


	<h1>FLOWMETERS</h1>
<h1>KAPPA</h1> <h2>TOOLS</h2> <h3>Module #5 Flowmeters</h3> <p>© KAPPA 1988-2009 1</p>	

	<h1>Flowmeters</h1>
<p>Flowmeters measure fluid movement..... Hence they are used to detect flow phenomena, for example:</p> <ul style="list-style-type: none">• Where is the flow coming from?• Are all perforations flowing?• Is there crossflow?• Are there any leaks? <p>© KAPPA 1988-2009 2</p>	

 **Flowmeters**

Courtesy - SONDEX



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


Measures: **RPS**

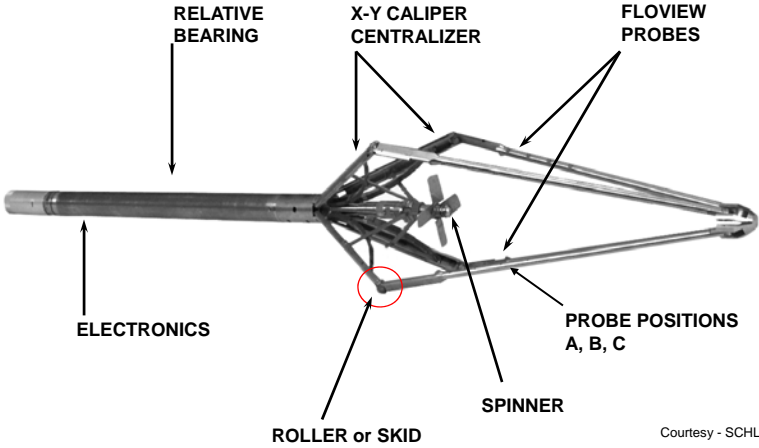
But we need:

- **FLUID VELOCITY**
- **RATE**

Fullbore Inline/Continuous Diverter/Basket

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 **Schlumberger PFCS**



ELECTRONICS

RELATIVE BEARING

X-Y CALIPER CENTRALIZER

FLOVIEW PROBES


PROBE POSITIONS A, B, C

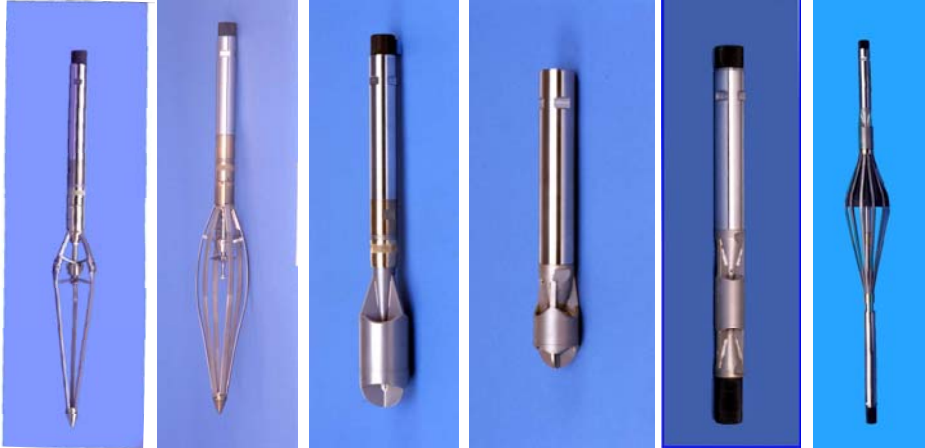
SPINNER

ROLLER or SKID

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


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 **More Spinners**




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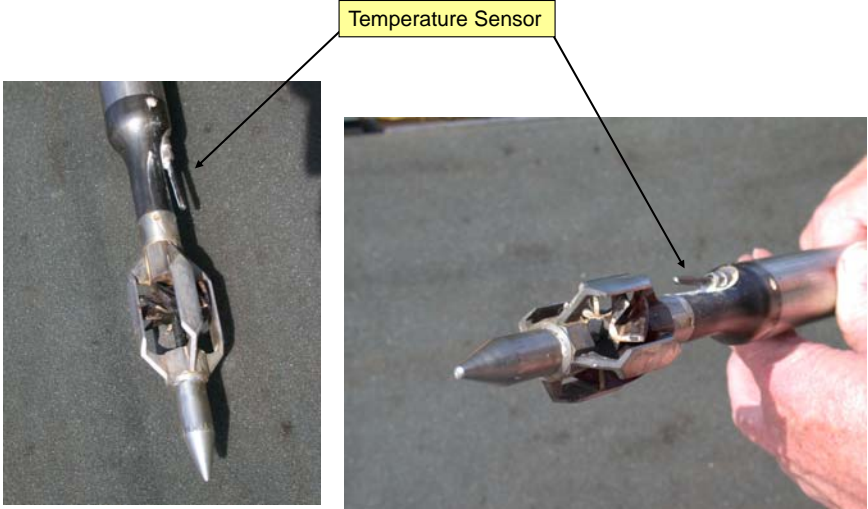
 **Sondex Flowmeters**




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 **Weatherford: Spinner & Temperature**

Temperature Sensor



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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

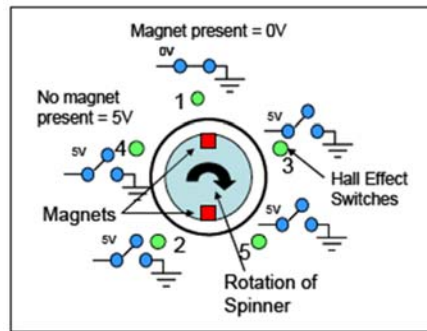
Courtesy: SPARTEK

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HALL effect

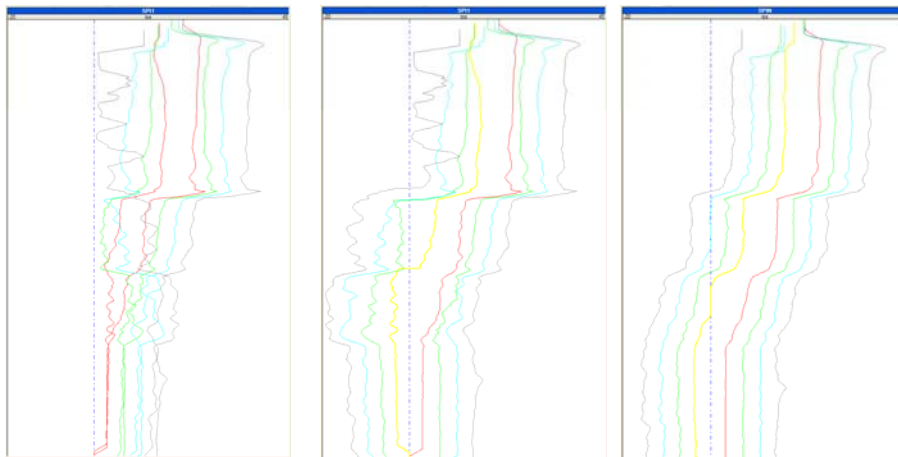
- The spinner action rotates the magnets, which pass the powered Hall effect switches
- Magnet present – switch is closed
- No magnet – switch is open
- The switches are opened and closed giving 10 pulses per revolution
- By counting the switchrate, and the order of closing, the direction of rotation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



Courtesy - SONDEX



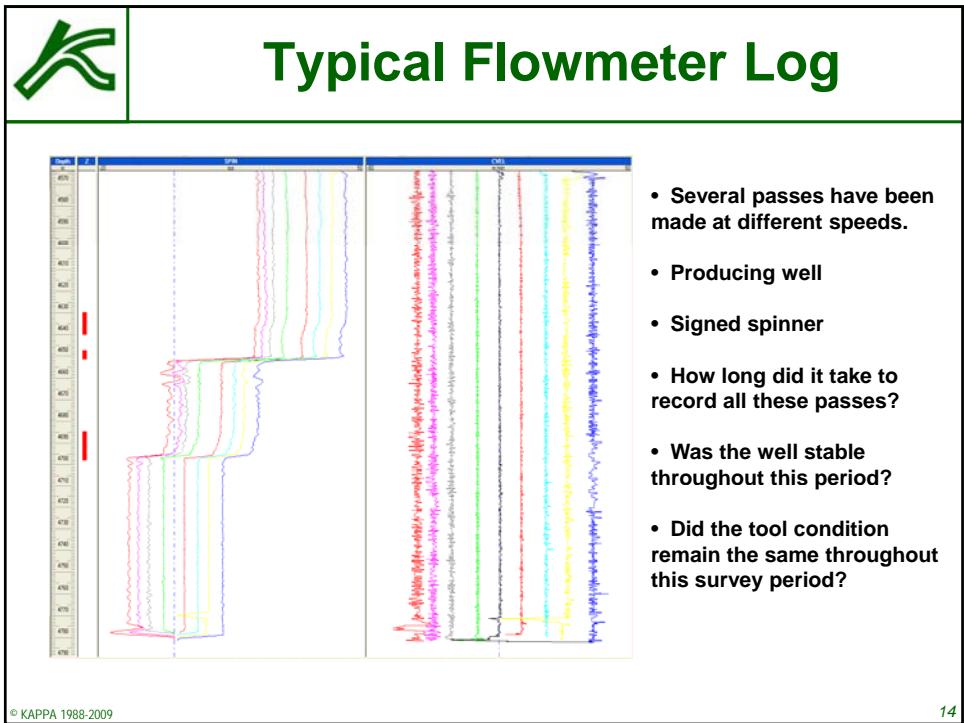
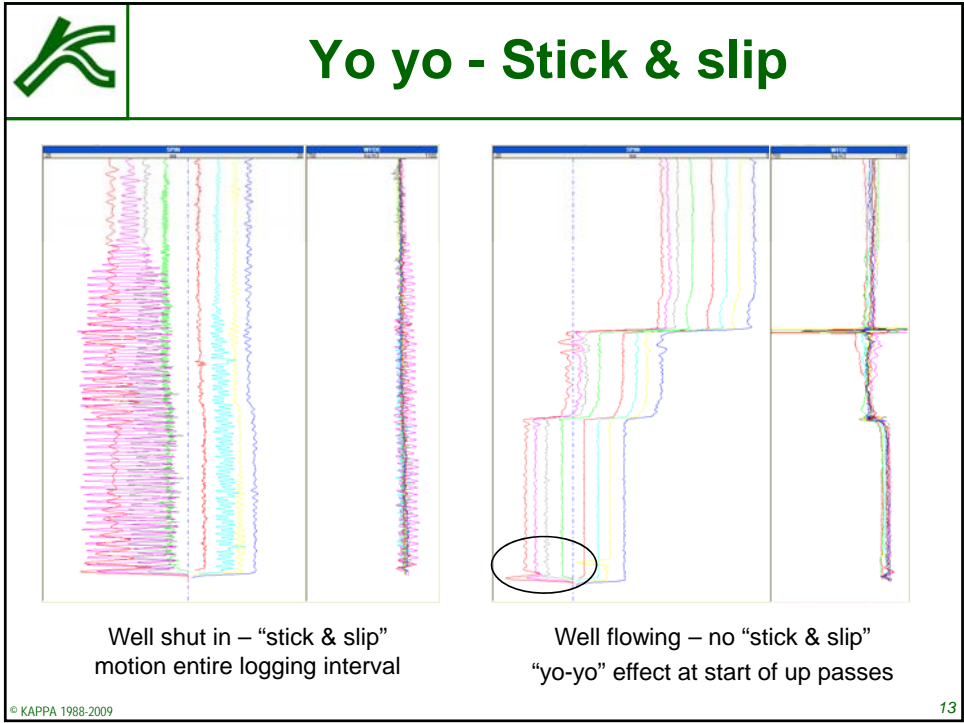
Spinner Reversal



**Unsigned
Inline spinner**

**Reversed unsigned
Inline spinner**

**Signed (normal)
Fullbore spinner**



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

$V_m = VPCF \cdot Vapp$

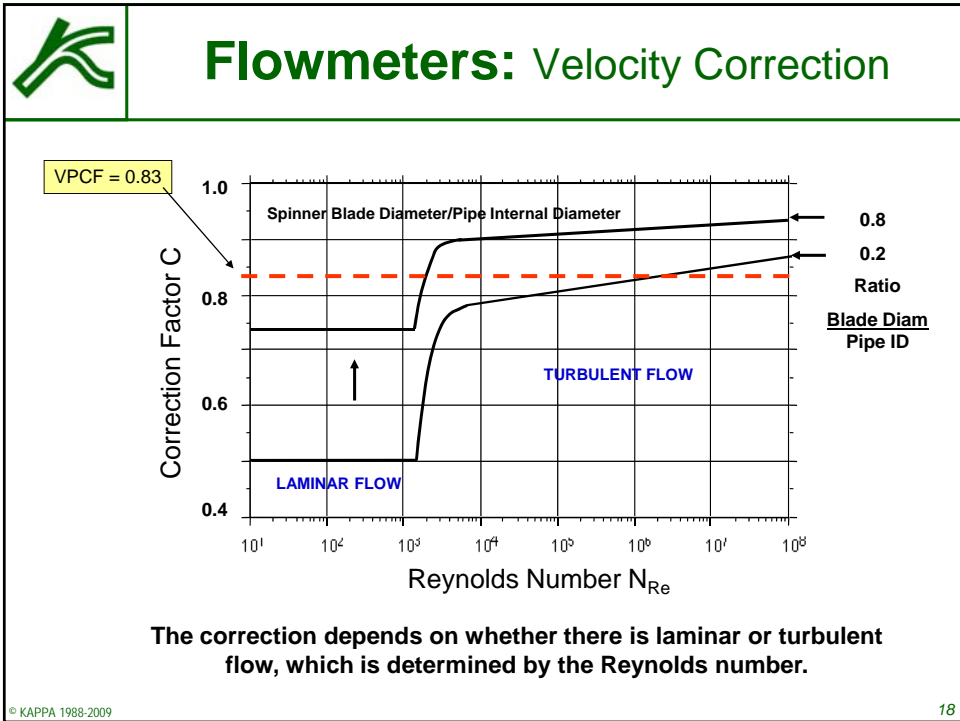
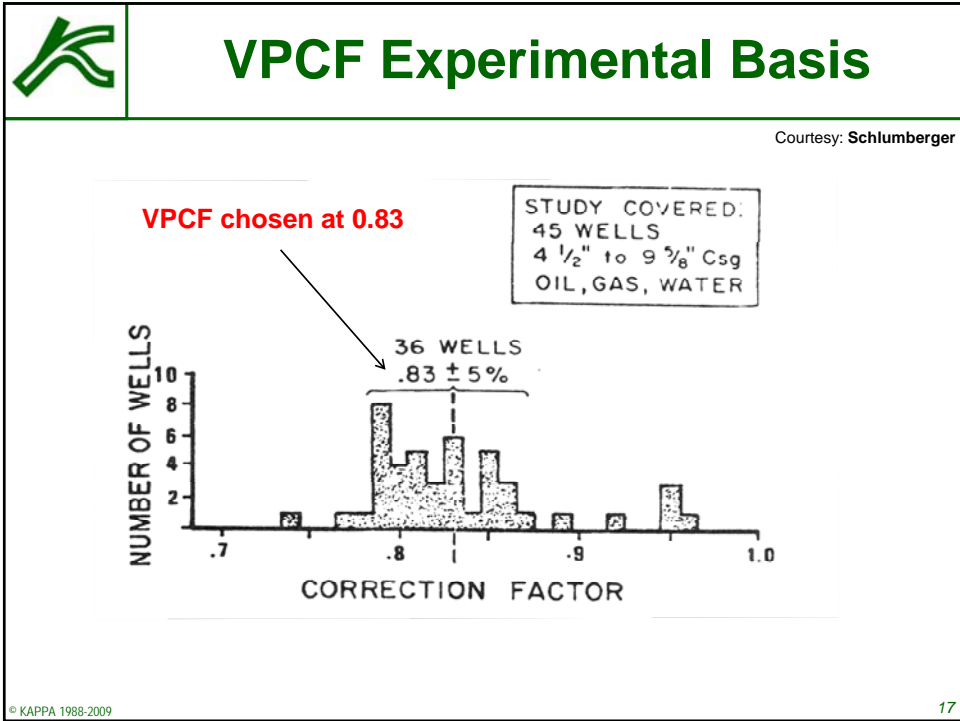
The velocity profile correction factor, VPCF, was historically taken as 0.83

The velocity profile correction factor actually depends on Reynolds number

$N_{re} = Area \cdot Velocity \cdot Density / Viscosity$

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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Spinner Response

The flowmeter measurement relies on relative fluid - tool velocity

Stationary tool

Fluid Velocity up V

≡

Tool Velocity down V

Stationary fluid

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Non-directional vs Directional Spinner Response

Fluid entries

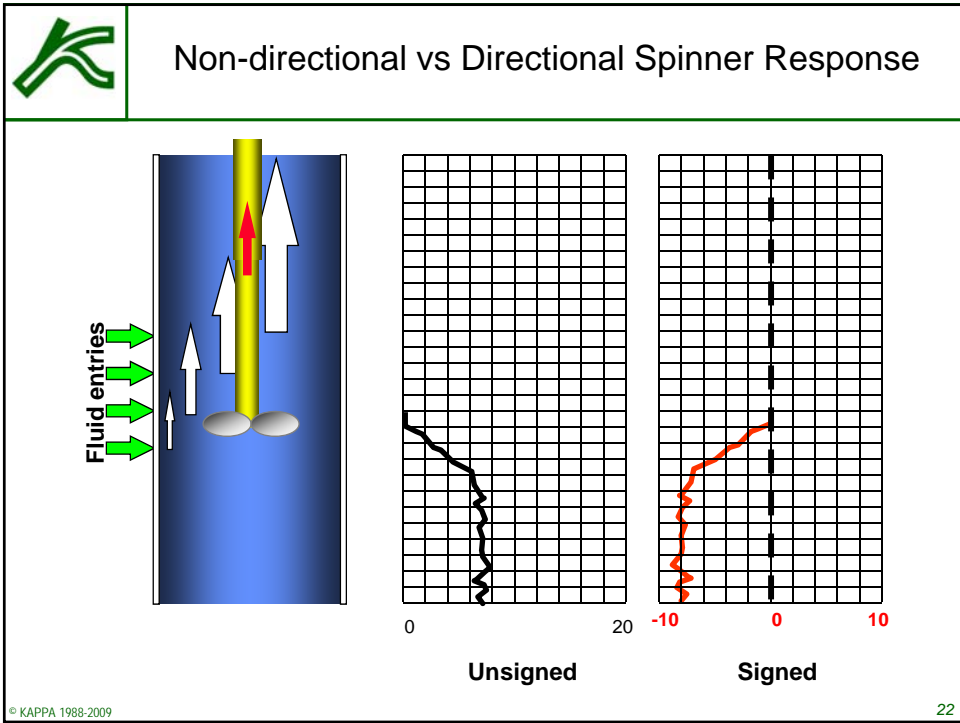
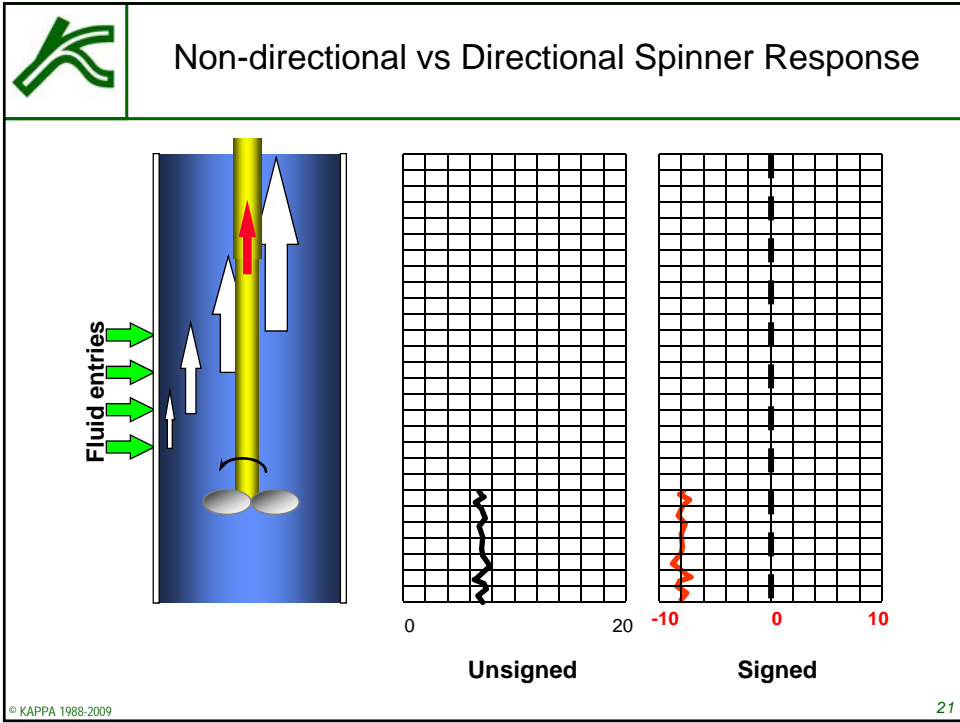
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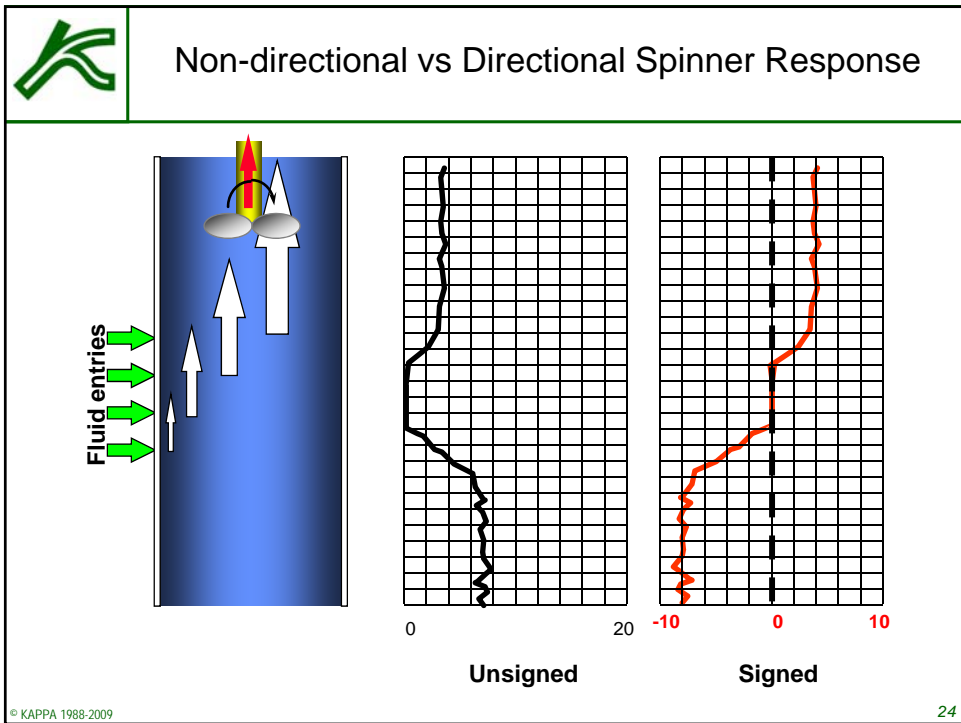
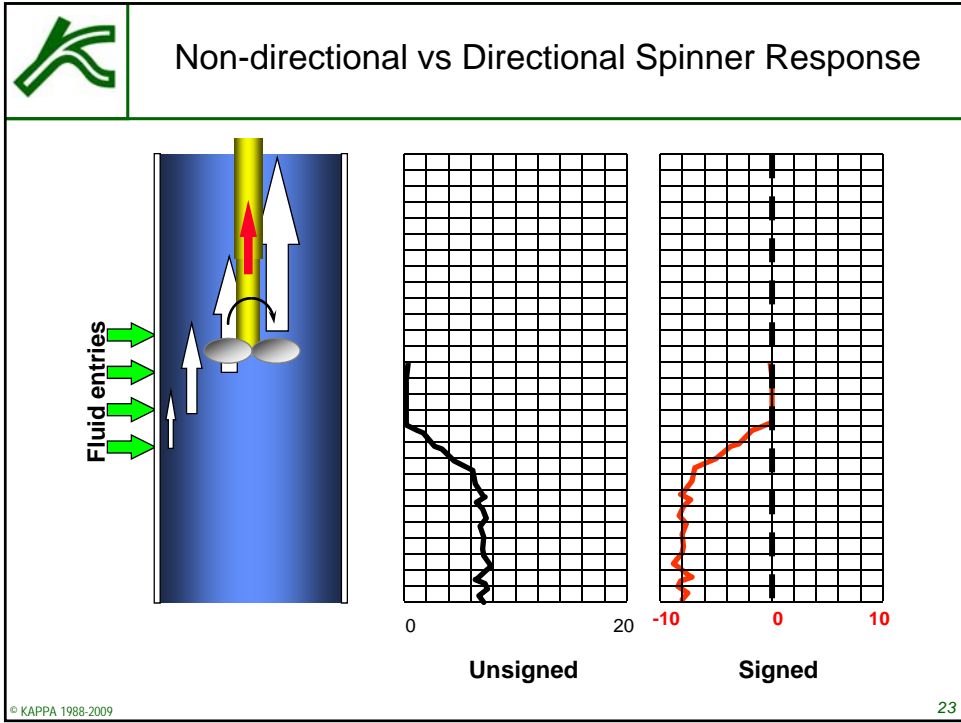
Unsigned

-10 0 10

Signed

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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.

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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!!!

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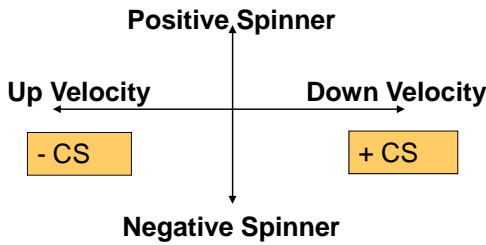
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Kappa Conventions

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



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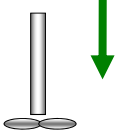


Ideal response: Zero Flow

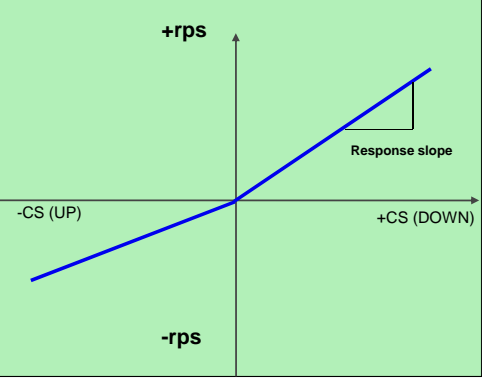
$$rps = a \times V_{fs}$$

rps: frequency of rotation
 V_{fs} : fluid velocity, relative to spinner
 a: pitch coefficient, function of tool geometry

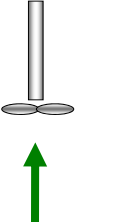
Negative rps



Typical FBS response slope
 0.05rps/ft/min
 0.15rps/m/min
 (Schlumberger x-3)



Positive rps



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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

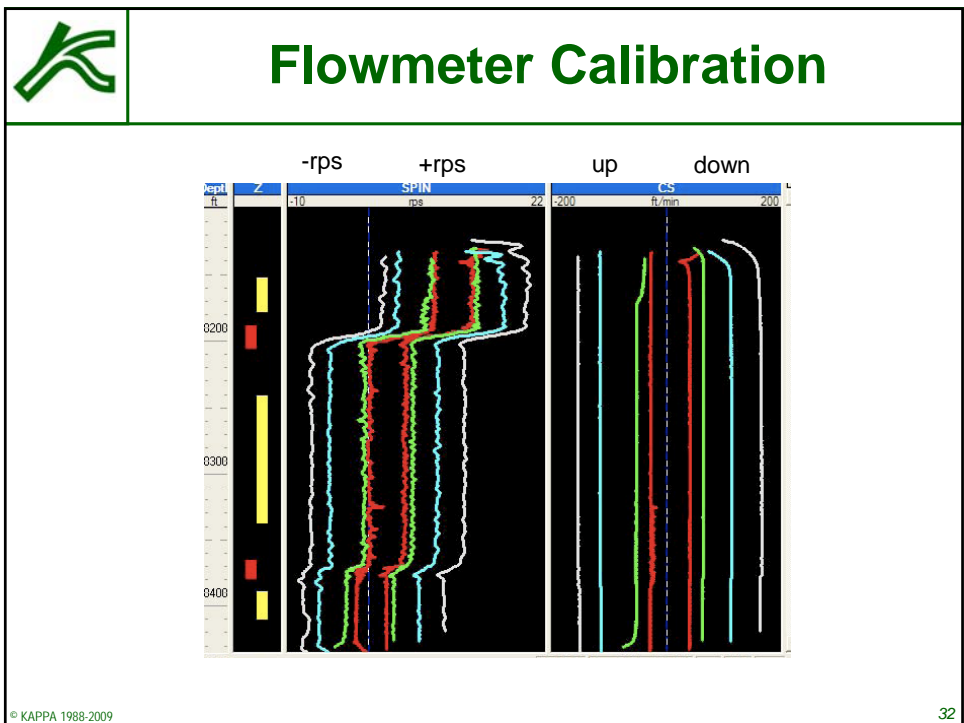
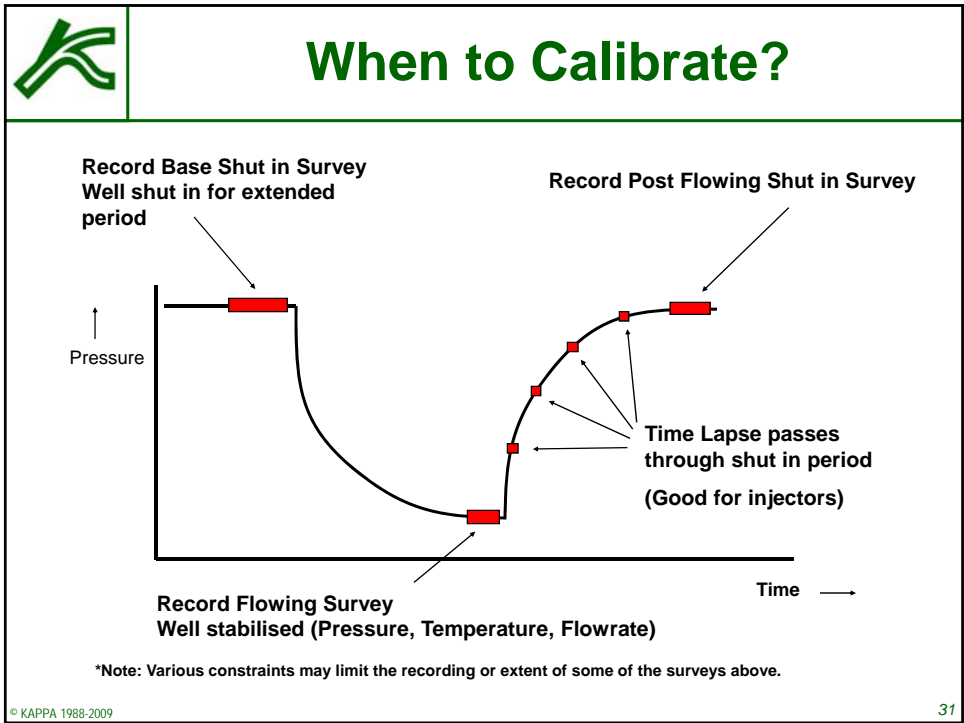
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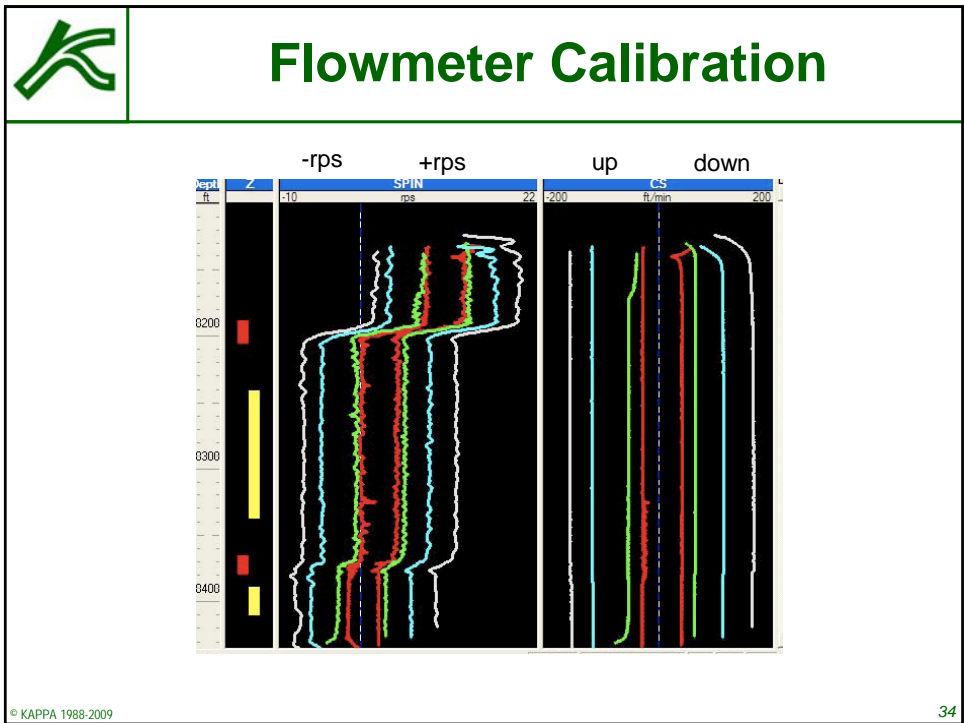
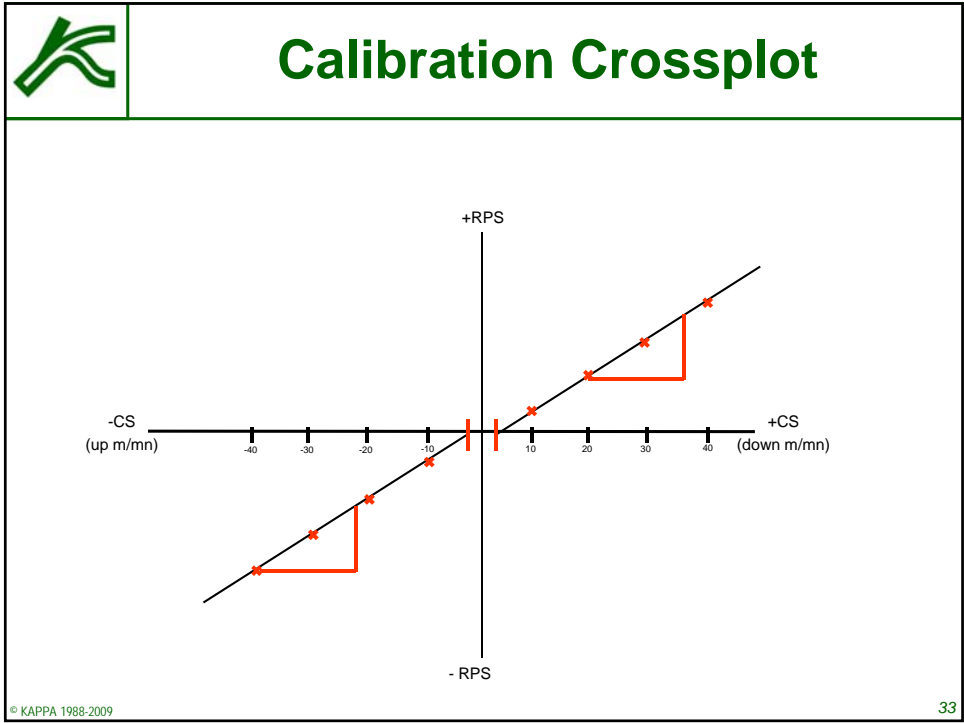
Effect of fluid type

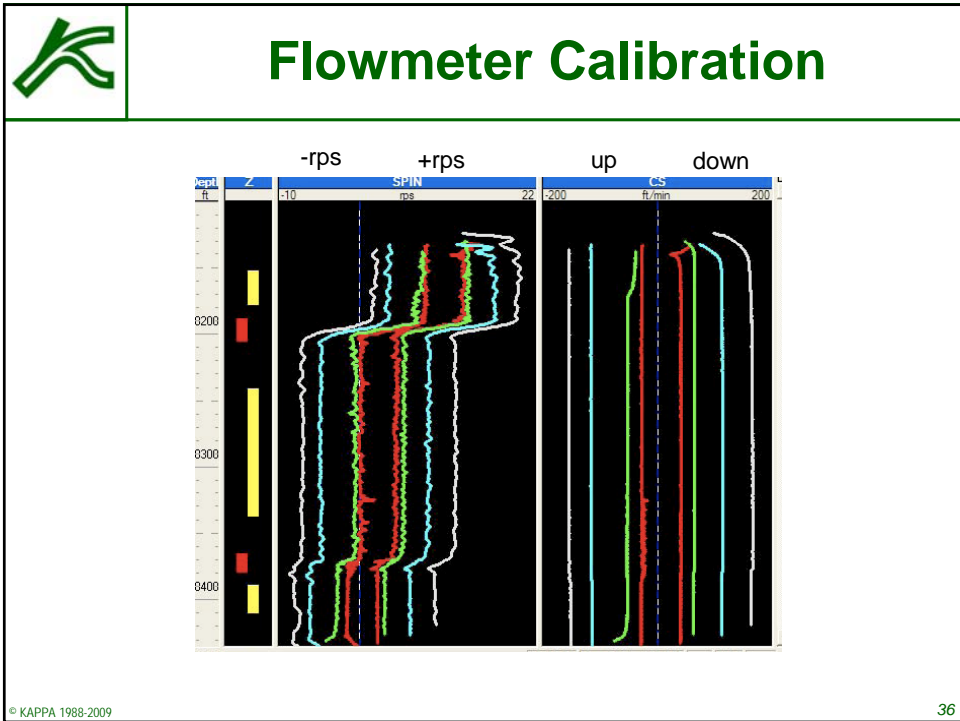
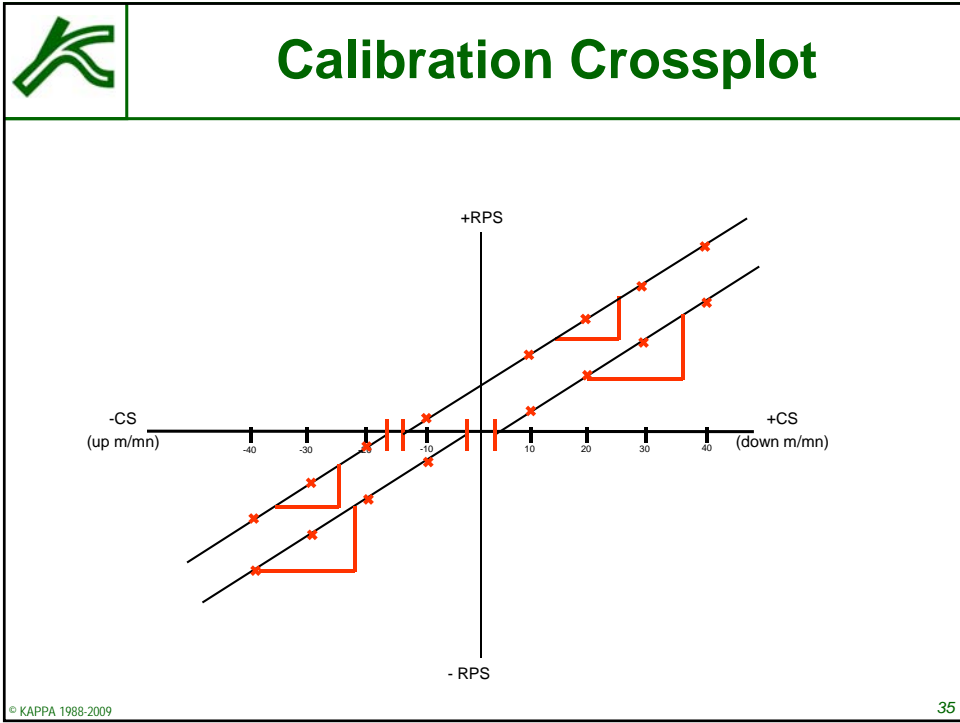
NOTE:
 Slope AND threshold change with fluid type
 (and possibly rate!)

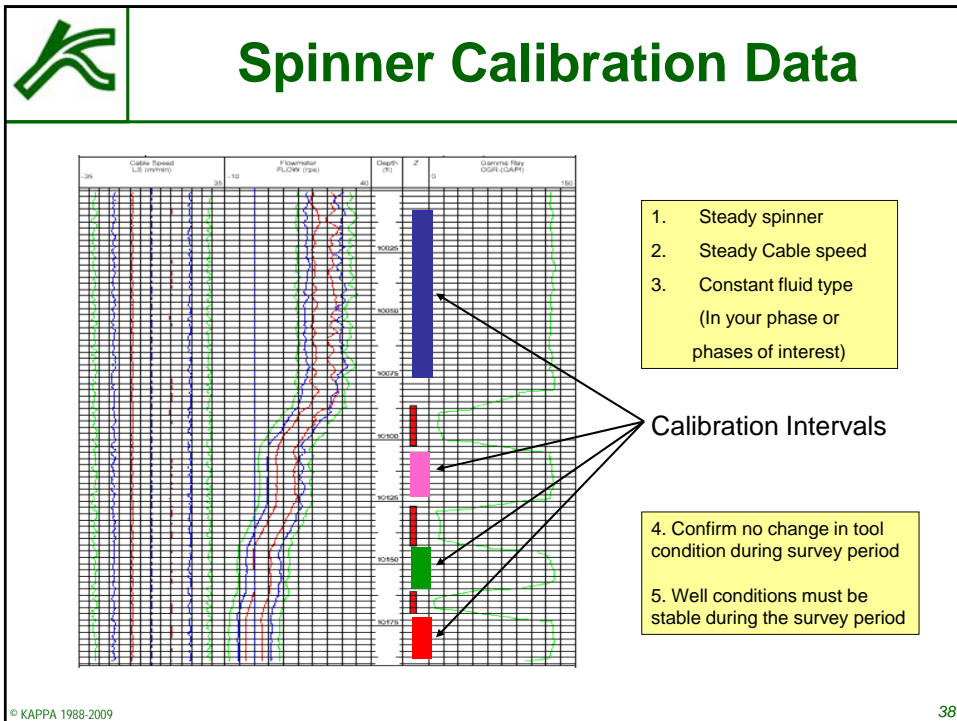
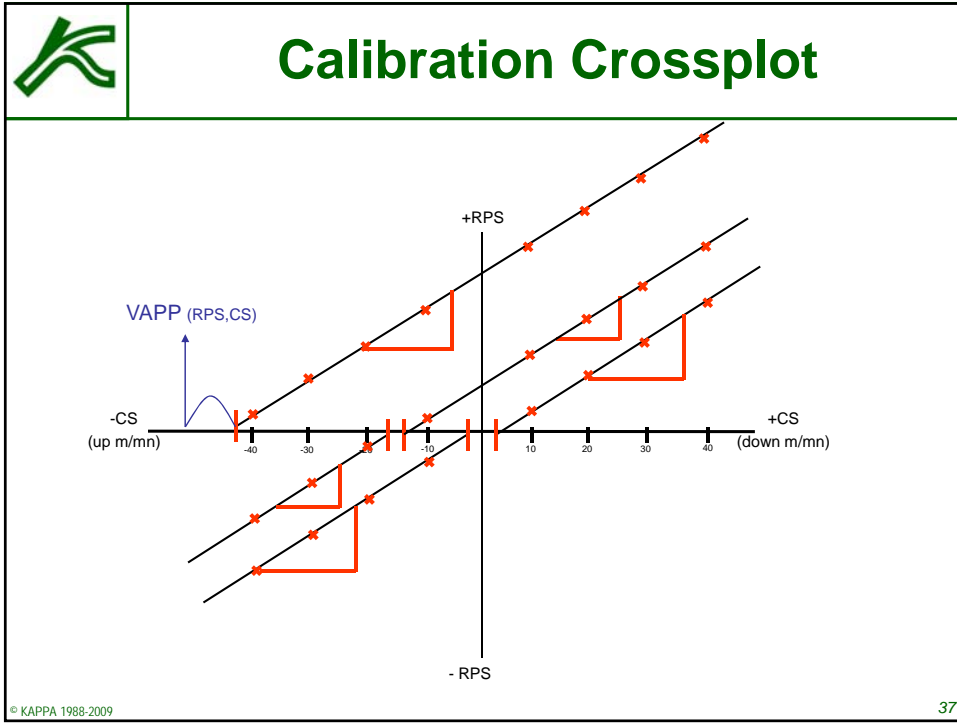
Increase in threshold from liquids to gas. →

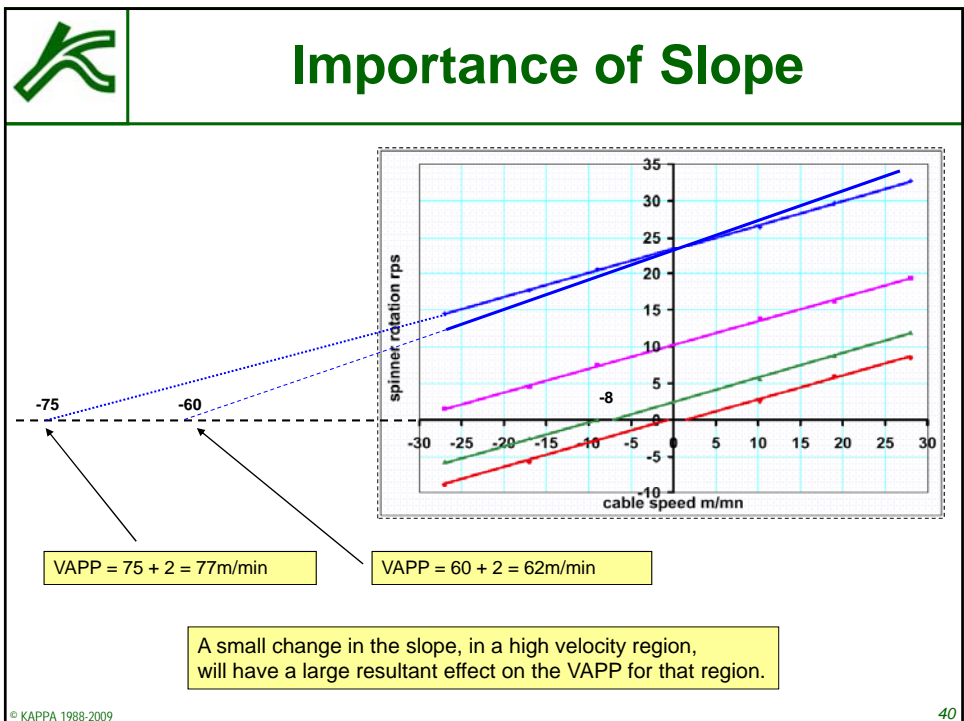
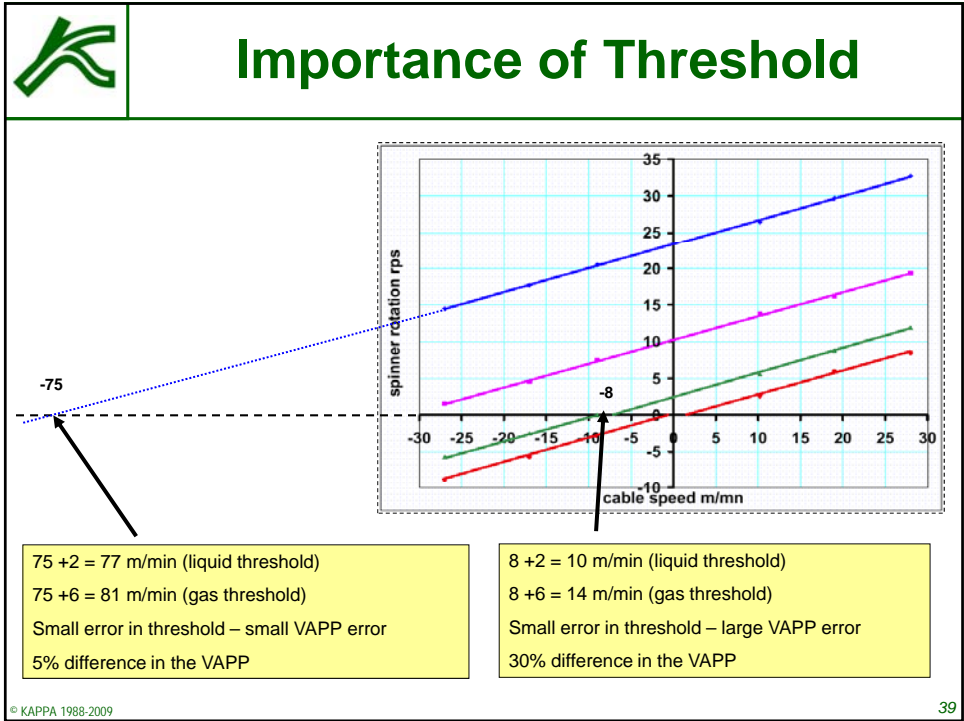
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Emeraude Calibration Modes

Mode 1

Unique value of (+) and (-) threshold

Mode 2

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

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Emeraude Calibration Modes

Mode 3


Multiple and independent, slopes and thresholds – “user defined”

Full flow zone

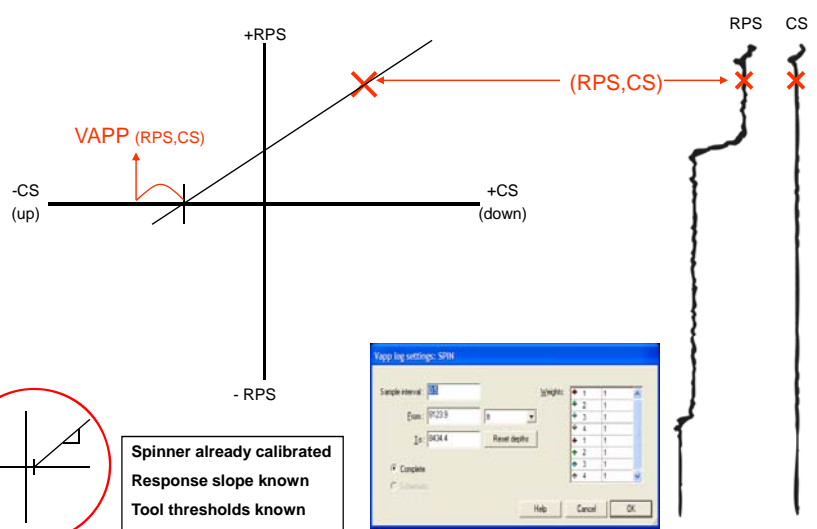
Intermediate flow zone

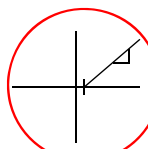
Zero flow zone

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Calculating VAPP





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

Vapp log settings: SPIN

Sample interval: 1

Com: 0.23.9

Ex: 0.00.4


Revel depth:

Complete

Help Cancel OK

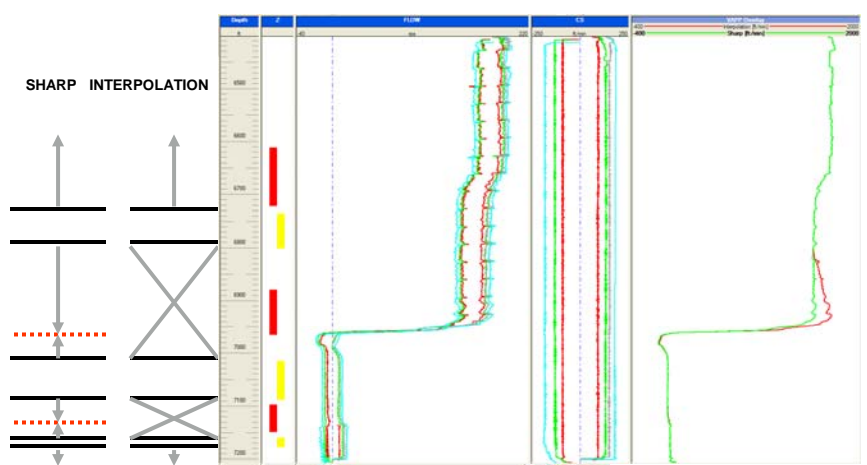
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Transitions

SHARP INTERPOLATION

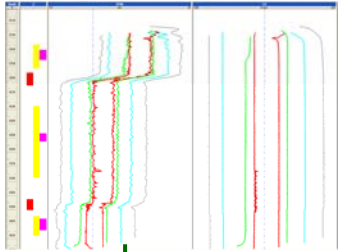


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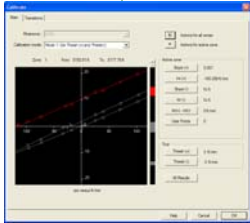
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Spinner to VAPP summary




- 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





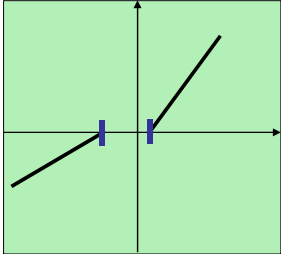


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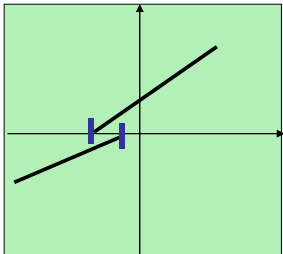
Anomalies

Different slopes & thresholds



It is normal that both the positive and negative thresholds and slopes are asymmetrical due to asymmetry 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.


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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

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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


Nom OD	DESCRIPTION				FLUID VELOCITY FOR FLOW RATE OF:											
	Wt	Int Diameter		1,000 B/D			10 cu m/hr			100 cu m/D			1,000 cu ft/D			
	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	
7" (177.8)	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	
	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	
	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

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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	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


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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.

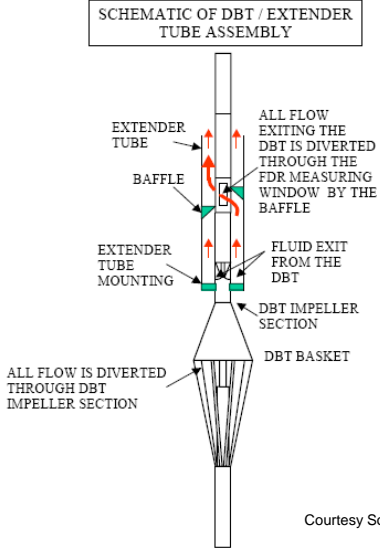
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Sondex Diverter Flowmeter



SCHEMATIC OF DBT / EXTENDER TUBE ASSEMBLY



EXTENDER TUBE
BAFFLE
EXTENDER TUBE MOUNTING
DBT IMPELLER SECTION
DBT BASKET


ALL FLOW EXITING THE DBT IS DIVERTED THROUGH THE FDR MEASURING WINDOW BY THE BAFFLE

FLUID EXIT FROM THE DBT

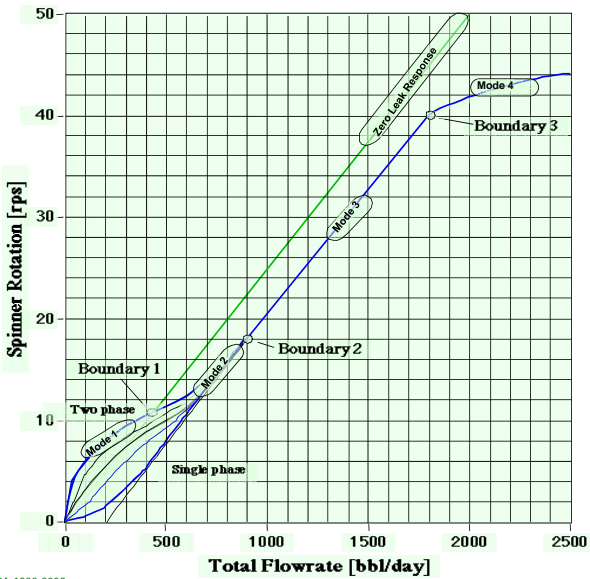
ALL FLOW IS DIVERTED THROUGH DBT IMPELLER SECTION

Courtesy Sondex

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Petal Basket



Spinner Rotation [rps]

Total Flowrate [bbl/day]

Boundary 1
Boundary 2
Boundary 3

Mode 1
Mode 2
Mode 3
Mode 4

Two phase
Single phase

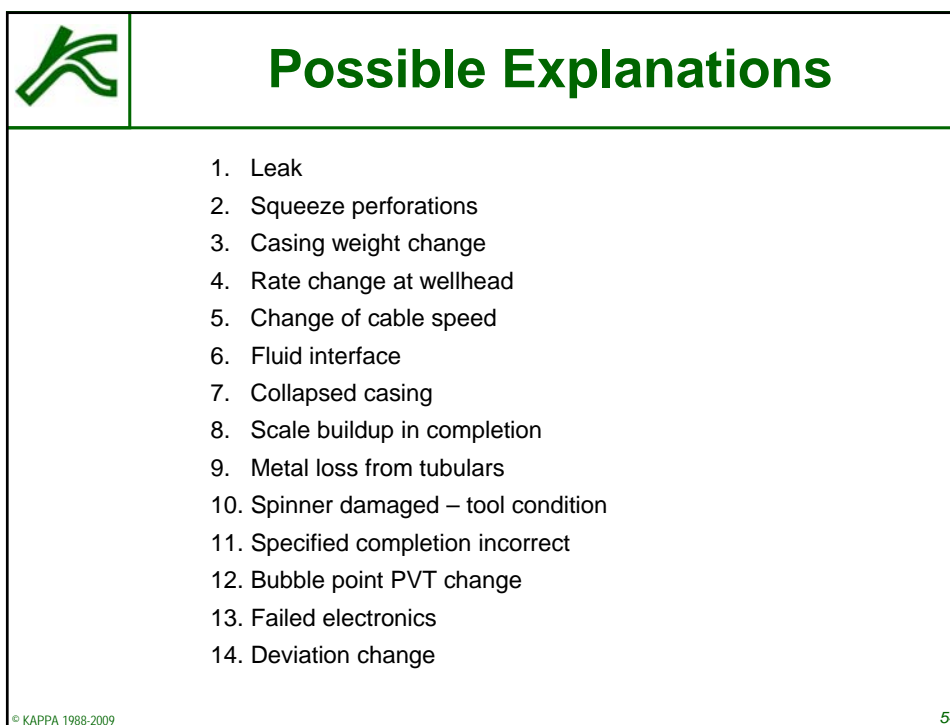
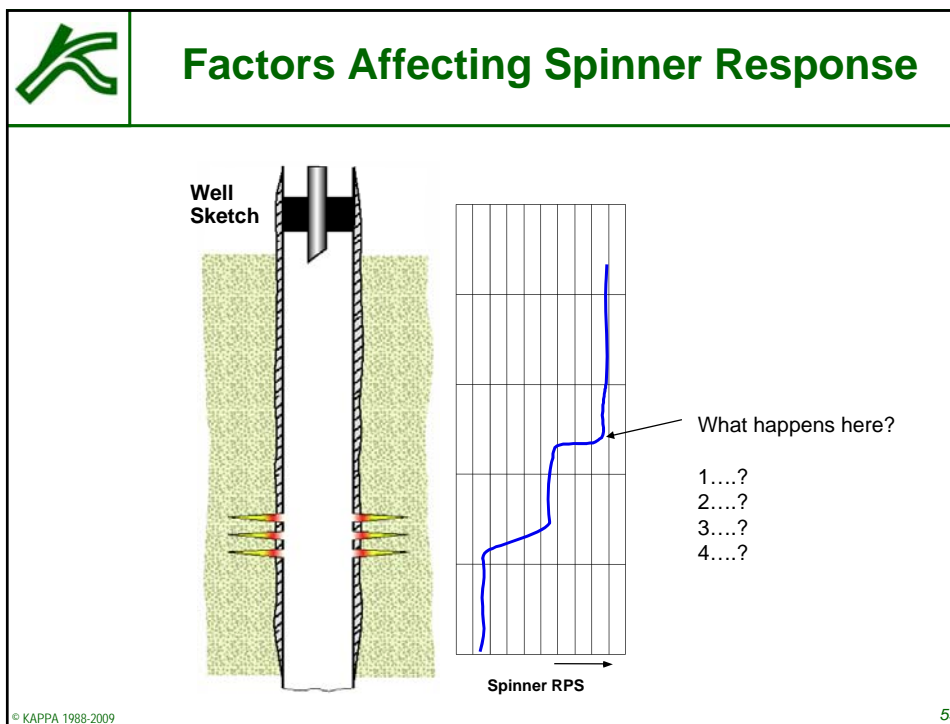
Zero Leak Response

Tool calibration chart, or equations, supplied by manufacturer

e.g. RATE

$$= (RPS * 75.2 + 25) / 6.2898$$

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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

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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

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