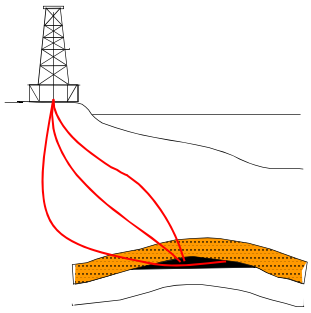
Deviated & Horizontal Wells

KAPPA

DEVIATED AND
HORIZONTAL WELLS

Module #17

Deviated Wells-shape



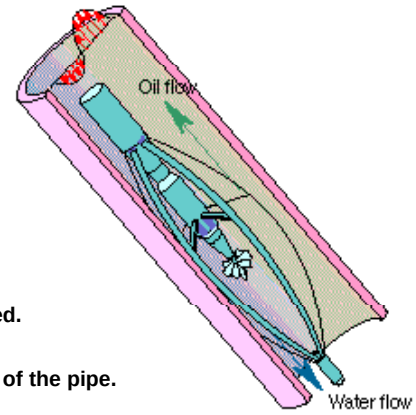
The deviated well can take any shape in three dimensions.

These changes in angle are what will cause problems.

Deviated Well: Apparent Down Flow

ADF requirements
- Deviation
- Multiphase
- Low velocity

No chart book available



- **In high angle wells, the flow is stratified.**
- **The light phase flows faster at the top of the pipe.**
- **The heavier fluid may flow back down the pipe.**

Apparent Down Flow

- The centered spinner measures the “wrong flow!
- The light phase is flowing on the high side of the pipe, much faster than the average velocity as measured by the spinner in the heavy phase on the low side of the pipe!
- The resulting flow profile can result in the spinner showing a downward crossflow “apparent downflow”.. ADF
- The density measurements could also give erroneous readings, depending on the tool type and position inside the wellbore (typically on the low side of the pipe, in the heavier fluid!)

ADF

#1 Ignore spinner data

#2 Set $V_{sH} = 0$

Liq – Gas	Dukler
Liq – Liq	ABB Deviated

#3 Use equation

$$V_{sL} = C * V_s (1-Y_H)$$

- An ADF will not follow IPR behaviour between different flow rates
- Need a shut in pass, or multiple flowrate to confirm or deny ADF
- Any suspected ADF should be discussed with the reservoir engineer
- NOTE: Only available in 2-phase models

Horizontal Wells

Horizontal wells have been drilled in large numbers since the 1980's.

There are a number of reasons:

- increased flow for low incremental cost
- reduced coning, especially in wells with large gas caps
- access fields or areas of fields far from the platform
- reduce the pressure drop across the reservoir
- intersect fractures to increase flow

Tractor and Coiled Tubing

These are specific conveyance techniques for horizontal wells

Advantages

- **can log horizontally**

Disadvantages

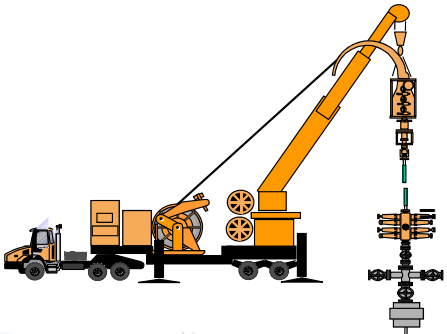
- **expensive**
- **logging speed not always constant due to friction between the pipes.**
- **Can be restricted to 1 direction due to tractor powering**
- **May not be able to log complete interval due to CTU "lockup"**
- **Very hard on sensitive logging sensors.**

Tractor and Coiled Tubing

Coiled Tubing Logging	
Advantages	Disadvantages
• High success rate • Rig not required • Maintains well control • Stimulation	• CTL unit mobilization • Extra personnel • Limited reach (Helixing)
Tractor	
Advantages	Disadvantages
• Fast • All standard PS services • Standard Field Crew	• Cased hole only* • Can only log in one direction* • Not suited for every well

* Tractors are available that can be run in open hole and are capable of logging in both directions

Coiled Tubing Logging



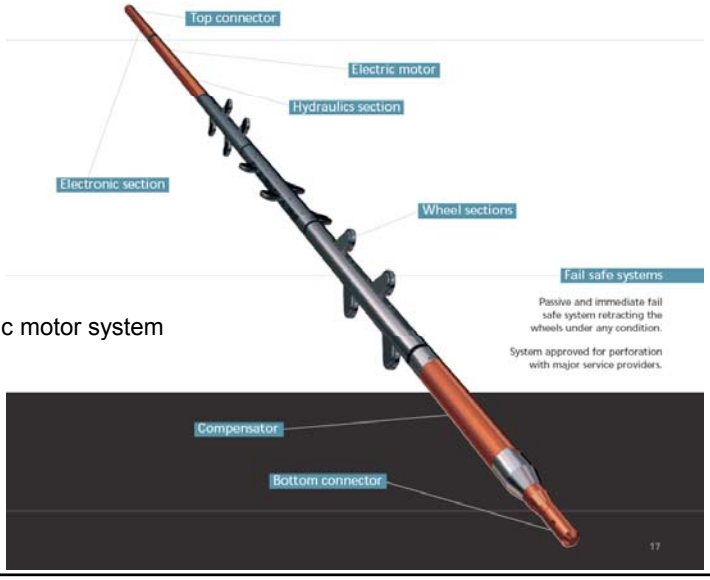
- Power Pack & Control Cabin
  2.50 x 4.60 x 2.50 m / 10 tons
- Injector Head
  2.75 x 2.50 x 3.00 m / 6 tons
- Tool Container
  2.50 x 2.45 x 2.65 m / 4 tons
- Coil Tubing Reel
  3.36 x 2.50 x 3.15 m / 27 tons

(Plus Nitrogen equipment)

Sondex Tractor

- **continuous pull 600 lbs.**
- **continuous speed 9 m /min**
- **weight 200 lbs.**
- **length 23ft (Including 2 drive sections)**
- **temperature rating 150 DegC**
- **pressure rating 15,000 psi**
- **electric motors**

Welltec Tractor



Hydraulic motor system

Schlumberger Tractor

- **Inchworm Traction System**
- **Low Power Requirement**
- **Modular Design**
- **Low sensitivity to borehole conditions, most suited to OH so far**
- **Log down PL tools, saving time with better data**
- **Run with standard cables, no stops to cool down**
- **Multi-sonde capability allows logging wide range of completions**

Courtesy SCHLUMBERGER

Schlumberger Tractor

Operational

Nominal Speed	2200 ft/hr @ 500 lbs.
Maximum Pull	1000 lbs
Casing range	2-7/8″ to 9-5/8″ for Tractoring (Min. restriction =2.21″)
Max Reach	Well dependant, must be modeled
Max Dogleg	45 deg/100ft in 7inch casing
Cable	All standard SLB cable types (mono & hepta)
Motion	Continuous, Downhole only
Well Bore	Cased Hole, Perforations, Slotted Liner, Consolidated OH completions

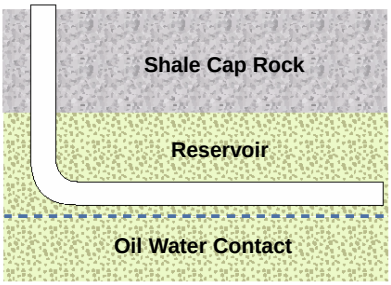
Functionality / Combinability

- Down logging while tractoring with PSP & compatible tools – RST, Flagship, SCMT
- Convey and up log non PSP monocable tools
- Convey and up log hepta cable tools
- Perforating

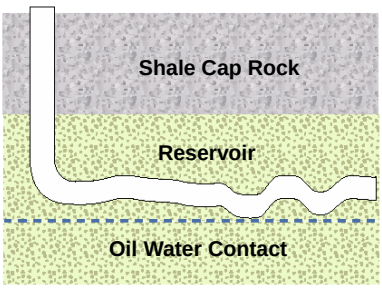
Mechanical

Max. Diameter	2-1/8″	Length	32 ft (2 sondes)
Max. Temperature	150ºC	Max. Pressure	15,000 psi
Fishing Strength	13,000lbs		

Horizontal Wells



The ideal horizontal well, exactly horizontal.



The real horizontal well, anything but horizontal.

Horizontal Well Shape

Horizontal wells are NEVER horizontal!

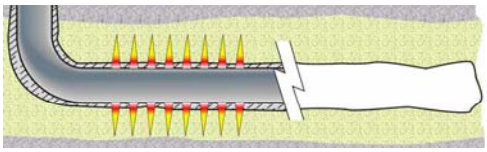
The section where the well goes from the vertical to the horizontal is called the “heel”, while the end of the well is referred to as the “toe”

It is critical to have access to view the wellbore trajectory, when interpreting PL data, since any changes in the inclination will severely affect the flow regime and subsequent flow profile.

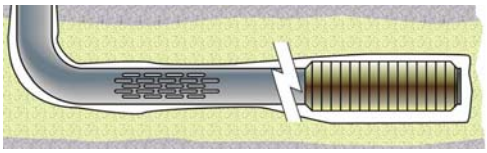
Various completion designs are used:

Open hole, slotted liner, conventional perforations, external packers, multilaterals.

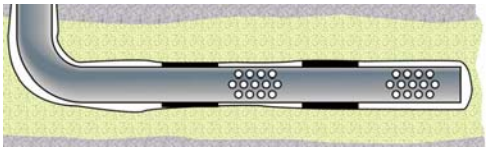
Horizontal well completions



Cemented/perforated casing **Open hole**



Slotted liner **Prepack gravel**



Multiple external packers

Horizontal Well: Questions

The first question is
- Where are the fluid entries and what are they?

The next question is
- What happens to the flow in the wellbore?

Although the questions appear simple, they are difficult to answer, using conventional PL tools, due to the segregated and mixed flow regimes, as a result of the deviation

Alternative tools are required to bring additional measurements to the PL Interpretation, to resolve the flow regime problems in the Horizontal flowing environment.

Horizontal wells tools

PL tools to address those issues, in particular with the objectives to:

- **Assess the flow regime while running the tools**

Sondex	***CAT, RAT, SAT***
Baker-Atlas	***MCFM***
Schlumberger	***DEFT, GHOST, FSI***

- **Measure phase velocities directly so that slip models are not needed and/or can be checked**

Schlumberger	***PVL, WFL (oxygen activation)***
Baker-Atlas	***MCFM***
Halliburton	***Spectral flow (oxygen activation)***

- **Record unfocused holdup measurements**

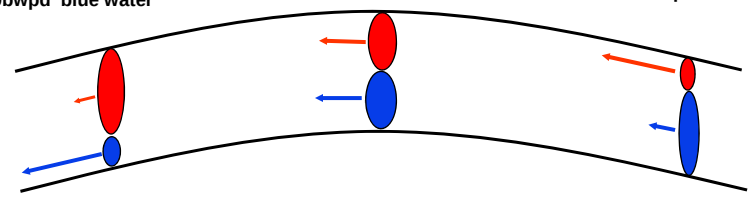
Schlumberger	***RST,***
Halliburton/Sondex	***GHT,***
Baker-Atlas	***PNHI***

Horizontal Problem

NOTE: only change of deviation

1000bopd red kerosene
1000bwpd blue water

1000bopd red kerosene
1000bwpd blue water



1). 90deg Deviation

Qoil = Qwater

Yoil = Ywater

Voil = Vwater

2). 92deg Deviation

Qoil = Qwater

Yoil >>> Ywater

Voil <<< Vwater

3). 88deg Deviation

Qoil = Qwater

Yoil <<< Ywater

Voil >>> Vwater

This behaviour demonstrates the need for probe type holdup measurements, and direct phase velocity measurements.

Horizontal Well: Flow

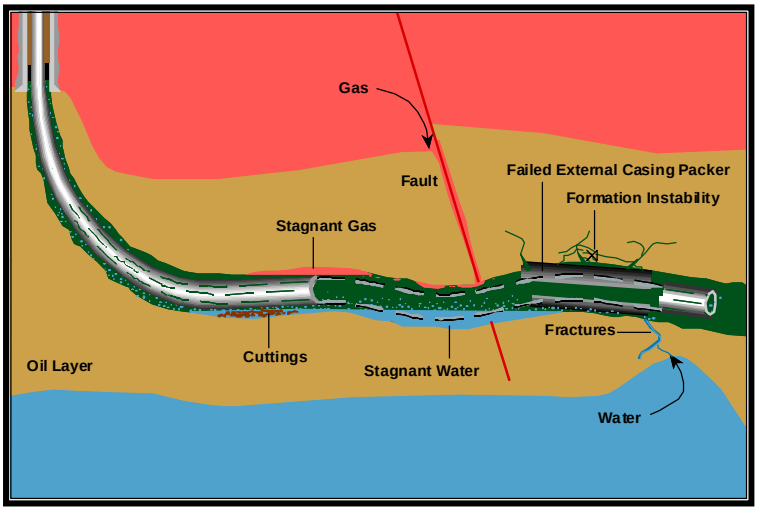
- **The angle of the horizontal well gives the major problem in analyzing the flow.**
- **Assuming the well is at exactly 90° and the flow of water and oil is equal, the flow, velocity and hold ups are split equally between the two fluids.**
- **If the angle goes to 88° the situation changes dramatically, the heavy phase, water, slows down and occupies most of the pipe, as it "climbs" up the slope.**
- **If the angle goes to 92° the water speeds up occupying only a small part of the pipe.**

Sumps & Traps

- The variations in the well track create lows (sumps), often trapping water in these areas.
- Oil flows from below this will pass over the top in a very thin layer, often at higher velocities, sometimes creating apparent inflow zones.
- It may be impossible to identify with the density tools.

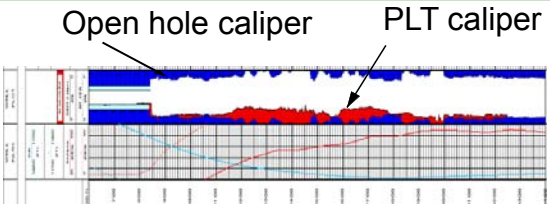
- The well track can also create highs.
- These “highs” can trap gas.
- If there is enough gas trapped, there could be a “gas lock” blocking fluid flow.

Some Potential Problems in Horizontal Wells



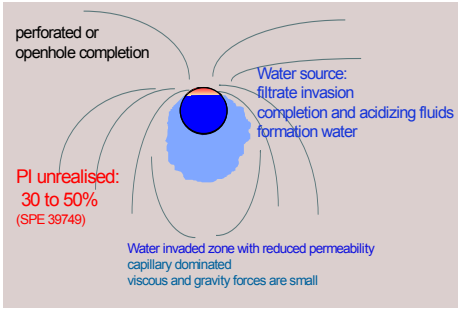
Courtesy SCHLUMBERGER

Horizontal Well Phenomena



Debris Filled Borehole

Water Sumps Affect Productivity



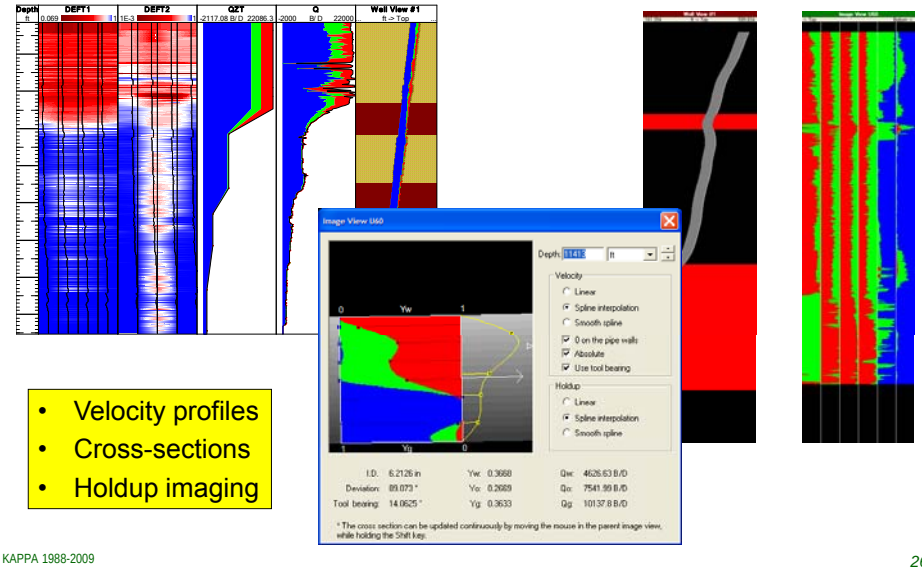
Horizontal well problems

- **Specific flow regimes occur with high segregation between the phases (stratified, stratified wavy, etc).**
- **Large "slippage velocities" are seen: a phase may flow with a significant rate, yet occupy a very small portion of the pipe (ie. Small holdup)**
- **Near horizontal, the dependency of the slippage velocity with angle is exemplified.**
- **The completions may produce channeling (gravel pack) for instance…**

Horizontal Wells: Summary

- Horizontal wells have PL logging problems because:
- They are NEVER horizontal, which causes complex flow regimes
- A phase flowing in part of the well may not flow everywhere and may never reach surface
- The well may cross undetected faults leading to unexpected fluids.
- Water will gather in the sumps and gas in the highs

Emeraude tools for Horizontal Wells



- Velocity profiles
- Cross-sections
- Holdup imaging

PL INTERPRETATION?