Insights Into the Physical Phenomena That Influence Automatic Gain/Loss Detection During Drilling Operations

Eric Cayeux
Int. Research Inst. Of Stavanger

Outline

- Introduction
- Gain/loss indicators
- Return Flow From the Annulus
- Return Flow in Pressurized MPD
- Normal Active Volume Variations
- Example 1: Kick Detection During Connection
- Example 2: Draw-Down Tests During an MPD Operation
- Conclusion

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Introduction

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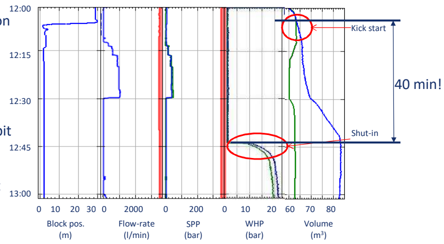
- Operator A
- Country 1
- During the connection procedure, after drilling a stand without any warning signs (neither connection gas nor drilling breaks), the pit volume start to increase
- The drilling team got confused and took a long time before shutin the well



Measured values
Modeled values
Maximum values

Introduction

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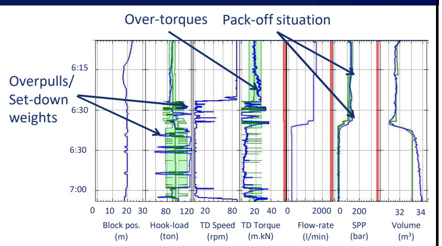
- Operator B
- Country 2
- During a pack-off situation



Measured values
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Introduction

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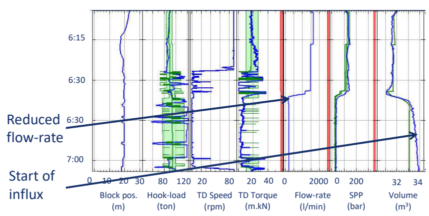
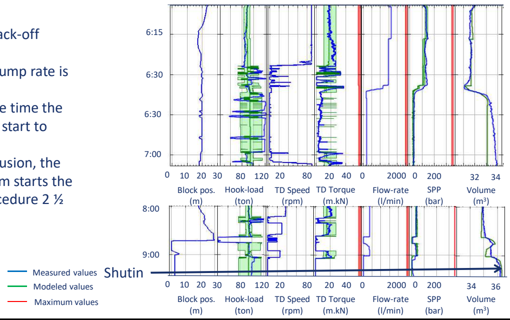
- Operator B
- Country 2
- During a pack-off situation
- The mud pump rate is reduced
- At the same time the pit volume start to increase



Measured values
Modeled values
Maximum values

Introduction

- Operator B
- Country 2
- During a pack-off situation
- The mud pump rate is reduced
- At the same time the pit volume start to increase
- In the confusion, the drilling team starts the shutin procedure 2 ½ later



Introduction

- In stressed situations, important information may be overlooked therefore impeding a timely decision taking under critical conditions
- Thus it could be desirable to automate the detection of abnormal gains or losses
- However, false positive or negative can reduce the trust in such automatic detection methods
- We will therefore review different physical phenomena that naturally influence the indicators utilized in gain and loss detection

Poll Question

Where are you located?

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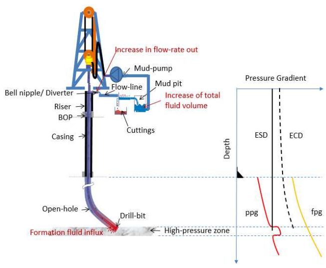
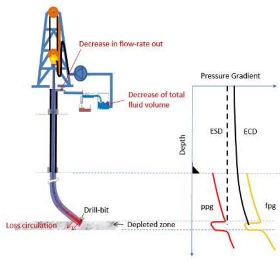
Gain/loss indicators

- When the annulus pressure is lower than the pore pressure somewhere along the open hole section
- Formation fluid can enter the annulus
- This creates an addition flow that can be detected with a flow-meter on the flow out of the well and an increase of pit volume



Gain/loss indicators

- Similarly, if the annulus pressure gets larger than the fracturing pressure limit along the open hole section
- The formation rocks start to fracture and the fractures continue to propagate inside the formation as long as the over-pressure is maintained
- This results in a loss of fluids that can be detected with a flow-meter on the flow out of the well and a decrease of pit volume



Gain/loss indicators

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- Similarly, if the annulus pressure gets larger than the fracturing pressure limit along the open hole section
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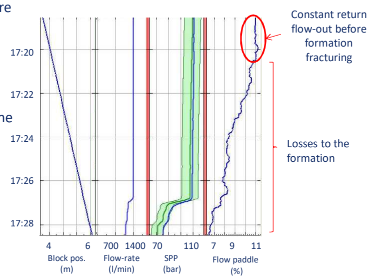

Measured values
Modeled values
Maximum values

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Gain/loss indicators

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Detection of formation fluid influxes or mud losses to the formation is done by checking:

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Gain/loss indicators

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Detection of formation fluid influxes or mud losses to the formation is done by checking:

- Abnormal variations of active volume
  - Easy when in steady state conditions
  - During transient period, use finger printing with earlier similar conditions
  - Changes may occur due to pit management or mud treatment

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Gain/loss indicators

Detection of formation fluid influxes or mud losses to the formation is done by checking:

- Abnormal variations of active volume
- **Delta-flow: $Q_{in} = Q_{out}$**
  - Only works in steady state conditions
  - Require a reliable measurement of the flow-rate out
  - Is the flow-paddle reliable enough?
  - Is the flow-rate in precise enough when based on pump-rate?

Gain/loss indicators

Detection of formation fluid influxes or mud losses to the formation is done by checking:

- Abnormal variations of active volume
- **Delta-flow: $Q_{in} = Q_{out}$**
- Variations of stand-pipe pressure and annular discharge pressure in steady state conditions
  - Only works in steady state conditions
  - Require a pressure drop on the outlet of the well

Gain/loss indicators

Detection of formation fluid influxes or mud losses to the formation is done by checking:

- Abnormal variations of active volume
- **Delta-flow: $Q_{in} = Q_{out}$**
- Variations of stand-pipe pressure and annular discharge pressure in steady state conditions
- Processed flow-rate out
  - Require a measurement of the flow-rate out
  - Require precise description of the borehole

Gain/loss indicators

Detection of formation fluid influxes or mud losses to the formation is done by checking:

- Abnormal variations of active volume
- **Delta-flow:** $Q_{in} = Q_{out}$
- Variations of stand-pipe pressure and annular discharge pressure in steady state conditions
- Processed flow-rate out

Detecting gain/loss during transient periods is a challenge

Poll Question

In your drilling operations, when do you mostly get kicks?

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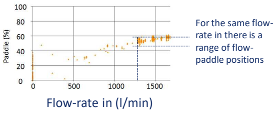
Return Flow From the Annulus

The most common measurement of flow-rate out of a well is the flow paddle.

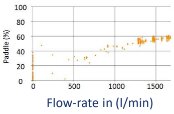
Return Flow From the Annulus

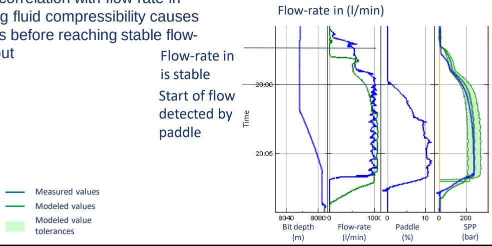
Flow-rate out measured with a paddle when flow-rate in is constant:
- For this example, flow paddle does not detect flow-rate below 500l/min
- Poor correlation with flow-rate in



Return Flow From the Annulus

Flow-rate out measured with a paddle when flow-rate in is constant:
- For this example, flow paddle does not detect flow-rate below 500l/min
- Poor correlation with flow-rate in
- Drilling fluid compressibility causes delays before reaching stable flow-rate out





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Return Flow From the Annulus

Flow-rate out measured with a paddle when flow-rate in is constant:
- For this example, flow paddle does not detect flow-rate below 500l/min
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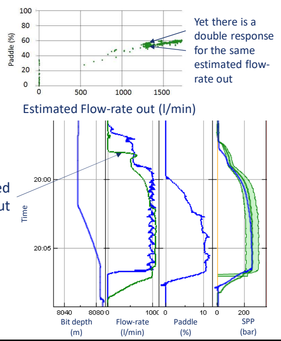
- Drilling fluid compressibility cause delay in stable flow-rate out
- Better correlation with estimated flow-rate out



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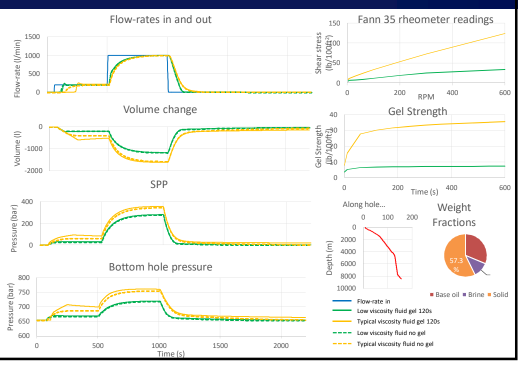
Return Flow From the Annulus

Delays depend not only on compressibility but also rheological properties



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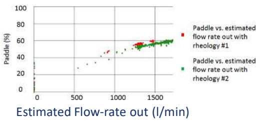
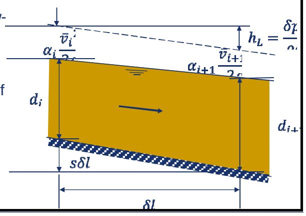
Return Flow From the Annulus

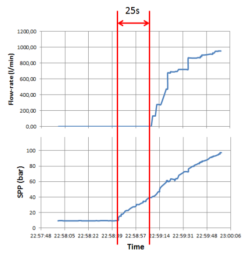
Flow-rate out measured with a paddle when flow-rate in is constant:
- For this example, flow paddle does not detect flow-rate below 500l/min
- Poor correlation with flow-rate in
- Drilling fluid compressibility cause delay in stable flow-rate out
- Better correlation with estimated flow-rate out
- Correlation changes with drilling fluid rheology properties as level in flow-line depends on viscous properties of fluid





Return Flow From the Annulus

Flow-rate out measured with a paddle when flow-rate in is constant:
- For this example, flow paddle does not detect flow-rate below 500l/min
- Poor correlation with flow-rate in
- Drilling fluid compressibility cause delay in stable flow-rate out
- Better correlation with estimated flow-rate out
- Correlation changes with drilling fluid viscosity
- Timing is important, but flow-rate based on stroke counter can be misleading at low flow-rate



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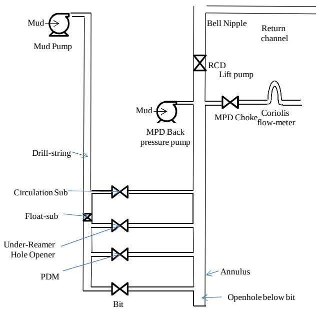
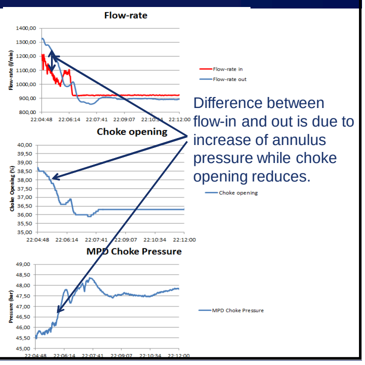
Return Flow in Pressurized MPD

- With pressurized MPD, usually a Coriolis flow-meter is placed after the MPD choke



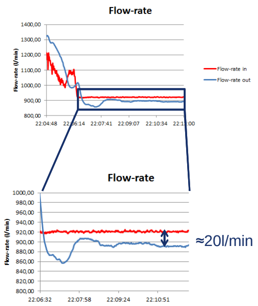
Return Flow in Pressurized MPD

- With pressurized MPD, usually a Coriolis flow-meter is placed after the MPD choke
- Any changes of choke opening cause transient variations of flow-rate



Return Flow in Pressurized MPD

- With pressurized MPD, usually a Coriolis flow-meter is placed after the MPD choke
- Any changes of choke opening cause transient variations of flow-rate
- Coriolis flow-meter before back-pressure pump differs slightly from the one behind the MPD choke



Coriolis flowmeter in conventional drilling

- In conventional drilling, the annulus is not sealed
- Therefore a Coriolis flowmeter should create as little pressure drop as possible to avoid an overflow at the top of the annulus
- Therefore Coriolis flowmeters have to be of large dimensions and require a substantial footprint to be installed
- Coriolis flowmeters should always be filled with liquid, thus their highest point should be below the bell nipple or diverter level
- If they are mounted flat, then cuttings tend to accumulate on the low side therefore necessitating regular flushing to regain the full precision of the apparatus
- However, if there is enough room to install properly a Coriolis flowmeter at the rig site then it is a precise instrument to measure the flow-rate out of the well

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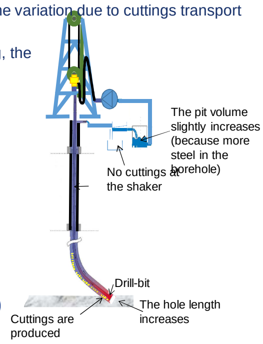
Normal Active Volume Variations

Active volume variation due to cuttings transport

When drilling, the hole depth is increased



Normal Active Volume Variations

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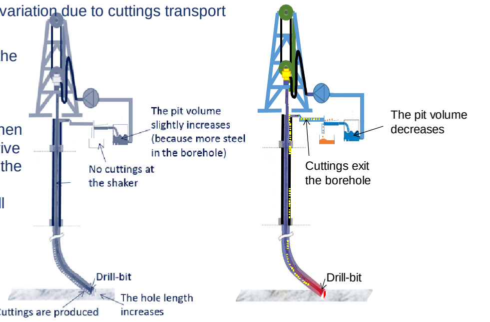
Active volume variation due to cuttings transport

When drilling, the hole depth is increased

But it is only when the cuttings arrive at surface that the pit volume decreases to fill the longer hole that has been created



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Normal Active Volume Variations

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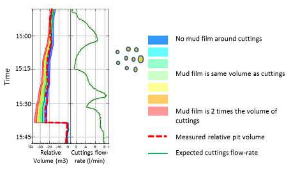
Active volume variation due to cuttings transport

- Therefore, pit volume variations are expected that correspond to cuttings transported to surface
- Some mud is lost together with the cuttings
- With proper transient cuttings transport modelling, it is possible to estimate possible variations of the active volume related to hole cleaning



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Normal Active Volume Variations

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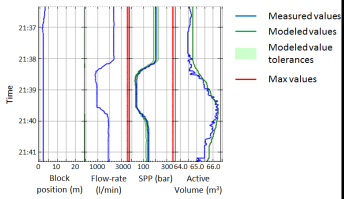
Active volume variation due to change of flow-rate

- Active volume depends on flow-rate



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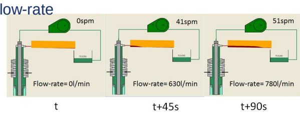
Normal Active Volume Variations

Active volume variation due to change of flow-rate

- Active volume depends on flow-rate
- Because some volume is accumulated in the return flow-line, shale shakers and other mud treatment pits
- When flow-rate increases, more mud is accumulated



Normal Active Volume Variations

Active volume variation due to change of flow-rate

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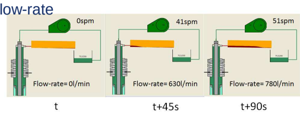
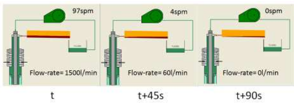
- When flow-rate decreases, less mud is accumulated

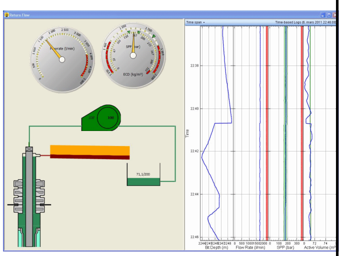




Normal Active Volume Variations

Active volume variation due to change of flow-rate

- Active volume depends on flow-rate
- Because some volume is accumulated in the return flow-line, shale shakers and other mud treatment pits
- When flow-rate increases, more mud is accumulated
- When flow-rate decreases, less mud is accumulated
- The effect of mud retention in the return flow-lines is superposed to the effect associated with mud compressibility inside the borehole



Normal Active Volume Variations

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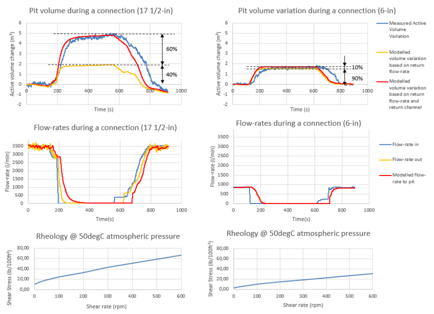
Active volume variation due to change of flow-rate

- The relative importance of mud retention and mud compressibility depends the flow-rate, mud volume contained in the wellbore and pressure losses along the hydraulic circuit



Normal Active Volume Variations

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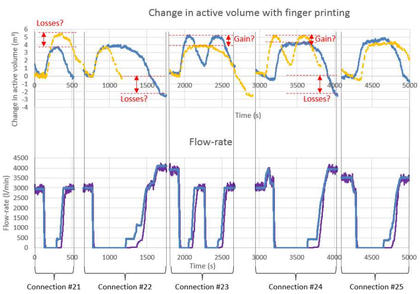
Active volume variation due to change of flow-rate

- Finger printing consists in comparing the current flow-back pattern with a previous one to determine whether there is an abnormal evolution
- This works fine with reasonably consistent connection procedures but can be challenging otherwise



Normal Active Volume Variations

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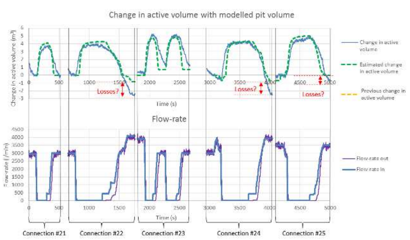
Active volume variation due to change of flow-rate

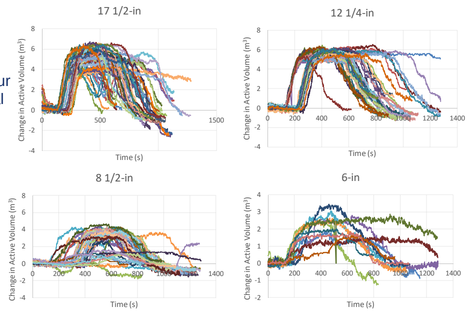
- But using models of both the effect of mud compressibility inside the borehole and retention in the return flow-lines can provide a more versatile solution



Normal Active Volume Variations

Active volume variation due to change of flow-rate

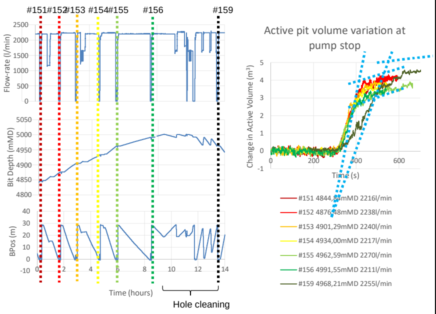
Here are all the pit volume variations while drilling the four sections of a typical well in the North Sea



Normal Active Volume Variations

Active volume variation due to change of flow-rate

- The mud retention in the return flow-lines is also affected by the presence of cuttings
- When drilling fast, cuttings accumulates in the flow-line
- While with slow drilling, accumulated cuttings can be eroded from the return flow-line



Poll Question

What do you based your kick detection on when circulating?

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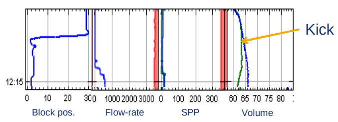
Example 1: Kick Detection During Connection

- Drilling 9 ½ x 10 ¾ "
- No connection gas prior to event

Example 1: Kick Detection During Connection

- Drilling 9 ½ x 10 ¾ "
- No connection gas prior to event
- At mud pump stop, take a kick while pit volume is changing due to mud accumulated in return flow lines
- Easily visible when comparing measured active volume with estimated one using transient model



Example 1: Kick Detection During Connection

- Drilling 9 ½ x 10 ¾ "
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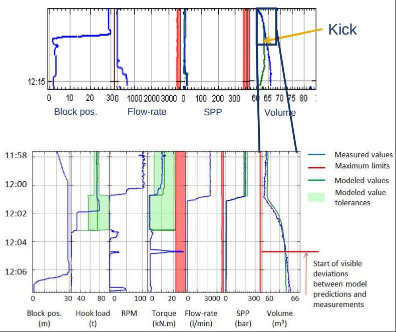
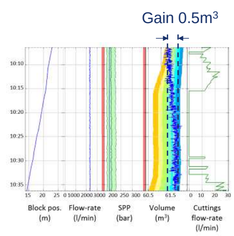


Example 1: Kick Detection During Connection

- There was an observable gain that started about half way through the drilling of the last stand
- But because the mud was oil based, gas that entered the annulus gets absorbed in the oil phase of the drilling fluid and the gain receded
- It would be difficult to spot that gain without some reference to expected cuttings return at the surface



Poll Question

By wells drilled, how often do your experience kicks?

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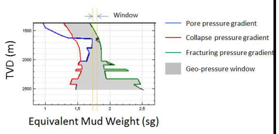
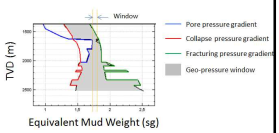
Example 2: Draw-Down Tests During an MPD Operation

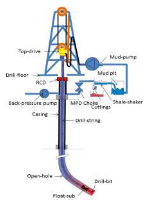
- Narrow geo-pressure window



Example 2: Draw-Down Tests During an MPD Operation

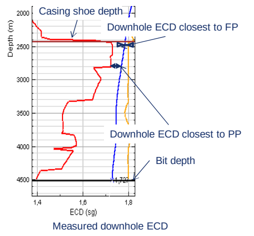
- Narrow geo-pressure window
- Drilling with pressurized MPD





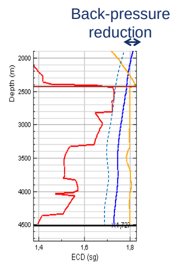
Example 2: Draw-Down Tests During an MPD Operation

- Narrow geo-pressure window
- Drilling with pressurized MPD
- Draw-down test to check max pore pressure while drilling narrow geo-pressure window



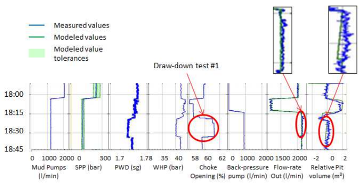
Example 2: Draw-Down Tests During an MPD Operation

- Narrow geo-pressure window
- Drilling with pressurized MPD
- Draw-down test to check max pore pressure while drilling narrow geo-pressure window
- Reduce downhole pressure by 1 bar for 10min. and observe if flow-rate out increases or gain in pit
- Repeat procedure until max pore pressure is observed



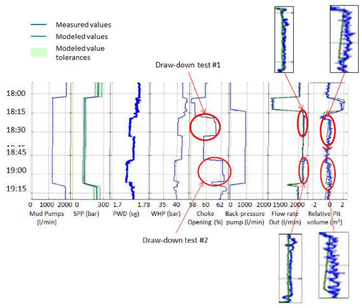
Example 2: Draw-Down Tests During an MPD Operation

- First draw-down test:
- Difficult to see increase in flow-rate out
- Gain in active pit is visible if one compare to estimated active volume including thermal effects



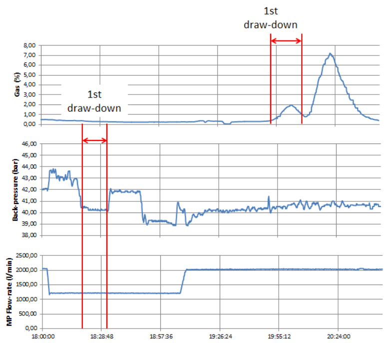
Example 2: Draw-Down Tests During an MPD Operation

- First draw-down test:
  - Difficult to see increase in flow-rate out
  - Gain in active pit is visible if one compare to estimated active volume including thermal effects
- Second draw-down test
  - Increase in flow-rate out i more visible
  - Gain in active pit is visible compared to estimated pi volume but barely visible otherwise



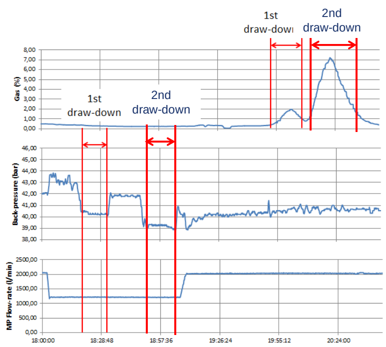
Example 2: Draw-Down Tests During an MPD Operation

- First draw-down test resulted in small quantity of gas



Example 2: Draw-Down Tests During an MPD Operation

- First draw-down test resulted in small quantity of gas
- Second draw-down test caused more gas to be observed at the surface



Outline

- Introduction
- Gain/loss indicators
- Return Flow From the Annulus
- Return Flow in Pressurized MPD
- Normal Active Volume Variations
- Example 1: Kick Detection During Connection
- Example 2: Draw-Down Tests During an MPD Operation
- Conclusion

Conclusion

- Transient periods are important for gain and loss detection
- Mud compressibility plays an important role in return flow
- Thermal exchange changes the mud density and influences pit volume
- Cuttings transport and separation cause variations in pit volume
- Transient hydraulic helps to estimate flow-rate out of well
- Modeling of flow in return flow-line, shale shaker and other mud treatment pits gives good estimates of transitional variations of pit volume

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- The modeling of all these effects combined together gives a precise determination of gain and loss conditions

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Thank you for your attention
Any Questions?