As featured in Offshore Engineer and OE Digital

Sealing Integrity Management (SIM)

A new approach for a new age

by Robin McGowan, Chief Technology Officer of Peak Well Systems, Dubai

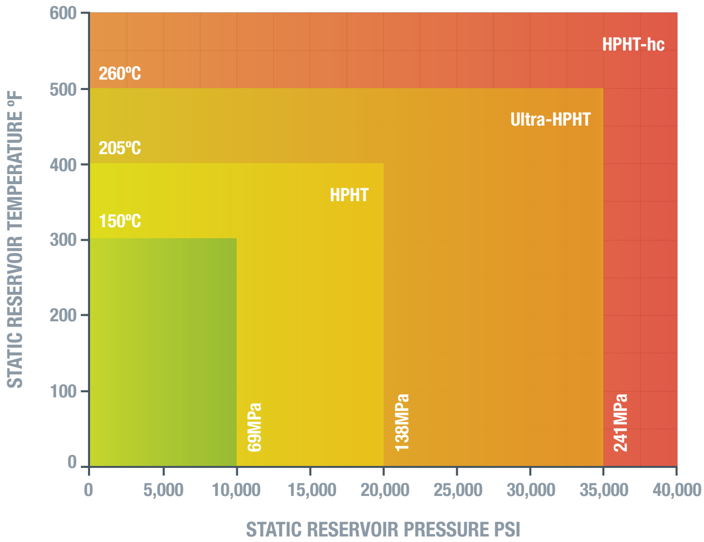
Sealing technologies are absolutely vital in our industry. The life and productivity of a well depends on the reliability of the seals found in a wide range of downhole equipment, from the tubing and liner hangers that support the flow to surface, to the plugs, packers and control devices that isolate one zone from another. In particular, downhole plugs and packers provide a vital function, separating successful operations from disaster and efficient production from expensive intervention.

Elastomer sealing elements have long formed the technological mainstay of these tools, providing cost effective, reliable and versatile sealing capability. Since their first introduction to the industry over 75 years ago, solid elastomer plugs have been successfully used across a wide range of applications and have developed from the initial natural compounds to include a wealth of polymer options for different technical and environmental situations.

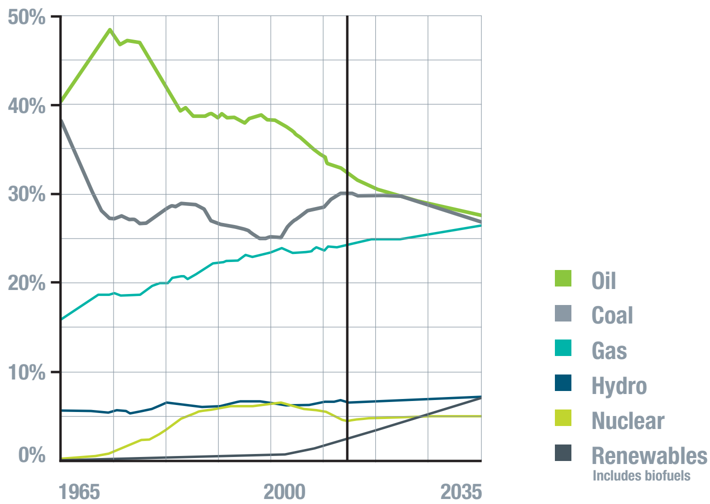
However, as the industry has advanced, regulatory standards have tightened, temperatures and pressures continue to increase and gas production increasingly shapes the technical challenges we face. We must ask ourselves whether traditional elastomers are up to these new challenges? Are we reaching the limit of innovation in solid elastomer plugs and packers and should we look for its technological successor?

More gas, more heat, more pressure

It is undeniable that, in contrast to the last century's focus on oil, the hydrocarbon industry will be dominated by gas development and production in this century. Whether from conventional or unconventional resources, issues of security of supply, available reserves and cost are driving an increasing emphasis on gas exploration and production and gas is expected to overtake oil as the dominant fuel by 2031. Already we see a clear evolution towards a gas dominated industry and that will inevitably mean higher downhole operating temperatures and pressures for conventional reservoirs. Moreover, with deepwater exploration, future seal systems will need to routinely operate in pressures beyond 10,000psi with the possibility of extreme differential pressures. Today's plugs and packers need to respond to these challenges and a recent industry survey found that the majority of respondents considered Well Intervention as the biggest industry challenge in the HPHT (High Pressure, High Temperature) arena with seal technology easily topping the list of client concerns on technology needs. Although industry definitions of HPHT criteria vary, in general in excess of 150°C and 10,000psi is considered HPHT territory. However, bearing in mind the shift to gas and the difficulty in making gas tight seals, we need a broader definition of High Performance plugs and packers that includes not only HPHT criteria but also a gas tight specification.



Shares of Primary Energy



Source: IEA World Energy Report

Failures and Failure Modes

With careful selection of elastomers and an understanding of the operating environment, solid elastomer seal elements can be designed to achieve reliable sealing in up to 200°C and 10kpsi. Reliable retrievability however is another issue and one where the solid elastomers in use today are falling short when operating in High Performance environments, or even when simply designed to these specifications and used in much more benign environments. Some operators have reported recovery failure rates of as much as 20% in such equipment, which is clearly unacceptable.

Elastomers struggle in High Performance applications with four distinct types of failure modes prevalent:

- Time/temperature dependent effects
  - Compression set
  - Thermal expansion
  - Chemical degradation
- Mechanical packaging effects
  - Extrusion damage
  - Nibbling
- Application effects
  - Rapid Gas Decompression (RGD)
  - Thermal cycling
- Wear and fatigue effects
  - Physical damage during run into the well

Any of these effects can cause damage to a solid elastomer seal downhole that in turn is likely to cause severe problems during recovery. Unsurprisingly, given the higher setting forces used in High Performance solid elastomer seals and the presence of gas in many wells, Compression Set and RGD are perhaps the single biggest causes of recovery failure for these types of plugs and packers.

Retrievable solid elastomer bridge plugs that have experienced downhole failure a) compression set, b) Rapid Gas Decompression

Standards and standard bearers

Within the oil and gas sector API, ISO, NORSOK and other standards have rightly taken an increasing importance in order to assure operators, regulators and other service provider partners that products meet acceptable industry levels of performance. The ISO/API standard is specifically designed to address some of these limitations of bulk elastomer based plugs in respect to temperature and pressure cycling whilst the NORSOK standard focuses on RGD however neither specifically addresses the fundamental issue of plug recoverability.

Work started on the plug standard in 1994 by API before being transferred in 1995 to ISO ahead of full adoption by both bodies in 2001. The API and ISO standards define seven categories, or grades, of certification depending on the test criteria but for retrievable bridge plugs there are effectively three broad categories, which build on each other to comprise:

- liquid pressure testing
- temperature cycle testing
- gas pressure testing

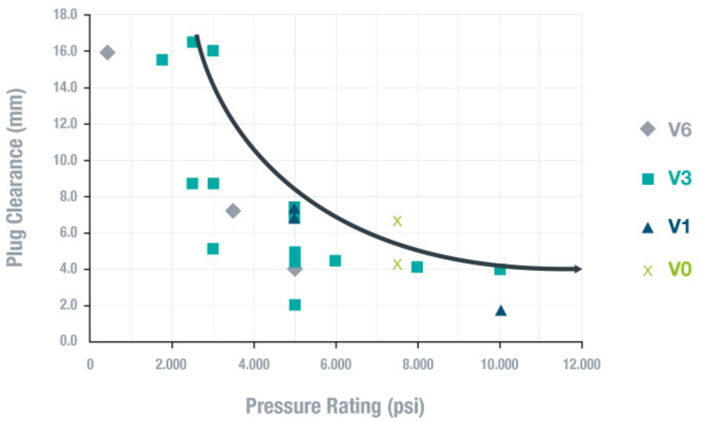
Increasingly the gold standard of these tests, the "V0" (V-zero) gas pressure test that specifies zero gas bubble leakage is being used by operators as the mark of highest quality but this omits to understand the limitations of both the test and of the underlying elastomer based plug technology.

Defining High Performance plugs and packers as those specified for ISO grade V0, pressures above 7,500psi or temperatures above 150°C, then this performance can only be achieved by some combination of higher setting forces on the elastomer element, harder and stiffer elastomer compounds or reduced expansion of the elastomer relative to standard performance plugs and packers. It is not uncommon to find running clearances of only a few millimetres on these types of plugs and, using stiffer elastomers compressed at higher forces, this only increases problems with permanent set and therefore inevitably increases recovery problems.

WELL SYSTEMS

Similarly the NORSOK M-710 standard introduced in 1994 and last revised in 2001 is commonly used as a benchmark for elastomer material performance but was originally intended to target the specific elastomer aging and RGD effects encountered at that time in the Norwegian sector of the North Sea.

The NORSOK test defines the gas composition for testing, the test environment and the rating scale for tested elastomers. The highest temperature / pressure range in the NORSOK test is 200°C and 4,410psi already well below a reasonable definition of a High Performance seal and more often than not elastomers are rated at the lowest 100°C, 2,205psi level. Furthermore, the NORSOK tests are performed on O-rings over 10 cycles which can at best be considered only as an indicator of performance for a solid elastomer seal which is normally >20mm thick, comprised of more than one type of bonded elastomer and undergoes a single rapid decompression at a higher rate than tested and after a longer period in the well absorbing gas. To compound matters further, NORSOK compression set and swell measurements are taken 24 hours after the seal has been depressurised whereas, in normal operations, retrievable plugs would be recovered immediately on equalisation or after only a short "waiting" time.



Need for a Better Technology: Plug clearance currently only comes with a compromise on pressure rating

A new seal for a new era

In the face of all of these difficulties it is not surprising that many operators are reporting significant difficulties with High Performance plug and packers – put simply they are not getting the performance they are paying for.

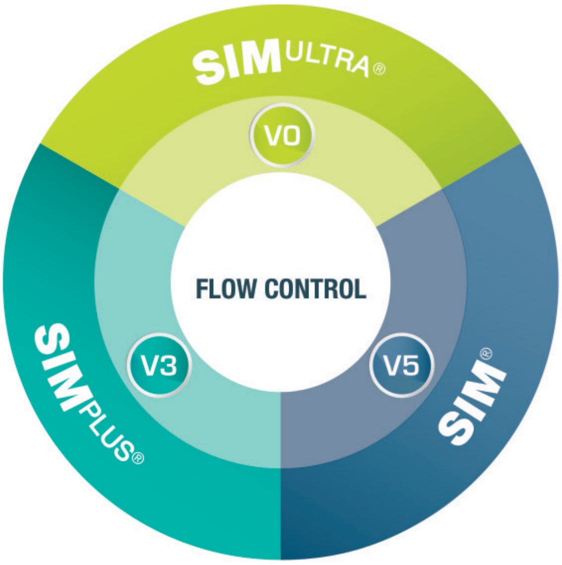
Solid elastomeric plugs and packers clearly have a vitally important role to play in a wide range of sealing applications, however the recent trend to define a better seal in terms of performance along only one axis, such as the ISO standard, is clearly flawed. Rather than a better plug using the same technology, what is required is a better technology to confront the same problem. Solid elastomeric seals are ideal for plugs and packers in flexible, routine operations and in standard environmental conditions but a new, more robust seal technology is required for High Performance applications.

To fill this gap, Peak Well Systems has developed MetaPlex®, a hybrid metal-elastomer seal that uniquely combines the best attributes of solid elastomer seals with a simple metal structure that provides the necessary mechanical support for High Performance operations. The seal has already been fully qualified to the highest ISO 14310:V0 standard but, more significantly, it utilises only a small elastomeric element and therefore avoids all of the failure modes associated with solid elastomer seals. The metal support enables an expansion ratio higher than typical elastomer seals (18% as opposed to a norm around 9%) but without the normal problems in the mechanical strength of the seal. In addition, the seal does not rely on the natural elasticity of the element to return to its original size but rather is actively pulled back to a diameter smaller than its original size. It is these three features that translate directly into assured recovery and trouble free intervention for operators using the new seal.

A further benefit of the seal lies in its through bore. The thin steel envelope of the seal enables the through bore of associated plugs to be maximised making the seal also ideal for packer and straddle applications.

In many senses the MetaPlex® seal is no different from a traditional elastomer element in that it relies on a simple linear compression to deform the element and create the sealing action. As the seal is energised it deforms sequentially; first forming a lower continuous metal contact with the wellbore before the upper section of the seal expands to create a second continuous metal contact compressing and fully encapsulating a thin elastomer element into the space between. The seal is a true hybrid relying on the elastomer to provide a seal that can accommodate surface defects and corrosion in the tubing whilst the metal body provides support for the elastomer, a barrier to extrusion and provides mechanical strength at high pressure.

In order to retrieve the seal the setting process is simply reversed with a linear extension drawing down the element and a marginal over-extension ensuring that the seal returns to a diameter smaller than its original size.

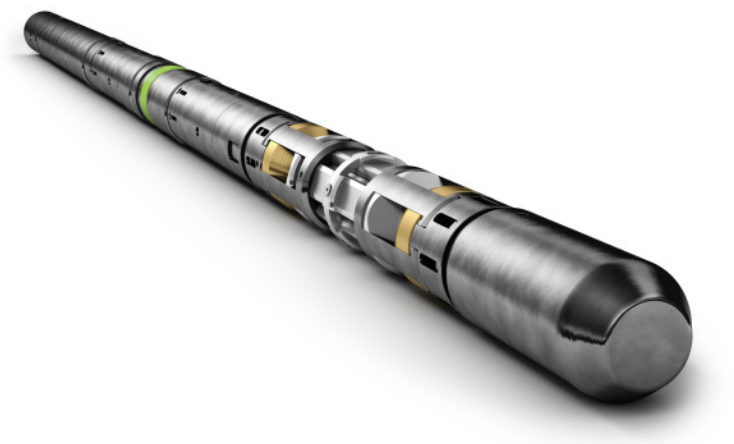


Compressional force is applied causing the MetaPlex® seal to expand radially.

Hybrid metal-polymer structure forms a high expansion full metal contact with the well bore.

Fully encapsulated, low profile, elastomer ensures reliable, zero leakage, sealing in gas wells.

Upon recovery, the MetaPlex® seal retracts to smaller-than-original outside diameter.



SIMULTRA *Retrievable Bridge Plug*

Building on the success of its proven V5- and V3-rated **SIM** and **SIM**PLUS systems, Peak has developed a new V0-rated **SIM**ULTRA plug to be used with the MetaPlex® seal. As with others in the **SIM** range, the plug uses a traditional mandrel and sleeve plug architecture with slips and locking ratchets to deploy the MetaPlex® seal. Peak has also developed a simple non-explosive modular running tool that can be used with all conveyance methods – e-line, slickline, drill pipe, coiled tubing and tractor – and that can be simply reversed to recover the plug.

With the development of MetaPlex® and the **SIM**ULTRA plug, Peak has completed its line of Seal Integrity Management systems providing optimal seal solutions for operators across the spectrum of applications. **SIM** and **SIM**PLUS systems use solid elastomer for many standard operations. **SIM**ULTRA incorporates MetaPlex® technology offering peace of mind to all operators for whom the reliability of their downhole seal technology is critical without compromising on performance, even up to the highest V0 specification.

References and acknowledgments:

BP 4th Energy Outlook 2014
http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook/outlook-to-2035.html

Oil & Gas IQ. Data compiled for 9th HPHT Wells Summit 2013