Early borehole survey instru

James Tweedie traces nearly 60 years of innovation in the search for better equipment

THE Sperry Drilling History document on the Halliburton website states: "Beginning in the 1870s, many attempts were made to devise an instrument that could measure borehole inclination. But these attempts proved unreliable." This short sentence dismisses nearly 60 years of invention and ingenuity in the search to find methods to survey deviated boreholes. It, perhaps, illustrates our myopia in regard to past technological developments.

It was only when researching a lecture earlier this year that I came across a book, published in 1931 by MH Haddock, which details a wide range of survey instruments developed after 1870, together with sentiments about surveying boreholes that have changed little in the 79 years since its publication.

Like many of my generation, I assumed that the main development of borehole surveying technology occurred in the second half of the C20th and knew little of any earlier work in this field. This article takes a brief and somewhat selective look at some of these early attempts to survey boreholes and shows that the reasons for, and principles of, surveying boreholes were well understood over a century ago.

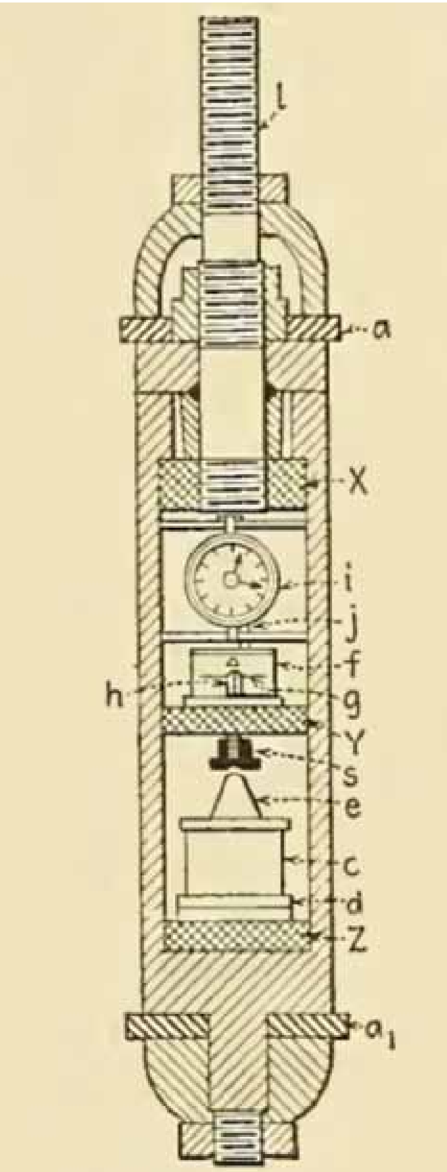

Figure 1: Nolten's acid-etch apparatus. Item c is the glass acid container (for dip); items g, h and f make up the lockable compass (for direction), and i is the clock that locks the compass after a pre-set time

THE NEED TO SURVEY

In 1859, Edwin Drake drilled specifically for, and found, oil. Arguably, this was the start of the oil industry as we know it today. Rotary drilling was introduced in France in 1861 by Loschot, and spread to North American projects over the next couple of decades.

Drilling techniques advanced rapidly in the search for 'black gold', and as the holes became deeper it was recognised that they did not follow a straight line: that is, they deviated. This was true in all sectors of the drilling industry.

Some methods were needed to measure this deviation, and 1872 saw the appearance of the first of these when a Mr G Nolten of Dortmund, Germany, used an acid-etch system with a mechanical lock on a compass to provide both inclination and dip.

ACID TESTS

Figure 1 shows the Nolten instrument in some detail. This was purely a single-shot instrument and was the ancestor of the acid-etch systems that were abandoned by the petroleum industry before the 1940s, but were still used, to my knowledge, in some areas of mineral exploration until the early 2000s.

The instrument contains the basic operating principles of all survey instruments: time-based recording methods to obtain both dip and direction at a given point in a borehole.

A simpler, and more elegant, method developed by Maas used an acid-etch test tube in parallel with a compass needle that would 'lock' into cooling gelatine (figure 2). A vacuum flask was used to protect the gelatine from external heat in the borehole. This is described from about 1912. The same heat-shield principle is still used in modern survey instruments.

The Maas method is similar to the dip-only etch systems in recent use in mineral exploration.

BLOSSOMING TECHNOLOGIES

Mr Haddock listed ten methods used in surveying instruments:

- fluid;
- plummet and magnetic needle;
- electrical;
- pendulum;
- photographic;
- gyrostatic;
- plastic cast;
- pricker;
- inertia, and
- seismographic.

These are considerably more than the methods commonly used today, but we can recognise at least three that are the ancestors of modern systems – electrical, photographic and gyrostatic (gyroscopic).

It is interesting to note that, according to Mr Haddock, core orientation instruments were in

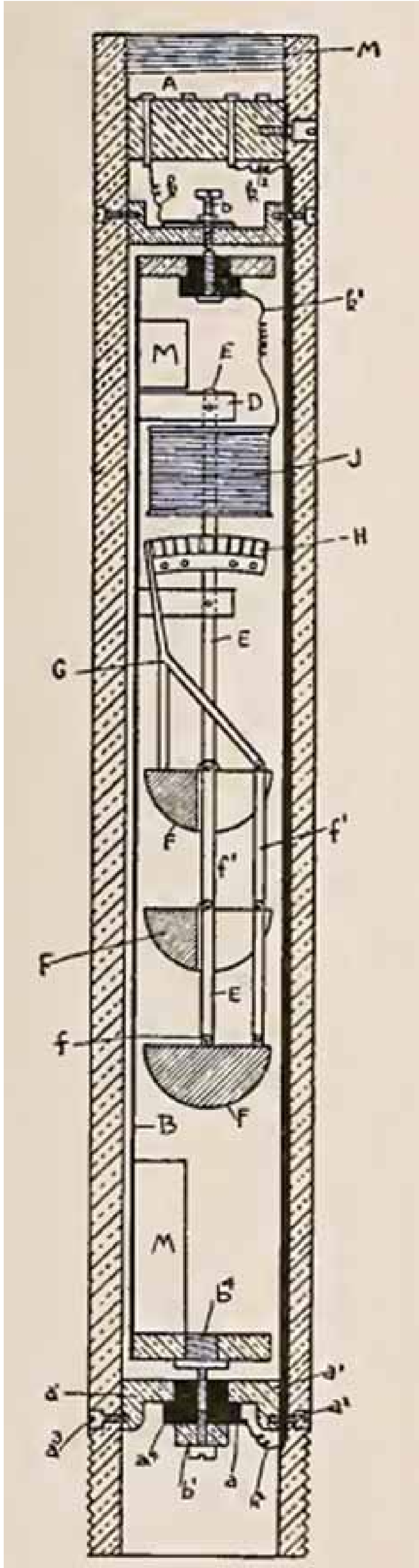

Figure 6: Marriott's instrument showing the three plumbs (f)

mentation: 1870-1930

existence from the mid-1840s, preceding the first locational survey instruments by some 28 years and establishing the principles of core orientation some 170 years ago.

NOTHING NEW UNDER THE SUN

The first survey instrument I used was the Reflex Fotobor; a non-magnetic, optical/photographic tool, the development of which was previously detailed by *GeoDrilling International* (see 'Fotobar in focus', March 2008, p39). The techniques it used were considered innovative; the concepts, apparently, were developed in 1954, but not technically realised until 1972.

It was surprising to find an instrument developed by Mr Haussmann in 1907 that contained a number of the main features of the Fotobor. Namely: light source; auto-advancing film; multi-shot images and a bubble level.

Mr Haussmann's instrument used a level bubble to indicate inclination and two compasses located a few centimetres apart to record the direction (see figures 3/4). The two compasses also allow the instrument to detect zones of anomalous magnetism as they point in different directions where the Earth's magnetic field is distorted (a form of data-quality checking). All this was encased in a 40mm-diameter, 750mm-long tube, which is comparable to the size of today's instruments.

In the early 1990s, I was involved in the testing of a magnetic tool that used two sets of magnetometers at a fixed distance apart. It was intended that, by moving the tool over this fixed distance, the magnetic readings could be 'linked' to negate the effects of anomalous magnetism.

However, because each set of magnetometers had three individual sensors a finite distance apart, this failed in rapidly changing magnetic fields – for the very reasons that the 1907 instrument had two compasses! It seems there are lessons from the past if only we care to look for them.

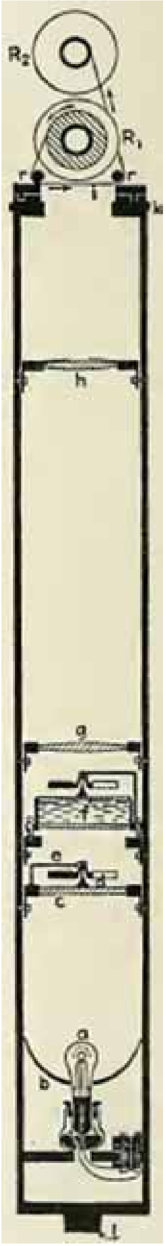

Figure 4: Haussmann's apparatus, showing the film reels (top), lenses, compasses, and light source (bottom)

OTHER METHODS/TOOLS

In 1924, Thomas Reinhold, chief geologist at the Geological Survey Department of Holland, invented a down-hole camera system to photograph rock walls (figure 5). It could rotate to take a 360° view of the wall rock at a given point. It used a motor-driven film with lamps that were switched on to take the image and a 45° mirror to reflect the borehole wall image to the camera. This appears to be the forerunner of the borehole camera systems in use today.

Perhaps the most intriguing survey instruments are the compass and plumb-bob and pendulum types as these, to my knowledge, have no direct equivalents today (though the tri-axial magnetometer is effectively a compass).

The earliest use of a compass in the UK was made by a Mr Haddow at Youngers Holywood Brewery in Edinburgh in 1884. In this case, a borehole of 60m had not intersected a cross mine and the compass was used to detect the location of bar magnets lowered down the borehole. This is more of an early borehole geophysical method than a surveying technique.

Compass and plumb-bob instruments usually worked by locking a compass at a given point, either by the action of reaching the bottom of the hole or by mechanical timer. Simultaneously, the plumb-bob was lowered to strike a wax or similarly impressionable disc.

One of these systems was the first continuous recording instrument (dip only) invented by HF Marriott in 1904. It was used extensively in the gold fields of South Africa. It used three plumbs to control a rheostat (potentiometer) and the signal was transmitted to the surface where it could be observed and continuously recorded (see figure 6).

A second Marriot instrument allowed recording of both dip and direction at discrete stations, but was essentially single shot – Mr Haddock records it as "a time consumer".

These methods were improved over the next three decades, with the last described being Maillard's apparatus (1925, France) and the Driftmeter, developed in Tulsa, Oklahoma, US. However, most of these tools were rather cumbersome and had the problem of using a plumb-bob within a necessarily restrictive case diameter.

QUANTITATIVE PROOF IN TOOL DEVELOPMENT

In the 1920s, Alexander Anderson developed a photographic, multi-shot instrument that took photos of three pendulums to obtain dip. It was also 'self-checking' because the points had to fall on a curve when plotted (another instance of quality control).

His detailed study, published in 1928, of 142 holes, 1.5-1.8km long, showed large horizontal deviations and convinced the oil industry of the need to use survey instruments, both during drilling and on completion of the hole. It also occurred at the right time to have spurred on the development of other survey methods.

Most of the instruments designed and developed up to the mid-1920s appear to be time-consuming, cumbersome and complex to operate, and were mostly single shot. Because of these difficulties, most of them seem to have been superseded by the development of the gyroscopic systems in the late 1920s and early 1930s.

The Sperry-Sun SURWEL instrument was introduced by Elmer Sperry in 1928. This was the first advanced gyroscopic system that became widespread in the petroleum industry and marked the start of modern borehole surveying. Being both non-magnetic and continuous (multi-shot), it

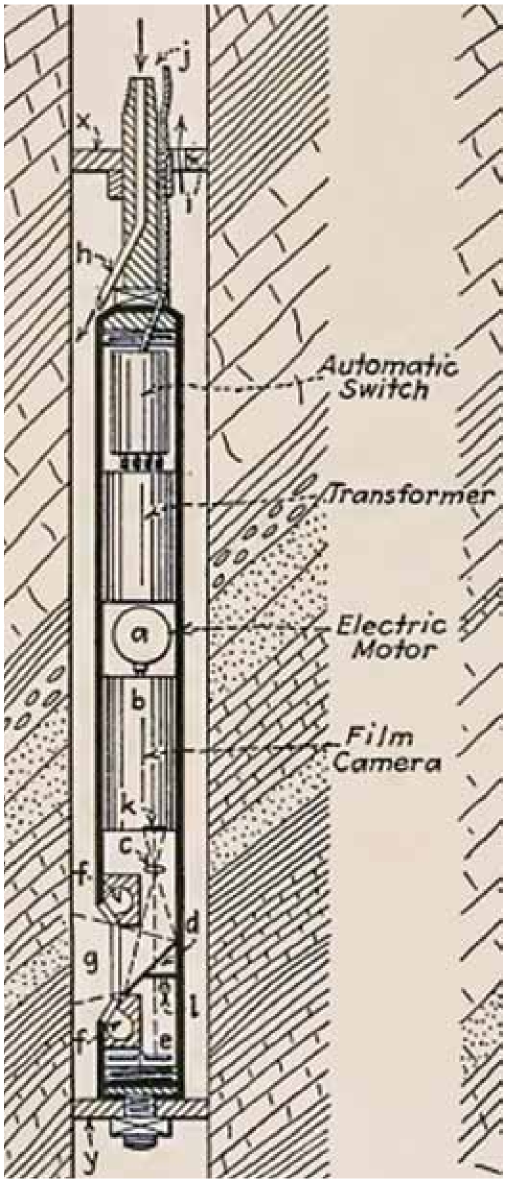

Figure 5: Reinhold's borehole camera

represented considerable operational and cost advantages over its predecessors.

EARLY KNOWLEDGE

What is clear from Mr Haddock's book is that, from relatively early in the C20th:

- The need to survey boreholes was well understood;
- Methods of surveying had been in development from 1870;
- De-surveying calculations were advanced, and included self-checks and quality control;
- Recognition of the need for non-magnetic instruments was established; and
- The equivalents of most 'modern' methods of surveying were already in use.

It also shows that the comment of unreliability in the Sperry Drilling History is inaccurate – there were many reliable methods. However, they were mostly time-consuming, complex, single-shot systems and, therefore, would not have been popular in industries under considerable time and cost pressure. ➔

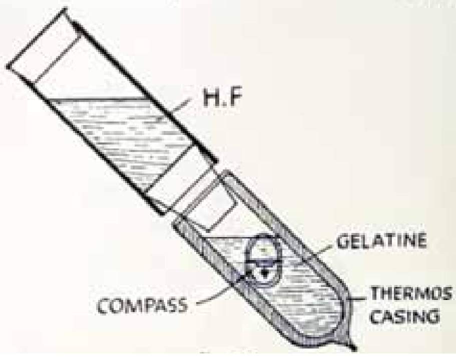

Figure 2: Maas' acid-etch apparatus

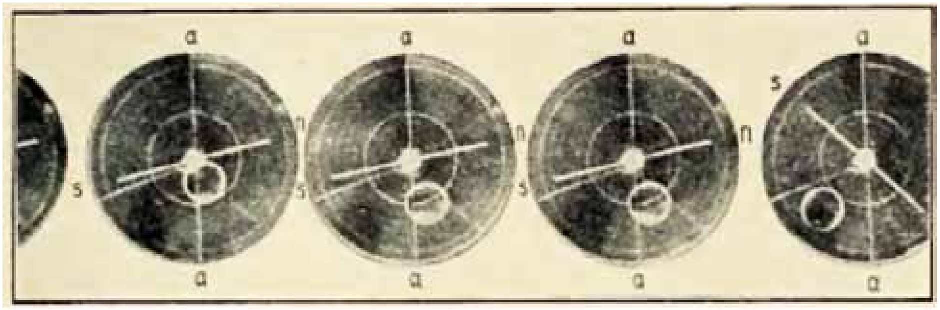

Figure 3: film strip from Haussmann's apparatus, showing two compass needles and level bubble

KNOWLEDGE TRANSFER?

The arguments, and pleas, for the use of borehole surveying during and after drilling in 1931 are remarkably similar to those being made 70-80 years later for the mining and exploration industries.

It seems almost incredible that it takes decades, if not centuries, for knowledge and techniques to become accepted and applied between industries. Some quotations serve to illustrate this point rather well.

Firstly, from Mr Haddock (1931): "The amount of trouble, litigation and random speculation that could be avoided by a correct knowledge of the course of deep boreholes is immeasurably great. Generally speaking, the present geological engineer does not seem to be enamoured of the highly ingenious and exact suite of post-war instruments, being in many cases content to sacrifice precision to rapidity, ease and cheapness."

And, more recently, Prof Michael Hood, CTME, said in 1999: "The amount of drilling for exploration is vast, and this drilling is expensive. Notwithstanding this large investment, the quality of the information obtained from these drilling programmes is relatively poor."

Anton Wolmarans of De Beers also commented in 2005: "We are still accepting borehole surveys with inaccuracies of the order of 10% of the distance down hole."

HISTORY REPEATS ITSELF

Recently, we have seen the rapid expansion of geothermal/ground source energy. Some versions of this involve drilling to depths of 100-150m, and I know from experience that deviations of up to 50m are possible (although 10-20m is more likely). However, at a recent exhibition I asked a representative from a geothermal drilling company how they would survey their holes to prove they were where they should be.

Their reply was that they drill straight, vertical holes. This sounds remarkably similar to claims by exploration drillers that they drilled straight when this author started his career in the 1980s. Déjà vu anyone?

James Tweedie, director of GeoMEM, has been involved in borehole surveying, both as a surveyor and developer of software systems, since 1980. GeoMEM currently represents Devico survey instruments in the UK and Ireland. Dr Tweedie recently started the Professional Borehole Surveyors group on LinkedIn to campaign for the wider recognition of borehole surveying as a professional skill (http://www.linkedin.com/groups?mostPopular=&gid=2896260). For more information, contact him at james@geomem.com or www.geomem.com