Tight gas: a new technological frontier for PDO
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His Majesty Sultan Qaboos bin Said
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If oil was the natural resource that fuelled the emergence of modern-day Oman, the Sultanate’s future economic prosperity is probably more dependent on gas – a source of power for homes and industries as well as a strategic export product in the form of Liquefied Natural Gas (LNG).

Gas differs from oil in Oman because it is 100% owned by the government, which licenses exploration & production companies such as PDO to produce it. However, while overall gas production is still on the rise, it’s struggling to keep pace with ever-growing demand. Equally, it’s widely understood that just about all the major conventional gas reservoirs in the country have been found and are producing.

So, where will all the extra gas needed to balance supply with demand come from? The answer is almost certainly unconventional fields. The term ‘unconventional’ is a catch-all that basically means the reservoirs have some characteristics that make extracting from them impossible using the normal drill and drain methods.

The most common of these unconventional characteristics is tight rock, where the permeability – or capacity for transmitting fluids – is so low that gas molecules cannot flow through the rock and into production wells without help. In Oman, these tight reservoirs throw up an additional major problem: they’re situated much deeper underground than tight gas found elsewhere in the world, up to 5.5 km deep in some places.

Given these enormous technical challenges, coupled with the availability of plentiful ‘conventional’ gas, it’s no surprise that PDO has historically focused on conventional gas production – indeed 99% of the Company’s stated gas reserves are in conventional formations.

The good news is that the north of Oman contains vast quantities of tight gas not currently counted in those reserves, gas that...
could change the country’s supply and demand dynamics for a generation. Even better news is that PDO, together with specialist operators from overseas such as BP and BG Group, are breaking new technological ground in trying to produce this gas efficiently and economically.

**How to get at tight gas**

As already noted, tight rock formations with low permeability do not allow gas to move freely into producing wells. The unit for measuring permeability is the darcy, and conventional reservoirs would normally have permeabilities ranging from 0.1 to 0.5 darcy. Tight formations, by contract, can be measured in fractions of milidarcies or even microdarcies.

This is why the key to producing tight gas is reservoir stimulation – the term used in the industry for various treatments that can boost production. Tight gas stimulation is a new technological field for PDO but the Company has already scored a major success with its Khulud-2 well in north Oman, which marked the culmination of four years of work by its gas exploration team.

Khulud-2 was drilled into the tight and deep-lying Amin and Nimr reservoirs in the Fahud Salt Basin, using Under-Balanced Drilling (UBD) techniques, a process that cuts the pressure levels maintained in the well bore while drilling is taking place. Using UBD enables gas to be produced during drilling, so the PDO team were able to ascertain where there was moveable gas in the reservoir and where stimulation would be required, enabling them to tailor the stimulation programme much more accurately.

Stimulating the well involved creating fractures in the reservoir rock, in this case by pumping in water under high pressure. The fractures act as pathways for the gas to flow through. At Khulud-2, PDO instigated five fracture zones, rather than the typical two or three, and the fracture fluids were also pumped out immediately afterwards, leaving clean fractures for the gas to flow through. This process is known as ‘frac and flow’ and Khulud-2 was the first time it has ever been used in Oman.

The result was better than expected gas flow from the reservoir, giving a positive

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Khulud-2 discovery was a major success in the north of the concession area and demonstrated the hard work of the exploration team.
platform for PDO’s quest to produce tight gas. The next, and most important, step is to bring the well stimulation costs down to improve the economics of these projects, something the team hopes will be helped by implementing fit-for-purpose drilling and testing technologies that have proven successful in tight gas production elsewhere in the world.

One way that PDO might reduce its costs is in drilling its wells differently. Later this year the Company will be experimenting with slimmer wells with fewer casings than the typical deep gas wells, something that, if successful, would cut a couple of million dollars from the cost of each well. Trials will also take place where wells are drilled using the faster UBD method from shallower depths (UBD traditionally only takes place at reservoir level) and using lighter muds (drilling lubricants), both of which should cut the drilling time, and therefore cost, of each well.

Technological advances are not just being applied to the production of tight gas, however. The Amin and Nimr reservoirs were also the focus for a wide azimuth seismic survey which was completed in October 2009. Preliminary data from initial processing of the survey show improved images of the subsurface compared to existing narrow azimuth data sets.

Wide azimuth seismic is a derivation of 3D seismic – in this case using a wider spread of receivers (known as geophones) at the surface compared with a normal seismic ‘shoot’. When processed using advanced imaging algorithms, the extra seismic data received helps to improve the imaging of complex geology.

Wide azimuth seismic is particularly effective in improving images of reservoirs buried at depth, in an excess of 4000m, a profile that fits much of the tight gas in Oman. In North America, where tight gas exploration and production is an established process, good quality seismic data has also been used to reveal reservoir rock that is subject to intense natural fracturing. Once these areas have been identified, wells can be drilled into them, in the knowledge that no further man-made fracturing is necessary.

“Effective stimulation is key to improving reservoir delivery. The challenge is to manage the stimulation costs.”
required. Having a clearer subsurface ‘map’ also creates the possibility of connecting existing fractures by highly targeted stimulation, which should also translate into better productivity.

New players in the quest for tight gas
PDO is not the only company entrusted by Oman’s government with exploiting the potential of tight gas. Both BP and BG Group (formerly British Gas) have been awarded assets previously discovered by PDO and both have already drilled a number of appraisal wells and acquired seismic data.

Although competitors, all the oil and gas companies focusing on tight gas in Oman are keen to share knowledge and experience with each other. A workshop on this subject was held in 2008 and another is proposed for this year. PDO specialists have also visited Shell Canada, one of the leading practitioners in this field, to discuss stimulation and drilling techniques as well as the organisational requirements needed to run a successful tight gas operation.

Canada is one of the countries that provide a beacon of encouragement for all the operators going after tight gas in Oman. There, most gas production is from unconventional reservoirs that require stimulation, but thanks to years of experience this is now done on a scale – and to a proven formula – that makes it economical.

All this activity means it’s an exciting time to be in the gas business at PDO, particularly for experienced geoscientists, petroleum technologists, reservoir engineers and petrophysicists”

Lots of thanks to Dr. Hisham Al-Siyabi (from PDO) for his help in the preparation of this article.
Concession Map of Oman
SAFETY BEHAVIOURS

SAFETY IN MIND: TAKING A STAND AGAINST WORKPLACE DEATHS AND INJURIES

al manhal looks at how PDO is trying to crack the issue of safety at work by winning the hearts and minds of employees and — more importantly — contractors.
No employees setting off for work intend to injure or even kill themselves in the process of doing their jobs. So, why is it so difficult to get safety messages through to people?

This was a question that PDO had to ponder at the beginning of 2009, as it announced accident figures for the previous year that were, in the words of Managing Director, John Malcolm, “disappointing”. During 2008 the Company suffered seven work-related fatalities, all from road accidents, plus a further 120 injuries which necessitated time off work to recover – so-called lost time injuries, or LTIs. This compared with two fatalities in 2007 and 72 LTIs.

Had driving and working for PDO suddenly become a lot more dangerous? The answer was actually ‘yes and no’. The increase in deaths and LTIs was on one hand related to a massive rise in the number of kilometres driven on company business and of man hours worked, as PDO ramped up its efforts to find and produce more oil and gas, and, on the other hand there was the Galfar bus accident with three fatalities and 33 LTIs. To illustrate, the number of man hours worked across the Company had risen from 109 million in 2007 to more than 133 million just 12 months later.

But clearly no responsible company could hide behind this statistic and wash its hands of the harm that was being caused in the name of producing oil and gas. Indeed John himself said, “The increasing hours of work and number of kilometres driven are no excuse for letting safety slip.” Analysis of the various incidents backed up this straight talking, with many accidents caused by sloppy behaviour, breaking rules, not understanding the rules or taking short cuts.

As a first step towards reversing the trend, PDO announced a far-reaching HSE (Health, Safety & Environment) programme under the heading ‘Goal Zero’ – i.e. zero harm to people or the environment. Four HSE Must-Win Projects were quickly put in place, representing big must-win projects that had to be addressed as top priority. In addition a Change Director position was created and a project office to support the four must-wins was established. These must-win projects are championed by Directors of the Company and their progress is reported to and discussed by the Managing Directors’ committee on a monthly basis. The following are the must win-projects:
PDO’s HSE Must-Wins launched in 2009

Road Safety

As the recent feature in al manhal explained, road safety is one of the most critical problems in the whole of Oman, not just for PDO. To help its employees and contractors do their bit to cut accidents, last year PDO embarked on a programme of some 40 driving forums that took place at locations across the interior. At the same time the Company began rolling out safety technology such as In Vehicle Monitoring Systems (IVMS), which help to identify bad driving that can be addressed before it leads to an accident.

Process Safety

Here, the focus was on six of PDO’s key assets, including the main oil line and the gas central processing plants in Saih Rawl. Each facility was thoroughly audited, identifying gaps in process safety that could then be closed. For example, is the right equipment in place and is its maintenance up to date? Is the emergency shutdown working? Or are workers fully briefed on how to operate certain equipment? Around 700 workers were also given specific training on process safety.

Worksite hazards

Oilfield facilities can be dangerous for the unwary or careless, but there are plenty of examples where facilities can go for years or even decades without an LTI. For example, a PDO engineering workshop in Marmul has now passed 25 years LTI-free, even though its people operate power tools and other heavy machinery. And the Geomatics team, despite frequent survey trips into the interior, has now been LTI-free for 28 years and counting.

As part of this Must-Win programme, frontline workers throughout PDO have undertaken new-look training courses to help them operate machinery and perform other tasks with safety at the top of their mind. Meanwhile, divisional management has been charged with investigating LTI incidents themselves, rather than the corporate HSE team doing it, so as to increase their awareness of risks and how to mitigate them.

Contractor HSE management

Recognising that contractors are at the heart of the safety problem – accounting for all the workplace deaths and LTIs recorded in 2008 – a big effort has been made to get the contractor companies that PDO works with up to a good standard of HSE performance, by ensuring the contractors CEOs focus on HSE through letters of assurance by leading accident investigations.

In addition, PDO has also adopted a ‘cost-plus’ approach to its tenders, where contractors that have attracted safety concerns must agree to take – at their own cost – PDO safety specialists on board, who will help them to bring their practices up to the desired level. Meanwhile, PDO employees who manage contracts have also been given safety competency training and the Company now tries to make sure they have sufficient time to focus on safety matters.
By the end of 2009 the effect of these Must-Win programmes and other safety-specific initiatives could clearly be seen, as the number of road deaths fell from seven to four, while the number of LTIs was reduced from 120 to 45. And this in a year when miles driven and hours worked across the Company rose to new records – 260 million kilometres and 157 million man-hours respectively. In fact the ratio of LTIs to millions of man-hours worked, at 0.29, was the best in PDO’s history.

However, as if to prove the difficulty of permanently embedding safe behaviour, 2010 was barely underway when a spate of serious road accidents claimed the lives of four people. These tragedies have refocused everyone’s minds, with all involved recognising that it will take several more years before the good practices launched in recent times truly begin to take hold.

As the Must-Win programme is given fresh impetus, its scope has also been broadened, with the addition of a fifth workstream: NORM and oily waste.

NORM stands for Naturally Occurring Radioactive Materials which are found throughout the earth’s crust and within the reservoirs where oil and gas are produced. These elements include uranium and thorium and their daughter products radium and radon.

PDO has identified NORM fixed to down-hole pumps, joints, sucker rods and surface equipment such as Christmas trees and flow-lines. NORM has also accumulated as non-fixed sludge in separators, tanks, pigging receivers and evaporation ponds. The presence of NORM presents a potential health risk to people maintaining and servicing production equipment or handling waste streams if the NORM procedures are not rigorously followed.
In the past, PDO has stored NORM in special licensed facilities, but now a contract has been issued to decontaminate and permanently dispose of it.

Oily waste, as its name indicates, is water, sand and other material that has been contaminated with oil. Big efforts are now being made to dispose of oily waste in a more environmentally-friendly manner, including the creation of a large-scale reed bed facility, which was profiled in the last issue of al manhal.

Safety: a rallying point for the key players in Oman’s oil industry

The healthy competition for oil and gas opportunities between PDO, Occidental and BP has not prevented these firms from maintaining a united front in the area of HSE. Indeed, each has agreed to take the lead in one of three important areas of focus, while at the same time sharing the practical knowledge their people have built up through years of front-line oilfield experience.

PDO’s chosen area is fatigue management. This has come about because accident investigations have revealed that tiredness is very often a big factor, from falling asleep at the wheel to opening the wrong pressure valve because concentration levels have been affected.

BP, meanwhile, is taking the lead on medical screening of contract workers, looking for previously undiagnosed conditions such as heart defects that could be fatal in the harsh conditions of the interior oilfields. And Occidental is spearheading a programme to raise awareness of the dangers of drugs and alcohol, both within the working environment and more generally as a threat to good personal health.

While no company underestimates the task ahead, neither does any concede that the ultimate goal of zero deaths and injuries in the workplace is an impossible dream. It can be done – just ask the Geomatics or Marmul workshop teams.
**H₂S: PROTECTING AGAINST ONE OF NATURE’S DEADLIEST GASES**

H₂S, or hydrogen sulphide, is a highly dangerous gas. One breath of it is enough to kill.

So, the only option for people working around H₂S is to carry serious levels of protection – Gas detector & Escape set or even full self-contained breathing apparatus. Since H₂S is often found mixed with crude oil that is pumped to the surface, this sort of safety equipment is common in the oil and gas industry, but PDO’s new miscible gas Enhanced Oil Recovery (EOR) project in Harweel has had to take this type of protection to new level, as this photo feature explains.

**Why safety comes first at Harweel**

Miscible gas injection works by compressing unusable recovered gas back into the reservoir at much higher pressures so that it mixes with the oil, forming a lighter, less viscous fluid that is easier to extract. Unfortunately, at Harweel, the best gas for this job is deadly H₂S and the force required so that the gas reaches the 5 km deep reservoir at miscible pressure is around 550 bar – or 550 times atmospheric pressure. Needless to say, the combination of these two factors makes safety an absolute priority at Harweel. The EOR facility, pictured here, has a 10 km exclusion zone around it and the staff camp is a further 2 km beyond that, a distance by which any cloud of H₂S will have dispersed to safe levels. The plant itself has also been divided into red, yellow and so-called ‘safe’ zones, with the red zones requiring full breathing apparatus (see next photos for more details) to be worn at all times.

**Revolutionary new breathing apparatus for workers in the ‘red zone’**

As already mentioned, full breathing apparatus is an essential piece of kit for people working in the plant’s designated ‘red zone’. But PDO found that no apparatus currently available on the market offered the level of protection needed to ensure safe working at Harweel especially for people with facial hair. So the Company approached a British safety equipment firm, Cam Lock, to develop an enhanced breathing apparatus with a mask derived from those worn by pilots of the Eurofighter jet aircraft. The apparatus has an umbilical that the user connects to the plant’s own air supply system, and in case of emergency he/she also carries a special lightweight carbon fibre air tank with sufficient air to breathe for 15 minutes – ample time to reach the nearest site refuge point (see picture 3).
A fast-fit gas mask for when speed is of the essence

Cam Lock with input from PDO also developed an innovative escape kit for workers in the plant’s yellow zone to carry with them in case of emergency. Even though the threat from a gas leak is less immediate in this area, time is still of the essence if the alarm sounds. So the new FAST-mask is designed to be fitted with one hand in less than three seconds, thanks to a harness that inflates automatically when the first breath is taken, fixing the mask to the wearer’s face/head without the need for manual tightening.

Special protection for bearded workers

Recognising that a number of its Harweel workers wear beards, PDO engaged Cam Lock to devise a special pressurised cowl system for use with both the breathing apparatus and escape kit. This features an extra hood around the shoulders and neck, inside which air pressure is maintained sufficient to prevent any H2S getting in, so that it’s not necessary for the mask to make a tight seal around the face. This type of hood was tested and approved by the BSI in the UK.

A refuge in the event of H2S leakage

Within the Harweel plant there are three Temporary Safe Refuge areas where workers can evacuate to if the H2S alarm sounds. Everyone going into the plant gets a full briefing beforehand, telling them where their nearest TSR is. The main shelter is shown here – this bright orange building is hard to miss and it can hold up to 70 people. It is pressurised inside, like the cabin of an aircraft, and this prevents the H2S from entering. There’s enough stored air to last two hours, a good margin given that the Harweel plant takes just one hour to depressurise in the event of an incident.

Intensive training for the Harweel workforce

As the Harweel plant prepares to get up and running, all who will be based there were flown to Singapore, where the workers underwent six weeks of intensive safety training at a petrochemical plant that has been specifically designed for this purpose. The team operated the plant 24 hours a day, just as they will for real in Harweel, and worked through various exercises such as tackling fires, plus emergency escape and rescue drills culminating in an assessment to NVQ Level 3 competency. Once Harweel is up and running only those fully trained in using enhanced breathing apparatus and the other key elements of the plant’s safety Emergency Response programme will be allowed in through the controlled gates. That should ensure that – whatever the inherent dangers of H2S – the Harweel team will be prepared for anything.

Many thanks to Anthony Cotterill (from PDO) for his help in the preparation of this article.
Catching up with my management team
By 10 am I’m already well into my working day, having arrived at the office around 7 am and immediately set about checking over reports and other information sent overnight (our rigs operate 24 hours a day) by our teams in the field, as well as dealing with an email inbox that receives more than 150 messages each day. Now, though, it’s time for my daily meeting with my head office-based management team. I have two Operations Managers plus six Workover Superintendents and this meeting is our chance to catch up on our current contracts, dealing with any problems or issues as they crop up. We also look at incoming tenders that might need some points clarifying before we can set our price for the work involved.

Off for some ‘face time’ with my clients
As any contractor will tell you, having good relationships with clients is absolutely vital to success. Here I am meeting Mohammed al Maharbi (Hoist contract holder) at PDO, which is the biggest of my eight workover clients in Oman. We have strong links with PDO – indeed our founder and Chairman, Mohamed Al-Barwani, was a petroleum engineer for the Company before striking out on his own – and I feel really at home here. I’ve even been able to share in one of PDO’s Chairman’s Awards for Excellence, given for an innovative Progressive Cavity Pump (PCP) that was the result of a collaborative project between MB Petroleum Services and PDO. The new design enables us to work on the well while it is still producing, saving PDO $10 million a year.
Amid the operational detail, there’s still time to look at the big picture

In our business if you are not moving forwards then you are definitely moving backwards! So, while I devote a lot of my time to the here and now I must also focus on the future, in particular opportunities for us to grow in size and strength as a company. That’s why I regularly sit down with our Group CEO, Eamon Gorman, to look at prospects both inside and outside Oman. We are already the biggest workover contractor in the Middle East but MB Petroleum Services has even broader horizons, with interests in Australia, Austria, China, Germany, Hungary, India, Indonesia, Libya, Malaysia and New Zealand. Of course our primary activities are still in Oman, with 92% of my workforce being Omani. I’m proud of our contribution to the livelihoods of those families as well as to the national economy.

Field visits help keep me close to the action

Twice a month I visit our rigs in the field, in the north and south of Oman. I can visit most of our rigs and meet clients and field personnel in Fahud, Lekhwair, Daleel and Safah, all of which can be reached by road from our office in Muscat. I talk to our field manager for each area as well as to the field superintendents who report directly to them. Like me, most of these people came from the rig floor so they know the nuts and bolts of our operations and I can trust them to keep things on track. That said, managing people is the toughest part of this job, especially keeping rig teams fully resourced, because it’s too costly to keep ‘spare’ workers on standby. If one team member is missing the rig’s operations can be compromised. The best part of the job? Meeting challenges and driving constant improvements in the way we work!
THEY CAME FROM OUTER SPACE...

METEORITES IN OMAN

Did you know that in recent years Oman has been one of the world centres of meteorite discovery?

In fact, in the years leading up to 2007 the Sultanate contributed around 14% of all the world’s meteorite finds excluding Antarctica finds, a figure topped only by inhospitable and hard to reach Antarctica. That pace of discovery has fallen a little since 2007, but scientists are still building their knowledge of our planet and solar system thanks to Omani meteorite finds.

This feature explains a little more about meteorites and how they find their way to Earth. We also spotlight one of the most significant and celebrated Omani meteorite finds of recent years – the moon rock Sayh al Uhaymir (SaU) 169.

More information about meteorites can be found by visiting the dedicated website of Washington University at St. Louis www.meteorites.wustl.edu

SaU 094 Martian meteorite on the ground in Oman
Photo: Natural History Museum, Berne, Switzerland

Why is Oman such a fertile hunting ground for meteorites? There are a number of reasons, but topography is the primary one. The central and southern deserts of Oman are generally flat, making them relatively easy for meteorite-searchers to explore, while the sand and carbonate rocks that abound in the desert landscape, being light in colour, also provide a contrast to the dark colour that characterises meteorites. This makes it a little easier for a trained eye to spot rocks that could potentially be meteorites, although their true origin can only be determined by laboratory testing.

Meteorites are studied by taking a section from the rock and examining it using two advanced forms of microscopy – reflected light (which shows up the metals present) and transmitted light (to identify other minerals such as olivine). Most meteorites that fall to earth are chondrites, named for the tiny rounded silicate particles called chondrules that they contain. Most meteorites originate from the asteroidal belt which occurs between Mars and Jupiter, but over the years a few have been found that have travelled all the way from Mars and the Moon.

This is the lunar meteorite named Sayh al Uhaymir (SaU) 169, which made international headlines when it was found in 2002 by three geologists, Ali Al-Kathiri, Beda Hofmann and Edwin Gros, during a joint meteorite search project by the Government of Oman and the University and Natural History Museum of Berne, Switzerland. SaU 169’s unique composition enabled it to be directly linked to the Imbrium impact basin on the moon, thanks to rock samples taken by the Apollo 14 lunar mission, which landed nearby.

Most large meteorites disintegrate into a shower of fragments when entering the Earth’s atmosphere. The speed and angle of entry of these fragments spread their landing over a large area, known as a strewn field. The footprint of one of Oman’s well known meteorite showers – Sayh al Uhaymir 001 – is shown in this graphic. Some 2,670 fragments from this meteorite have been recovered, weighing a total of more than 450kg! Not very far from them was the celebrated SaU 169, shown elsewhere on these pages. Strewn fields are elliptical in shape, with the smallest fragments touching down first and the largest being the last to hit the ground.

SaU 169 Martian meteorite
Photo: Peter Vollenweider.

Lots of thanks to Dr. Ali Alkathairi (from Bahwan LHOIST) for his help in the preparation of this article