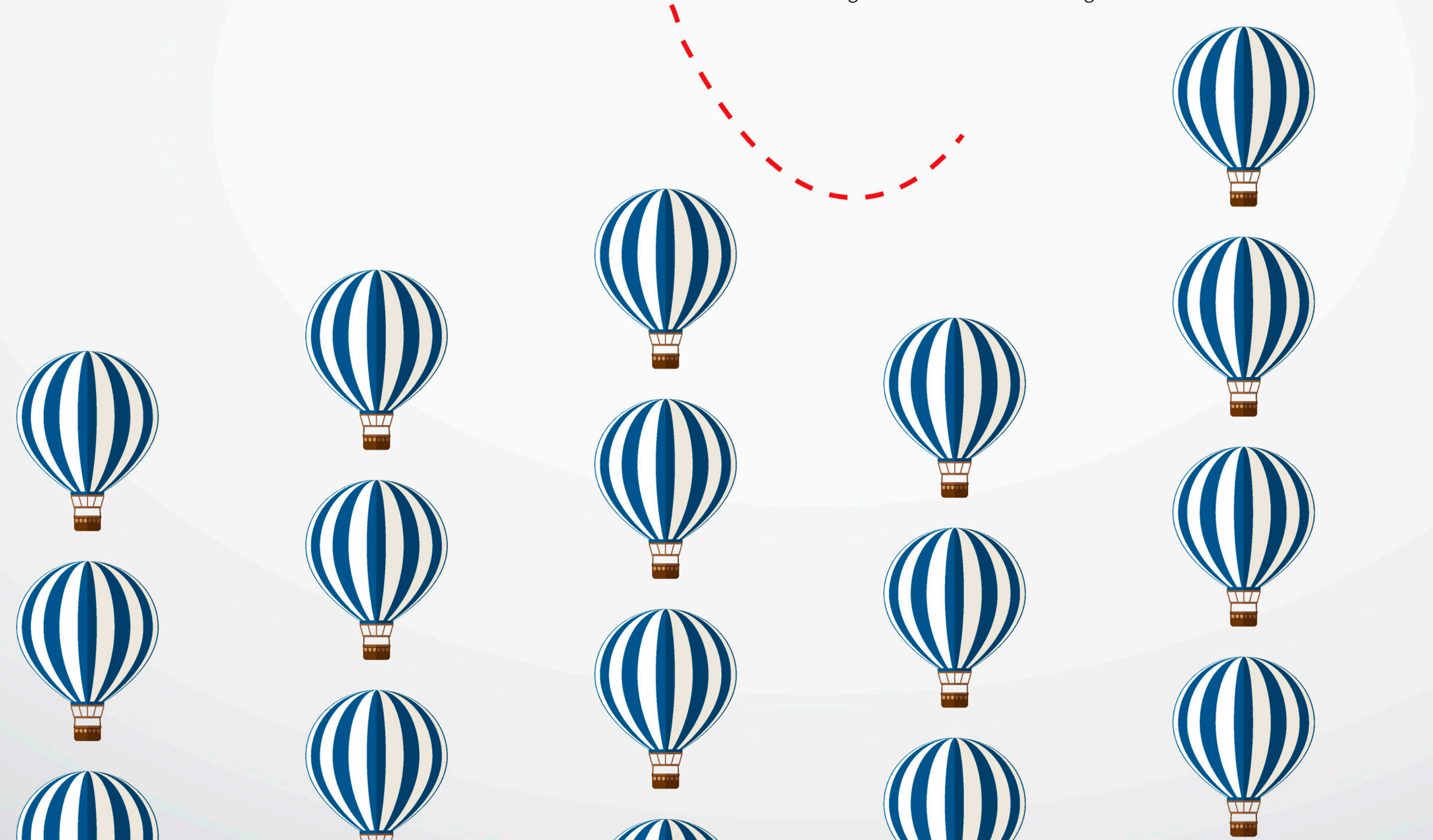
CHANGING THE GAME

Maurillio Addario, READ Cased Hole, UK, discusses recent developments in the use of MEMS technology downhole.

MEMS, or microelectromechanical systems, is the technology of very small things. They can be found almost everywhere these days, from mobile phones to cartridges of ink on home printers, from blood pressure sensors to satellites and, with ever increasing frequency and prominence, they are being deployed downhole.

Being able to accurately measure, record and ultimately interpret and understand the physical attributes and complex dynamics of the downhole environment has always been a major challenge for operators. This understanding is fundamental in making sure each asset delivers



long term financial results, extending and maximising recovery being as much, if not higher priority than minimising costs.

In this context, the evolution of sensor technology currently available has come a long way from the first resistivity logs, with an ever increasing gamut of choice going from simple mechanical caliper measurements, acoustic and magnetic investigation and many others, all the way to nuclear techniques. The latest chapter of this evolution now is being written by MEMS.

The technology

MEMS are created using the same integrated circuit (IC) techniques used to create just about every microprocessor, voltage regulator, FPGA and any number of other ICs out there in combination with micromachining processes. Ranging in dimensions from a few micrometres to millimetres, these tiny devices combine the ability to perceive, control and act on the micro scale with the capacity to respond on the macro scale.

These incredibly minute 'machines' offer a number of advantages when compared to their standard electromechanical counterparts. Being in essence a solid-state solution they are inherently more robust, using less energy and performing more reliably and accurately in the harsh environments so common to the oil and gas industry.

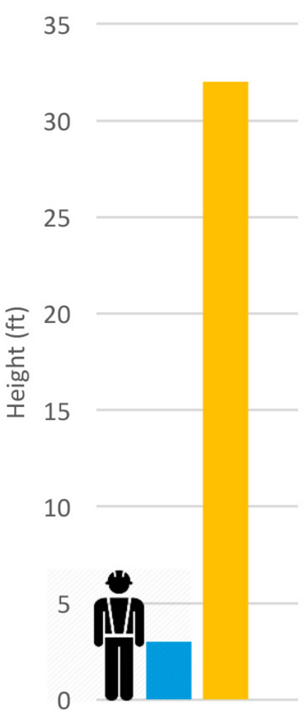


Figure 1. *Blue – FAST tool; Yellow – typical array PLT string.*

Take for example quartz crystal resonators. These are common place in most devices. If it has a circuit inside chances are it has a timing device, an internal clock of sorts that is used to keep everything in check, and that timing device is almost always a quartz crystal that resonates at a known frequency. Quartz has many strong suits but it is no longer the go-to, obvious solution for every case and certainly not the only solution.

MEMS oscillators, for example, offer tangible benefits over quartz resonators in many areas. One advantage is that they can take up to 65% less PCB footprint, not requiring external components such as power supply decoupling caps. In the case of a particular 32 kHz quartz crystal, not needing the extra load capacitors can make the board for the MEMS solution three times smaller than the quartz equivalent.

There are quite a few other advantages too: being less prone to the adverse effects of electromagnetic energy; having much lower sensitivity to vibration – mainly due MEMS having a total mass thousands of times lower than the equivalent crystal counterpart; lower MTBF and DPPM; etc.

A new approach

For more than 30 years, READ Cased Hole has taken an active role in developing new technology. The company recognised how the many advantages of MEMS based downhole tools could prove a game changer for both well integrity and production logging solutions.

The technology of choice for READ's initial approach to the MEMS applications in the oil and gas sector was the Flow Array Sensing Tool (FAST). This particular downhole probe combines a variety of interchangeable sensors in the same mechanical platform, including pressure, temperature, micro-spinners, conductivity and optical gas-oil-water holdup amongst others. Due to its compact design and the extreme miniaturisation of its sensors, it is capable of replacing a typical array production logging string measuring over 30 ft with a single 3 ft long tool.

MEMS are being used extensively, with multiple sensors being based on that technology. Pressure and temperature measurements, for example, employ MEMS sensor instead of the ubiquitous quartz based measurement, where the resonant frequency of the crystal is affected by the borehole pressure and temperature. The casing collar locator (CCL), which is often a tool in itself requiring permanent magnets and wound coils, is replaced by a MEMS magnetic locator (MML), which allows for the clear identification of the casing collars, all with a footprint and power consumption that is orders of magnitude smaller.

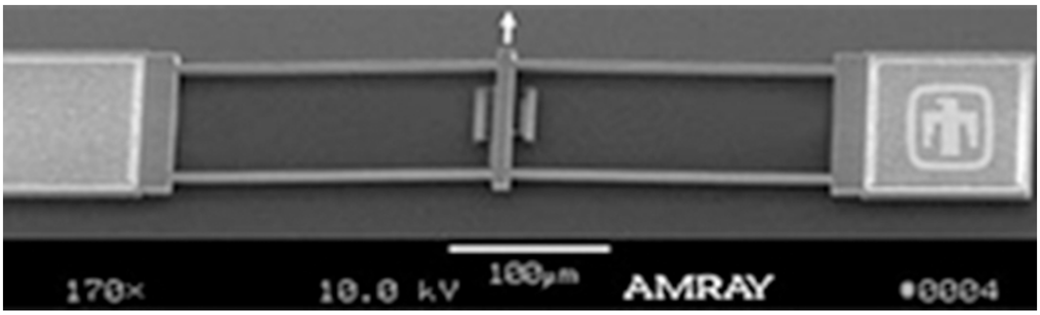


Figure 2. *V-shaped thermal actuator. The constrained thermal expansion of the angled beams results in the motion of the centre shuttle in the direction indicated by the arrow. (Image curtesy of Sandia National Labs).*

Figure 3. *FAST tool, which offers functional replacement for an entire 30 ft long array production logging string.*

Case study

Customers used to deploying the array production logging strings necessary to identify the zonal contribution of complex, often multilateral and highly deviated wells, have but a few images in their minds when they picture such toolstrings. They are very long, often requiring a two-man team to safely handle them; they struggle where rig-up height is limited; they are very expensive and fragile.

It is not just cost and format limitations that help to make the case for MEMS based tools. New sensors such as an optical three-phase holdup available on the FAST platform also make a compelling argument. This particular transducer perceives ultra-fast changes in the refractive index of the fluid in contact with the tip of what looks like a small glass needle (it is actually made of synthetic sapphire). It works by computing the time the tip of the needle is in contact with either oil, gas or water and is able to count what it can determine to be bubbles on the majority phase.

One recent use of this technology came about when a customer needed a clearer picture of the gas-oil ratio (GoR) on a high rate producer. A suite of (MAPS) tools, one of the two de-facto standards when it comes to array production logging strings, was proposed. It included a resistance array tool (RAT – with 12 resistivity sensors) and a capacitance array tool (CAT – with 12 capacitance sensors) combined with multiple auxiliary sensors. In the same run a FAST tool configured with four optical three-phase probes was deployed in a memory mode below the MAPS.

READ's toolstring design in this instance was focused on delivering an extra set of sensors, the MEMS optical three-phase holdup, to offer additional insight in areas where both the CAT and RAT technologies would potentially struggle, namely the clear identification of the gas phase. This opportunity to deploy both MAPS and FAST technologies at the same time also offered invaluable comparisons between the datasets from each tool, allowing not only clearer identification of gas phase as per the customer's objective but also giving credibility to the newer technology by measuring it against the widely accepted MAPS results.

As predicted, the calculation of a gas holdup figure was made possible by the response of the FAST optical probes, which were much better at differentiating the gas from oil. This meant all the necessary data was acquired without the added risk of deploying a nuclear gas hold-up tool, which operates based on the emission of low energy gamma rays and the detection of the backscatter radiation.

Away from the areas where interpreting the free gas phase was more challenging, the log data acquired also revealed outstanding correlation between the MAPS and the newer MEMS based technology, reassuring the company that, in a scenario where the full MAPS string was to be replaced, they could deliver the level of accuracy and detail needed to make informed decisions fast and with confidence.

The next step

As the industry redefines itself, facing the challenges presented by the past few years with renewed energy and focus on new ways of delivering extended value from ageing assets, the quest to expand and enrich the industry's understanding, from the wellbore to the reservoir, has never been as important.

Staying ahead of the technology wave is all but the only way to deliver the answers necessary to underpin this understanding. To create the truly holistic model operators need to maximise reserve value, one cannot underestimate how fundamental the accuracy, reliability and the diversity of necessary data input is. All of these strands are deeply woven into the MEMS downhole revolution.