Original of an article on the development of the Fotobor for GeoDrilling International, February 2008. Written by: James Tweedie, GeoMEM (www.geomem.com).

"The right time, the right people, the right technology or how a survey instrument was born".

Many of those involved in drilling and borehole surveying are familiar with optical surveying instruments, in particular, the Reflex Maxibor systems and (if you are as old as the author) the Reflex Fotobor.

Perhaps not many operators of these instruments will give much thought to where the technological concepts came from or when the original ideas were realised and by whom because the technology is part of their everyday working lives.

They may, perhaps, browse the history on the Reflex company web site and find **(see end of document): "*It all started in 1974 (sic), at the LKAB Malmberget Mine in northern Sweden. One of the engineers, Mats Haglund a keen photographer, toyed with the idea of a long probe holding a miniature camera that would photograph the actual bending of the probe from the inside. Tests were made, the feasibility of the idea was proved, and a patent applied for.*" and "*With help from one of Sweden's high speed photography specialists within the Defence Research Authority and precision manufacturing resources of a Stockholm company, Fotobor saw the light of day.*"
This brief resumé covers the basic facts except that the quoted date of 1974 is incorrect and the story starts much earlier.
This short article throws some light on the missing years and shows how tenacity and the serendipitous meeting of people with complementary skills resulted in such an innovative and revolutionary product. It will, hopefully, also provide a small acknowledgement to the contribution these "pioneers" made to the drilling industry.

It was, in fact, 1952 when Mats Haglund, a mining engineer working at the LKAB company in Sweden developed a new principle for measuring dips and directions within a borehole (BT, 1984). The method used light and optics and, *it is said*, was based on the old miners practice of lowering a lamp or torch down the hole to get an indication of the curvature from the light position and reflections. However, once the light was no longer visible the miners could no longer judge the deviation or direction of the hole. This method was, at best, semi-quantitative tending towards very qualitative.

Haglunds ingenious solution was to apply the same principle but move the "eye" down the hole at a fixed distance from the light "reflections". The eye would record the deviations as shown by the light and be analysed when the survey tool returned to the surface.
He managed to test the idea in the late 1950s but could not realise the concepts because the technologies were not available to develop the instrument further.

It was through meeting "skilled colleagues" (MH, 1987) and the appearance of the required technologies that led to the new instrument being designed and, at last, constructed in 1971. The first field trials in February 1972 were successful and the Fotobor was launched later that year, *twenty years* after the initial concept (BT, 1984). It was launched with the cumbersome name of the ABEM Reflex-Fotobor Dip and Direction Indicator, thankfully abbreviated to (R-F DDI) and marketed by Atlas Copco ABEM. Thus the Fotobor was in existence and use some 2 years before what appears to be its generally accepted "birthdate" of 1974.

In 1987 Mats Haglund wrote a forward or introduction to a 42 page document detailing the theory and practise of the Fotobor in which he names two other people that were involved in the

development of the Fotobor. *Sture Örtenblad* was the owner of Reflex AB Industri, a designer and manufacturer of electrical and "programmable" clocks and time pieces (RRC). Örtenblad must have provided the expertise to create and manufacture the accurate timing devices that the Fotobor needed. The third person was *Trygge Ramquist* whose role is not specifically mentioned but it may be that he provided the high speed photography expertise needed.

Haglund also comments about the requirements of the development: "*It showed that solving of the problem did not demand for a high grade genius, but perhaps a unique combination of fairly elementary knowledge and interest within different sectors of general technics.*
Technical imagination makes possible in such cases a synthesis of known parametres to working units. If the imagination includes a capability to understand one's own limitations, a step is short to find skilled colleagues." (MH, 1987 – quoted verbatim).

Thus, as is often the case in technical development, the Fotobor came about because of the timely meeting of people with the required skills, knowledge, expertise and tenacity, and the availability of appropriate external technologies.
It is worth noting that, in the introduction mentioned above, Mats Haglund quite specifically credits the three people who developed the Fotobor system, although he appears to be quite modest about his part in it.

The Fotobor used three reflector rings equally spaced (either 3m or 1.5m) within rods – these were the light sources – below the "eye", a camera lens that recorded the ring images onto high speed film (the "memory" system of the instrument). A "ring" bubble level provided a "way-up" reference. The reflector rings and the "bubble" were lit by powerful bulbs in a ring outside the lens (so no direct light reached the lens). The bulbs were switched on and off for a short period at 10 second intervals. This exposed the ring and bubble images on the film and then the film was advanced one frame.
The whole system was inside a sealed and, therefore, dark unit so there was no need for a shutter mechanism.

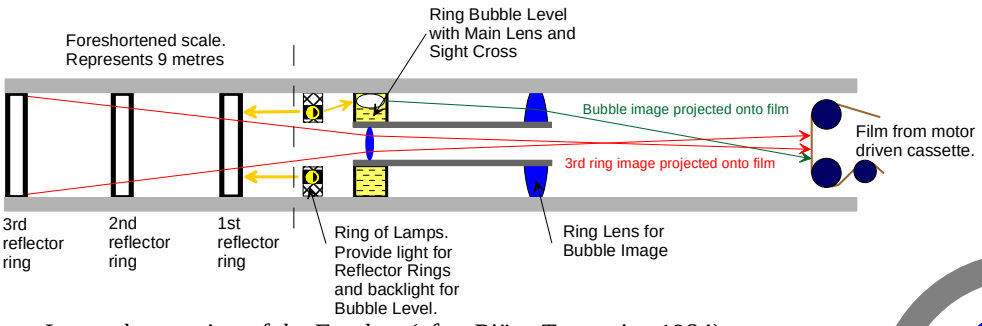

Diagram one: Internal operation of the Fotobor (after Björn Tornquist, 1984)

Operationally, the surveyor would start the instrument and a stopwatch at the same time, then record the elapsed time when the instrument was "on-station". Stations were the same distance apart as the ring spacing (either 1.5m or 3m). At the end of the survey the film was developed and projected to get the angular offsets of the rings from a reference (using the bubble). These angular offsets were used to calculate the Dip and Direction angles at each station down the hole and hence the 3D co-ordinates. In effect, the borehole survey was achieved using a method very similar to that used by a land surveyor (angles between known survey points).

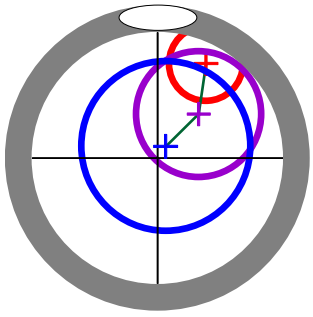

Diagram two: Representation of the rings and bubble as they would appear on the film with added centres crosses and green line showing deviation of borehole.

Currently, Reflex manufacture and sell the Maxibor (now into its second

generation). It is still based on the Fotobor principles first developed by Mats Haglund in the early 1950s but with a number of enhancements permitted by rapidly developing technologies.

It is, perhaps, interesting to speculate about what would have happened if Mats Haglund had abandoned his idea in the late 1950's. The Fotobor would not have been developed, Reflex would not have manufactured and sold the Fotobor nor entered the world of borehole survey instruments. The Reflex survey instruments (Minibor, Maxibor, EMS, EZ-AQ, EZ-Trac etc) would never have been developed and supplied to the drilling industry world-wide. And our industry would have been a poorer place for this.

References and sources:

BT, 1984: How crooked is a straight borehole? The benefits of drillhole surveying. Author: Björn Tornquist, Geodrilling Issue 14, February 1982. Pages 18-21.

MH, 1987: The Fotobor System: An integrated system of borehole measurement with depth prognostication, curvature drilling hole branching and core orientation within the field of diamond drilling technique. Author: Mats Haglund. November 1987

Reflex web site: http://www.reflex.se

RRC: Web reference to the Reflex Robot Clock (Roboturet Reflex): http://www.antikurmakaren.se/svenska-ur.html (in Swedish).

** ***This information was correct at the time of writing. The web site (as at Nov. 2012) no longer has any information about the inventor of the Fotobor, the product that changed Reflex from a clock and timepiece company to an international borehole survey instrument company.***