Using Magnetic MWD near Existing Casing

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MagVAR creates high accuracy magnetic models for the directional drilling industry.

SURCON uses these models together with Multi-Station Analysis and advanced QC methods to provide real-time corrections and Quality Control of Wellbore Surveys.
This fire was apparently caused by leakage from a nearby gas well which charged up a shallow aquifer. A shallow collision with a pressured well would produce the same result.

When the wellbore encountered this shallow gas there was no BOP or Diverter in place. The rig crew evacuated but had no way to prevent the rig from burning.

No operator or service company wants this on the front page of the local newspaper.

(from Enid News Sept 2011)
The limitation of using magnetic MWD near existing casing

- Nearby steel casing “interferes” with the earth’s magnetic field
- This magnetic interference causes MWD surveys to fail their Field Acceptance Criteria (FAC or QC values)
- This justifies use of gyroscopic surveys or spacing wells further apart.
External Magnetic Interference

- Direction is from MWD sensor to magnetic pole(s) on nearby casing.
- This will be both horizontal and vertical. In the worst case the horizontal field is about 3x the vertical field. On average they are about the same.
- The peaks in $B_{\text{Horizontal}}$ and $B_{\text{Vertical}}$ are in different places.
- Only the Horizontal East component changes the measured azimuth.
- It is unlikely that several surveys in a row will only have horizontal interference. Some will have vertical interference which can ALWAYS be measured.
- By surveying more frequently (every single) it is unlikely that external interference will be missed even if the offset casing is due East (or West).
This example is from a wellbore intercept and re-entry. The offset well has drill pipe rather than casing. The distance is <10 feet to the offset fish.

Scales are the same for both horizontal and vertical components of the measured field. Red dots are actual measured points. Blue dots are the “expected” field without interference.
MWD FAC are very conservative in the vertical section

- FAC must match the error model (IPM) that is used to calculate uncertainty.
- The IPM determines the size of the Ellipse of Uncertainty (EoU)
- The IPM has all the factors used to estimate the uncertainty in MD, Inc, AZI
- EoU is used to calculate the Separation Factor (SF) for anti-collision rules.
- Larger FAC -> larger EoU
Separation Factor Calculation

When Ellipses touch: SF = 1
Twice that distance Center to Center (CC): SF=2
Typically the wellbore and casing diameter is added to the EoU.
Anti-Collision Rules

- Typical AC Rule: 2 Sigma EoU (95% confidence in each direction)
- Minimum SF = 1.5
Wellbore Survey Error Models
also called ToolCodes or Instrument Performance Model (IPM)

- Uncertainty in measurement of depth, inclination, and azimuth.
- In a vertical well, only Inclination uncertainty matters.
- When near vertical, azimuth uncertainty has little effect on BHL.
- Typical MWD EoU at 1000 ft MD is less than 3 feet Radius.
  - FAC around 300-500 nT BTotal, equivalent in Dip angle.
- Increasing FAC to ~2000 nT (4x) increases EoU by 2X.
  - Depends on inclination. This is for inclination < 5 degrees.
Example: (exact values vary depending upon latitude and wellbore inclination).

Wells 20 feet apart. EoUs grow at 3'/1000 using conventional MWD without external interference.

At about 2200 ft MD the separation factor is 1.5 so the AC rule is reached. The well must be nudged away to avoid violating the AC rule.

If there is no HSE risk, some operators will go to SF=1, allowing drilling to 3300 ft MD.
The Lake Benbrook Project used unconventional survey methodology in drilling 57 wells from 2 sites. The northern site with 36 wells in 3 groups is shown. MWD surveys were allowed with higher than normally acceptable levels of magnetic interference in the top section (to 1000 ft. depth) near other wellbores. Gyro surveys were not needed. The Ellipses of Uncertainty were larger but passed stringent anti-collision rules without significant impact on the overall positional uncertainty.

**Estimated $2M savings without compromising safety or production.**

[www.iscwsa.net > meeting minutes > ISCMIN34_P4_Pad_Drilling_Using_Magnetic_MWD](http://www.iscwsa.net)
Why not do a nudge away from other wells?

- Conventional wisdom requires use of gyro for kickoff when magnetic interference is high.
- Most wells will eventually require artificial lift
  - Not applicable to gas-only wells unless dewatering is needed
- Non-vertical wells or doglegs near the surface create excessive wear on rods.
- Cost of pump maintenance can exceed drilling costs over the life of the well.
Reducing the size of the EoU

- In near-vertical wells, misalignment of the MWD tool with the wellbore is the major source of positional uncertainty.
- A set of Rotational Check Shots (4-6 survey shots at the same depth but different toolface) can be used to calculate corrections that reduce this uncertainty by ~ 50%.
- Multi-Station Analysis (MSA) will also reduce EoU sizes.
- IFR has little effect in near-vertical wells, as it only reduces azimuth uncertainty.
Trade-off: Increased FAC > larger EoU

- At inclination of 0, there is no increase
- At inclination <= 5 degrees, FAC x4 gives EoU x2

- Even with massive magnetic interference (up the horizontal earth field) the azimuth will be in the right quadrant (+/- 45 degrees), which allows kick-off away from adjacent wells on magnetic toolface.
What if interference is greater than expected?

- Go up to a larger EoU with greater FAC, and/or
- Nudge away from nearby well, or
- Do passive magnetic ranging to find distance and direction to nearby well.

Reasons:
- Closer than expected to offset well
- Stronger magnetic poles than expected. Usually due to magnetic inspection of the casing that was not degaussed after.
Pre-Job considerations

- Have casing vendor meet ASTM (or DS-1) standard for degaussing of tubulars. Not required by API spec. Measure the residual magnetism when casing arrives on site.
- ASTM E-1444 and DS-1 specify less than 3 Gauss.
- Plan well and calculate anticollision using a toolcode with FAC that exceed the expected magnetic interference.
Sample Workflow

- Take rotation check shots to reduce misalignment errors.
- Survey at least every single.
- Apply MSA corrections and offset center corrections.
- If FAC are exceeded, invalidate that survey point and the previous two. Apply an IPM starting two surveys prior with larger FAC, and recalculate AC.
- In the very worst case use an Inc-Only IPM that allows unlimited magnetic interference. That might happen when the MWD sensor is only a few feet from the offset casing.
Sample workflow (continued)

- If there is little interference for 3 survey points in a row (that are at least 10 ft. apart), a toolcode with a lower FAC can be used starting at the third “clean” survey.

- If projecting ahead shows AC rules will be violated:
  - Nudge away on magnetic toolface, or
  - Use Passive Magnetic Ranging (PMR) to determine distance and direction to offset well. Reset combined EoU size to the uncertainty in the ranging.

- When section is completed, run a gyro to get a definitive survey.
Passive Magnetic Ranging (PMR) Procedure

- After a survey shot is taken, pull back a few feet.
  - Recommended: ¼ estimated distance to offset well
  - Best results if toolface can be held constant for all shots
  - There must be sufficient magnetic interference to measure. Typically >100 nT.
  - Closer shots is better but takes more time

- Repeat over a full joint of offset casing or until an up-down-up signature is seen in all 3 axes of magnetics. Typically this is 12 – 20 shots.

- PMR Analysis of raw MWD sensor data will give distance (+/- 20%) and direction referenced to highside of well.

- Distance in Highside +/-20% and Right +/-20% gives direction accuracy.

- In vertical wells direction can be ambiguous.
Don’t use single-station axial corrections (Short Collar Correction) to correct for external interference. These are intended to correct for Drill String Interference (DSI). An average Z-axis correction can be used instead.

MWDs with continuous magnetics or EM telemetry can save a lot of time.

Shorter bit-sensor spacing reduces the uncertainty in projecting ahead.
Conclusion

- It is possible to drill safely with standard AC rules even when magnetic interference is present.
- Kickoffs on magnetic toolface will be in the right quadrant (away from adjacent casing) even with massive magnetic interference up to ~20,000 nT. Caution: in worst case only 1/3 of this may be measurable.
- Pre-job planning is very helpful
- PMR can be used in cases of unexpected magnetic interference.
More Info?

- SPE Wellbore Positioning Technical Section
  - Industry Steering Committee for Wellbore Survey Accuracy
  - [www.iscwsa.net](http://www.iscwsa.net)
  - Next meeting: San Antonio, October 12, 2017

- E-Book: “Introduction to Wellbore Positioning”
  - Accompanying video and powerpoint
  - Link on [www.iscwsa.net](http://www.iscwsa.net) website under “docs and publications” for Education sub-committee.
Thank You
Crude Estimate of Pole Strength

- 100 uW pole on a motor gives ~1 gauss at 6 inches.
- No gaussmeter? Does a paper clip stick?

Available from McMaster-Carr as field strength indicators
[https://www.mcmaster.com/#magnetic-field-indicators/=19j3o1l](https://www.mcmaster.com/#magnetic-field-indicators/=19j3o1l)
I recommend -10-0-10 gauss.

AC Degaussing requires Low Frequency

An old rule-of-thumb states: The harder and tougher a material, the more difficult its degaussing will be.

4.3 Frequency of the degaussing field

In order to assure permanent degaussing, it is not enough to only demagnetize the surfaces. The remaining residual magnetic fields in the center of an object will emerge outwards with the result that, after a few days, the residual magnetism existing before the degaussing procedure will again be measurable.