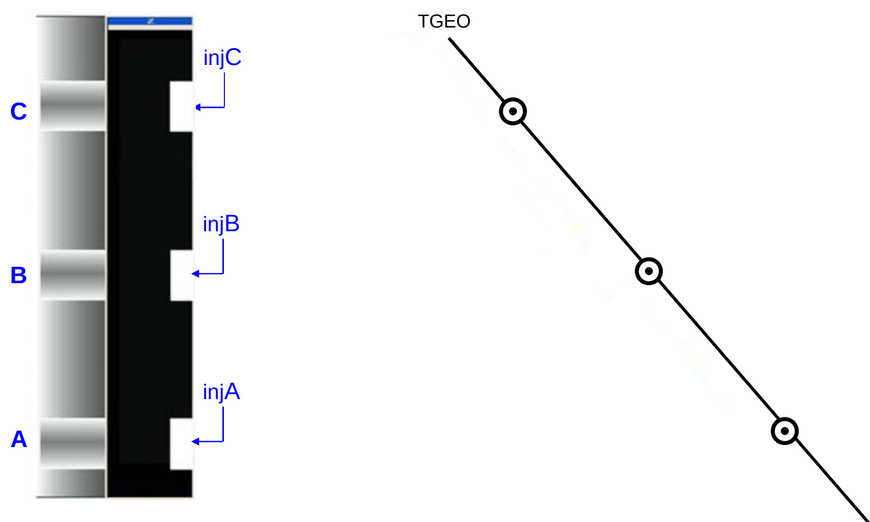
Water Injection



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Heat Capacities

Enthalpy balance :

$$H_t = \left(Q_{ot} \times C_{po} \times \rho_o + Q_{wt} \times C_{pw} \times \rho w + Qt \times C_{pg} \times \rho g\right) \times T_t$$

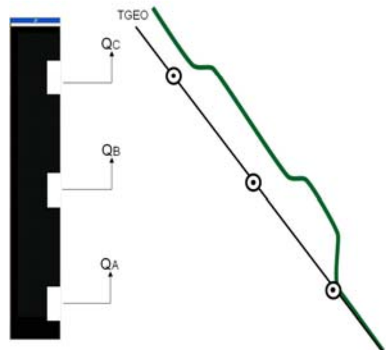
$$=$$

$$\Delta H = \left(dQ_w x\ C_{pw} x\ \rho_w + dQ_o x\ C_{po} x\ \rho_o + dQ_g x\ C_{pg} x\ \rho_g\right) x\ Tgeo$$

$$+$$

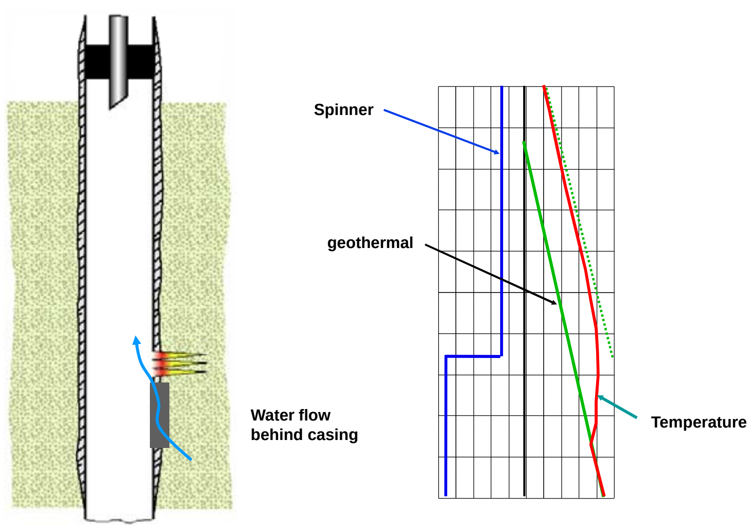
$$H_b = \left(Q_{ob} \times C_{po} \times \rho_o + Q_{wb} \times C_{pw} \times \rho w + Q_{gb} \times C_{pg} \times \rho g\right) \times T_b$$

From: Q's, dQ's, Densities,Cp's[*], Tgeo, Tb
Get: Tt



Heat capacities (PVT)		
Water	*= 0.993*	*1*
Oil	*= 0.4897*	*0.5*
Gas	*= 0.2598*	*0.25*

Temperature: Channeling



Temperature Tools

	SONDEX	SPARTEK	SCHLUMBERGER
Accuracy	+/- 1degF	+/- 1degC	+/- 1degC (+/- 1.8dgeF)
Resolution	0.0055degF	0.01 degC	0.006degC (0.01degF)

QA/QC - Temperature

- Normally use slowest down pass for qualitative interpretation
- Normally use slowest down pass for reference channel for defining PVT in the calculation process.
- Check for repeatability in sump/no flow zone to validate sensor
- Look for repeatability to see if well is stable or not
- Make dT/dZ to emphasize temperature events, change of gradient
- Check for consistency with other sensor response (e.g. spinner)
- Use “draw line” provided in Emeraude to compare with “field” temperature gradient
- Used as qualitative indicator for flow behind casing
- Temperature can show fluid entries not detectable on the spinner
- Verify temperature data is suitable for input to PVT determination