Uncertainty In Depth: Reduced

Managing Along-hole Depth Measurement Uncertainty

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Depth Solutions
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speaker background

Depth Solutions, DwpD Ltd

30 years after trying to figure out where TD is

Now trying to figure out how correct it is

DwpD Ltd. specializes in

- Along-hole depth
- Determining requirements
- Measurement and correction
- Uncertainty
- Process, audit and training
Why bother?

One end of the spectrum:

“We never have a depth problem …”

Until “the problem” occurs.

Then the other end of the spectrum:

“We had no end of depth correlation problems on the recent XXX intersect P&A well”

“The FWL’s don’t agree across the reservoir”

“The horizons just don’t match”

“We are not actually sure if there is a fault”

“Maybe the depth is wrong ...”
## Accuracy expectations

How do we define expectations for along-hole depth measurement accuracy in different domains?

<table>
<thead>
<tr>
<th>Measurement relevance</th>
<th>Domain relevance</th>
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</thead>
<tbody>
<tr>
<td>Geological mapping</td>
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<td>Pressure gauge accuracy/resolution</td>
<td>Very detailed events, Compaction events</td>
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</table>
Accuracy components

Requirements! (no requirements = no accuracy!)
Measurement methodology
Calibration system
Correction model and calculation
Uncertainty model and calculation

Depth measurement + Correction +/- Uncertainty
= True Along-hole Depth, TAH
Basic uncertainty relationship

\[ \sum \frac{u(z)}{Z} = \sqrt{\left(\frac{u(x)}{X}\right)^2 + \left(\frac{u(y)}{Y}\right)^2 + \cdots + \left(\frac{u(z)}{Z}\right)^2} \]

calibration  correction  model

My nomenclature:

Accuracy = proportion of a result
Uncertainty = result value
Calibration accuracy

- Measurement standards
- Calibration variables
- Environmental effects
- Measurement effects
- Shelf life
Correction calculation parameters

Thermal expansion

Elastic stretch

Other corrections
## Typical accuracies

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Method</th>
<th>Accuracy, +/- per 10,000 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill pipe length calibration</td>
<td>Strapped pipe</td>
<td>+/- 5 ft to +/- 20 ft</td>
</tr>
<tr>
<td></td>
<td>Lasered pipe</td>
<td>+/- 1.5 ft to +/- 2.5 ft</td>
</tr>
<tr>
<td></td>
<td>On site measurement</td>
<td>Accuracy + 50% to 100%</td>
</tr>
<tr>
<td>Wireline length</td>
<td>Measurehead</td>
<td>+/- 3 ft to +/- 10 ft</td>
</tr>
<tr>
<td>Wireline calibration</td>
<td>Magnetic marks</td>
<td>+/- 1 ft to +/- 2 ft</td>
</tr>
<tr>
<td>ZDP pipe joint identification</td>
<td>Rig floor pipe stick-up</td>
<td>+ 0.25 ft to + 3 ft</td>
</tr>
<tr>
<td>Surface hook load</td>
<td>Hook load</td>
<td>+/- 5% to +/- 10% load</td>
</tr>
<tr>
<td>BHA mud temperature</td>
<td>LWD temperature</td>
<td>+/- 1% of measurement</td>
</tr>
<tr>
<td>Stretch coefficient</td>
<td>Young’s Modulus for steel</td>
<td>+/- 5% of value</td>
</tr>
<tr>
<td></td>
<td>Pipe ID/OD (from specifications)</td>
<td>+/- 5% of value</td>
</tr>
<tr>
<td>Thermal coefficient</td>
<td>Coefficient for steel</td>
<td>+/- 5%</td>
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Wellbore Positioning Technical Section
Correction model

Single point

Straight line

Way-point
Correction model differences
Example (N.Sea): DwpD from 15,000 ft
DwpD correction calculation

**Thermal correction**

\[
\text{TotalThermalElongation} = \sum_{HUD}^{TieIn} \left( \left( \frac{BHT_{TopSeg} + BHT_{BtmSeg}}{2} \right) - \text{TempCalb} \right) \times \text{Calb. Length}_{Seg} \times \text{Th. Coeff}_{Seg}
\]

**Elastic stretch correction**

\[
\text{TotalElasticStretch} = \sum_{HUD}^{TieIn} \left( \left( \frac{Surf. Ten_{TopSeg} + Surf. Ten_{BtmSeg}}{2} \right) - \text{TenCalb} \right) \times \text{Calb. Length}^{1}_{Seg} \times \text{St. Coeff}_{Seg}
\]
Calculated DwpD correction

Driller’s pipe tally depth, ft

Correction, ft

Total correction, ft
Elastic stretch correction, ft
Thermal correction, ft

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)
Differences in correction models

WP and SL correction differences

Correction, ft

Driller’s pipe tally depth, ft

Correction, /ft

0

1000 2000 3000

4000

5000 6000 7000

8000 9000 10000 11000 12000 13000

14000

15000

0

10000 20000 30000

40000

50000 60000 70000

80000 90000 100000 110000 120000 130000

140000

150000

Thermal correction, way-point

Thermal correction, straight-line

Per interval correction/ft, way-point

Per interval correction/ft, straight-line

Total correction, way-point

Total correction, straight-line

Correction, ft

Correction, /ft
Uncertainty, ft, per method

Uncertainty +/-, ft

Driller's pipe tally depth, ft

Wellbore Positioning Technical Section

Strapped pipe, straight-line
Lasered pipe, straight-line
Strapped pipe, way-point
Lasered pipe, way-point
Accuracy, per 10,000 ft, per method

Accuracies per Measurement Method

- Driller’s pipe tally depth, ft
- Accuracy +/-, /10,000 ft

Strapped pipe, straight-line
Laser pipe, straight-line
Strapped pipe, way-point
Laser pipe, way-point
Accuracy improvement actions:
1. Improving laser calibration to +/- 0.015%
2. Improving modeling fidelity to 5%
3. Improving stick-up measurement to +/- 0.2 ft

Laser pipe, way-point, standard accuracy/wp/10000 ft

Reistle & Sikes, 1938 +/- 2 ft/10,000 ft
## Managing expectations

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Understanding the model

- High technical/operational complexity
  - Way-point correction
  - Off-site lasered pipe w/ RFID

- Low technical/operational complexity
  - Manually strapped pipe
  - No corrections

Accumulation:
- Accuracy: 10,000

Effect on drilling budget, $:
- More
- Less
Conclusions

Accuracy is determined by requirements

Uncertainty variables are:
- measurement method used
- calibration methodology
- correction model
- correction elements

The result depends on the investment
Further uncertainties

Your comments on accuracy …