Minutes of the Ninth Meeting of the

Industry Steering Committee on
Wellbore Survey Accuracy

Dresser Facility, Houston
7 May 1998

Present:

Hugh Williamson (Chairman and Minutes)	BP Exploration
John Turvill	Halliburton
Shaun Hingerty	Halliburton
Brett Van Steenwyk	Scientific Drilling
John Barlow	Scientific Drilling
Jim Towle	Scientific Drilling / ATA
Tim Dallas	Gyrodata
Roger Ekseth	Statoil
Torgeir Torkildsen	Statoil
Paul Rodney	Sperry-Sun Drilling Services
Dave McRobbie	Sperry-Sun Drilling Services
Patrick Knight	Sperry-Sun Drilling Services
Billy Hendricks	Sperry-Sun Drilling Services
Jack Emmen	Shell International
Wayne Phillips	Anadrill
Philippe Theys	Anadrill
Gordon Shiells	Baker Hughes INTEQ
Steve Mullin	Baker Hughes INTEQ
Robert Estes	Baker Hughes INTEQ
Andy Brooks	Baker Hughes INTEQ
Steve Grindrod	Copsegrove Developments
Bob Twist	Consultant
Denis Weisbeck	Geoservices
Todd Caspary	Sharewell

1 Introduction and Actions from Last Meeting

Hugh Williamson welcomed those present and outlined a proposed agenda for the meeting. He then summarised the progress on actions arising from the Trondheim meeting:

- Magnitude of depth error contributions. A quick-and-dirty investigation of the relative magnitude of thermal expansion and stretch was included in the minutes of the Trondheim meeting. The conclusion was that either could be larger depending on the location and shape of the well and the geometry of the drillstring.
- Two standard well profiles had been condensed from the syndicate work (see below).
- John Turvill had made an investigation of BHA radial misalignment.
- Jack Emmen and Robert Estes had investigated Shell's and INTEQ's standard field quality measures in relation to known sensor performance (see below).

2 A New Error Propagation Document

Hugh Williamson passed round a draft of the revised BP/Statoil/INTEQ/Sysdrill error propagation document. This revised document is somewhat simpler than the previous version, and explains some of the finer points in more depth. The initial circulation of the document will be a "bare-bones" presentation of the equations necessary to code the method. These will be incorporated in a paper intended for wider readership at a later date.

Action Authors to finalise document containing propagation equations. Hugh Williamson to circulate prior to next meeting.

3 MWD Sensor Errors

No further information was presented on the work of establishing estimates of the field performance of MWD sensors.

4 Magnitude of Magnetic Error Terms

Steve Grindrod showed the user interface of some software he had developed for establishing Wolff and de Wardt error terms. Underlying the interface was a decision tree containing the error terms appropriate for each combination of running condition and correction method.

Steve then compared some daily declination records from Lerwick with the declination value predicted by three main-field models. The differences - of about 0.8° - were indicative of a magnetic anomaly in the area. Patrick Knight confirmed that such an anomaly was indeed known to exist. Steve suggested that the values for magnetic field uncertainty currently adopted by the Group should be revised upward. Hugh Williamson explained that the current values were based on a BGS study incorporating all the major sources of uncertainty, but were dominated by the effect of crustal errors. Time variations were either of low magnitude or of relatively rare occurrence. He felt there was insufficient evidence to challenge the current values.

Steve stated that some surveys appeared to show evidence of variations in the ambient field being magnified by the measurement process. Whether this was the effect of geology, the drillstring or the instrumentation was unclear.

Torgeir Torkildsen showed some old aeromagnetic data covering several fields in the NCS. They showed anomalies of up to 1.0° in declination.

Steve then presented a series of comparisons of magnetic versus gyro surveys for a single North Sea field. It was suggested that the seemingly cyclic nature of the differences could be attributable to changes in the version of the main-field model used for declination and interference corrections.

5 MWD Survey Acceptance Criteria

Jack Emmen described the results of a study he had carried out with INTEQ to investigate the relationship between calibration checks, field QC parameters and error models for MWD tools.

As an example, according to the tool error model currently used by INTEQ, specification for agreement between MWD tools at a benchmark survey should be 0.3° in inclination and 1.3° in azimuth (incl>20°). Currently, typical specifications are 0.5° and 3.0° respectively. Again, by considering the combined effect of sensor errors and uncertainty in the magnetic field, realistic specifications for Btotal, Gtotal and dip angle are 230nT, 3mg and 0.34° respectively. These specifications are considerably tighter than those currently in use.

Jack's concluded that:
- error models should be related to the known accuracy of calibration check stands, because tools are typically not recalibrated as long as they pass tests in these stands.
- check stand pass/fail criteria should be relaxed until there is a direct link between them and field pass/fail criteria (unless there is good evidence that tools are out-performing the field criteria).
- field pass/fail criteria should be based on predictions of error models.
- the benchmarking example is a good starting point for implementing this general approach.

Robert Estes explained a little of how calibration pass/fail criteria are determined. Factors to be considered include:
- what values will give reasonable assurance that later tests are passed ?
- what are the limits imposed by resolution of the tool measurements ?
- what are the expectations of the Industry ?

This topic will be further pursued at future meetings.

6 Field Calibration Verification Methods

Bob Twist defined the purpose of the field office calibration verification as answering:
- does the tool measure gravity and magnetic field parameters correctly ?
- does it need recalibrating ?

He stressed the importance of the test as being the last chance to check the tool before it goes down hole.

Bob described and compared two methods of calibration verification: Helmholtz coils and the check stand. He explained how both could be used to determine individual sensor biases and scale factors. In particular, several examples showed how a roll test in a check stand could be used as a diagnostic tool. Bob recommended that:

- a standard method, including hardware and test procedure, be adopted for verification of MWD tool calibration
- a uniform means of presenting the results and analysis be devised.

In this way, field personnel would become familiar with the standard and be more able to interpret the results.

Jack Emmen asked how clean a magnetic environment was required for these tests. Bob felt that field gradients of 15nT/ft and 10nt/ft were adequate for check stand and Helmholtz coil measurements respectively.

Wayne Phillips felt that Helmholtz coils were effective at determining sensor biases, but less so for scale factors and misalignments. Patrick Knight confirmed that all Sperry-Sun district offices are equipped with Helmholtz coils and triangular check stands, and that different tests are available to check for other parameters in addition to those mentioned.

7 Directional Crossing Contractors Association

Todd Caspary introduced the Group to the DCCA and to the directional crossing industry in general. Last year, some 300 million feet were drilled in this way. Typically, holes of 300 ft to 500 ft in length are drilled by smaller, 30 klb rigs, while holes of up to 1000 ft are drilled by larger rigs of 50 klb capacity and above.

The aim of the DCCA is to promote the interests of the contractors and to educate the industry. Their achieve this through encouraging use of their logo, taking stands at trade shows, and producing joint-industry guidelines on an annual basis. The Association is currently working on setting standards for surveying.

The directional crossing industry faces many of the same difficulties as the wellbore survey industry - for example collision avoidance and magnetic interference. Equally important are the issues of data management and traceability, especially of “as-built” surveys. The surveying standards will cover recommended contents of the as-built (definitive) data package. This will include tool calibration records, data interpretation, survey calculation method etc.

Todd thought that in his industry, the move towards standardisation was due to increased safety concerns, for example when drilling close to existing gas lines. In addition, drilling into fibre-optic lines could result in a significant financial loss.

8 Standard Well Profiles

Hugh Williamson presented two well profiles which he suggested could be adopted as standards for software testing and error model development. The first was a North Sea extended reach/ horizontal well heading ENE. The second a Gulf of Mexico “fish-hook” type well with a long turn at about 30° inclination.

It was noted that the two profiles did not contain examples of:

- a southern hemisphere well
- an azimuth in the NW quadrant
- a horizontal east/west section
- a section parallel to the Earth’s spin axis
- a section at greater than 90° inclination

- a drop-off section

Andy Brooks pointed out that different type of survey tie-in would also need to be specified in any prospective test of software. Jack Emmen asked about the inclusion of look-up tables for survey errors as discussed in Trondheim. Hugh Williamson felt that the same purpose could be served by evaluating the contribution of individual error sources over separate hole sections from the standard well profiles.

Action: Hugh Williamson to revise the profiles, and devise a third, to meet the shortcomings identified by the Group.

Follow-Up: A third profile, named "Bass Strait Designer", has been devised. It fulfills all the requirements above, and in addition incorporates a medium-radius build section. It is described, together with the other two standard well profiles "ISCWSA Standards - version 3", which accompanies these minutes.

9 BHA Radial Misalignment

John Turvill had investigated the sources of misalignment between the tool sensor and the (nominal) collar OD. He identified four possible sources:

Collar Straightness
The API specifies a tolerance of 1/160" per ft (=0.1875" at 30ft), slightly less stringent than the HES specification. This equates to an angle of 0.03°.

Collar Bore in Collar
Assuming the maximum bore dogleg and offset at centre defined by specifications, John had used well planning software to find the maximum possible misalignment of the bore in the collar. His results were 0.16° and 0.05° for API and HES specifications respectively.

Sensor Housing in Collar Bore
John calculated that for tools of typical dimensions, misalignments of 1.01°, 0.063° and 0.015° were possible for uncentralised, retrievable case (ie. sonde type) and collar mounted tools respectively.

Sensor in Housing
Combining the effects of clearance, concentricity and straightness, John calculated the total budget for sensor misalignment within the sensor housing to be 0.057°.

In summary, for a typical tool meeting HES specifications, a total misalignment in excess of 0.1° was to be expected.

Follow-up: Assuming misalignment angles are normally distributed in magnitude and uniformly distributed in toolface direction (and uncorrelated), it is valid to sum them statistically in quadrature (I've checked this numerically). Thus, assuming that all four of the misalignment angles identified by John rotate with the BHA, they would produce a combined effect of $\sqrt{(0.03^2+0.05^2+0.063^2+0.057^2)} = 0.103^\circ$ *for a sonde-type tool. This value will be compared with the empirical results to be presented at the next meeting.*

10 MWD Error Model Action Plan

Hugh Williamson reviewed the current status of the Basic MWD error model, and declared an objective for it to be finalised at the next meeting. The discussion and actions arising were as follows.

10.1 Sensor Errors

Action: The four major directional drilling companies will complete/update their estimates of field sensor performance for at least one of their tools by the next meeting. The estimates are to be based on an analysis of historical calibration or other data, and are to include estimates of axis non-orthogonality if significant.

10.2 BHA Misalignment

It was felt that the value of 0.2° for BHA sag error, based on the results of 2D model predictions, did not require further work. Although an estimate of post-correction residual error would be required for operational work, it was not needed as part of the basic MWD error model.

The preceding discussion had raised the possibility of estimating the "coning" component of radial misalignment by studying the variation of inclination over rotation shots. Gordon Shiells suggested data from electronic multishot surveys (EMMS) could also be informative. Not being rigidly centralised, these tools tend to lie flat on the inside of the collar. The "coning" effects should therefore be smaller than for well centralised sonde-type MWD tools.

Action: Each member to make best efforts acquire data from a number of rotation shots (suggested number 5 to 20) for MWD and/or EMMS tools for next meeting. Data should include inclinations recorded, toolface values if available, BHA type (slick, rotary, steerable) and MWD type (sonde, collar mounted)

Andy Brooks noted that BHA radial misalignment should be treated as systematic between surveys, since the associated weighting factors included a dependency on toolface.

10.3 Magnetic Field Errors

The group were in general agreement that the currently adopted values for magnetic field uncertainty were typical for a sedimentary basin, and did not require further work.

10.4 Magnetic Interference

John Turvill noted that cross-axial interference can be caused by "hot-spots" within the steel elements of the BHA if they are significantly off the centre-line. He cited a hot stabiliser blade as an example. Paul Rodney confirmed that the data collected by Anne Holmes and presented at the last meeting had not been "cleaned-up" significantly, and could be expected to include such effects. Andy Brooks had worked out that a 400 micro-Weber monopole 5m distant from the sensor and 15cm off-axis would cause a cross-axial field of a similar order of magnitude to the 30nT currently incorporated in the Group's model.

Patrick Knight noted out that the model was incomplete without a value for the distance from the magnetic pole(s) to the sensors. He estimated that 90% of surveys worldwide

have an interference correction applied. He felt that uncorrected surveys were generally restricted to well-spaced survey tools. An appropriate pole-to-sensor distance would therefore be 15m.

In contrast, John Turvill pointed out that many MWD tools are run in a single collar, with no interference correction applied, this practice being common in the onshore US fields. In this case, a pole-to-sensor distance of 3 to 4 metres would be appropriate.

10.5 Measured Depth Errors

Hugh Williamson reminded the Group that the current values originated in a detailed study of the physical errors affecting depth measurement by Roger Ekseth. The values were clearly sensitive to the physical parameters assumed in the model.

Actions: Hugh Williamson to list the physical parameters used to derive the depth error terms currently incorporated in the Model. Members to critically review these numbers prior to the next meeting.

Follow-Up: The terms in the simplified model for measured depth are more sensitive to some physical parameters than to others. The parameters most critical to determining stretch and thermal expansion, and the values used to derive the error terms currently incorporated in the Model are:

Physical Constant	*Value*	
Young's modulus of drill pipe steel	2.12×10^{11}	N/m^2
density of drill pipe in drilling mud	*6250*	kg/m^3
geothermal gradient	*0.04*	*°C/m*
thermal expansion of steel	1.2×10^{-5}	*per °C*
length of drill collars	*120*	*m*
ratio of drill collar to drill pipe cross-section	*7.15*	

Both thermal expansion and drill string stretch are of determinate sign (otherwise known as "bias" errors). If they are to be included in the basic MWD error model, they must be assigned a somewhat arbitrary confidence level. Up to now, a 2 s.d. level has been used. It is arguable that a 1 s.d. level would be more appropriate for the Basic MWD error model, given its main purpose.

11 Next Meeting

Gordon Shiells suggested that the BGS in Edinburgh could be invited to host the next meeting. The date was left open, but it is likely to be mid-September.

Action: Hugh Williamson, and Dr. David Kerridge (BGS) to confirm date and venue to participants.

Follow-Up: SPE forum (on 3D visualisation etc.) in Aviemore is confirmed for 7-11 September. Therefore suitable dates for ISCWSA are Sept 14-15 (visit to BGS observatory at Eskdalemuir on Monday 14th for those interested, main meeting at BGS on Tuesday 15th). These dates are convenient for David Kerridge and are unlikely(?) to change.