EPRASHEED
signature series

2013 – Issue 32

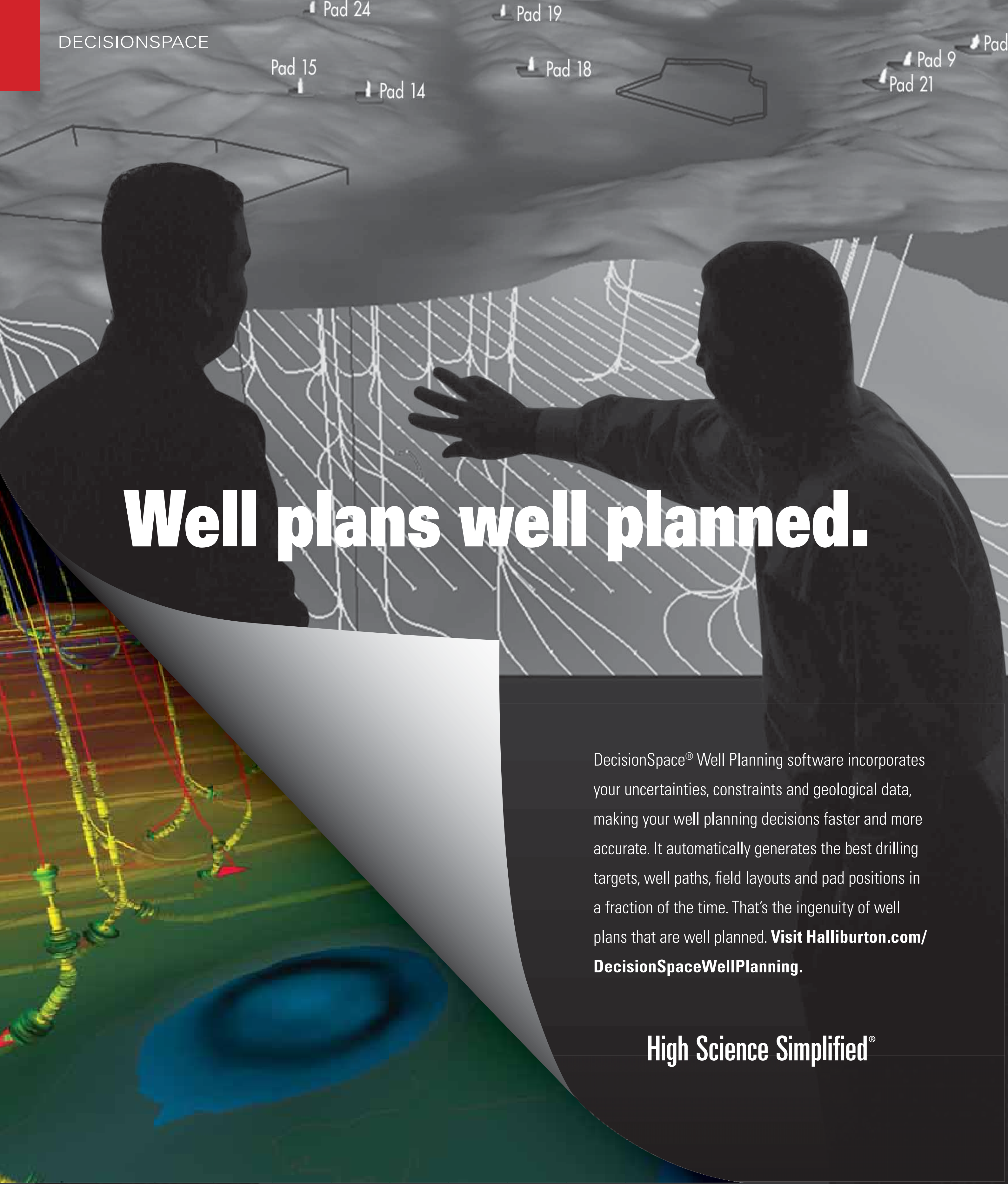
Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com

Official Publication ATS&E 2013

THE UPSTREAM
INNOVATION SPARK
Lighting our Way to a Better Tomorrow

ATS&E
ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION



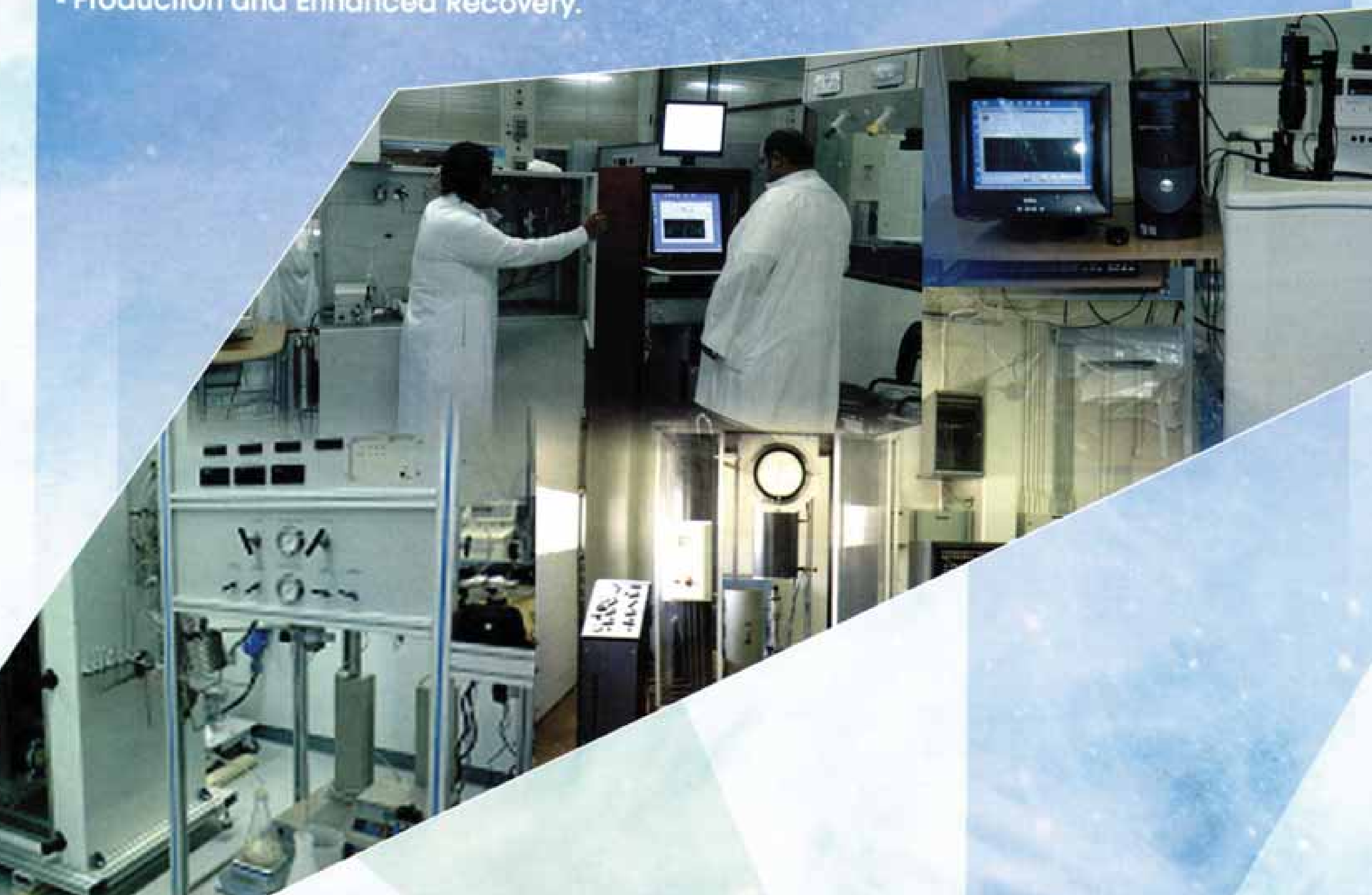
HALLIBURTON | Landmark Software & Services

مدينة الملك عبدالعزيز
للعلوم والتقنية KACST

Oil and Gas Research Institute

Hydrocarbon resources (crude oil and gas) are the main source of world energy, and as the international demand increases, the technical challenges increase to meet that demand. Hydrocarbon production optimization at minimum cost and the need to serve the national petroleum industry has been the driving force behind the establishment of the Oil and Gas Research Institute (OGRI) at King Abdulaziz City for Science and Technology (KACST). OGRI is a governmental research and development entity. Its applied research activities concentrate on the upstream sector of the petroleum industry. Fields of interest cover most of the petroleum science and engineering aspects through four main divisions:

- Reservoir Characterization and Numerical Simulation,
- Drilling Engineering,
- Rock Mechanics,
- Production and Enhanced Recovery.



Services Provided

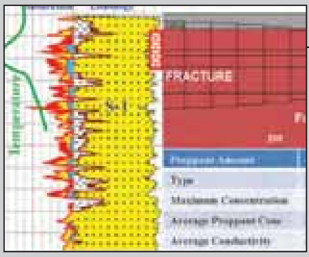
Service	Techniques
CONVENTIONAL CORE ANALYSIS	➤ Helium Porosity (Ambient Conditions) ➤ Gas Permeability & Porosity (Low and Reservoir Overburden Stress) ➤ Klinkenberg Correction ➤ Liquid Permeability (Reservoir Conditions)
SPECIAL CORE ANALYSIS (SCAL)	**CAPILLARY PRESSURE TESTS** ➤ Centrifuge Techniques (Reservoir Conditions) ➤ Low and High Pressure Mercury Injection and Withdrawal Technique ➤ Pore Size Distribution (PSD) **RELATIVE PERMEABILITY MEASUREMENTS** ➤ Unsteady State Flooding Technique (Reservoir Conditions) ➤ Centrifuge Technique (Reservoir Conditions) **WETTABILITY TESTS** ➤ Centrifuge USBM Method ➤ Contact angle Measurement (Ambient and Reservoir Conditions) ➤ Interfacial Tension Measurements **PETROGRAPHIC SERVICES** ➤ Sieve Analysis ➤ Particle Size Analysis ➤ Thin section
RESERVOIR FLUID ANALYSIS	➤ Interfacial & Surface tension ➤ Gas and Gas Condensate Viscosity ➤ Refractive index and pH ➤ Contact angle
ADVANCED RESERVOIR ENGINEERING	➤ Water-Oil /Water-Gas Displacement ➤ Gas Flooding and WAG ➤ Chemical Flooding
PETROLEUM RELATED ROCK MECHANICS	➤ Uniaxial, Triaxial, and Hydrostatic Compressive strength ➤ Stress-Strain Behavior ➤ Failure Envelope ➤ Elastic moduli ➤ Bulk and Pore Compressibility ➤ Fracture Toughness

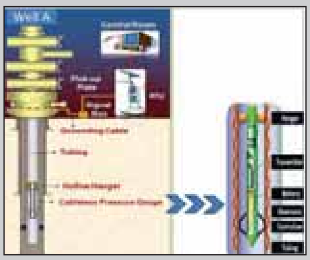
OGRI - KACST - K.S.A - P.O. Box. 6086 Riyadh 11442
Tel. : +966 1 4813307 Fax : +966 1 4813526

www.kacst.edu.sa

EPRASHEED
signature series
2013 – Issue 32
Saudi Arabia oil & gas
Saudi Arabia Oil & Gas (Print) ISSN 2045-6670
www.saudiarabiaoilandgas.com
Saudi Arabia Oil & Gas (Online) ISSN 2045-6689

Contents





CEO and Founder EPRasheed
Wajid Rasheed
wajid.rasheed@eprasheed.com

Editors
Majid Rasheed
Mauro Martins

Design
Sue Smith
sue.smith@eprasheed.com

United Kingdom
Head Office
Tel: (44) 207 193 1602

Adam Mehar
adam.mehar@saudiarabiaoilandgas.com
Main: (44) 1753 708872
Fax: (44) 1753 725460
Mobile: (44) 777 2096692

Saudi Arabia
Akram ul Haq
PO BOX 3260, Jeddah 21471
akram.ul.haq@saudiarabiaoilandgas.com
Tel: (966) 557 276 426

Mohanned AlSagri
mohanned.alsagri@saudiarabiaoilandgas.com

Brazil
Ana Felix
afelix@braziloilandgas.com
Tel: (55) 21 9714 8690

Fabio Jones
fabio.jones@braziloilandgas.com
Tel: (55) 21 9392 7821

Roberto S. Zangrando
rzangrando@braziloilandgas.com
Tel: (55) 22 8818 8507

Welcome Message by the Chairman

It gives me great pleasure to welcome you to the 2013 Annual Technical Symposium & Exhibition (2013 ATS&E), organized by the Saudi Arabian Section of the Society of Petroleum Engineers (SPE-SAS).

This gathering of upstream professionals has taken center stage as the premier annual gathering for the oil and gas industry in the region. Since its inception the Symposium has served as a platform for knowledge transfer and experience sharing in the Gulf region, serving the men and women that power the energy hub of the world.

This year's theme, 'The Upstream Innovation Spark, Lighting Our Way to a Better Tomorrow', shines the spotlight on one of the main factors for our industry's continued success, the innovation brought forth by the talented and dedicated professionals of our industry. From the early beginnings of the Drake well, to today's advanced drilling and production systems, we as an industry have relied on technology innovation to drive us forward. Such innovations, driven by our professionals and proliferated by events such as the Annual Technical Symposium & Exhibition, will continue to place oil and gas as the energy resources of choice for the world.

The 2013 Annual Technical Symposium offers a rich program consisting of 3 pre-event courses, 20 technical sessions, and a high-profile panel discussion. In addition, the associated exhibition will showcase new technology advancements. This program will be complemented by recognized keynote and distinguished speakers.

On behalf of the program committee, I would like to thank you for your support in making the 2013 SPE-SAS Annual Technical Symposium & Exhibition a success, wishing that you find it a rewarding experience. I would also like to thank our official publication, Saudi Arabia Oil & Gas magazine.

Ali Habbtar
Chairman
2013 SPE-SAS Annual Technical
Symposium & Exhibition

Oil and Gas IT Group Meets at The Hague

From left are Alan Matula, Shell; Alvardo Adriano Rocha Martins, Petrobras; Louie Ehrlich, Chevron; Abdulaziz Al-AbdulKarim, Saudi Aramco; Dana Deasy, BP; Sonja Chirico Indrebo, Statoil; Patrick Hereng, Total; and Ennio Fattiboni, Repsol.

THE HAGUE, 20 February 2013 – Information officers from nine of the world's leading oil companies met recently to share best practices for information technology.

Called the Oil and Gas IT Benchmarking Group (OGBG), the current membership includes BP, Chevron, ENI, Petrobras, Repsol, Saudi Aramco, Shell, Statoil and Total. ExxonMobil is expected to join later this year. The group's objective is to benchmark both qualitative and quantitative information, so that each company can maximize the delivery of its IT services.

The information and insight gained from the benchmarks is used to improve internal IT processes and capabilities. There is no exchange of cost or sensitive data.

The meeting featured four agenda items with companies taking the lead on each topic. Chevron prepared a report on information risk management and IT security; Shell tackled process control automation; Statoil and BP joined to examine IT consumerization — basically allowing employees to use their own communications devices to access company data and work processes; and Repsol and ENI looked at future IT business models.

"This is a new experience for me – sharing best practices supporting Saudi Aramco plans to secure our network and plants," said Abdulaziz Al-AbdulKarim, Saudi Aramco's executive director of Information Technology.

"I found valuable insights which will help me improve the way I run IT," said Dana Deasy, CIO of BP.

A variety of benchmarks are used to evaluate IT issues. The Full Spend Benchmark (FSB) is the most important benchmark for the group and provides a quantitative look at costs. The Maturity Assessment Benchmark provides a qualitative perspective. Other benchmarks currently ongoing, either in design or execution, are in the area of information risk management, applications and ERP/SAP.

All benchmarks are conducted with respect for competition laws and other agreements. Often a third party facilitates the benchmark. This party then reports company data against a backdrop of the averages and other statistical data of the companies that take part in the benchmark. This way no individual company data is revealed.

Program Helps Teach the Teachers

AL-KHOBAR, Saudi Arabia, 13 February 2013

The Basic Teaching Skills in Math, Science and English Language for Intermediate Teachers Program was recently launched in cooperation with The Ministry of Education and The Teaching Experts Co. at an al-Khobar area hotel.

The aim of the project is to improve skills and allow for practical implementation of the new curriculum's philosophy.

Ahmad Ghamdi, project supervisor, kicked off the program. "Saudi Aramco is delighted to meet on this day with this group of teachers practicing the most noble of professions," he said. "This training program is in the context of a series of social responsibility programs that Saudi Aramco offers to the local community. We give many thanks to the Ministry of Education for allowing us this opportunity, and we look forward to achieving its goals so it may have a positive reflection on our students who are the hope of this country and its bright future."

Relaying Experiences

The manager of the Math and Natural Sciences Professional Development Program at the Ministry of Education, Mush'i B. Dossary, thanked Saudi Aramco for its exceptional community outreach programs, especially those designed to develop teachers.

"Saudi Aramco's sponsoring of this program is a great example of the true partnership the Ministry of Education and the company have. We are happy today to launch this initiative targeting 150 male and female teachers of math, science and English language."

In his speech, the project manager at The Educational Experts Company, Ahmad Zahrani, said, "True construction of countries is dependent on true construction of human beings. This is why we made people the center of our concern – because people are the core of continued development and the greatest contributor to the rise of a country. Therefore, we consider this training program as a practice in critical thinking."

Connecting Curriculum with Reality

The 10-week program is targeted at English language, math and science teachers and includes a learning philosophy, science curriculum, student-based learning,

> “We give many thanks to the Ministry of Education for allowing us this opportunity, and we look forward to achieving its goals so it may have a positive reflection on our students who are the hope of this country and its bright future.”

lifelong continued learning, next step in conceptual comprehension, science technology and evaluation in science curriculum’s and math curriculum’s learning philosophy.

At the end of the program, an evaluation process will be conducted to measure the effectiveness of the proposed development methodology, by examining the following levels:

- **Reaction:** Teachers’ satisfaction level with certain aspects of the training program, such as training material, trainers and training methods. This will be measured through a questionnaire handed out to all trainees.

- **Learning:** This will measure trainees’ level of understanding of the concepts, theories and skills by conducting exams before and after they’ve received training. The purpose of the exams is to measure the trainees’ level of attainment and command of skills and information.

- **Behavior:** This will measure changes in trainees’ behavior as a result of the program. It will be evaluated through gathering field information from the trainees’ direct superiors, their colleagues and the trainers themselves.

- **Results:** This will focus on the training outcomes and the impact they have on an institution’s efficiency and its ability to attain the aspired goals. Measurement criteria include production quality and competency achievements.

Saudi Aramco Hosts Geology Field Seminar

DHAHRAN, 20 February 2013

Geology students and faculty from King Fahd University of Petroleum and Minerals (KFUPM) and Stanford University, with support from Saudi Aramco and Aramco Services Co. (ASC), conducted a geology field seminar Jan. 13-19 in Dhahran and Riyadh.

A group of 32 geoscientists from Saudi Aramco, ASC, KFUPM and Stanford gained hands-on experience in recognizing and interpreting carbonate rocks that are time-equivalent to some of the most prolific reservoir rocks in the world.

Within hours of arriving in Saudi Arabia, the delegation from Stanford and ASC toured the KFUPM campus and met with faculty members to learn about programs in geoscience. The group next visited Saudi Aramco facilities, including the Upstream Professional Development Center (UPDC), the EXPEC Computing Center and the Geosteering Center.

While at the UPDC, the group visited the CAVE immersive visualization environment to view a 3D model of the rocks they would see in Riyadh. Later, a tour of the Saudi Aramco core warehouse demonstrated the substantial efforts the company undertakes to gain knowledge about its producing reservoirs through core acquisition and analysis.

The following day, led by Saudi Aramco geologists Bob Lindsay and AbdulJaleel AbuBshait, a convoy of six SUVs drove from Dhahran to Riyadh. On arrival in Riyadh, the group enjoyed a guided tour of the King Abdulaziz Historical Center and al-Diriyah.

The next three days were spent at outcrops of Jurassic carbonate and evaporite rocks. The group divided into teams to view and describe different parts of the outcrops. This allowed all participants to think on their feet and learn from each other.

On return from Riyadh, the group visited the Dammam Dome and the Prosperity Well to learn about the history of exploration in Saudi Arabia. An afternoon visit to the Aramco Beach allowed participants to wade into the Arabian Gulf, a relaxing conclusion to a busy but fulfilling week.

The field seminar is part of a strategic alliance established in 2009 between Saudi Aramco, KFUPM and Stanford University to collaborate in geosciences and petroleum engineering education and scientific research. Many members of the group have connected on Facebook so they can exchange photographs and keep in contact about projects of interest. The faculty members and ASC Upstream Research staff are already discussing plans for future activities including short courses, research conferences and field seminars.

Remarks at CERA Week 2013

By Khalid A. Al-Falih, President and CEO, Saudi Aramco.

HOUSTON, Texas, 05 March 2013

"I know I speak for everyone when I say this event is the highlight of our calendars. It's an opportunity to network with friends, to take the temperature of our industry, and to talk about the future. Thank you for getting the extended family together in this very special way.

And it's always a pleasure to be back in Texas – one of the cradles of the oil and gas industry. Since the first gusher at Spindletop – not 100 miles from here – Texas and oil have gone together like brisket and barbeque! I vividly remember first coming to Texas A&M as a student in the 1970s, and I have felt at home in the Lone Star State ever since. For the industry, that was a special time when it seemed like the sky was the limit. So it's great to be with you during another period of expansion and prosperity.

Indeed, the oil and gas industry across North America is flourishing, and helping to drive national and regional economies, thanks to many of the enterprising companies and individuals in this room. You challenged pre-conceptions with your entrepreneurial spirit, and the 'can do attitude' which has always characterized this great nation. Once again, you've set the pace for the rest of us in the global petroleum industry.

Of course, these exhilarating developments are just the latest chapter in a storied history that has seen our industry fuel growth; power industrialization; develop nations; and make a very significant contribution to humanity. Since the one constant in our industry is change, I'd like to begin by describing four sweeping new realities behind a paradigm shift that is reshaping the energy world as I speak.

First, growth in global energy demand – and oil demand in particular – has moderated.

Before the financial crisis of 2008, global energy and oil demand were anticipated to grow rapidly – and, some argued, unsustainably. Now, forecast growth has moderated, not only as a result of economic stagnation but also through welcome and increasing gains in energy efficiency. Changing demographics and lifestyles, environmental pressures, and energy policies have played a role too.

So, while we believe long-term demand will be robust enough to provide us with the confidence to invest, it will not rise to the point where it creates market imbalances, and stretches the industry beyond its means. Indeed, sustained moderate growth in demand levels is very healthy for our industry.

Second, exaggerated concerns about scarcity and security of oil supplies have been dispelled.

Not long ago, the global media was replete with doomsday scenarios of 'Peak Oil' and the inevitable demise of the petroleum industry. Today, the narrative centers instead on the abundance of oil and natural

> The 'age of austerity' has seriously affected government support for renewables, while lower natural gas prices have aggravated the competitive position of alternatives in power generation.

gas resources, and the industry's unqualified success in being able to respond to unforeseen supply interruptions over the last couple of years.

It is a spectacular reversal and you helped engineer it! That said, although the size of the resource base is growing with the inclusion of unconventionals, these resources will be challenging to extract, requiring ever-advancing technology, enabling policies, a positive regulatory environment and, above all, a stable oil market and a resilient industry.

Third, the global financial crisis has forced policy makers around the world to re-examine priorities.

Because of global economic and fiscal constraints, the world simply cannot afford to squander its limited financial resources. Furthermore, there is a growing realization that there are tough choices to be made, and that energy regulations and policies can negatively affect national economies and hinder competitiveness. Affordability matters not only to nations but to consumers as well. Although this reality has been accentuated by the sustained economic crisis, it is a reality that is here to stay.

Fourth, largely because of this economic re-balancing, we are seeing a re-evaluation of the role of renewables and of some environmental initiatives.

The 'age of austerity' has seriously affected government support for renewables, while lower natural gas prices have aggravated the competitive position of alternatives in power generation. In the short- to intermediate-terms, renewables face competitive hurdles warranting more realistic targets for their gradual deployment. But, as they become more affordable, I believe renewables will have an important role to play in the long-term, and we are committed to invest in their development.

In terms of the environment, austerity has reduced the appetite of governments to make massive investments, while the need to stay competitive argues against further constraining consumers and the private sector through environmental regulation and taxation. It is not that policy makers are dismissing environmental priorities – and neither are we. But a better balance between environmental and economic objectives is not only rational but also necessary if we are to provide the world with the essential and affordable energy it needs.

Ladies and Gentlemen, in just a few years, these four realities have profoundly altered the world energy landscape, which is inducing a more pragmatic debate about global energy policies and regulations. For us, it is now more certain that our industry will continue to play the major role in fueling the transport, power, and chemicals sectors for many decades to come, and importantly providing a sustained environment of growth and investment for our individual companies.

However, amid all of this excitement, let me sound a note of prudent caution. This healthy picture I just described should not make us complacent. So ladies and gentlemen, although we are on the right track, if our history teaches us anything, it is that such rosy forecasts do not always become reality. And as the old cowboy philosopher Will Rogers once said, 'Even if you're on the right track, you'll get run over if you just sit there.'

So, my friends, let's just make sure that we are – collectively and individually – robust enough to withstand the shocks and black swans that we know are inevitably out there. Now is the time to think about preparing ourselves for their certain arrival.

I was actually pondering this at the World Economic Forum in Davos earlier this year, when I heard that their theme was "resilient dynamism" – the very DNA of our industry. And as we've all read in Dan's indispensable books, The Prize and The Quest, our industry's story is indeed one of resilience against multiple shockwaves thanks to dynamic individuals and companies, but regrettably with some casualties along the way and hard-learned lessons to stiffen the spines of the survivors.

So I believe that if we are to position our industry for the future we surely need to build greater resilience. I'll talk briefly about five features which I believe are central to achieving this objective.

Perhaps the first thing to recognize is that market stability will make us more resilient.

Market stability is not only essential for economic recovery today but is also necessary for sustaining long-term global growth and prosperity and for the global economy – as well as the good of our own industry. Last year, Saudi Aramco responded at great expense to natural disasters, geopolitical shocks, and fluctuations in our customer demand. In fact, we saw fluctuations of demand of over 1 million barrels in the last year.

Once again, we helped maintain oil market stability and played a pivotal role in protecting the world's economic health. Of course, no single player can shoulder the burden, as ensuring stability is a collective responsibility.

Second, we need to heed the lessons of the past and better manage our risks.

Indeed, despite our efforts to bring stability, we should all anticipate volatility and build prudent conservatism into our financial strategies. In very recent memory, we saw prices swing between $35 and $150 a barrel within a period of a few months. And on the other hand, as we know from painful experience, what happens to one company affects us all. It could be an industrial accident, a crisis of trust in corporations, or a security breach. As I know from last year's malicious cyber-attack on Saudi Aramco, there are a lot of bad guys lurking out there!

We therefore must fortify our defenses – both physical and virtual – to protect ourselves and the stakeholders who are so dependent on us. At a more fundamental level, if our commitment to managing risk is unwavering and we weave strong values into our corporate cultures, then our long-term chances of success are exponentially greater.

Furthermore, prudent diversification of our business portfolios makes our companies more robust and resilient over the long-term, no matter how attractive one business sector may appear in the short- to intermediate-term. Although it goes against the prevailing currents today, Saudi Aramco is doing just that; investing massively in expanding our downstream portfolio, growing petrochemicals, pursuing unconventional gas, and assessing solar.

Third, we need to take a broader view of the industry we work in and be more closely connected to societal expectations.

In particular, safety and protecting the environment have never been more important to society, and hence to us. Yet there are safety and environmental issues – real and imagined – which could derail our entire industry. Ladies and gentlemen, let us take ownership of the environment and accept that it is our responsibility by embracing absolute excellence in our operations, jointly undertaking R&D efforts, and sharing our safety- and environmental-related technologies and best practices. This will better position us to serve the collective good while also safeguarding our people, our communities, and the natural world.

Fourth, we will significantly bolster our resilience if we continue to create truly transformative, game-changing technologies.

Our business is already technology intensive, but we must aim even higher. In other words, we have to devote even more resources to R&D and technology creation directly within our companies. For example, could our investments in R&D at least be doubled?

"Market stability is not only essential for economic recovery today but is also necessary for sustaining long-term global growth and prosperity and for the global economy – as well as the good of our own industry."

Could we aim for 70 percent recovery of conventional resources? And could we look to double or even triple recovery from unconventional resources? As a result, we would almost quadruple the reserves of global liquids from our combined conventional and unconventional resources.

On the consumption side, should we aim to convert crude oil directly into chemicals bypassing the refining process? Why not team-up with the auto industry to quadruple fuel efficiency and capture the carbon along the way? Should we then convert that carbon into valuable products rather than venting it into the atmosphere? These are certainly bold targets, but I know we can meet them if we widen the circle and bring our collective strength to bear.

Finally, we need to attract and harness the right talent.

All too often our industry is portrayed as low-tech, out of date, and part of the problem rather than being part of the solution; indeed many young people see us as a 'sunset industry'. This is deeply concerning, as well as highly misleading. We need to spark the imagination of young people, and show them the abundant high-tech, complex, and exciting opportunities our industry has to offer, as well as better articulate the societal contributions we constantly make. And we should never stop investing in people no matter where we are in the business cycle. In fact, this is a key part of improving our industry's image more broadly.

Ladies and Gentlemen, at Saudi Aramco, as we transform ourselves, we are embedding these five features, which will ensure our continued resilience, and contribute to the resilience of our industry.

My friends, we have rarely talked about resilience as an industry, particularly when times are good. So, this time around, as we gather here at CERA Week, let us dare to be different.

Even as our industry enjoys a renaissance, enabled by the convergence of the four new realities I described, we must inspire the world's best and brightest to join hands with us; aspire to develop the game-changing technologies of the future; better manage our risks and make prudence an integral part of our financial strategies; while ensuring market stability and demonstrating how much we care for our people, our communities and the natural world.

If we can do this, then I firmly believe we will achieve the desired resilience and propel the global economy, prolong our cycles of prosperity, and position this incredible industry of ours to safely and reliably provide the world with the essential energy it needs, far into the future.

That future, ladies and gentlemen, is in our hands."

Exploration Shares Knowledge with KAU

Members of the King Abdulaziz University delegation pose with visit organizers Shukri Al-Khunaifer and Sultan Al-Buqaimi.

DHAHRAN, 13 March 2013

Exploration recently played host to an academic delegation from the Earth Sciences Faculty at King Abdulaziz University (KAU).

Headed by Dr. Mohammed Basyuni of KAU, the visiting group spent a week touring Saudi Aramco facilities and took part in fieldwork activities. Among the delegation were seven faculty members and 24 students.

The purpose of the visit was to cultivate students' understanding of earth sciences on the practical level.

The five-day program began with a welcoming speech by Exploration general manager Misfir AzZahrani, followed by presentations by KAU students.

They were then taken to see the advanced software used in the acquisition and processing of geophysical data.

Next up was a visit to the 'Uthmaniyah seismic crew, where the group was shown how to conduct a seismic test and gather information to study the geology of a certain area.

The group was also given the chance to visit the Halliburton Facility and Saudi Aramco Well Samples and Core Lab where they were shown how to describe and study cuttings and cores, gaining hands-on experience and a better understanding of the subsurface.

They also visited the Upstream Professional Development Center to learn more about technical development programs provided to Upstream professional employees.

At the end of the tour, the delegation expressed their appreciation for the company's commitment to support earth science academic programs and Saudi Aramco's outreach with universities.

Engineers and Inventions Shine at MEOS

BAHRAIN, 3 April 2013

"Transforming the Energy Future" was the theme of the Middle East Oil and Gas Show (MEOS) held March 10-13 in Manama, Bahrain. In his speech at the popular event, Amin H. Nasser, Saudi Aramco senior vice president of Upstream, said MEOS had matured into an event "that industry players always put on their calendars."

MEOS 2013 opened with a speech by Abdulaziz Al-AbdulKarim, conference chairman and Saudi Aramco executive director of Information Technology.

Al-AbdulKarim highlighted the distinctive role of the conference in supporting the oil and gas industry through its introduction of the latest technologies in oil exploration and drilling, as well as the training of qualified nationals to handle industry related jobs, especially in petroleum engineering, drilling and producing, as well as other technical and administrative positions.

Al-AbdulKarim also stressed that MEOS represents a great opportunity for oil and gas field professionals to learn the latest technological solutions in increasing oil reservoir recovery.

Nasser noted that technology has already transformed the energy business, with more changes expected in the near future.

"Many view us as a 'sunset industry.' I strongly disagree," he said. "In fact, I would stress that… we are not even at mid-day… I would even advocate that we have the power of time travel by renewing, reinventing and rediscovering ourselves in meeting tomorrow's energy challenges.

"A few years ago, 'Peak Oil' theorists were abundant, professing increasing unsustainable demand," Nasser said. "However, the industry's ingenuity, through technology and exploration advancements – notably with tight oil and shale gas in the United States – have made oil abundant and natural gas even more so.

> “Nasser also noted that Saudi Aramco is committed to investing in research and plans on doubling or even tripling its manpower in science technology around the world.”

The picture of 2020 or even 2030 is much different now.”

“Much of the Kingdom of Saudi Arabia remains unexplored or under-explored for oil and gas,” Nasser added. “We have very recently expanded our exploration operations in the Red Sea.

“In the past few years, we have completed a series of seismic surveys and are now drilling our first deep-water prospects.”

Highlighting his words, Saudi Aramco showcased at its MEOS 18 pavilion a new technology invented by Constantinos Tsingas, a geophysical consultant in EXPEC Advanced Research Center (ARC).

The new technology, represented by a device called SpiceRack, features a low cost, highly effective and totally automated tool that can be used in shallow waters. The self-propelled device applies a subsea technology that can be used to acquire and retrieve seismic data. Each device consists of four parts that helps it spread over a large area, complete the subsea survey and return again to the seismic survey boat.

According to Tsingas, EXPEC ARC is planning, in association with CGG, to develop and test the device to offer more features such as low-cost sea operations (first phase at 300m deep), simple design and the ability to work in areas where traditional seismic surveying isn’t an option, especially near subsea pipelines and offshore platforms and drilling rigs.

Nasser also noted that Saudi Aramco is committed to investing in research and plans on doubling or even tripling its manpower in science technology around the world. “To complement our capable and expanding Research and Development Center at our headquarters in Dhahran, we are opening global research centers in North America, Europe and East Asia, all to be operational by this year. Some are already operational,” he said.

Saeed Al-Mubarak, an intelligent-field team leader, participated in one of the conference technical sessions and highlighted the rapid movement and development in intelligent-field technologies and their ability to meet operators’ needs around the world.

Al-Mubarak also pointed out the leading strategies

> "Al-Othman asserted that the Arabian Gulf region is stable and unlikely to witness financial crises, adding that investment opportunities are available in petroleum projects."

adopted by Saudi Aramco to maintain its position as a global leader in this field and to achieve the highest return on investment in a manner consistent with the company's values and objectives.

Emphasizing the importance of developing young professionals, Al-Mubarak concluded his remarks by saying that intelligent-field management requires competence and skill to ensure sustainable growth as well as leaders who aspire to achieve constant technological and administrative development.

Perhaps the most distinctive event of MEOS 18 was the panel discussion on financing petroleum projects that took place on the side of the conference on March 12, with about 200 participants from oil, gas and banking sectors attending.

HE Abdulatif A. Al-Othman, governor and chairman of the Saudi Arabian General Investment Authority, was the panel keynote speaker. The event was also attended by Sheikh Ahmad M. Al-Khalifah, banking presidents, executives and investment decision makers and high-ranking officials from the oil sector.

Al-Othman asserted that the Arabian Gulf region is stable and unlikely to witness financial crises, adding that investment opportunities are available in petroleum projects. He also urged companies to endeavor to develop fields, services and investments, citing Saudi Aramco's continuous efforts to develop its oil and gas technologies as an example to be followed in the Gulf region.

"I wanted to seize this opportunity in the presence of energy decision makers, businessmen and officials, to send an important message that the oil and gas industry is the most vital sector and main driver of the region's economy," Al-Othman said.

"And despite all the great achievements and initiatives that we take pride in, the region is still in an urgent need to adopt new policies for manufacturing industries, to increase local levels of job creation and to transfer advanced and modern technologies to this important sector."

Following the inauguration of Saudi Aramco's Pavilion and reception of VIPs, Ali H. Habtar, who heads the Hawiyah Gas Reservoir Management Unit, briefed HH

Sheikh Ali ibn Khalifah Al Khalifah on the Khurais field and its energy production technology.

Habtar provided an overview of Khurais field, which is considered the largest field to be completed with an initial production capacity of 1.2 million barrels per day. Habtar also explained intelligent wells, a Saudi Aramco innovation that capitalizes on nano sensors.

He described these sensors, saying: "If we gather a thousand pieces of these sensors, they would be the size of a single human hair. Can you imagine that? And, Saudi Aramco has already obtained a patent for them. These sensors are pumped into the well to come out later with the oil produced from an adjacent well. Yet before coming out, the sensors record all well characteristics, which will be analyzed after their extraction to develop the well and turn it from an ordinary well into an intelligent one."

Khaled Al-Buraik, Saudi Aramco vice president of Petroleum Engineering and Development, emphasized the importance of MEOS to Saudi Aramco, saying it was an opportunity to exchange expertise and knowledge, as well as being a good chance for Aramco engineers and scientists to share their scientific research and studies.

Abeer M. Al-Olayyan, an EXPEC ARC petroleum researcher who joined Saudi Aramco in 2011 after a 12 year career as a professor and researcher of analytical chemistry at Dammam University, has been studying water ions to find out which concentration increases oil recovery when injecting water into reservoirs. This helps in maintaining ideal oil flow.

"It is known that Saudi Aramco oil reservoirs have natural water mechanisms that are supported by water injection programs since the mid-1950s," said Al-Olayyan. "The growth witnessed by the water injection system over the past decades has led to a noticeable development in injection water infrastructure that is considered the largest of its type in the world."

"Currently, the main source of water is the sea. EXPEC ARC has developed the Smart Water Injection Program, which helps increase oil recovery via the improvement of water characteristics such as salinity, ionic composition, surface resistance, viscosity and so on," he added.

"This technology targets hydrocarbon reservoirs that show an increase of 9 percent in oil recovery after the injection of conventional seawater. This advanced technology is going through more field tests to improve the current process and provide the main standards for designing the whole project."

MEOS 18 attracted nearly 7,100 oil and gas officials, professionals and enthusiasts, and about 300 companies from 30 countries. It showcased 36 technical sessions, five discussion panels, and for the first time ever, MEOS featured a special session on petroleum project financing.

Al-Falih Points Toward Path for Success

BEIJING, 3 April 2013

Amid a period of sustained growth that is expected to increase exponentially in the coming decades, there is no doubt that China will require, more than ever, access to enormous supplies of reliable and affordable energy if they are to power the "great renaissance of the Chinese nation" called for by the country's new President Xi Jinping.

However, when it comes to economic development, the environmental acceptability of energy is as important as its availability and affordability in enabling the Chinese people to live the "China dream" also promised by President Xi.

It is this challenging, but vital, balancing act that Khalid A. Al-Falih, president and CEO of Saudi Aramco, addressed at the China Development Forum held March 25 in Beijing.

"Balancing a robust, multi-fuel energy mix with due emphasis on ecology is no easy task," Al-Falih said addressing an audience of China's top decision makers and economists at an annual forum that brings together global business and academic leaders to interact with the country's leadership and economic planners.

This year's event – which attracted more than 1,000 distinguished participants from China's government and its business sector, as well as the new Vice Premier Zhang Gaoli – featured the theme "China in Transition."

While admitting the difficulty of the task, Al-Falih provided a possible road map with four specific markers for success.

• To meet the country's huge energy requirements, an appropriately balanced energy mix is essential, and oil will remain a central component of the mix in the

> "To meet the country's huge energy requirements, an appropriately balanced energy mix is essential, and oil will remain a central component of the mix in the foreseeable future, particularly in transportation and petrochemical feedstock."

foreseeable future, particularly in transportation and petrochemical feedstock.

• Efficiency enhancement is one of the best strategies that will help the environment without sacrificing economic objectives. Al-Falih said that since much of China's energy infrastructure is yet to be built, it should be designed to be efficient and clean. As for current transportation and infrastructure, he added, it should be upgraded to reduce emissions and conserve energy resources to enhance efficiency.

• Carbon management is crucial. Al-Falih applauded China's efforts to curb carbon emissions, adding that developing a greater role for gas in electricity generation could aid these efforts.

• In particular, Al-Falih noted technology's role as the ultimate enabler. He noted that with an "all of the above" energy strategy that rests on a foundation of hydrocarbons, the focus should be on research and development and technology that cleans these fuels and reduces their environmental footprint. Al-Falih pointed to examples such as minimizing flaring and converting CO_2 into useful products.

"Our people expect higher living standards and a cleaner environment – both at the global and local levels. This is the challenge faced by China as it moves to the next stage of modern industrial development," Al-Falih said.

"But China's pragmatic approach to its energy portfolio shows that economic development and ecological stewardship are not mutually exclusive.

"We commend China's desire to achieve both, and we are ready to play our part," he concluded.

Balance the Key to Future Growth in China

BEIJING, 3 April 2013 – On the heels of his speech at the China Development Forum, Khalid A. Al-Falih, president and CEO of Saudi Aramco, emphasized the need for resilience in a dynamic energy market while speaking at the CEO Plenary Session of the 6th International Petroleum Technology Conference (IPTC), also held in Beijing on March 26.

More than 3,500 delegates from 65 countries attended this year's event, held for the first time in China.

During the event, Saudi Aramco representatives presented more than 40 papers and participated in two panel discussions.

Al-Falih kicked off the discussion by emphasizing that China's steady growth in petroleum demand has offset plateauing or declining demand in the OECD countries.

"It (China) does provide our industry with the level of confidence required for continued large-scale and long-term investments," Al-Falih said.

He then reiterated four key factors he shared recently at the CERA Week conference in Houston that have profoundly altered the world of petroleum.

• Growth in global demand for oil has moderated.

• Due in large part to technological advances, the specter of resource scarcity has been banished.

• Policy makers have recognized that competitiveness of entire countries as well as companies must be maintained.

• There has been a re-examination of the role renewables will play in the future, given their current low level of contributions and the considerable technical, economic and environmental hurdles and consumer acceptance hurdles they face.

"In this new energy landscape, the central importance of oil and gas in the global energy mix has been reconfirmed and reinforced," Al-Falih said. "Petroleum will remain the lifeblood of transport, trade and manufacturing, and the essential enabler of growth in both the developed and developing worlds for many decades to come.

“The prospects for our industry are therefore bright, and as I have said elsewhere, we in the oil and gas industry are enjoying a renaissance,” he added.

However, Al-Falih warned that the industry must take proactive actions to examine both upside and downside scenarios for the business “in the interest of greater resilience.” To prepare for volatility in the future, Al-Falih said, the industry must focus on several key elements.

The first factor is to create advanced and emerging technology, particularly in exploration and production. Al-Falih provided examples such as Saudi Aramco’s Smart Water and nanoparticles to increase recovery rates from its hydrocarbon reservoirs, the advent of “intelligent fields,” advances in drilling and downhole technologies and even deep offshore exploration and drilling as examples of how emerging technologies and new tools and techniques have positively impacted the company’s business.

The second key for building resilience is properly developing and managing talent. “Because in the end, for all of the high tech tools we use, the petroleum business is still all about the dedicated men and women who work in oil and gas, and the innovative solutions they develop and deploy,” he said.

The third aspect of becoming stronger and more resilient is enhancing safety and environmental performance by embracing operational excellence. “I personally believe that a renewed commitment to operational excellence and a values-driven approach to every aspect of our work, especially the value of safety, is not only essential to protecting our people and the natural world, but also – at the end of the day – it makes sound business sense,” Al-Falih said.

The fourth aspect is the prudent diversification of business portfolios along the petroleum value chain. Al-Falih elaborated that there is a need to take the holistic view of the petroleum value chain and to better understand the complex web of interdependencies that governs the business.

“While we will need to find and produce more petroleum in the years and decades to come, we also need to ensure that demand for that energy will be there and that we can get crude oil, refined products and natural gas where they are needed in a timely, economical, safe and reliable manner. So, rather than focus solely on the upstream push, I think the industry must also bring the downstream pull back into the equation when it comes to the discussion of our industry’s future,” Al-Falih added.

Al-Falih declared that in the years to come, Saudi Aramco will become the world’s single largest refiner and a top tier chemicals company, as it integrates chemicals production with refining assets both in the Kingdom and abroad.

“Our industry is indeed in the midst of a renaissance. We therefore have an obligation to make the most of the paradigm shift we’re witnessing and of the current ‘golden era’ for petroleum it has produced, by building even greater resilience for the future,” he concluded.

Afterward, Al-Falih fielded several questions from the audience.

When asked about how to best develop and nurture the petroleum industry’s highly needed skilled professionals, Al-Falih provided several strategies, including engaging young students from the early stages of their learning, tapping into the technical expertise of the recently retired industry professionals and instituting highly specialized training centers similar to the Upstream Professional Development Center (UPDC), which exists to meet these challenges and to bridge the experience gaps between retired professional and a large influx of younger professionals.

He pointed to Saudi Aramco’s practice of sending promising high school graduates to top-tier universities around the world to study various fields of engineering.

iDiscover Arrives in Jiddah

Jiddah, 17 April 2013

Under the patronage of HRH Prince Mishaal Ibn Majed Ibn Abdulaziz, governor of Jiddah, Saudi Aramco recently concluded its iDiscover program with an event at al-Nahkheel Hall at the Ar-Rehab Complex in the city.

Saudi Aramco launched the event in collaboration with the Ministry of Education, in the presence of Saudi Aramco Affairs manager in the Western Province, Samir A. Nasruddin; Jiddah traffic manager, Gen. Mohammed Hassan Al-Qahtani; assistant general manager of Education for Educational Affairs in Jiddah, Ahmad ibn Ali Al Zahrani, and a number of officials and managers of government agencies.

Fuad Al-Therman, director of the King Abdulaziz Center for World Culture, who delivered the closing speech of the program, emphasized the importance of iDiscover in Saudi Aramco's initiative to educate and train young Saudis.

In its first phase, the program will introduce an integrated series of 20 educational forums in five cities across the Kingdom.

"The success of this experience gives us more faith in the potential of this generation and encourages us to continue to create learning environments that elevate young minds, bringing them to the paths of science and knowledge."

Al-Therman added that the iDiscover session in Jiddah was rich and inspiring. "The experience made us discover that our homeland has a lot of mature and ambitious minds waiting for the right environment to innovate and discover," he said.

"The success of this experience gives us more faith in the potential of this generation and encourages us to continue to create learning environments that elevate young minds, bringing them to the paths of science and knowledge."

Al Zahrani then spoke about the importance of joint cooperation between Saudi Aramco and the Ministry of Education and the necessity for such partnerships that activate such valuable initiatives and have significant impact on transforming Saudi society into a knowledge-based society.

Meanwhile, Nasruddin also emphasized the importance of the strategic partnership between Saudi Aramco and the Ministry of Education, noting that it achieved its objectives of inspiring students to love science and math and to keep up with the developments of modern teaching aids.

While iDiscover attracted much attention when it was kicked off in Hayil, the efforts at its second stop in Jiddah were equally impressive.

Two hundred teachers in science and mathematics were trained in the first five days by Saudi professors who successfully completed intensive training courses in the United States on bringing students closer to the principles of science and making them accessible to them.

The program went on to further address this point in its second week by training 400 middle school students in Jiddah on iDiscover science and iDiscover mathematics.

Students who took the course expressed satisfaction with the program, noting how they benefited from its scientific content as well as enrichment programs that helped develop participants' character and discover various talents in the fine arts.

Assistant Director-General for Education for Girls in Jiddah, Nursaid Baqader, thanked Saudi Aramco for its unique scientific initiative and its partnership with the

> Students who took the course expressed satisfaction with the program, noting how they benefited from its scientific content as well as enrichment programs that helped develop participants' character and discover various talents in the fine arts.

Ministry of Education in the implementation of the program. "This program represents a unique experience for (female) teachers and students, as it presented to them an active enriching atmosphere, where everyone – including teachers, trainers and students – interacted with one another. It made us declare our wish to continue such experiments and projects that serve our girls and educators, giving them a wider scientific horizon."

Director of the Talented Students, Muzna Abdulrahman Al-Ghanim, expressed her happiness with the program, saying: "It is necessary to give adequate support to these young students, particularly the targeted students."

Girls' program supervisor Amnah Al-Fudhla noted that the students proved that they are competent and adequately qualified to participate in the program.

She said, "What really pleased me is that the mothers of the students were greatly excited about the program, which makes us really proud."

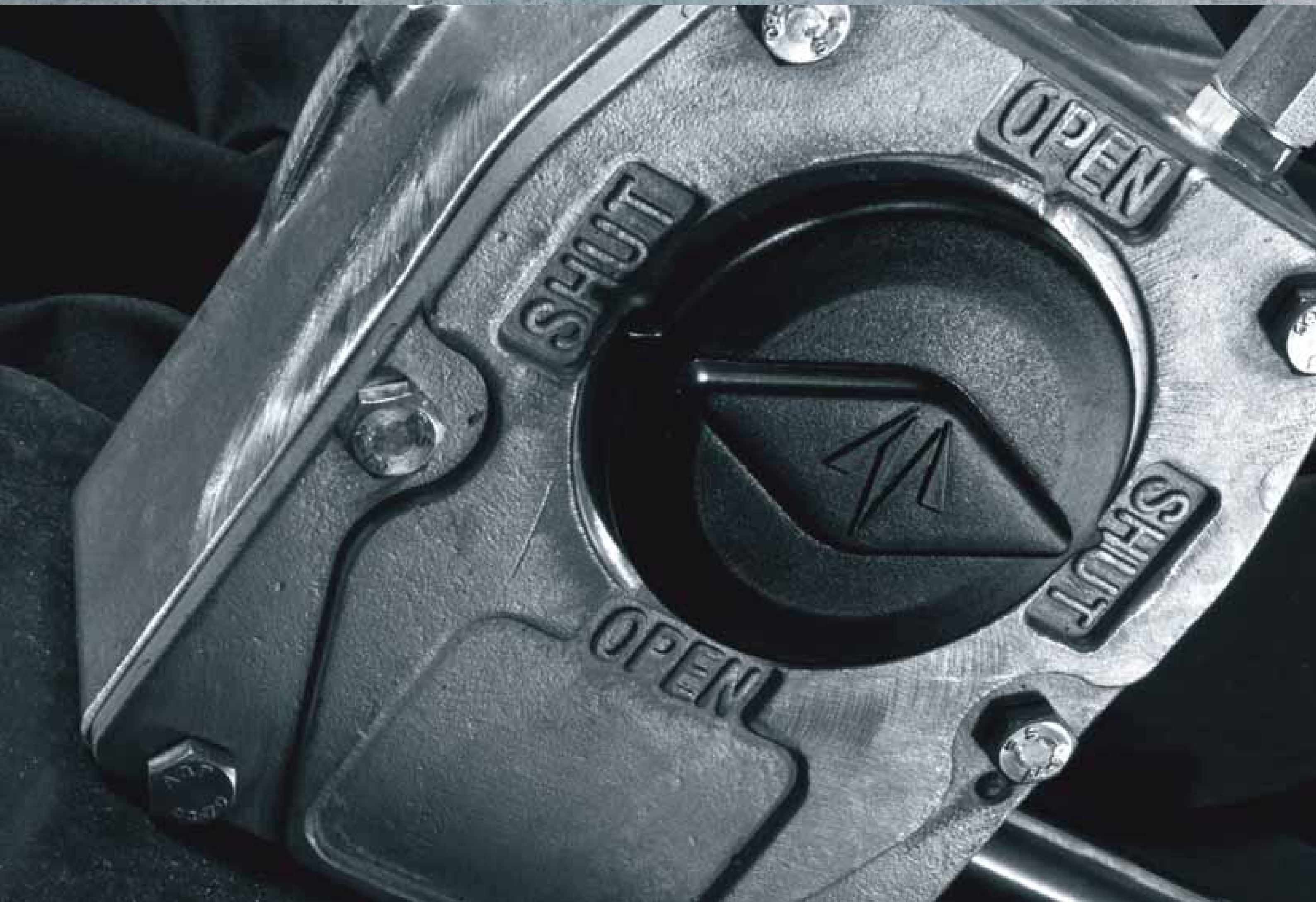
Hanen Fahd Balubaid said of her experience in the Mathematics and future leader course, "I had a very nice time in the program. I got to know myself more, and I discovered what I want in the future."

The program began its third tour on March 30 in Yanbu', where the program's instructors once again trained 200 teachers in science and mathematics, and on the fifth day, 400 middle school students were scheduled to be enriched according to the methodology of the program.

The program will continue with visits to Jazan and al-Hasa.

MASTERGEAR UK

The **Stainless Steel** Gearbox Range.



Built to withstand the World's most **extreme environments.**

www.mastergearworldwide.com

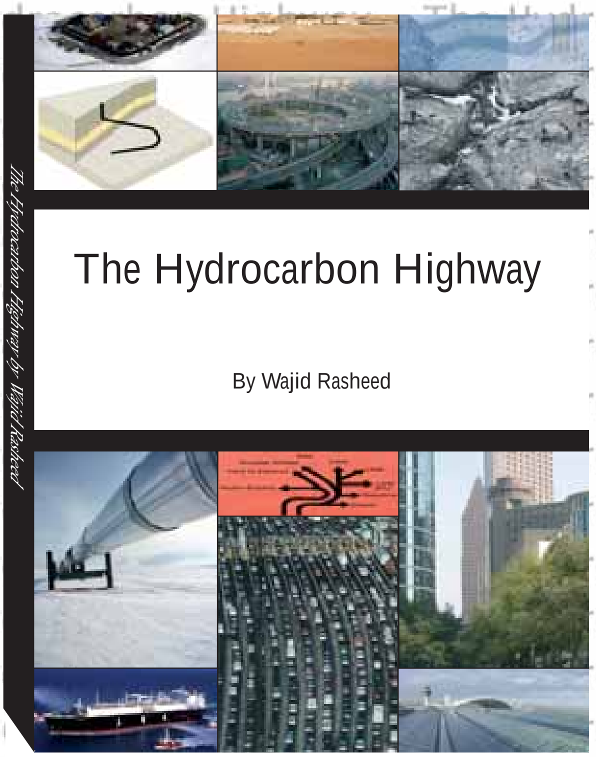
EPRASHEED
signature series

Purchase Now

The Hydrocarbon Highway

"I found the book excellent because it provides a balanced and realistic view of the oil industry and oil as an important source of energy for the world"

Dr AbdulAziz Al Majed, Chairman, Department of Petroleum Engineering, King Fahd University of Petroleum & Minerals.



Please send me ☐ copies of The Hydrocarbon Highway

Name: ....

Title: ....

Company: ....

Mailing Address ....

....

....

Phone: Fax: ....

Please debit my credit card:

Visa/Mastercard Number ....

Name on Card .... Expiry ....

☐ I enclose a cheque or banker's order in US Dollars, payable to EPRasheed Ltd

Charges Per Book:
The Hydrocarbon Highway: $39.95
Standard Delivery: $10.00 ☐ Express Delivery $30.00 ☐

Signature ....

Mail all Orders to:

11 Murray St, Camden, NW1 3RE, London, England

Integrated Water Management and Reservoir Surveillance Strategies Employed in a Carbonate Field in Saudi Arabia: Review and Results

By Mohammed A. Alghazal, Razally M. Ali and Dr. Ahmed H. Alhuthali.

Reprinted with kind permission from Saudi Aramco Journal of Technology.

Abstract

Excessive water production and unbalanced sweep in a waterflooded reservoir can significantly impact oil production and increase water handling expenses, jeopardizing the overall economic recovery of hydrocarbons within the field. The objective of this article is to provide a review of various integrated water management techniques successfully implemented in a carbonate field in Saudi Arabia under the critical monitoring eye of a systematic strategic surveillance program deployed to assess sweep efficiency across the field.

This carbonate reservoir is characterized by complex networks of super-permeable streaks and subvertical fractures highly influencing fluid transport media within the subsurface. Understanding the fluid flow mechanism in this heterogeneous, gravity dominated reservoir is a predominant factor influencing the various approaches designed to manage water production in the field. The key management strategies that have been introduced are horizontal sidetracking of existing vertical wells at the top of the reservoir, rigless water shut-off (WSO) jobs and employing a cyclic production mode for wells with very high water cut. In addition, inflow control device (ICD) completion technology is being deployed within lateral sections that have encountered flow dominating geological features, such as fractures or super-K, providing a practical, innovative solution for an effective homogenized flow distribution along the lateral intervals. Collectively, these employed practices have been found successful in substantially reducing water production and enhancing oil recovery as supported by field data.

Concurrent with these implemented strategies in the field, sweep conformance and flood front movement are regularly monitored by conducting a rigorous Strategic Surveillance Master (SSM) plan across the whole field. The results from saturation and production profile logs confirm efficient vertical and areal sweep conformance and ensure the effectiveness of the integrated water management strategies employed in the field.

Introduction

Water management in waterflooded reservoirs is important to prevent excessive water production, which could impact the overall recovery of oil in the field. The

Fig. 1. Core samples from Well-A showing indications of super K and fractures.

fluid flow process is an essential aspect in the design of effective integrated water management strategies. Data captured by a Strategic Surveillance Master (SSM) plan assesses this process, ensuring optimum sweep conformance and oil recovery.

The first section of this article gives an overview of the giant carbonate field targeted for water management and describes the different geological and fluid mechanism characteristics influencing the recovery process. The following sections review the various water management practices implemented in the field to enhance oil production and improve recovery. Finally, this article highlights the surveillance approach used to monitor the sweep efficiency across the field.

Field Background

Oil production from this field is currently driven by peripheral seawater flooding, which was initiated earlier to improve oil recovery while maintaining reservoir pressure. During the last decade of production, water management initiatives were introduced in the field to control excessive surface water production and conserve the reservoir's energy, which resulted in achieving maintained and stable water cut levels. This achievement has come through careful monitoring of sweep efficiency and oil recovery in the reservoir, which will be shown and discussed later.

Reservoir Geology

This carbonate reservoir is structurally folded within an anticline trap overlaid by a continuous impermeable layer of anhydrite acting as an effective seal throughout the reservoir areal extent. This reservoir is heterogeneous in nature: each zone has distinctive reservoir characteristics that can be distinguished from other layers. For instance, the top zone contains mostly skeletal oolitic limestone texture characterized by scattered, distributed super-permeable stratform layers and vugs[1]. Figure 1 shows an indication of these features as seen from cores in one of the wells.

In addition, the subject reservoir is commonly known to be naturally fractured, adding an extra level of heterogeneity affecting the fluid flow process. The existence of these fractures can be traced and validated by combining different sources and data, such as reservoir core sections, image logs, transient test and loss of mud circulation during drilling of horizontal well sections[2]. Figures 2 and 3 show some fracture examples identified using some of these methods. The orientation, length and aperture of these fractures vary across the field. Generally, these fractures are oriented subvertically, trending toward the NE-SW direction, aligned with the regional maximum stress direction.

Reservoir Fluid Flow Mechanism

In a waterflooded reservoir, it is imperative to appreciate the different types of forces acting on the reservoir and to understand their effect on transporting the fluid – both at microscopic and macroscopic scales – so as to know which of these forces dominates and influences the fluid flow process. Capturing the fluid flow mechanics is important to make certain that the designed reservoir management strategies will serve their purpose in enhancing the sweep and maximizing the oil recovery in the field.

The most important factors[3] influencing the efficiency of waterflooded reservoirs are mobility ratio, gravity and

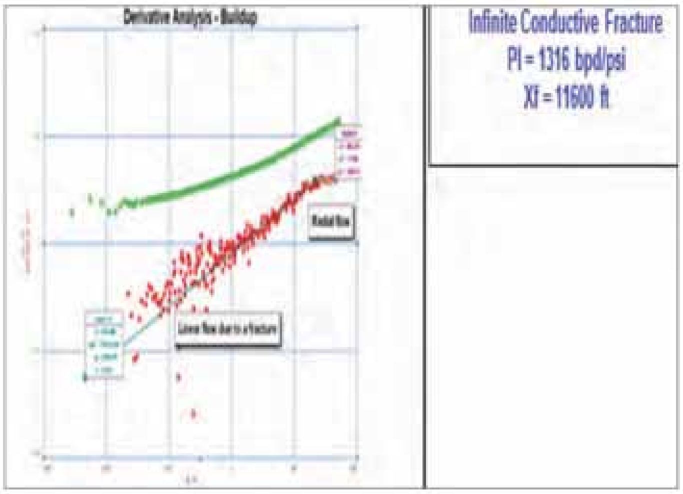


Fig. 2. Pressure transient analysis from a horizontal well intersecting a major fracture.

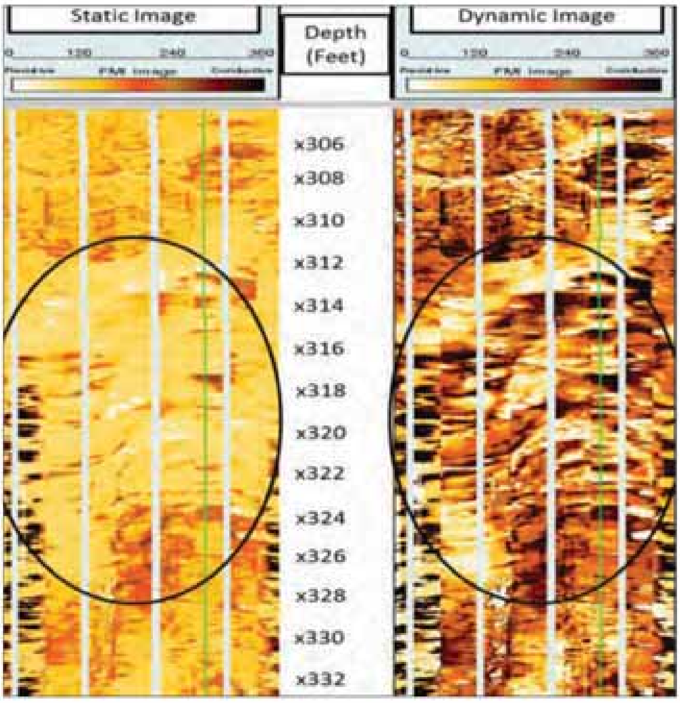


Fig. 3. Image log from a horizontal well intersecting fractures indicated by circles.

heterogeneity. Therefore, we will refer to these physical principles and how they relate to this particular reservoir.

Fluid's Mobility

The mobility of a fluid is defined as the ratio between the effective permeability for the fluid and its viscosity (k/μ). The mobility ratio, M, relates to the mobility of the displacing fluid, in this case water, to the displaced fluid, in this case oil. The physical meaning of the mobility ratio is significant as it represents the velocity at which each phase is flowing, which can be related to the type of displacement mechanism occurring during the flooding process[3]. Typical mobility values for both oil and water in this reservoir yield a mobility ratio of M~0.75. The fact that oil has a favorable low viscosity and that the mobility ratio is less than unity suggests that ideally the water phase will travel slower, pushing the oil phase forward and producing what is called a piston-like displacement in a core flood experiment[3]. This favorable mobility ratio is expected to yield a high

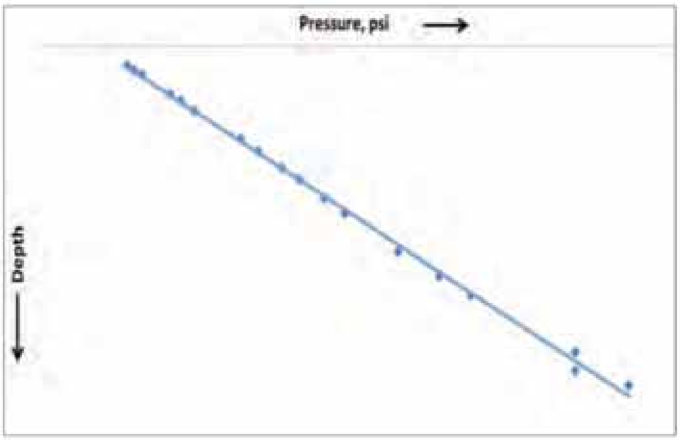


Fig. 4. MDT survey from one of the wells, showing excellent pressure communication across entire reservoir zones.

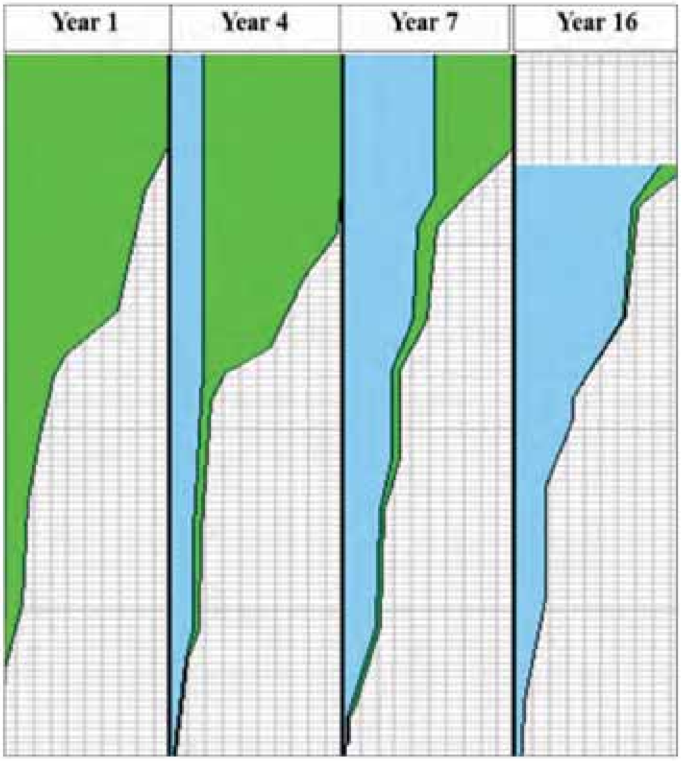


Fig. 5. Time-lapse flow meter profile from one of the wells, showing excellent bottom-up sweep

areal sweep efficiency – exceeding 70% – as reported in the literature for several values and correlations relating the mobility ratio to areal sweep efficiency for different flood patterns[4]. In fact, higher values of areal sweep efficiency were realized in this reservoir, as supported by data collected from the field by the SSM plan, which will be discussed later.

Gravity and Reservoir's Heterogeneity

At a larger reservoir scale, the effect of viscous forces becomes less significant and can be neglected in reservoirs showing higher production rates and maintained pressure[3]. In this case, other factors will have more influence on the flow process, in particular gravity and heterogeneity. Different elements, e.g., the degree of communication between layers, gravity drive and existence of fractures will need to be fully captured in terms of these two interrelated factors for an effective design of water management strategies within the field.

Gravity Drive Mechanism

The degree of communication between layers in this reservoir is excellent, exhibiting a vertical pressure equilibrium across the entire reservoir section, with

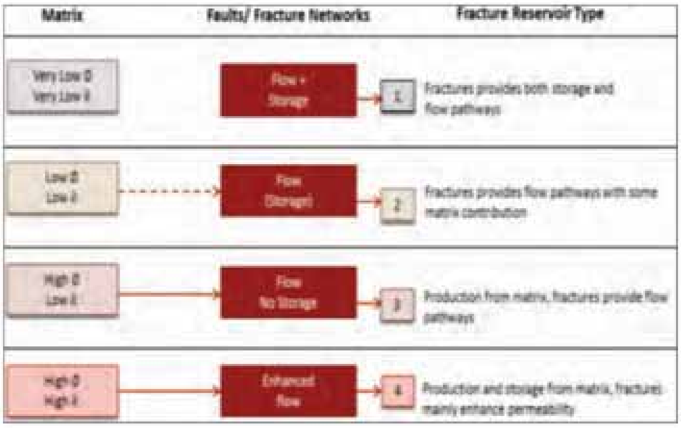


Fig. 6. Naturally fractured reservoir classifications[5].

Fig. 7. Normalized production performance plot for sidetrack wells in the field.

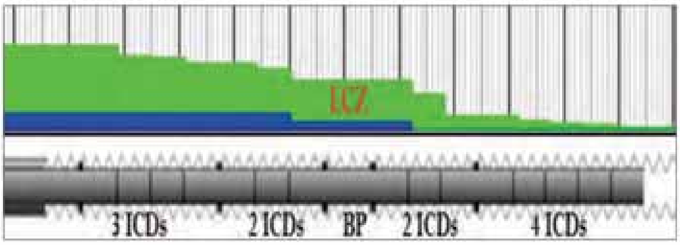


Fig. 8. A uniform flow profile achieved after deployment of ICDs for Well-A1.

a clear bottom-up sweep driven by gravity forces as observed from different collected and repeated formation pressure tests and flow meter surveys gathered across the field. Results shown in Figures 4 and 5 are given as examples. This is attributed to the good vertical permeability across different zones, where a ratio of (k_v/k_h) of more than 0.2 is typical in the reservoir, as observed from core data.

Heterogeneity and Fracture/Matrix Flow Mechanism

This heterogeneous reservoir is naturally composed of a complex network of fractures and a matrix system, a so-called dual porosity/dual permeability system. We can distinguished four different kinds of fractured reservoir in relation to storage and flow pathways, Fig. 6[5]. This reservoir is considered to be a mix between Type 3 and Type 4 reservoirs, in which both matrix and fractures play different roles transporting the fluid across different sections of the reservoir, depending upon the section's wettability and pore system. Some examples of poor water management strategies conducted in some fields have been documented in which fractures were allowed

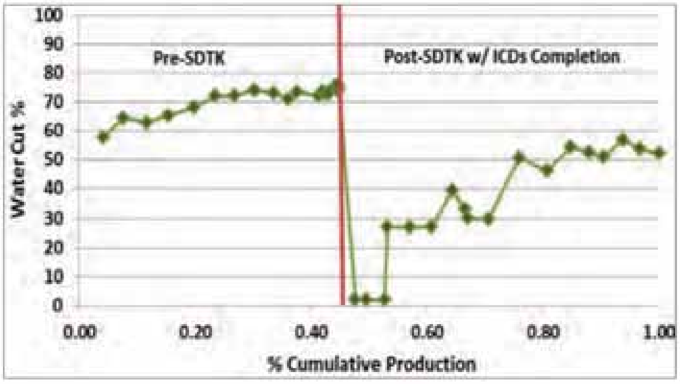


Fig. 9. Cumulative production plot vs. water cut for Well-A1.

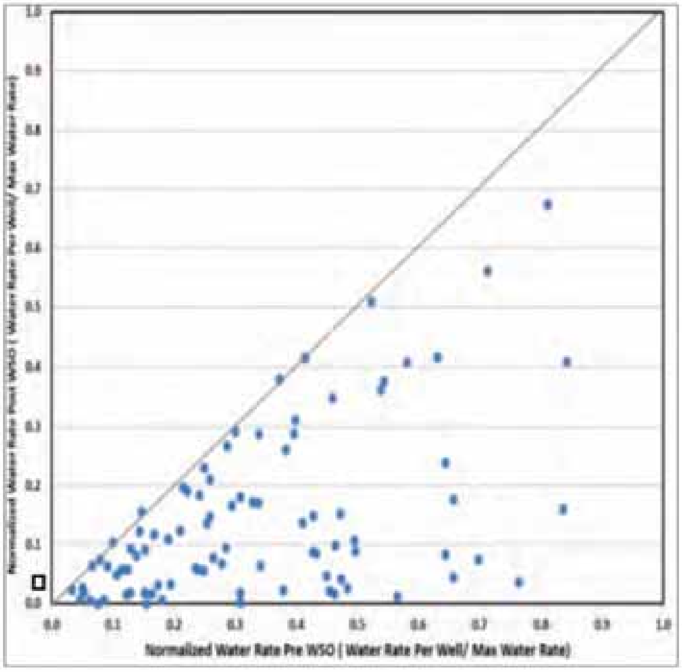


Fig. 10. Ratio of water rate before and after WSO jobs.

to excessively produce water, resulting in low ultimate recovery and emphasizing the importance of water management in fractured reservoirs[5]. Therefore, this type of flow is wisely appreciated within our designated reservoir management strategies implemented in the field. For example, fractures crossing the wet top oil section of the reservoir will act as conduits for water coming from lower watered out sections and will significantly reduce oil production. Therefore, this area must be managed properly, which will be discussed in later sections showing field initiative practices, by utilizing inflow control devices (ICDs) and blank pipes to manage fracture flow anomalies across horizontal laterals.

Water Management Strategies

The objective of the previous section was to highlight that a comprehensive understanding of fluid mechanics in any waterflooded reservoir is key for achieving an ultimate recovery following the successful application of designed and integrated water management and surveillance strategies.

This reservoir provides remarkable examples of successful reservoir management strategies, which will be discussed in further detail.

Horizontal Sidetracking

Horizontal drilling plans were initiated in the field to

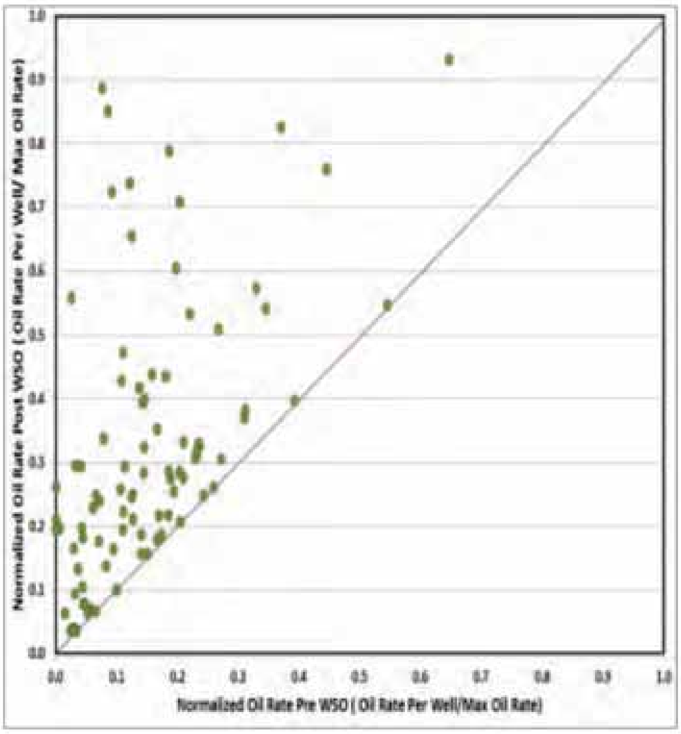


Fig. 11. Ratio of oil rate before and after WSO jobs.

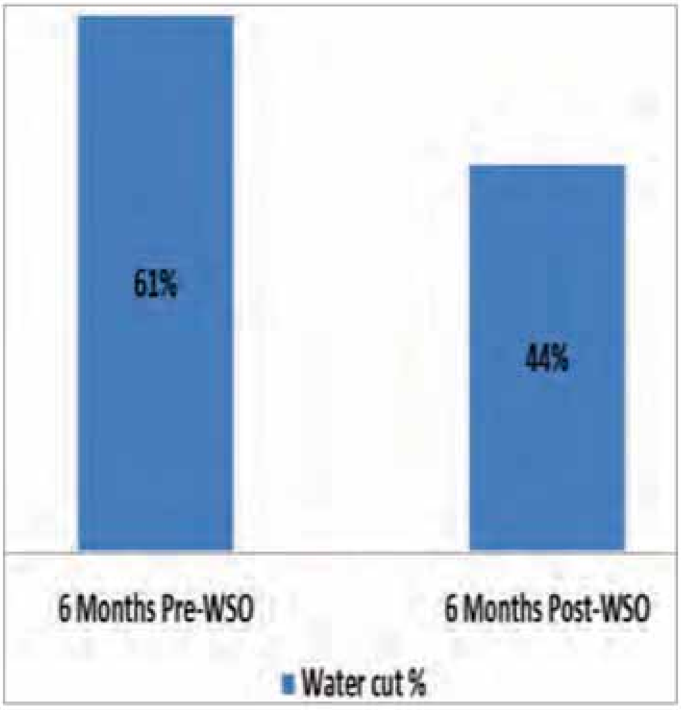


Fig. 12. Water cut before and after WSO jobs.

sidetrack existing dead or marginal vertical producers as horizontal laterals at the top 5 ft to 10 ft layer of the reservoir section. The main objective of this practice is to restore the productivity of those vertical wells that were mostly affected by water coning through efficiently enhancing the recovery of the remaining oil located at the top of the reservoir utilizing horizontal drilling technology[6].

Figure 7 shows a normalized cumulative production performance plot for 135 sidetracks performed in the field since 2000. This plot highlights the relative

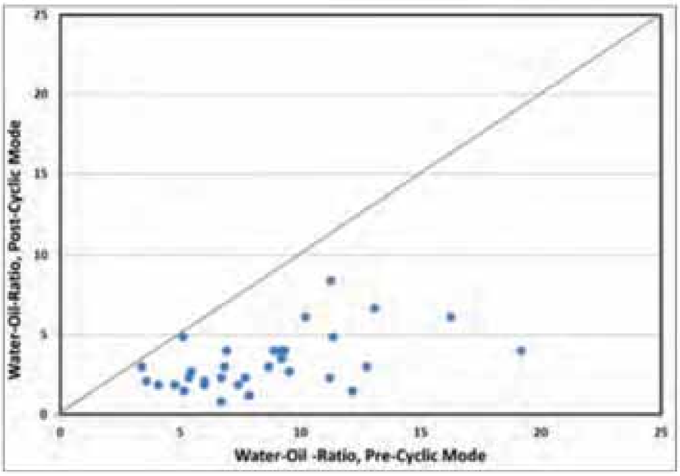


Fig. 13. Cyclic WOR performance before and after the shut-in periods.

cumulative oil production performance for all the wells – three years before and after the sidetrack – with the corresponding water cut per year. It can be clearly seen that these wells experienced a rapid decline in production rates before the sidetrack as a result of increasing water cut due to water coning. Comparing the production performance three years down the line following the sidetrack shows that oil production was restored and maintained for these wells with controlled and managed water production. This plot provides strong evidence of the continuous benefit of this successful sidetracking program and its success in achieving enhanced oil recovery by intelligently managing and reducing water production from these wells.

Deployment of ICDs in Horizontal Wells

As previously discussed, this heterogeneous carbonate reservoir is characterized by a complex network of fractures and super-permeable streaks, especially at the top zone of the reservoir. Loss of circulation is common while drilling horizontal wells in this area, due to the presence of such open fractures, which provide conduits for water, causing premature water breakthrough across the open hole laterals. The deployment of ICDs in horizontal wells is one of the successful practices that have been implemented in the field to manage water production, especially in those wells that have intersected fractures. Once fracture locations have been identified from image logs, ICDs and external casing packers (ECPs) are usually run to manage flow distribution along horizontal wellbores. This completion system can effectively regulate the nonuniform flow profile caused by reservoir anomalies (conductive fractures and super-permeability streaks), reservoir quality variation, pressure variation and heel-to-toe effects. Figure 8 shows an example of a uniform flow distribution realized after the deployment of ICDs and ECPs across the lateral of Well-A1 where the loss of circulation zone was left blank. Following this completion, an increase of cumulative oil production was achieved for Well-A1 at a lower water cut, Fig. 9.

Water Shut-off (WSO) Jobs

Rigless WSO jobs are performed in carefully selected well candidates, those with high water production arriving from lower zones in the reservoir. These jobs are usually done by installing a mechanical through-tubing bridge plug at the desired depth, where it is afterwards capped with a 5 ft to 10 ft cement column to ensure sealing[7].

This practice provides an economical solution for those wells with watered out lower zones. Results from the field show that a significant reduction in water production was observed following the WSO job, Fig. 10, highlighting the rate performance of 92 wells. Blocking water production from these watered out intervals reduces the water rate by minimizing the effect of water coning and improves oil recovery from the top reservoir zones. Figure 11 shows the improvement of oil production rate realized for those wells following the WSO jobs. In addition, normalized cumulative production results indicate that the water management benefit from this practice is most effective within a period of six months, with a significant reduction of water cut accompanying an oil gain of about 20%, Fig. 12.

Cyclic Production Scheme

The cyclic production scheme is one of the unique water management practices designed for this field. Although

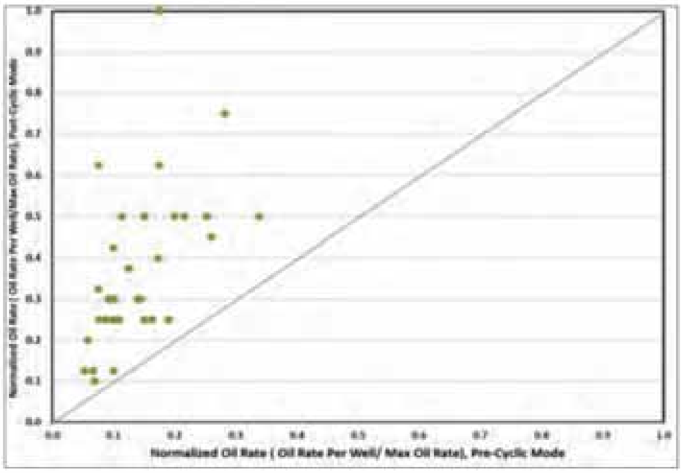


Fig. 14. Cyclic oil rate performance before and after the shut-in periods.

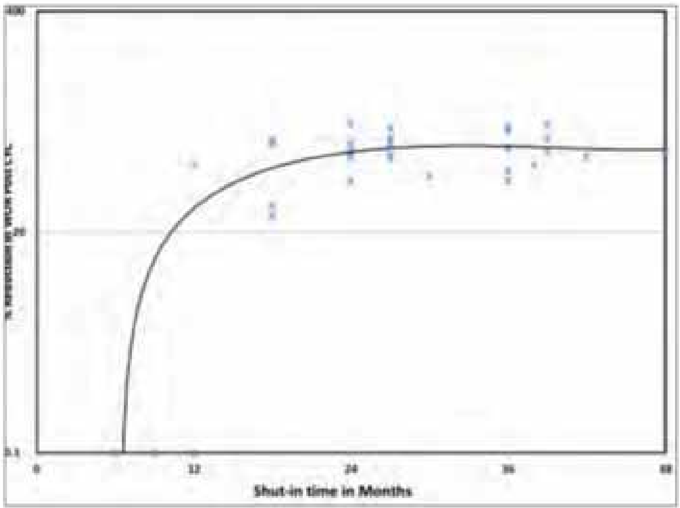


Fig. 15. Percentage of reduction in WOR as a function of cyclic shut-in time.

this technique is not well-known in the oil industry yet[8], it has been successfully implemented in this field. Wells targeted for this scheme are characterized by their limited productivity as marginal vertical oil producers; located in areas of thinner oil column down-dip near the flanks, the wells are producing at an excessively high water cut and water-to-oil ratio (WOR).

Under this scheme, these selected wells are produced in cyclic stages, with shut-in periods followed by production periods. In practice, this exploits the fact that this reservoir is a bottom-up drive and gravity dominated, as described in the previous section, allowing fluid segregation to take place during the shut-in stage, where heavier fluid (water) tends to settle down to lower sections of the reservoir, allowing the lighter fluid (oil) to be pushed up and accumulated at the top of the reservoir's sections, thereby improving oil production during the production stage[8].

In addition, this practice should also allow for oil to be recovered by free imbibition forces, allowing for the spontaneous transfer of oil and water between micropores and macropores, driven by the different wettability system between the two, a concept that was reviewed and discussed for this particular reservoir in earlier work[9]. As a result, this practice should cause the oil to be expelled from micropores by spontaneous imbibition and to be percolated upwards into the wet upper oil macroporous reservoir sections by the effect of gravity and fluid segregation, thereby further improving oil recovery while preventing excessive water production.

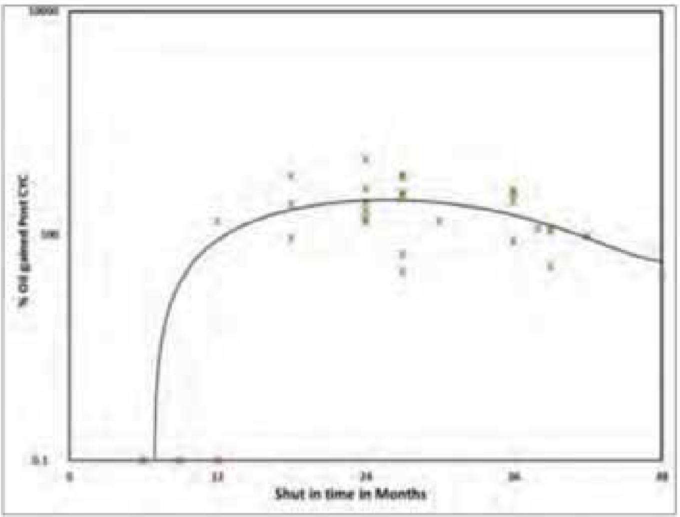


Fig. 16. Percentage of oil gained as a function of cyclic shut-in time.

Recent analysis of cyclic well performance in the field in the last 5 years shows that the WOR has been successfully reduced up to 88% and that a significant gain has been achieved in oil rate before and after the cyclic shut-in periods for each well, Figs. 13 and 14, respectively.

These cyclic wells collectively were put under different shut-in periods, from 6 to 48 months, to identify the effect of shut-in time on well performance, and in particular, the effect on reducing water production or reduction of WOR following a production period of 6 to 12 months. A scatter plot of shut-in time vs. the reduction in WOR and vs. the oil gain observed for each well is given in Figs. 15 and 16, respectively. In general, no significant improvements were observed for cyclic wells shut-in for periods less than 1 year. These two plots also indicate that the reduction trend levels out at an average WOR reduction of 60%, with a double improvement in oil rate for periods of 18 months and onwards. Therefore, by combining these results, and taking into account some operational constraints and the cost of mothballing the flow lines, the shut-in period was optimized for the cyclic wells in the field at a period of 18 months.

Strategic Surveillance Master (SSM) Plan

The previously discussed water management strategies are being rigorously monitored via a SSM plan implemented in the field. The main objective of this plan is to generate a comprehensive, reliable monitoring program for accurate determination of remaining oil saturation via regular monitoring of areal and vertical sweep conformance to achieve optimum sweep efficiency across the field[7].

This master program architecturally capitalizes on two sources of information: strategic information strips (SISs) and tie-in wells (TIWs). The SIS comprises strategic key wells distributed across different selected locations to honor the variance in the reservoir's heterogeneity, placing them along a number of strips bisecting the field from the flanks towards the crest, concurrent with the reservoir's symmetry and direction of flood front movement. The TIW comprises wells between the strips that provide additional source information and data control for better assessment and interpolation of SIS results to larger reservoir sections. Frequent episodic saturation and pressure surveys are conducted – for each well at different time lapses – based on careful consideration of the reservoir's heterogeneity and remaining oil thickness within the vacancy of the well. Figure 17 shows an example of the distribution of these wells.

Collected saturation logs demonstrate excellent results in time-lapse areal and vertical sweep conformance over the years throughout the entire reservoir extent, as indicated in Fig. 18, which shows examples of the vertical sweep conformance achieved and supported by saturation log results.

Conclusions

This article has reviewed the different integrated water management and surveillance strategies successfully implemented in this giant carbonate field. The various water management techniques employed, namely, horizontal sidetracking, deployment of ICDs, WSO jobs and cyclic production schemes, have been carefully designed to achieve optimum oil recovery from the

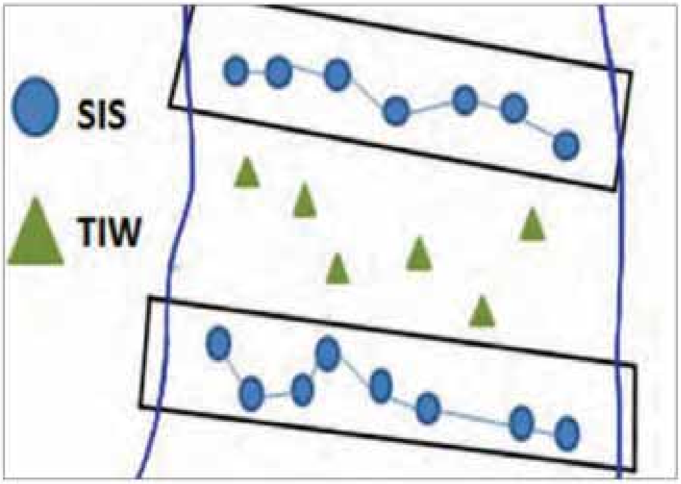


Fig. 17. Section of the field demonstrating the location of the wells under the SSM plan.

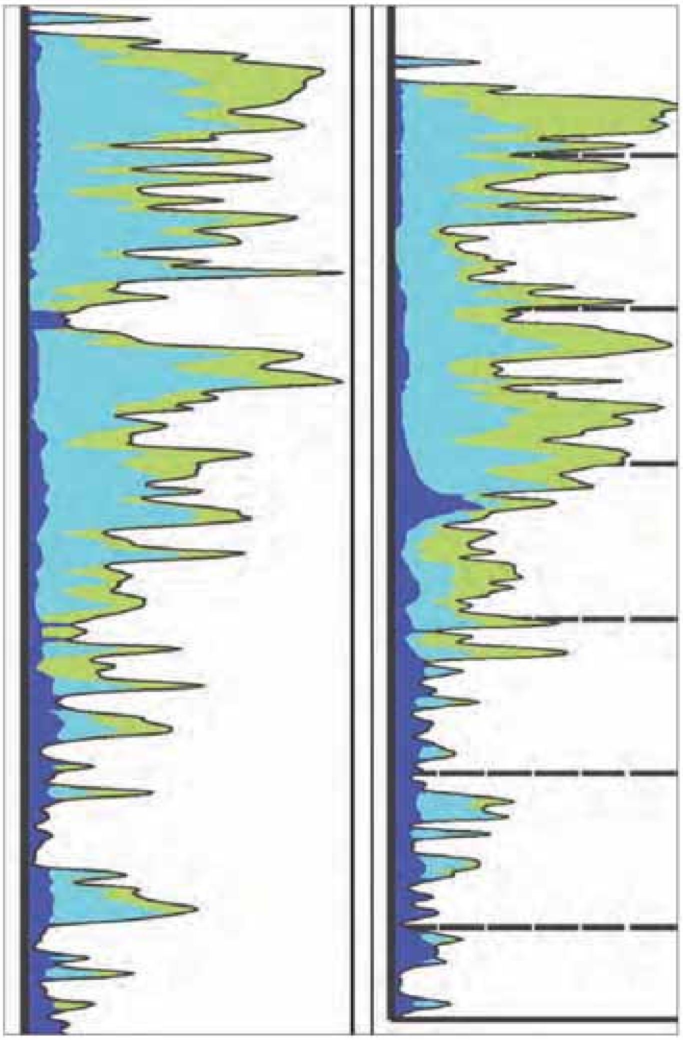


Fig. 18. Saturation logs from two wells west and east of the field, demonstrating the reservoir's sweep conformance.

field. A few specific conclusions can be derived from this study:

- Understanding the fluid flow mechanism in this heterogeneous, gravity dominated reservoir is the predominant factor influencing the various approaches designed to manage water production in the field.

- Horizontal drilling at the top zone of the reservoir presents the most effective solution to manage water production.

- ICDs are used efficiently to regulate fluid flow across the horizontal section and eliminate the adverse impact of fractures and premature water breakthrough.

- A rigless WSO job is one of the most economical solutions to reduce water production and restore well productivity.

- The cyclic production technique provides a unique approach to manage excessive water production. The underlying physics of this technique will be further studied to optimize its application in the future.

In addition, these pragmatic management practices are continuously balanced and checked by conducting a SSM plan engineered specifically for this reservoir, thereby ultimately ensuring high sweep efficiency results while managing water production and maximizing recovery.

Acknowledgements

The authors would like to thank Saudi Aramco management for their permission to present and publish this article.

This article was presented at the SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, March 10-13, 2013.

References

1. Al-Kaabi, A.O., Al-Afaleg, N.l., Pham, T., et al.: "Haradh-III: Industry's Largest Field Development with Maximum Reservoir Contact Wells, Smart Well Completions, and the Intelligent Field Concept," SPE Production & Operations, Vol. 23, No. 4, November 2008, pp. 444-447.

2. Alhuthali, A.H., Lyngra, S., Widjaja, D.R., Al-Otaibi, U.F. and Godail, L.: "A Holistic Approach to Detect and Characterize Fractures in a Mature Middle Eastern Oil Field," SPE paper 149046, presented at the SPE/DGS Saudi Arabia Section Technical Symposium and Exhibition, al- Khobar, Saudi Arabia, May 15-18, 2011.

3. Dake, L.P.: The Practice of Reservoir Engineering, revised edition, Amsterdam: Elsevier Science B.V, Co., 2011, pp. 311-366.

4. Craig Jr., F.F.: The Reservoir Engineering Aspects of Waterflooding, monograph series, Vol. 3, Dallas, Texas: SPE, 1971, pp. 45-55.

5. Allan, J. and Qing Sun, S.: "Controls on Recovery Factor in Fractured Reservoirs: Lessons Learned from 100 Fractured Fields," SPE paper 84590, presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, October 5-8, 2003.

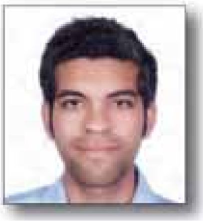
6. Al-Mutairi, S.M. and Al-Harbi, M.H.: "Water Production Management Strategy in the North 'Uthmaniyah Area, Saudi Arabia," SPE paper 98847, presented at the SPE Europec/EAGE Annual Conference and Exhibition, Vienna, Austria, June 12-15, 2006.

7. Alhuthali, A.H., Al-Awami, H.H., Krinis, D., Soremi, Y. and Al-Towailib, A.l.: "Water Management in North Ain Dar, Saudi Arabia," SPE paper 93439, presented at the 14th SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, March 12-15, 2005.

8. Al-Mutairi, S., Al-Yousef, H., Al-Ajmi, F. and Al-Hashim, H.: "Cyclic Production Scheme: Innovative Application in Reducing Water Production and Increasing Ultimate Recovery from Mature Areas," SPE paper 120818, presented at SPE Saudi Arabia Section Technical Symposium, al-Khobar, Saudi Arabia, May 10-12, 2008.

9. Clerke, E.A.: "Permeability, Relative Permeability, Microscopic Displacement Efficiency and Pore Geometry of M_1 Bimodal Pore Systems in Arab-D Limestone," SPE Journal, Vol. 14, No. 3, September 2009, pp. 524-531.

Biographies



Mohammed A. Alghazal is a Reservoir Engineer in Saudi Aramco's Southern Area Reservoir Management Department. He currently works in the 'Uthmaniyah Reservoir Management Unit, engaged in the management of the mature northern part of the 'Uthmaniyah field, and he conducts reservoir assessment studies, mainly in the area of water reservoir management and secondary reservoir evaluations.

Mohammed received his B.S. degree in Petroleum Engineering from the University of Manchester, Manchester, U.K.

He is an active member of the Society of Petroleum Engineers (SPE), participating in SPE technical symposiums, and young professional and student outreach events. In 2012, Mohammed received the Distinguished Young Member Service Award from the SPE Saudi Arabia Section.

Razally M. Ali is a Reservoir Engineer with Saudi Aramco's 'Uthmaniyah Reservoir Management Unit. He has 18 years of industry experience. Prior to joining Saudi Aramco in 2006, Razally worked as a Well Test/ Reservoir Engineer for Petronas Carigali in Malaysia, as a Reservoir Engineer/ Production Technologist for Brunei Shell Petroleum, Shell Expro in Aberdeen, Scotland, and Woodside Petroleum in Perth, Australia. He also spent 4 years with Schlumberger (Consulting Services) formulating integrated field development plans and production optimization projects for operators.

Razally received his B.Eng. and M.S. degrees in Petroleum Engineering from the Imperial College London, London, U.K.

He is a member of the Society of Petroleum Engineers (SPE).

Dr. Ahmed H. Alhuthali is a Supervisor in Saudi Aramco's Southern Area Reservoir Management Department. In addition to his current assignment, Ahmed is the Asset Team Leader of 'Uthamaniyah field overseeing various financial and technical activities. During his 14 years with the company, he has worked on multiple assignments concerning reservoir engineering aspects for four giant fields. Ahmed is interested in reservoir and production system integration and optimization. He is also interested in risk management and decision making under uncertainty.

In 1998, Ahmed received his B.S. degree in Electrical Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. In 2003, he received his M.S. degree in Petroleum Engineering from Texas A&M University, College Station, TX, and in 2011, he received his Ph.D. degree in Petroleum Engineering, also from Texas A&M University. He earned a business certificate from Mays Business School at Texas A&M University in May 2008.

Ahmed is a member of the Society of Petroleum Engineers (SPE). He has published many technical papers on topics related to reservoir management.

Effective Analytical Approaches to Enhance Productivity of Low Producing Gas Wells

By Dr. Zillur Rahim, Dwi T. Waspada, Dr. Hamoud A. Al-Anazi, Adnan A. Al-Kanaan and J. Eduardo Pacheco.

Reprinted with kind permission from Saudi Aramco Journal of Technology.

Abstract

Hydraulic fracturing is a widely used technology in the industry to enhance oil and gas production, particularly in tight formations. Tight gas and shale cannot sustain commercial production rates without fracturing. Although the technique has been used in the industry for many years and vast improvements have been made in upgrading fluid chemistry, proppant types, pump schedule sequences and overall well completion systems, a close evaluation is always required to ascertain that the fracturing has provided the level of productivity expected from the candidate well. Such evaluation and analysis will help improve and optimize the stimulation technique for any given reservoir and field conditions, address specific challenges in that area and determine remedial plans on any well that did not show expected results in terms of productivity enhancement.

Saudi Arabian gas wells are usually stimulated to enhance and sustain production. Wells drilled in the R-1 reservoir in Field-A, which exhibit low to moderate permeability, are routinely hydraulically fractured. Many of these wells produce a high sustained rate after a successful stimulation treatment. Some others do not perform up to expectation, as seen from the rate decline. This is caused mainly by inefficient fracture treatments, such as achieving a short half-length, limited vertical coverage and poor post-frac cleanup. A critical and intense study of numerous wells has been performed using available data from geology, open hole logs, cores, pressure transient tests, etc., to understand and quantify the reservoir characteristics, fracture properties and flow capacity of these wells to develop plans to improve productivity. Such plans include remedial treatments, such as refracturing, placing additional perforations in previously unperforated intervals, initiating hydraulic fractures in different layers, and sidetracking the well to change its trajectory and geometry to contact new producing intervals. This article summarizes the well conditions and complete evaluation process, and suggests remedial procedures for each well to ensure they achieve their full potential.

Introduction

The primary purpose of the hydraulic fracturing treatment is to enhance productivity. A successful treatment is characterized by numerous factors, of which the most important are to connect the wellbore with the

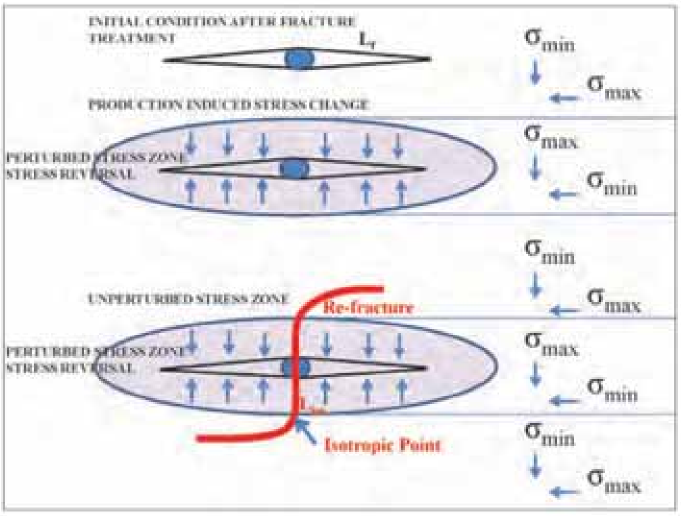


Fig. 1. Reorientation of in-situ horizontal stress regime[6].

entire net pay thickness, perform excellent post-fracture cleanup, place high conductivity proppant, significantly improve well rate and extend production sustainability. If the fracture treatments are mediocre or poor, the well productivity will decrease within a short period of time. Once it is identified that a well is not sustaining productivity to its expectation, based on reservoir quality and the designed hydraulic fracture treatment conducted, diagnostic work should be performed to properly evaluate the reasons for this production decline. Subsequently, remedial measures should be planned and extensive modeling work conducted to confirm the ideal solution for reviving well productivity[1-3].

Saudi Aramco has been successfully exploiting its gas reservoirs for the past decade with hydraulically fractured vertical and horizontal wells. Development of comprehensive geomechanical models has allowed optimization of perforation interval selection and fracture design[4-5]. Even with a rigorous work plan that is properly implemented, wells may not necessarily respond according to expectations after a fracture treatment. Among many reasons that may impair well productivity are: (a) the fracture's failure to cover the entire pay section, (b) insufficient fracture half-length, (c) inadequate proppant pack permeability, and (d) poor post-frac cleanup.

This article presents a few wells with low production rates and a complete diagnostic method to identify reasons for the low rates and propose remedial actions that need to be taken for the revival of the low producers.

Refracturing

Refracturing is used to enhance production in a poorly fractured well. (A different application of refracturing technology is to fracture wells with strong initial fractures.) This is due to the fact that once a well is hydraulically fractured and produced for a while, the stress orientation changes. Both mechanical effects (related to creation of the fracture) and poroelastic effects (associated with fluids production) contribute to stress orientation. A second fracture that is initiated therefore orients in a different direction up to certain point (isotropic point) and so does not necessarily overlay the initial fracture. The fracture is therefore exposed to a new reservoir area. The process is referred to as altered-stress fracturing[6-8].

Periodic refracturing has been deployed in many oil and gas fields across the world. Among several criteria to consider when selecting the most appropriate candidate are wells with a poor initial fracture treatment (limited penetration, damaged proppant conductivity, etc.) and locations where stress orientation has changed due to

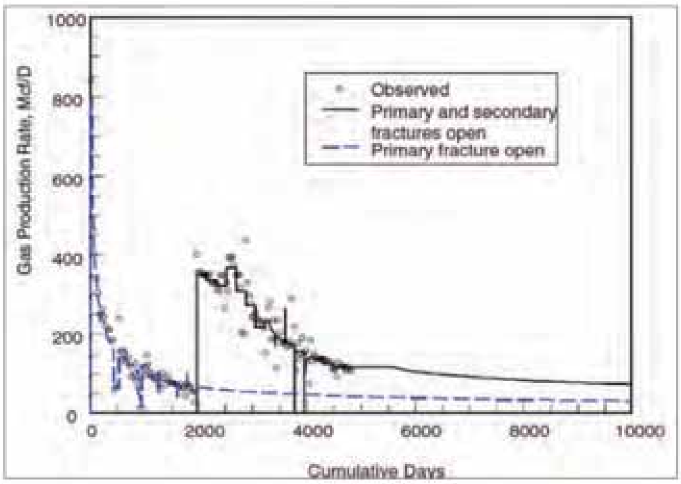


Fig. 2. Production enhancement from refracturing[6].

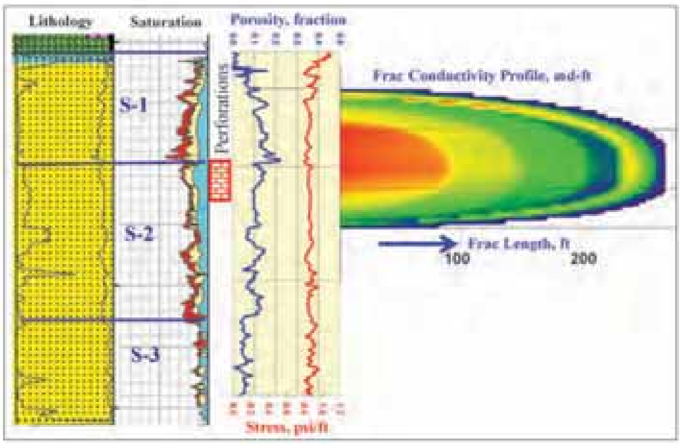


Fig. 3. Well-A: Reservoir development, stress and porosity logs, and fracture conductivity profile[9].

production and where new fractures are assumed to assume different azimuths, thereby contacting new formations. Poor initial fracturing mainly occurs due to premature screen out. It may also happen due to severe proppant degradation and damage, which significantly reduces proppant pack conductivity. It is therefore important to understand the reasons for such screen outs and overcome them to make the second treatment successful.

Propped refracturing treatments are usually done some time after the initial production period. This allows redistribution of the stresses around the near-well production area.

The change of in-situ stress direction can be either production induced and/or deformation induced. Because reorientation of stress direction may vary significantly from one field to the other, every field, reservoir and well must be studied individually to select the suitable candidate. During the depletion process, the maximum horizontal stress decreases faster than the minimum horizontal stress due to higher depletion in the fracture direction, which causes stress reversal near the fracture[7]. As a result, the second fracture may propagate orthogonally to the first one up to the isotropic point (L_{iso}), which has been numerically shown to be 0.58 Lf. The actual value varies and may be much higher.

Many factors contribute to the reorientation of the stress regime, which helps the refracture propagation into the unfractured interval. These factors include pressure change due to production (P_i-P_{wf}), Young's modulus, Poisson's ratio, horizontal stress difference (σ_{max} - σ_{max}),

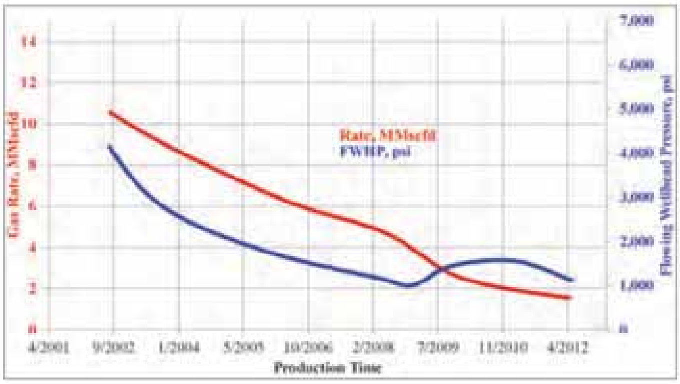


Fig. 4. Well-A production and pressure history[1].

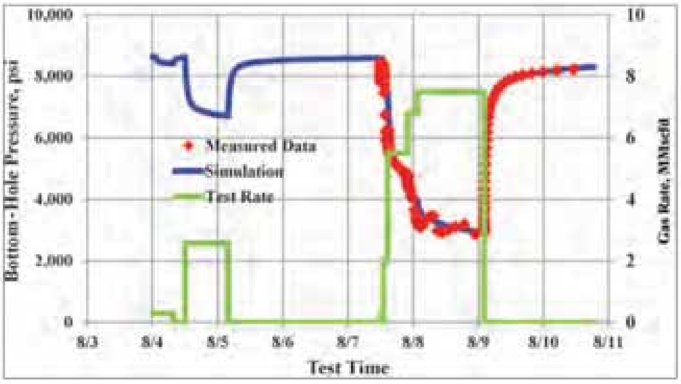


Fig. 5. Well-A: Pressure transient data match (S-2).

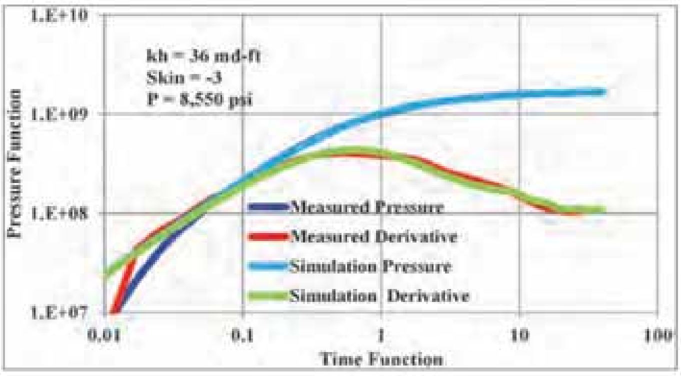


Fig. 6. Well-A: Pressure transient data analysis (S-1 and S-2).

aspect ratio (H_n/L_f) and production time (t_p). Recent 3D modeling has shown that the stiffer the bounding layer, the smaller the reorientation area is.

Figure 1 is a schematic representation of the concept of refracturing reorientation. The figure shows a horizontal section of a vertical well containing the initial fracture, oriented west to east. After producing from the well for a while, the pore pressure will be redistributed in an expanding elliptical region, which changes the stress distribution in the reservoir. The horizontal stress component parallel to the initial fracture reduces quicker than the orthogonal one as a function of time. When the induced stress changes are large enough, the direction of minimum horizontal stress becomes the maximum within the elliptical region, as shown in the figure. The hydraulic fracture therefore turns in that region, contacting the new area. The boundary of this elliptical region is called the isotropic point, which is dependent on fluid flow, fracture characteristics and

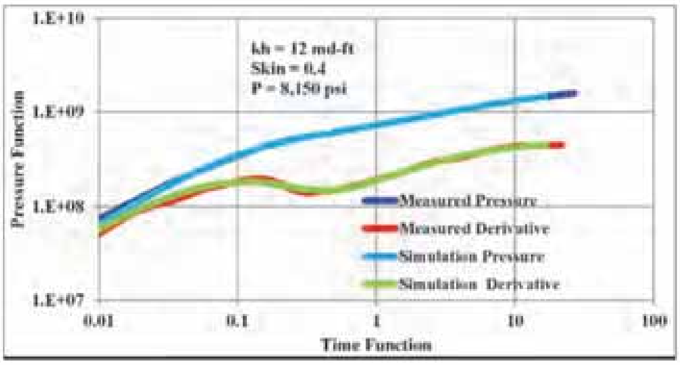


Fig. 7. Well-A: Pressure transient data analysis (S-1)[1].

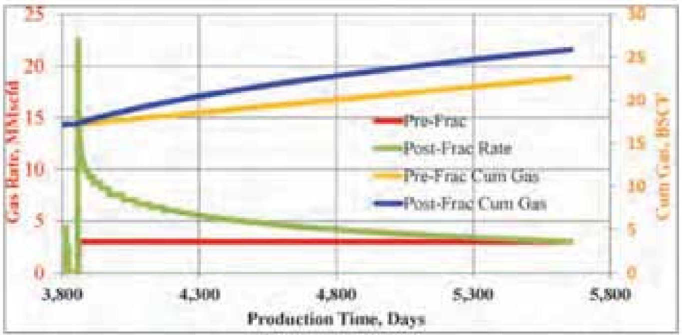


Fig. 8. Well-A: Production forecast, pre-frac and post-frac cases.

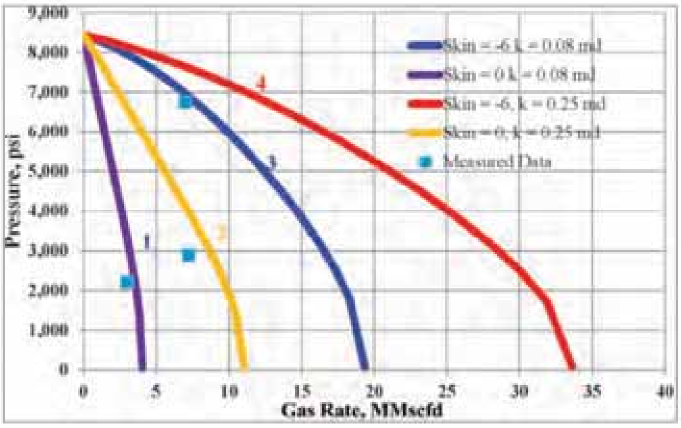


Fig. 9. Well-A: Modeling of inflow performance.

rock mechanical properties. All parameters must be considered when selecting a refracturing candidate. Past the isotropic point, the maximum principal stress switches back to its original direction. The induced fracture at that point starts turning and eventually returns to its original azimuth.

Figure 2 shows an improved production rate after refracturing treatment.

Example Well-A

Well-A was drilled vertically across two sandstone reservoir intervals, S-1 and S-2. At the location of the well, these reservoirs exhibit low permeability, high temperature (300 °F) and high reservoir pressure (>8,000 psi). A geomechanical model was used to predict the in-situ stress profile, Young's modulus and Poisson's ratio. The reservoir development and mechanical properties are illustrated in Fig. 3[9] and the production history is shown in Fig. 4.

This well had already undergone a different evaluation process. The well was first perforated and tested as a cased hole across the S-1 reservoir. The rate was low, and consequently, more perforations were added in the S-2 reservoir. This time the rate and wellhead pressure

Event	Measured Data	Ref**	Comment
S-1 perforation	2.7 MMscfd at 1,550* psi	1	Insufficient rate; kh = 12 md-ft
S-1 + S-2 perforation	7 MMscfd at 2,210* psi	2	Good improvement, still below expectation; kh = 36 md-ft
Cased and fracked	7 MMscfd at 5,400* psi	3	Good improvement
Re-frac		4	Improved inflow performance relationship (IPR)

Table 1. Well-A events and results *Flowing wellhead pressure **With reference to Fig. 9.

improved, but still they were not up to the expectations based on reservoir development. The well was then cased off, and a new set of perforations was added. Subsequently, the well was hydraulically fractured.

The pre-fracture cased hole pressure buildup tests, Figs. 5 to 7, show reservoir flow capacity, kh, varying between 12 and 36 md-ft, depending on the perforation intervals, which contribute to the flow rate (either S-1 or S-1 and S-2 combined). Subsequent to the cased hole tests, a 4½" liner was installed and cemented, and the middle section was perforated in anticipation that an induced hydraulic fracture will grow vertically and effectively cover both reservoir intervals. This was also predicted by the fracturing model. Consequently, about 400,000 lb of proppant was successfully pumped during the fracture treatment. The initial well rate improved, but there was a strong indication from the preliminary analysis of the well performance that not all the interval was covered. The well was put to production and the rate declined with time. A comprehensive evaluation was conducted, and the history matching of the production and pressure data using reservoir properties calculated from pressure transient analysis confirmed that the induced fracture had not effectively connected with the higher permeability interval in S-2.

As a remedial action, a second fracture treatment is recommended in the S-2 reservoir interval. Obviously, this operation has to be done after isolating the upper portion. Eventually this upper portion will be re-perforated and both intervals will be opened for production. With two fractures now covering both S-1 and S-2 reservoirs, the modeling results show significant improvement of production rates. A 5 billion cubic ft (BCF) of production gain is expected within a 4-year period after the refracturing treatment, Fig. 8. Figure 9 presents the modeled inflow performance of the well for different well configurations, and Table 1 summarizes all results obtained from the individual scenarios.

Example Well-B

Well-B was drilled across S-1, a sandstone reservoir, then perforated in a 30 ft interval and fractured with 450,000 lb of 20/40 intermediate strength proppant (ISP). Based on the porosity, permeability and other reservoir characteristics, Fig. 10, the post-fracture rate of about 5 or 6 million standard cubic feet per day (MMscfd) fell below expectations, Fig. 11.

The diagnostics indicated limited vertical growth of the induced fracture, which was also confirmed by the temperature log that was run immediately after the fracture treatment. A numerical simulation model was run and the well performance history was matched. This simulation model also confirmed limited fracture height growth and indicated that the fracture was restricted within the upper 100 ft interval. With results from these diagnostics and from the reservoir performance history, it became obvious that much of the formation was not stimulated and not contributing to the post-frac performance of the well.

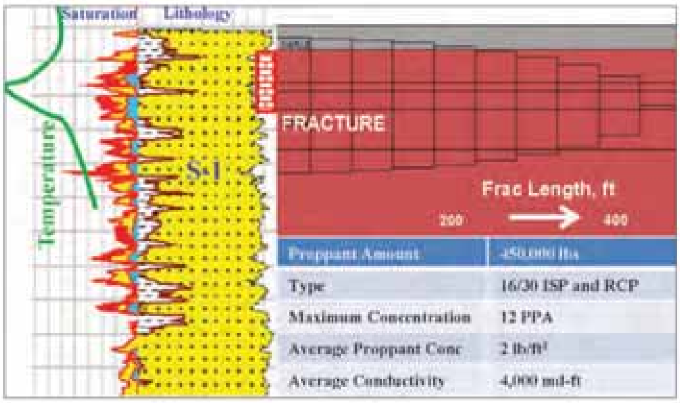


Fig. 10. Well-B: Reservoir development and fracture treatment.

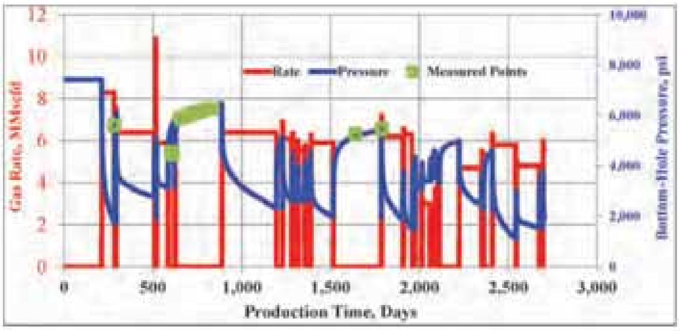


Fig. 11. Well-B: Production and pressure history match.

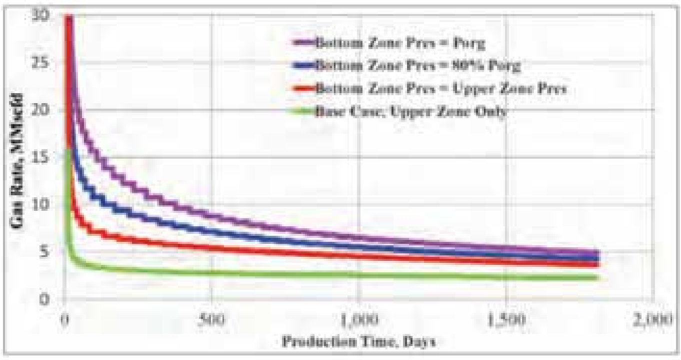


Fig. 12. Well-B: Production performance forecast scenarios.

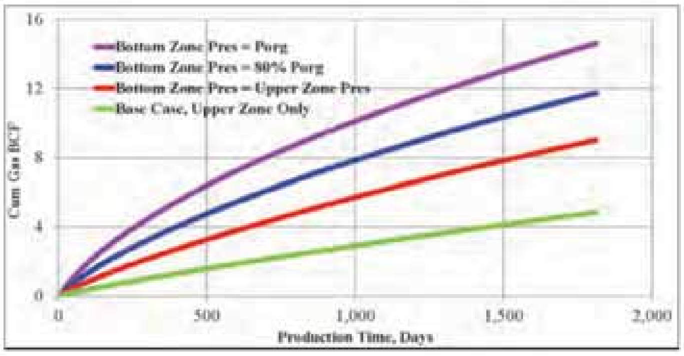


Fig. 13. Well-B: Cumulative performance forecast scenarios.

Subsequently, modeling was done with a second hydraulic fracture in the bottom of the S-1 reservoir to cover the interval not contributing to well performance. Four different scenarios were investigated to see the benefit of refracturing the well, Figs. 12 and 13. The base case scenario was if the well produces in its current condition. Three other scenarios were run with different reservoir pressures in this bottom section. In the best case scenario, where the lower interval is at the reservoir's virgin pressure, the gain in cumulative production in a period of 5 years is 11 BCF. Even if the bottom interval is depleted and has the same pressure as the upper producing zone, the gain is about 4 BCF. The benefit from refracturing is therefore evident.

Example Well-C

Well-C was drilled across the S-1 reservoir, Fig. 14, which has two distinct reservoir developments, the lower and the upper. The first proppant frac treatment across the lower S-1 ended prematurely with about 44,000 lb of proppant inside the formation, which was only 25% of the design amount. The decision was made to refracture the formation to generate the fracture dimensions required to achieve the target production rate from the well. After noticing a high near-wellbore friction pressure loss, re-perforation was conducted to achieve better communication between the wellbore and reservoir.

In the refracturing treatment, low proppant concentration stages were pumped so as to further reduce the near-wellbore friction pressure loss. The designed 180,000 lb of proppant was then successfully placed at a maximum concentration of 7 pounds of proppant. Then the upper S-1 section was perforated and hydraulically fractured. After the well was placed for cleanup operations, the gas flowed at a rate of 7 MMscfd with almost no fracture fluid recovery. This was alarming and a strong indication that the fracturing fluids had not broken down after the treatment and placement of the proppant.

If the fracture fluid gel residue is not properly removed, severe damage to the proppant pack can occur and consequent results can be detrimental to the fracture permeability, thereby severely restricting gas production. Figures 15 and 16 provide some analytical modeling runs for a well with kh = 50 md-ft and proppant fractured to achieve a propped half-length of 200 ft. The plots

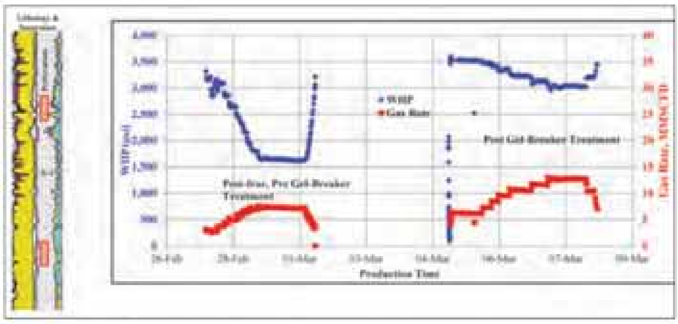


Fig. 14. Well-C: Reservoir development and production history.

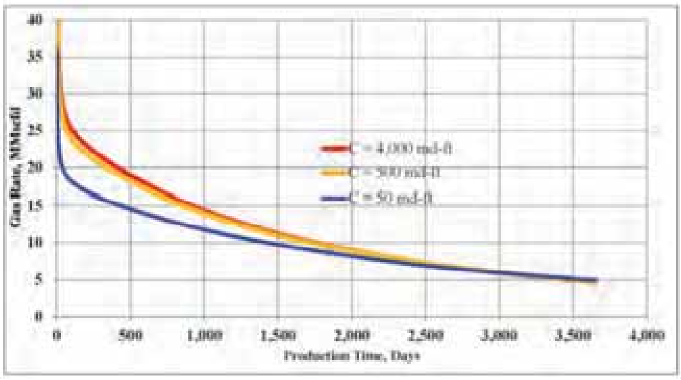


Fig. 15. Production performance as functions of conductivity.

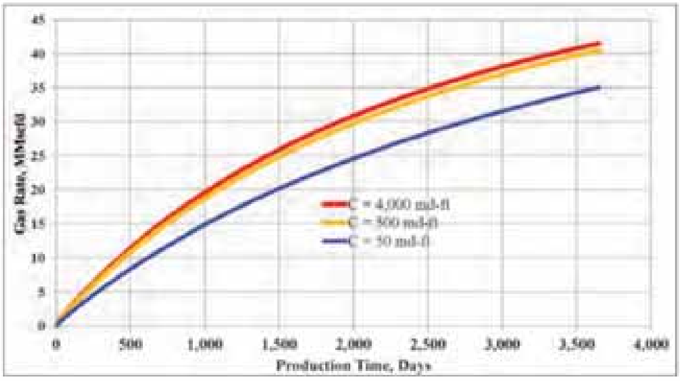


Fig. 16. Cumulative production as functions of conductivity.

show the effects of fracture conductivity on gas rate and cumulative production. There will be no production gain with a fracture that has a conductivity of 50 md-ft because there is no difference between the fracture's low capacity and that of the formation. If the flow capacity ratio is 10 (C = 500 md-ft), a gain of 5 BCF of gas is expected in a period of 10 years.

Therefore, to revive the well from the damage incurred from poor cleanup of fracture fluid, additional treatments were pumped that included gel breakers, surfactants and other chemicals to enhance fluid degradation. The results from the treatment, presented on the right-hand side of the production performance graph in Fig. 14, clearly indicate considerable gain in gas rate. Therefore, the proper diagnostics and appropriate treatment conducted on the well made a significant impact on well deleverability and the ultimate reserves recovery from the area. The actual condition of the well pre- and post-treatment is shown in Figs. 17 and 18. The long-term rate shows stabilization at a much higher wellhead pressure, and the inflow performance matches show significant improvement in well productivity.

Conclusions

Based on numerous diagnostics conducted on wells that did not perform up to expectation, forward action plans are introduced to revive their productivity. The following are some conclusions drawn from the diagnostics, modeling and implementation of remedial processes on a few low producing gas wells.

• The stress orientation can change in the vicinity of the well due to fracturing and/or production.

• Change of stress orientation depends on several mechanical and reservoir properties, such as Young's modulus, Poisson's ratio, flow capacity and flowing bottom-hole pressure.

• Well performance can be severely impaired if hydraulic fracturing does not vertically cover all producing intervals.

• Well performance is compromised due to degraded proppant conductivity attributed to non-optimal post-treatment cleanup.

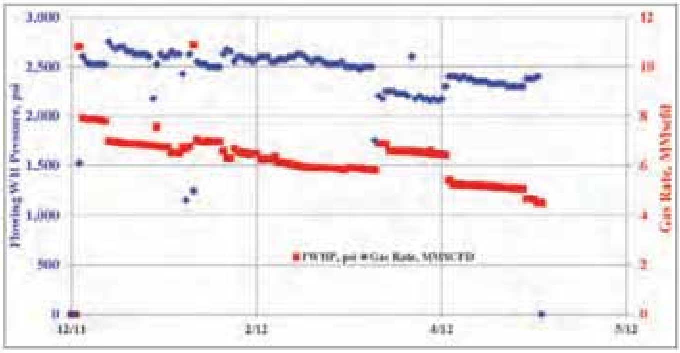


Fig. 17. Well-C production profile.

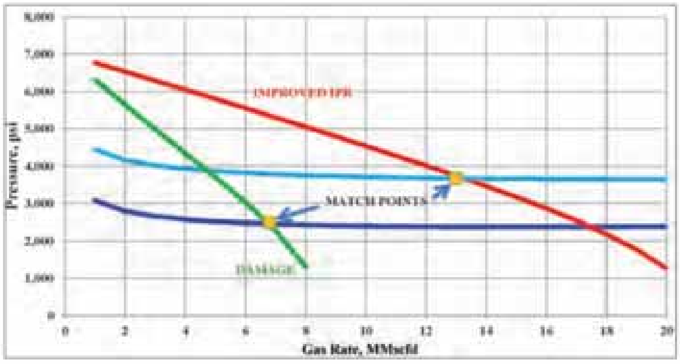


Fig. 18. Well-C inflow performance matches.

• Optimal fracture fluid cleanup is thereby essential and has immense impact on well deliverability. Residual gel from fracture fluid is detrimental to the proppant pack and can severely damage fracture conductivity.

• Refracturing is a viable method to restore production from wells where initial fracturing treatment was poorly conducted (premature screen out and/or damaged proppant pack).

Acknowledgements

The authors would like to thank Saudi Aramco management for their permission to present and publish this article.

References

1. "2009-2011 Gas Program," Saudi Aramco Gas Reservoir Management Division Internal Documentation.

2. Rahim, Z., Al-Anazi, H., Malki, B. and Al-Kanaan, A.: "Optimized Stimulation Strategies Enhance Aramco Gas Production," Oil and Gas Journal, October 4, 2010.

3. Rahim, Z., Al-Kanaan, A., Al-Anazi, H., et al.: "Open Hole Multistage Fracturing Boosts Saudi Arabia Gas Well Rates," Oil and Gas Journal, June 6, 2011.

4. Al-Qahtani, M.Y. and Rahim, Z.: "A Mathematical Algorithm for Modeling Geomechanical Rock Properties of the Carbonate and pre-Khuff Reservoirs in Ghawar Field," SPE paper 68194, presented at the SPE Middle East Oil Show, Bahrain, March 17-20, 2001.

5. Rahim, Z., Al-Qahtani, M.Y., Bartko, K.M., Goodman, H., Hilarides, W.K. and Norman, W.D.: "The Role of Geomechanical Earth Modeling in the Unconsolidated pre-Khuff Field Completion Design for Saudi Arabian Gas Wells," SPE paper 84258, presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, October 5-8, 2003.

6. Roussel, N.P. and Sharma, M.M.: "Quantifying Transient Effects in Altered-Stress Refracturing of Vertical Wells," SPE paper 119522, presented at the SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, January 19-21, 2009.

7. Eibel, J.L. and Mack, M.G.: "Refracturing: Observation and Theories," SPE paper 25464, presented at the SPE Production Operations Symposium, Oklahoma City, Oklahoma, March 21-23, 1993.

8. Siebrits, E., Eibel, J.L. and Detourney, E., et al.: "Parameters Affecting Azimuth and Length of a Secondary Fracture during a Refracture Treatment," SPE paper 48928, presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, September 27-30, 1998.

9. Rahim, Z., Al-Qahtani, M.Y. and Buhidma, I.: "Improved Gas Recovery from Acid of Hydraulic Fracturing," Saudi Aramco Journal of Technology, Spring 2001, pp. 50-60.

Biographies

Dr. Zillur Rahim is a Petroleum Engineering Consultant with Saudi Aramco's Gas Reservoir Management Department. His expertise includes well stimulation design, analysis and optimization, pressure transient test analysis, gas field development, planning, and reservoir management. Rahim oversees all stimulation treatments on nonassociated gas wells for Saudi Aramco. Prior to joining Saudi Aramco, he worked as a Senior Reservoir Engineer with Holditch & Associates, Inc., and later with Schlumberger Reservoir Technologies in College Station, TX, where he consulted on reservoir engineering, well stimulation, reservoir simulation and tight gas qualification for national and international companies. Rahim is an instructor for petroleum engineering industry courses and has trained engineers from the US and overseas. He developed analytical and numerical models to history match and forecast production and pressure behavior in gas reservoirs. Rahim also developed 3D hydraulic fracture propagation and proppant transport simulators and numerical models to compute acid reaction, penetration and fracture conductivity during matrix acid and acid fracturing treatments.

He has authored 55 SPE papers and numerous in-house technical documents. Rahim is a member and a technical editor of the Society of Petroleum Engineers (SPE) and the Journal of Petroleum Science and Technology (JPSE), a registered Professional Engineer in Texas and a mentor for Saudi Aramco's Technologist Development Program (TDP). He is an instructor for the Reservoir Stimulation and Hydraulic Fracturing course offered by the Upstream Professional Development Center (UPDC) of Saudi Aramco.

Rahim received his BS degree from the Institut Algérien du Pétrole, Boumerdes, Algeria, and MS and PhD degrees from Texas A&M University, College Station, TX, all in Petroleum Engineering.

Dwi T. Waspada is a Petroleum Engineer with Saudi Aramco's Gas Reservoir Management Department. His major responsibilities include working in multidisciplinary gas field development projects with an emphasis on studying and analyzing the reservoir's potential to maintain desired field production targets, and on the integration of the work of multidisciplinary teams with that of different technical groups directed towards maximizing ultimate recovery from the oil and/or gas reservoir.

Prior to joining Saudi Aramco in 2008, Dwi worked with Conoco Phillips as an exploration team leader in North Belut field in Indonesia for 1 year. Prior to that, he worked at VICO Indonesia for 16 years. Dwi's main responsibility there was for Base Decline Management, including reservoir monitoring and production optimization to achieve optimum reserves recovery, which covered network (pipeline) reconfiguration, debottlenecking and deliquification.

He received his BS degree in Petroleum Engineering from Trisakti University, Jakarta, Indonesia.

Dr. Hamoud A. Al-Anazi is the General Supervisor of the North Ghawar Gas Reservoir Management Division in the Gas Reservoir Management Department for Saudi Aramco. He oversees all work related to the development and management of gas reservoirs in Ain-Dar, Abqaiq, Shedgum and 'Uthmaniyah gas fields.

Hamoud's areas of interest include studies on formation damage, fluid flow in porous media and gas condensate reservoirs. He has published more than 49 papers in local and international conferences and refereed journals.

In 1994, Hamoud received his BS degree in Chemical Engineering from King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia, and in 1999 and 2003, respectively, he received his MS and PhD degrees in Petroleum Engineering, both from the University of Texas at Austin, Austin, TX.

Hamoud is an active member of the Society of Petroleum Engineers (SPE), where he serves on several committees for SPE technical conferences and workshops. He is also teaching courses at KFUPM as part of the KFUPM Part-Time Teaching Program.

Adnan A. Al-Kanaan is the manager of Gas Reservoir Management Department (GRMD) where he oversees three gas reservoir management divisions. Reporting to the Chief Petroleum Engineer, Adnan is directly responsible for taking strategic decisions to enhance, sustain, and deliver gas to the Kingdom to meet its ever increasing energy demand. He oversees the operating and business plans of GRMD, new technologies and initiatives, unconventional gas development programs, and the overall work, planning and decisions made by his more than 70 engineers and technologists.

Adnan has 15 years of diversified experience in oil and gas reservoir management, full field development, reserves assessment, production engineering, mentoring young professionals and effectively managing large groups of professionals. He is a key player in promoting and guiding the Kingdom's unconventional gas program. Adnan also initiated and oversees the Tight Gas Technical Team to assess and produce the Kingdom's vast and challenging tight gas reserves in the most economical way.

Prior to the inception of GRMD, he was the General Supervisor for the Gas Reservoir Management Division under the Southern Reservoir Management Department for 3 years, heading one of the most challenging programs in optimizing and managing nonassociated gas fields in Saudi Aramco.

Adnan started his career at the Saudi Shell Petrochemical Company as a senior process engineer. He then joined Saudi Aramco in 1997 and was an integral part of the technical team responsible for the on-time initiation of the two major Hawiyah and Haradh Gas Plants that currently process more than 6 billion cubic feet (BCF) of gas per day. Adnan also directly managed the Karan and Wasit fields – the two major offshore gas increment projects – with an expected total production capacity of 4.3 BCF of gas per day.

He actively participates in the Society of Petroleum Engineers' (SPE) forums and conferences and has been the keynote speaker and panelist in many such programs.

Adnan's area of interest include reservoir engineering, well test analysis, simulation modeling, reservoir characterization, hydraulic fracturing, reservoir development planning, and reservoir management.

He chaired the 2013 International Petroleum Technical Conference held in Beijing, China.

Adnan received his BS degree Chemical Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia.

J. Eduardo Pacheco is a Petroleum Engineer Specialist for gas and oil well evaluation and productivity improvement at Halliburton. Located in Saudi Arabia, he works on the Middle East Technical Solution Team as a Reservoir and Production Engineer. With 33 years of experience in the oil and gas industry, Eduardo has worked in a variety of positions, including teaching at the Petroleum University in Mexico. He worked on numerous projects for well testing and productivity evaluation, in both onshore and offshore fields, with major oil and gas operators. Eduardo successfully led the development and implementation of productivity increase strategies while working with Landmark. He also successfully led a number of significant project implementations as a consultant for major clients in Latin America such as PDVSA, Ecopetrol, Petrobras and Pemex.

Eduardo has recently been focusing on the development and implementation of a strategy for testing oil and gas wells to enhance production by applying stimulation, sand control, conformance and hydraulic fracturing.

He received his BS degree from the National University of Argentina, Mendoza, Argentina, and a MS degree from the University of Oklahoma, Oklahoma City, OK, both in Petroleum Engineering.

Optimization of Cableless Technologies to Obtain Reservoir Pressure and Temperature for Real-time Monitoring

By Karam S. Al-Yateem and Khalid I. Al-Omaireen.

Reprinted with kind permission from Saudi Aramco Journal of Technology.

Abstract

Acquiring downhole pressure data is essential for successful reservoir management: it paints a picture of the reservoir's behavior. Over the last decade, the intelligent field concept has matured to such an extent that several major oil operators in the world now have fields where intelligent technologies have been deployed on a large scale. Saudi Aramco is one of these pioneering oil and gas operating companies that have made a large investment to transform their oil fields into intelligent fields with an expectation to maximize the hydrocarbon recovery, simplify operations and minimize human interaction, thereby enhancing safety. As the concept of the intelligent field has matured, more and more operators are embracing this new concept with expectations for higher recovery factors. The permanent downhole monitoring system (PDHMS), one such intelligent field component, provides continuous monitoring of reservoir pressure. The PDHMS has become an indispensable tool for reservoir surveillance, particularly for offshore fields in which gauge deployed pressure and temperature surveys are always affected by external factors, such as the weather. PDHMSs are installed to eliminate wireline units and/or expensive barge visits. Another obvious advantage is that the system can treat any shut-in time as an opportunity for both pressure survey and well testing, thereby largely reducing the nonproductive time of a producer and significantly improving the reservoir surveillance frequency.

The PDHMS consists of two electronic gauges normally installed at the end of the well tubing with a distance of some 200 ft to 300 ft of true vertical depth (TVD) between the gauges to allow them to profile the gradient. These gauges are connected to surface recording and data transmitting equipment through an electrical cable or fiber optics attached to the outside of the well tubing. The installation and retrieval of the PDHMS, in case of malfunction, requires capital investment (the cost of rig utilization). Rigless wireline deployed gauges have been considered in the past, but with cable running inside the tubing, this presents more disadvantages than advantages. Therefore, the next improvement on this technology was a wireline retrievable gauge that does not require any cable. A cableless pressure gauge was therefore developed that allows a wireless broadcast of data. These battery operated gauges can be set without a rig and left in the hole for an extended period of time – up to three or more years, depending upon data transmitting frequency. This technology was recently trial tested in a Saudi Arabian field for about a year with promising results. The goal of utilizing such a system is to improve well intervention safety, control costs and optimize resources. Additionally, like the PDHMS, cableless gauges have a huge potential to simplify logistics compared to conventional surveying. They are superior in that they are wireline/slick line deployed. This further opens the opportunity to replace failed PDHMSs with cableless gauges, in an offshore environment in

particular, to continue monitoring pressure without waiting for workover rig resources to arrive.

Saudi Aramco's strategy is to further revolutionize the use of the technology behind cableless gauges by installing them in selected observation wells at the datum point depth, if feasible. With the cableless gauge, only one gauge will be required compared to the conventional practice of installing two PDHMS gauges. This article will address old and new methods utilized to obtain downhole pressure, including conventional wireline survey, well testing, the PDHMS and cableless gauges, to establish a tangible comparison between them. The article also discusses a method to estimate the static bottom-hole pressure (SBHP) through an "extrapolation to datum" empirical study.

Introduction

Equipment using electromagnetic (EM) wave technology has been widely pioneered for meeting public needs, such as in biotechnology research, medical applications and all sorts of related telecommunications. The recognition of opportunities presented by this technology for the oil and gas industry provoked an affirmative change. For many years, operators wished they could recover data from downhole without the need for cables, either through permanently installed gauges or in the form of a temporary wireline. Recently, the cableless pressure gauge technology was successfully trial tested as an alternative downhole monitoring tool in one of Saudi Arabia's offshore fields. This three-year battery operated system is hung inside the prospective well production tubing, where it transmits pressure data to the surface in real time without a direct cable connection in the well. This is achieved through the EM interference with the steel pipe: the gauge uses the tubing/casing steel as the transmission media. Deployment can be conducted through a standard slick line without the need for a rig or for cable or fiber optic connections, compared to other monitoring devices, such as the PDHMS. Most in-well wireless telemetry systems employ one or more of the following[1]:

- Pressure waves within the product.
- Acoustic/Sonic waves through the tubing wall.
- EM communication through the formation.
- EM communication through the casing and tubing.
- Coaxial current loop systems.

Previously, to effectively map the pressures of any field and thoroughly investigate the status of any well, acquisition of essential data, such as pressure and temperature, was conducted through well intervention; this cableless technology eliminates this requirement. It is vital to understand that knowledge of continuous pressure is truly beneficial as it leads to the better understanding and management of the field in real-time fashion. Therefore, the primary objective of installing the PDHMS is to eliminate the need for a wireline unit and/or expensive barge visits when conducting the pressure surveys required for reservoir surveillance. Another direct advantage of a PDHMS is that the system can turn any well shut-in time into an opportunity for both pressure survey and well testing, largely reducing the nonproductive time of a producer and significantly improving the reservoir surveillance frequency. The installation of a PDHMS, however, entails some risk and resource use; it consists of placing an electronic measuring gauge at significant depth below the ground and connecting the gauge to recording equipment through an electrical cable or fiber optics attached to the well pipe. Therefore, the application of cableless technology can further improve well intervention safety and optimize resource utilization.

In addition, the new technology provides a less costly competitor to the routine slick line intervention and serves as a supplement to the PDHMS. The trial test of this technology was conducted over three onshore and offshore wells with different configurations encompassing both single well and multi-well platforms. The pressure data was continuously transmitted from the bottom-hole to the surface every three hours with no interruption. Moreover, the data showed good pressure response at different rates, thereby exhibiting no rate limitation. Based on the trial assessment, it was obvious that this technology would bring vast benefits to the industry. It was also estimated that the battery life, in the worst-case scenario, could easily last up to three years. The proposed initial stage involves the retrofitting of through-tubing cableless gauge systems into existing monitoring and production wells in the field to enable real-time reservoir surveillance, optimize the annual barge visits and activities, and improve the field requirement's annual efficiency.

Technology Utilization Progression

The industry is tackling problems through the use of exhilarating new technologies – from mega-cell reservoir simulation to implementation of fully integrated intelligent fields, geosteering and laser drilling – that offer a wide range of interdisciplinary domains for development and progression[2]. The quest for technological advancement in Saudi Aramco is across the board and reaches beyond that of any other national and international oil company. That is because Saudi Aramco

Item	Electronic	Cableless	PDHMS*
Cost (3 years)	$192,000	$96,000	$450,000
Cost (6 years)	$384,000	$120,000	$450,000
(45 years)		$432,000	$450,000
Barge visits in 3 years	12	1	N/A
Operational Complexity	Wireline retrievable	Wireline retrievable	Requires a rig
Replacement Flexibility	Requires a boat	Requires a boat	Requires a rig
Application	No limitation	No limitation	Limited

Table 1. Comparison of technology for measuring downhole pressure.

has different needs compared to most other companies. Most are using new technologies to increase production, cut costs and accelerate recovery as much as possible in a drive to maximize value for their shareholders. These are goals of Saudi Aramco as well with the important exception of accelerating recovery. Saudi Aramco instead strives to reliably sustain production levels and maximize recoverable resources. The transformation of well intervention technology therefore is recognized as a fundamental core business practice, needed to simplify operation logistics, optimize resources and enhance safety. The application of new technology is also needed to cope with the increasing number of wells, growing field maturity and the new field increments and developments. Pressure and temperature surveys usually represent more than 60% of the yearly well intervention and data acquisition conducted, of which 80% are completed utilizing jack-up barges and floaters, while the remaining surveys occur via a PDHMS in the case of offshore fields. Therefore, it is vital not only to look for an integrated technology deployment but also to look for alternatives.

The development of static bottom-hole pressure (SBHP) measurement tools went through three progressions. Old and new methods of attaining pressure readings are discussed to establish a tangible comparison between normal surveys, use of a PDHMS and use of cableless gauges; Table 1 exhibits the differences between the subject progressions. Amerada gauges (Amerada was created by the Geophysical Research Corporation) were initially utilized, with an average of about 20% of validated data erroneous. Amerada also required 10 gauges per well. Electronic gauges were introduced at a later stage and reduced the error rate drastically to about 1% by running a single recording gauge per each run instead of 10 in the case of Amerada. The progression to PDHMS design and data utilization was associated with a transformational advance in that it allowed the attaining of real-time data. PDHMSs were widely utilized in Saudi Aramco as part of intelligent field activities. Usually, two sensors are installed by a rig to calculate the gradient and thereby estimate the reservoir pressure. In the case of a failure, a rig has to replace the sensors. The PDHMSs are also an integral part of artificially lifted wells where pressure is measured through the electrical submersible pump (ESP) sensors. In the case of a single gauge, an "extrapolation to datum" empirical study was performed to estimate the reservoir pressure by extrapolation from a single downhole measurement of pressure acquired using one PDHMS, one cableless gauge or one ESP sensor.

SBHP surveys are routine activities conducted by well services vessels using electronic gauges separately in each well. This procedure entails rigging up the well with safety equipment, a lubricator and the pressure gauge. The gauge is then run to roughly 300 ft above the end of tubing (EOT). It stops there for five minutes to record the pressure (gradient stop). The gauge is then lowered even further, to approximately 100 ft above EOT, to take the bottom stop reading. The difference between the gradient stop and the bottom stop readings is used to generate the gradient for the subject well in psi/ft, which in turn is used to extrapolate the bottom stop reading to the middle of perforation depth, commonly referred to as the midpoint. Pressure at midpoint is then referenced to the original oil-water contact, based upon which either a pure oil gradient or a pure water gradient is used to extrapolate the midpoint pressure further to the datum depth. Due to the increasing number of wells and the growing installation of PDHMSs and other intelligent field equipment, it was time to investigate other methods that can deliver this pressure measurement with engagement of the least amount of resources. This new urgency and the high rig operation cost to install and replace a PDHMS have inspired the search for alternative technology to improve the pressure survey operation and overcome obstacles. In Table 1, costs have been rounded up and should be considered as estimates. The following major assumptions were made in calculating costs:

- The PDHMS gauge and cable cost is around $350,000.
- Installation of a PDHMS takes about two rig days at about $50,000/day.

Fig. 1. Physical appearance of tool prior to installation.

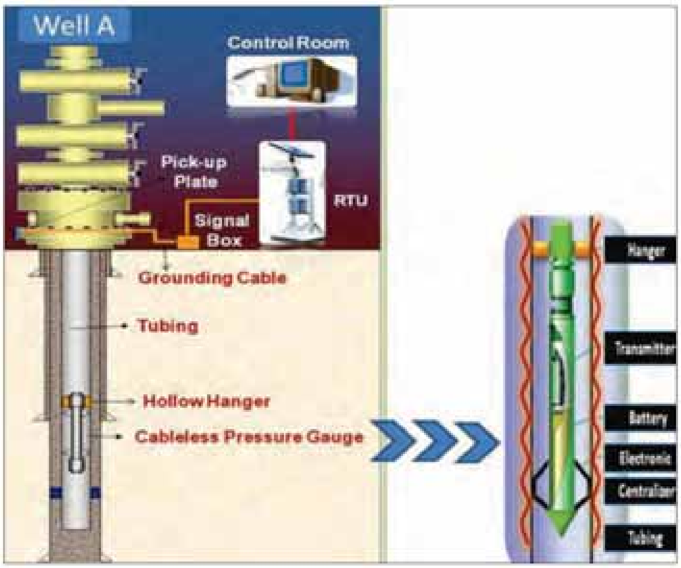


Fig. 2. Conceptual drawing exhibiting the major component of the cableless gauge system.

• Each barge visit costs around $16,000.
• The three gauge types never fail or break, and require no maintenance except a battery change for the cableless gauge every 3 years at $8,000.
• Wells with a PDHMS are never worked over (eliminating the cost of new cable after a workover).
• Pressure surveys are required four times a year at a minimum.

Cost was therefore another factor in the trial test of the last evolvement of the SBHP measurement tool: the cableless pressure gauge. The cableless gauge also tackles several Health, Safety, Security and Environmental (HSSE) concerns, and improves logistics and utilization of company resources. Because it is deployed riglessly, it complements the PDHMS in the case of malfunctions. Moreover, through the empirical study, the unit can be deployed at any depth. This telemetry technology package includes a downhole gauge, hanger, surface receiver, surface panel and Supervisory Control and Data Acquisition System (SCADA) communication equipment, all of which make the components very similar to those for the conventional PDHMS.

Cableless Pressure Gauge Technology

The cableless pressure gauge is a permanent wireline retrievable gauge with a long-life battery that is hung safely inside the production tubing. Figure 1 shows the tool prior to installation. Figure 2 is a representation of the unit and how it is stationed inside the hole. It transmits pressure and temperature data constantly by sending coded EM waves. The system transmits these low frequency EM waves from downhole to the surface using the well's metallic construction as the transmission medium. The system can be deployed via either wireline or coiled tubing into existing wells as a retrofit device, or it can be alternatively deployed in a mandrel configuration as part of the well completion.

The gauge can be installed in the well tubing conduit, production casing or liner using the XN nipple profile and gauge hanger with no flow restriction. Cableless pressure gauges are installed in the wellbore without the need for a rig. Continuous real-time pressure and temperature data is then transmitted from downhole to the surface without a direct cable connection in the well. The big safety advantage of this gauge is that it can be set in the hole using wireline tools and left there for about three years, which improves platform safety and eventually optimizes the resources utilization. System component requirements are a gauge, receiver, signal pickup on the well, ground anode, power for the receiver (solar, portable battery or main connection) and a SCADA data interface.

Deployment Procedures

Prior to addressing the scope of work and strategy behind the trial test, the major deployment steps are described here. Fundamentally, the cableless gauge is rigged up with a slick line, then a hollow gauge hanger is set inside the well and the line is rigged down.

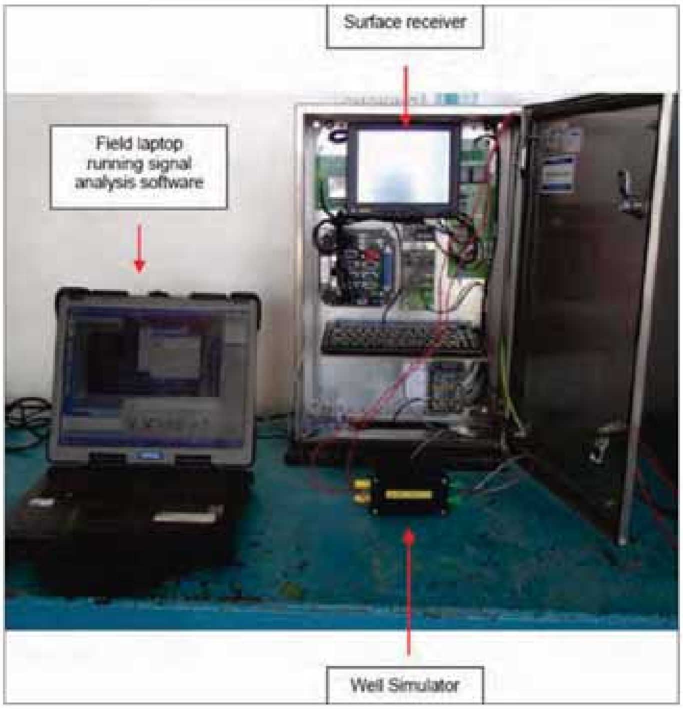


Fig. 3. The cableless system transmitting inside 4½‰ tubing.

- Install the pole for the receiver and solar panels.
- Dig a trench for the cables and anode.
- Attach the signal pickup on the well.
- Install the ground anode.
- Run cables from the well and anode to the receiver.
- Mount the receiver and terminate the cables.
- Rig up the slick line equipment, pressure control equipment and drift well.
- Program and test the gauge at the surface.
- Assemble the gauge vertically into the lubricator.
- Run in hole with the gauge and test the gauge by analyzing data on the receiver.
- Set the hanger in the nipple profile and the gauge inside the well.
- Rig down the slick line equipment.
- Configure the receiver at the surface.
- Connect the receiver to the SCADA system to transmit data.

The trial period was oriented to achieve two scopes of activity: (1) an initial trial lasting for about 100 days to be completed in two stages, and (2) the reliability testing. Stage one of the initial trial lasted for around 10 days. The first part of the stage one objective was to assure the wireless gauge communication, and the quality and frequency of the pressure and temperature data. The second part of the stage one objective was to determine the optimal tool settings required for robust wireless communications from downhole to the surface. Stage two lasted for roughly 90 days. The stage two objective was to program the wireless gauge with the optimal settings as defined in stage one. This was achieved by incorporating a transmission schedule to simulate a two-year or longer data acquisition program, mainly to prove that communication can still be acquired after a period of one year. The second tier of the planned series of channel tests enabled the determination of performance with shorter battery configurations and tool communication in the liner vs. tubing. Figure 3 shows the tool communicating inside the 4½" tubing.

Trial Test Objectives

The cableless gauge was installed on an onshore well, Well-A, by Saudi Aramco, deployed via wireline inside the production tubing. The gauge effectively transmitted temperature and pressure electromagnetically through the tubing steel to the surface, then to the control room of a gas-oil separation plant (GOSP). The success of this installation encouraged further evaluation of the technology in the same well, extending the testing period by 90 days to verify the battery run life, gauge reliability and centralizer contactability. The last is necessary to ensure a better signal and gauge energy savings. The exceptional first trial results supported conducting another trial test at an offshore well. Well-B was selected to test this technology in an offshore environment and with a different well configuration. A third trial was

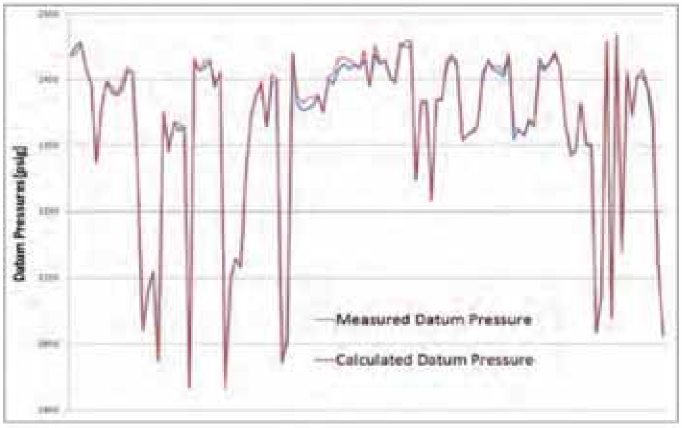


Fig. 4. Pressure from different methods overlaid on the same plot.

conducted of a cableless gauge installed in Well-C, an observation well, which called for the utilization of a temporary remote terminal unit and solar panel.

The trial objectives of this first time deployment of cableless technology were to test:

- The signal strength received at the surface.
- The running, setting and retrieving of the tool.
- The gauge accuracy compared to the conventional methodology.
- The surface devices' compatibility and data transmission through the existing SCADA system.
- The matching accuracy of the gauge memory data and the surface captured data.
- Ideas for the best future equipment modifications and the way forward.

An Extrapolation to Datum Empirical Study

This section of the article provides a solution for obtaining the datum pressure from solely one sensor installed in a well, as is the case with cableless gauges, wells equipped with either only one PDHMS or two PDHMSs where one is malfunctioning, and ESP wells during the shut-in period. To prove the applicability of the proposed technique, which uses mixed fluid gradients for datum pressure estimation, over 100 wells were studied to estimate the right pressure gradient that can be utilized to extrapolate the downhole pressure measurement to datum pressure[3]. The datum pressure extrapolated using this method was compared to the datum pressure extrapolated using a fluid gradient acquired through the conventional two stops of the regular gauges conveyed by slick line. The study also used linear programming to find best-fit gradients. A sensitivity analysis was conducted of different gradients and found insignificant differences.

No change in procedure was considered for acquiring SBHP values from ESP sensors where those were installed in the field. This is mainly because these pumps have two pressure sensors, one at the multisensor assembly (considered to be measuring the intake pressure) and one at the discharge point. These intake and discharge pressure sensors are connected to a SCADA system, and their measurements can be read at the engineer's desktop using the productivity index (PI) data historian system. The pressure data collected at a static condition revealed that these pressures cannot be depended on to form a representative gradient. Most calculated gradients using ESP sensors were less than expected and some were extremely erroneous. Preliminary analysis indicates that this is largely due to a suspected imprecise reading of the discharge pressure because it is masked by different components of the ESP, whereas pressure from the multisensor assembly is deemed more reliable due to its location in the lower section of the pump, leading to an accurate gauging of the formation pressure. This unreliability in calculated gradients triggered the need to start a comparison study that would look back at all SBHP surveys conducted using the conventional electronic gauges with a gradient calculated from two pressure stops; then back calculate the datum pressure using the water cut of each well at the time of the SBHP survey; and finally compare the two readings. The exercise was done for over 300 wells. The practice was then narrowed down to the selection of 100 wells based on:

- Reservoir completion.
- Availability of a valid water cut value at the time of the survey.
- Matching reproduced datum pressure to the originally calculated datum.

Linear programming of ExcelTM was used here to iterate

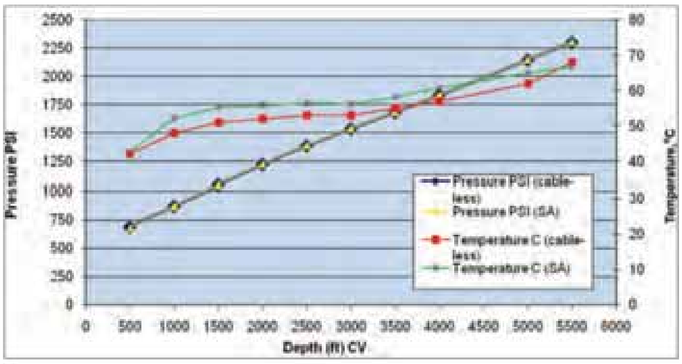


Fig. 5. Pressure and temperature readings of the Saudi Aramco wireline gauge compared to those of the cableless gauge.

for the best solution by utilizing the Solver Add-in. In the solver equation, the objective was set to minimize the sum of the absolute values of the entire difference between datum pressures in both cases. The iteration values were oil and water gradients, and they were restricted by minimum values of 0.361 psi/ft and 0.461 psi/ft, respectively. The optimum values came up to be equal to the minimum set values. Results were over- whelmingly encouraging. Figure 4 includes the final datum (measured/calculated) pressure using the wireline method and assumed gradient. The majority of the data difference falls within the +/- 5 psi. The results have opened doors for a variety of applications, such as estimating pressure from ESP wells during shut-in, estimating pressure from a PDHMS if one gauge malfunctions, and in the future for estimating pressure from the cabeless gauges if only one gauge is installed in a given well.

Factors Affecting Cableless Technology Performance

Several factors can affect the performance of this cableless technology; these all combine to ultimately define the performance envelope of the system. The factors include:

1. Well resistivity. The gauge utilizes the available steel of the well structure as a transmission medium for the EM signal. Therefore any formation that is in contact with the well structure that also has the ability to conduct electrical energy can have an effect on the system performance, which needs to be accounted for.

2. Setting depth. The greater the transmission distance, the more energy is required to transmit the EM signals – especially when the formation resistivity of the well is also taken into account. The system uses an "energy per bit" concept, meaning the more energy needed to transmit, the fewer readings can be provided.

3. Tail ratio. This is the ratio of the measured distance from the system to the cased depth of the well and the measured distance from the system to the surface. Generally a tail ratio of 1:10 is desirable.

4. Downhole power availability. Since there is no wire to power the downhole components from the surface, the wireless product must be able to store energy downhole. Because only a finite energy source is currently available (in the form of lithium batteries), this energy source has to be managed in such a way as to give the optimal number of data transmissions over a given time period at a given depth.

5. Condition of tubulars. For the system to function optimally, it is necessary to have a good electrical continuity between the system centralizers and the tubing/casing. Therefore, if the wellbore is badly corroded or is covered in scale, the poor continuity between the system and the tubing/casing could affect system performance. Likewise, if the tubing or casing is parted, this will cause poor electrical continuity, thereby affecting the system performance.

6. Surface earthing (i.e., grounding). The downhole data is transmitted to the surface utilizing EM energy. Consequently, to successfully decode the data, it is necessary to have an earth reference available where the decoding is taking place.

Results and Analysis

The two objectives – (1) receiving strong signals at the surface, and (2) proving the simplicity of running and retrieving the gauge – were achieved during the first attempt on the onshore well, Well-A, as the cableless assembly was run and easily recovered by the wireline. The test indicated strong wave propagation, and data

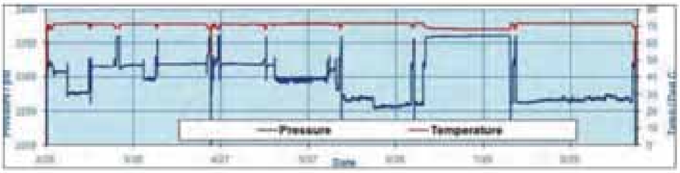


Fig. 6. Pressure and temperature readings for a certain period of the extended trial of the cableless gauge.

was successfully transmitted from the bottom-hole and recorded at the surface with no interruption for four days. For data accuracy verification, Well-A's trial test included running a high resolution electronic wireline gauge on a different day as a base reference to compare both gauge survey results and to evaluate the new cableless technology data's accuracy. The comparison showed that the high resolution electronic wireline gauge and the cableless gauge had an excellent pressure data match. Additionally, a further compatibility test was performed with the surface equipment, and the cableless technology was found to be fully well suited with Saudi Aramco's SCADA system as Well-A data was successfully configured and displayed at the offshore GOSP.

All shortfalls were captured, and lessons learned were applied in a second modified trial test procedure, designed and carried out on Well-B in an offshore environment and with a different well profile. Unlike Well-A, the high resolution electronic wireline gauge and the cableless gauge were run in tandem at Well-B to eliminate depth slippage effects and to provide similar evaluation conditions. The pressure data analysis for the Well-B trial test found an exact match at all depths of investigation for both gauges, Fig. 5. It was evident that the reading variance was further reduced to one decimal when the two gauges were run in tandem. The trial also showed that the cableless gauge is not affected by depth nor flow regimes. Therefore, a decision was made to continue hanging a gauge in Well-A for 90 days to further assess the gauge durability, battery lifetime and hanging tool compatibility. Figure 6 shows the results during this period. The gauge was programmed to send data to the surface every three hours so as to prove that the gauge can remain in the hole and keep transmitting pressure data accurately as long as possible. The last test was flow rate testing of Well-A with the tool hung in hole, which confirmed the well's ability to produce as much as 8,000+ barrels of fluid per day (MBFD) through the hollow hanger with no restriction. Generally, data analysis confirmed that the cableless gauge readings matched those of the high resolution wireline electronic ones. A perfect match was found for pressure, and an engineering acceptable match was achieved for temperature. The cableless memory gauge data was also compared with the data received at the surface and found to be equal, assuring gauge competitiveness: its sending of strong signals is independent of the gauge depth and flow regime, and possibly time, as it is being tested[4].

In brief, the evaluation of the cableless technology was carefully designed to include current and future implications. The initial trial test of seven days was successfully completed and all objectives were met. Also, the ability to produce the well with no restriction after the gauge was installed was confirmed as the well continued producing at full potential. The ability to conduct a PI test at any desired time to evaluate well performance was also tested. It took about six hours to reach the stabilized PI. The well was then shut-in for almost 20 hours and the PI was recoded. Afterward, another PI test was conducted to assess the first PI and confirm its accuracy. The centralizer was proven to be capable of reliably transmitting high signal strength and quality data to the surface. In Fig. 7, the signature of the bottom-hole pressure data in blue shows a matching trend with surface wellhead pressure in red, recorded via the SCADA system. The results attained from the cableless gauge exactly match those attained from the conventional SBHP measurement method.

The results showed that the gauge delivered good pressure and temperature readings to the surface when compared to historical surveys on the subject well. The cableless gauge had good communication at all depth points in the well. The preliminary results indicate that the gauge can communicate pressure and temperature readings to surface for more than two years. Understanding the well's data frequency requirements is essential to enable proper planning of the gauge duration. For instance, for wells that require data only every two weeks, the gauge can be programmed to communicate pressure and temperature up to five years. The gauge reliability and accuracy was tested for nine months. This extended trial

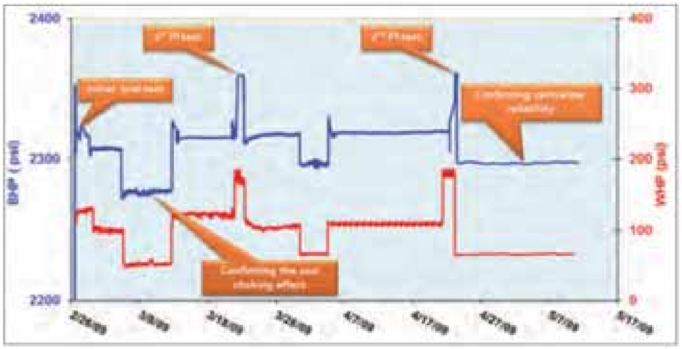


Fig. 7. Results of the analysis and tests conducted.

test showed continuous data transmission through steel pipe every three hours with good pressure response at different production rates. Overall, the trial test showed reliable data that are in excellent matching accuracy with data from the electronic gauge for both onshore and offshore wells.

Trial Test Assessment

The technology of the cableless pressure and temperature downhole gauge system was trial tested successfully as an alternate downhole monitoring tool that provides continuous real-time pressure and temperature data. The trial's goal was to test the credibility of the technology and its ability to reduce the routine well interventions for SBHP temperature, especially in an offshore environment. The trial was successful and was extended to test the unit reliability as well. This trial test was intended to show the technology's potential to improve well intervention safety and control costs in a harsh offshore environment. The technology can further help optimize resources and meet the annually increasing well services requirements. Currently, it has been extensively tested for longer periods in three different wells, onshore and offshore, including single well and multi-well platforms. The analyses of the first cableless trial test indicated excellent matching results with data from the wireline electronic pressure gauge. Saudi Aramco was the first in the Middle East to adapt such technology[2].

In summary, the three subject test wells have shown cableless data that is excellent in matching accuracy to data from the currently utilized electronic gauges, both onshore and offshore. In addition, the 9-month extended trial test showed continuous data transmission through the steel pipe every three hours with good pressure response at different production rates. Strong signals for pressure and temperature were received at the surface at all times, Fig. 8. The running/setting and retrieving of the tool was proven to be operationally simple and safe. The cableless gauge pressure and temperature data accuracy was found to match the data from conventional high resolution electronic gauge that is currently used for routine pressure and temperature surveys. The memory data vs. the surface captured data was compared and found to be perfectly matching. The surface equipment was function tested and found to be fully compatible with Saudi Aramco's SCADA system as data was successfully transmitted.

Lessons Learned

The main features and benefits of the cableless technology in this well monitoring application as well as the lessons learned can be summarized as follows:

- The technology can be retrofitted into an existing well to enable real-time downhole data acquisition with no cabled connection to the downhole gauge required.
- The ability to retrofit (install) a real-time data acquisition system means that current field operations involving the regular deployment of memory gauges from barges can be avoided.
- The flow restriction as a result of hanging the gauge can be easily minimized or eliminated by better modification of the hollow hanger to accommodate as high as 10 MBFD with no significant pressure drop.
- It was learned that a special wireline scratcher or a brush should be used for installations in old tubing to improve tool-to-tubing contact. Chemical cleaning can be an option.
- The best time for data collection was found to be from midnight until morning due to low boat traffic. Therefore, data receiving can be programmed during the first six hours of the day.
- Confirming the low level of noise with no anode installation is another step toward cost containment,

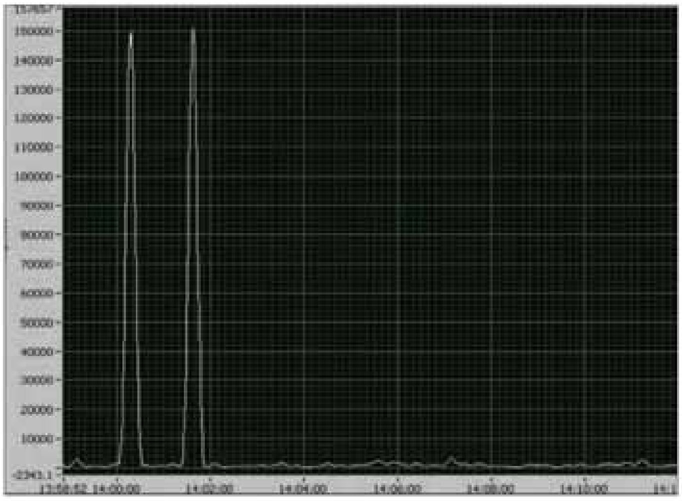


Fig. 8. Strong signal as received during the trial.

simplification of installation and installation space optimization. Grounding to a nearby well has proven to be effective toward installation cost reduction.

• Running and retrieving the gauge tools was proven to be operationally simple and safe. A modified centralizer is now recommended for better conductivity and operational flexibility.

• An EM signal means no requirement for feedthrough or penetrations at the plug or at the tubing hanger or Xmas tree.

• The EM telemetry is addressable, thereby enabling multiple installations in a single well for zonal reservoir monitoring purposes.

Conclusions

The downhole cableless pressure and temperature system has been successfully tested as an effective monitoring device with excellent results. The trial test was carried out on Well-A, Well-B and Well-C – selected to confirm technology operability in an extremely complex environment. The key objective of verifying the delivery of strong signals to the surface was certainly achieved despite the gauge depth and flow regime. This system was also proven to be compatible with Saudi Aramco's SCADA system and showed superior data matching when compared to data from the wireline high resolution gauge. It was affirmed that this is a potential technology that can simplify logistics compared to the conventional pressure/temperature surveys and PDHMS system, with a great compelling argument for its application to single well platforms, freestanding conductors and tripod platforms that mostly reduce offshore barge efficiency.

• This technology would be best in wells associated with an offshore and/or harsh environment, producing a dramatic reduction in data acquisition visits to such locations and therefore providing room for better resource utilization optimization.

• Old wells that have been installed with a PDHMS, if such wells are available, seem to be the most favorable options for such an application.

• The technology complements the PDHMS where a rig is required for installation. Cableless gauges can be deployed with or without a rig, offering huge cost savings and assurance of data attainment in real time in the case of PDHMS failure. In other words, the new technology proved to be a cost containment competitor with the routine slick line intervention and a supplement to the PDHMS.

• The deployment of cableless gauges is associated with fewer barge visits, minimizing human exposure and increasing efficiency, especially in surveying key offshore wells that are normally surveyed four times a year. It has a huge potential for simplifying logistics compared to the conventional pressure and temperature surveys and PDHMS, with a possible particular relevance for single well platforms, free-standing conductors and tripod platforms to minimize visit requirements.

• The deployment of this technology has proven to enhance data acquisition, add economic benefits, and help increase the well services vessel's efficiency, improve operation safety and simplify logistics.

• The continuously attainable datum pressure data is essential to monitor any abnormal well behavior.

• Saudi Aramco will continue to widely utilize such technologies with due diligence towards capturing the lessons learned that will facilitate the way forward for this kind of application to be used in other Saudi Arabian fields, especially those (1) offshore, (2) in a harsh environment, (3) within close proximity to populated residential areas, and (4) having minimal intelligent field infrastructure.

- The big safety advantage of this gauge is that it can be set in the hole using wireline tools and left for three years. This reduces the frequent barge visits from 12 times to only one time every three years, which results in a significant safety improvement on single well platforms and in well services resource optimization.
- Categorizing wells based upon the frequency of data acquisition requirements is important to manage the gauge duration.
- Broad utilization of this technology as appropriate helps in mitigating intervention risks, improving offshore traffic safety through minimizing visits, optimizing resource utilization and reducing operating expenditure.

Acknowledgements

The authors would like to thank Saudi Aramco management for their permission to present and publish this article. Special thanks go to Hassan B. Al-Qahtani, Nami A. Al-Amri and Eddy Sarhan A. Azizi of Saudi Aramco for their contributions and insightful feedback.

This article was presented at the SPE Intelligent Energy International Conference and Exhibition, Utrecht, The Netherlands, March 27-29, 2012.

References

1. Champion, B.P.: "A Novel Wireless Solution to Address Uncertainties in Reservoir Connectivity," SPE paper 102547, presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, September 24-27, 2006.

2. Al-Yateem, K.S., Aminzadeh, F. and Dasgupta, S.N.: "The Implication of Using State-of-the-Art Technologies in Oil Fields," Saudi Aramco Journal of Technology, Spring 2011 (additional online content).

3. "Cableless Technology – First Trial Test Updates," Saudi Aramco internal document, Northern Area Production Engineering & Well Services Department (NAPE&WSD).

4. Al-Amri, N.: "Extrapolation to Datum Pressure from a Single Downhole Measurement for SFNY Reservoir," Saudi Aramco internal document, Northern Area Production Engineering & Well Services Department (NAPE&WSD).

Biographies

Karam S. Al-Yateem started his professional career with Saudi Aramco immediately after graduation. Since then, he has completed several assignments in various onshore and offshore field locations. Karam has worked as a Reservoir Engineer, Field Engineer, Testing Engineer and Production Engineer.

He has authored or coauthored several technical papers. Karam is an active Society of Petroleum Engineers (SPE) member and currently serves as a committee member of the International Production & Operation committee and the Saudi Arabia Section of SPE.

In 2005, Karam received his B.S. degree in Petroleum Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. In 2010, he received his M.S. degree from the University of Southern California (USC), Los Angeles, CA, in Petroleum Engineering, specializing in Smart Oil Field Technologies and Management. In 2012, Karam successfully received SPE credentials.

Khalid I. Al-Omairen's career has spanned over three decades with Saudi Aramco, where he has become a domain expert in Production & Operation (P&O), especially in offshore operations. He has had several developmental assignments in a number of onshore and offshore fields. This includes division head of gas plants, gas-oil separation complexes and Well Services barges, with an extensive exposure to well control, asset integrity and processes evolution. Khalid has a unique passion to create a work culture that is committed to continuous simplification of routine tasks through the adoption of new technologies and process improvements.

He has authored and coauthored several technical papers and written numerous leadership articles for industry magazines.

He received his B.S. degree in Petroleum Engineering from the University of Louisiana, Lafayette, LA.

THE UPSTREAM
INNOVATION SPARK
Lighting our Way to a Better Tomorrow

ATS&E
ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION

SPE-SAS ATS&E 2013
Technical Sessions

Session 1 **Monday, May 20** **Session Room-A**

Petrophysics And Formation Evaluation (1) **08:00 - 09:45**

Session Chairpersons: Nedhal Musharfi, Saudi Aramco
Ali Belowi, Saudi Aramco

8:00-8:25	**Keynote Speaker:** Robert Kuchinski, Weatherford	
8:25-8:45	SPE-SAS 582	Core Acquisition from a New Sidewall Rotary Coring Tool: Overview and Experience from Saudi Arabia *Ahmed Al-Salim, Saudi Aramco; Aamir Siddiqui, Wafi Al-Algam, Baker Hughes*
8:45-9:05	SPE-SAS 619	Field Evaluation of LWD Resistivity Logs in Highly Deviated and Horizontal Wells in Saudi Arabia *Pedro Anguiano-Rojas, Doug Seifert, Saudi Aramco; Michael Bittar, Sami Eyuboglu, Yumei Tang , Burkay Donderici, Haliburton*
9:05-9:25	SPE-SAS 599	Fluid Identification in Complex Clastic Reservoirs using NMR 2D Maps : A case study from Saudi Arabia *Yacine Meridji,Gabor Hursan, Saudi Aramco*
	*SPE-SAS-711	Innovative Spectral Gamma Ray Complements Real Time Advanced Mud Logging Characterization While Drilling: *Alberto Marsala, Sauid Aramco; Farouk Kimour, Schlumberger*

Session 2 **Monday, May 20** **Session Room-B**

Production Operations (1) **08:00 - 09:20**

Session Chairpersons: Nahr Abulhamayel, Saudi Aramco
Nashi Otaibi, Saudi Aramco

8:00-8:20	SPE-SAS 719	The Roadmap to Evaluate & Mitigate High Discharge Pressures at GOSP Water Disposal Systems–The Surface and Sub-surface Solutions: *Othman Alqasim, Khalaf Alotaibi, Loay Mashabi, Ramsey White, Salem Alnaimi, Saudi Aramco*
8:20-8:40	SPE-SAS 647	Comprehensive Diagnostics and Water Shutoff in Openhole and Cased Hole Carbonate Horizontal Wells *Shauket Malik, Hussain Al-Shabibi, Murat Zeybek, Schlumberger; Nawawi Ahmad ,Saudi Aramco*
8:40-9:00	SPE-SAS 638	Using Slim-Hole Pulsed Transient Eddy Current Tool for Through Tubing Casing Corrosion Evaluation *Jassim Almulla, Saudi Aramco*
8:00-8:25	SPE-SAS 577	Systematic Approach Significantly Reduced Wet Gas Venturi Metering Inaccuracies in Saudi Arabian Gas Producers *Jairo Leal Jauregui , Mohammad Al-Dhamen, Ruben Villegas, Simeon Bolarinwa, Aqeel Awadh, Saudi Aramco*
	*SPE-SAS 576	Downhole Corrosion Monitoring: An Overview *Yahya Al-Janabi, Saudi Aramco*
	*SPE-SAS 707	I-field benefits and operational challenges *Mohammed Al-Bukhdaim, Mohammed Al-Omran, Saudi Aramco*

Session 3 | Monday, May 20 | Session Room-A

Well Stimulation And Productivity Enhancement (1) | 10:00 - 11.45

Session Chairpersons: Zillur Rahim, Saudi Aramco
Ataur Malik, Sauid Aramco

10:00-10:25	**Keynote Speaker:** Christopher Fredd, Schlumberger	
10:25-10:45	SPE-SAS 693	Hydraulic Fracture Geometry evaluation using proppant detection – Experiences in Saudi Arabia *Kirk Bartko, Ahmed Salim, Saudi Aramco; Daniel Kalinin,Pablo Saldungaray , Schlumberger; Pedro Saldungaray, Carbo Ceramics*
10:45-11:05	SPE-SAS 627	Wellbore Asphaltene Cleanout Using A New Solvent Formulation In A Horizontal Openhole Oil Producer In Carbonate Reservoir *Shatwi Al-Qahtani, Shoaib Murtaza, Saudi Aramco*
11:05-11:25	SPE-SAS 662	Benchmarking RPMs Performance to Reduce Water-Oil Ratio of Produced Fluids from Carbonate Formations *Ayman Al-Nakhli, Ghaithan Al-Muntasheri, Abdullah Al-Harith, Salem Balharth, Saudi Aramco*
11:25-11:45	SPE-SAS-731	A Novel Clay Control Approach in Water-Sensitive Sandstone Gas Reservoir of Saudi Arabia during Proppant Fracture Treatment *Ataur Malik, Nejla Senturk, Saudi Aramco*
	*SPE-SAS-575	Hydrolysis Effect on Properties of a New Kind of Viscoelastic Surfactant-based Acid and Damage Caused by its Hydrolysis Products *Zhenhua He, Texas A&M University*
	*SPE-SAS-562	On the Origins of Multiple Species of Iron Sulfide Scales and Iron Products in Acid Gas Wells *Jack Lynn, Saudi Aramco*

Session 4 | **Monday, May 20** | **Session Room-B**

Drilling Operations (1) **09:30-11:10**

Session Chairpersons: Khalifah Amri, Saudi Aramco
Fahad Mulaik, Saudi Aramco

9:30-9:50	**Keynote Speaker:** Ahmad Ashri, Baker Hughes	
9:50-10:10	SPE-SAS 601	A Safe and Efficient approach to 3-5/8" Coiled Tubing Re-entry Drilling in Deep Gas applications in Saudi Arabia *Malik Al-Humood, Shaker Al-khamees, Khalifah Al-Amri, Saudi Aramco; Pat Cain, Mohammed Al-Herz, Luis Fuenmayor, Schlumberger*
10:10-10:30	SPE-SAS 598	Successful Introduction of High Build Rate Rotary Steerable System *Luis Fuenmayor, Sukesh Ganda , Schlumberger*
10:30-10:50	SPE-SAS 579	Advanced Bottom-hole Assembly Design and Motor Technology Extends Reach and Optimizes Well Placement *Mohammed Al-Madan, Mohammad Al-Hudaithi, Saudi Aramco; Ali Al Dabyah, Fadi Toutoungy, Jahad Aldawood, Baker Hughes*
10:50-11:10	SPE-SAS-646	A Case Study of Drilling Across High Rock Stresses and Reactive Shale Formations *Gilberto Segovia, Hassan Sarrani, Zaki Baggal, Saudi Aramco; Rafael Pino, Baker Hughes*
	*SPE-SAS-718	Innovative Deployment Risk Management Technique Provides Solutions to Wireline Logging Deployment in Saudi Arabia *Ahmed Abbas, Baker Hughes*
	*SPE-SAS-600	Fit for Purpose Underbalanced Coil Tubing Surface Equipment Permits Safe Drilling of High H_2S Horizontal Wells in Saudi Arabia *Mohammad Al-Ali, Khalifah Al-Amri, Shaker Al-Khamees, Saudi Aramco; Ayman Marei, Weaterford*

11:15-12:30	**Keynote Luncheon Speaker:** Ashok Belani, Chief Technology Officer, Schlumberger
	Lunch & Prayer Break
	Luncheon Generously Sponsored by Schlumberger

Session 5 | Monday, May 20 | Session Room-A

Reservoir Engineering And Management (1) 12:35-14:10

Session Chairpersons: Ismail Buhidma , Saudi Aramco
Ahmed Hutheli, Saudi Aramco

12:35-13:00	**Keynote Speaker:** Jalal Khazanehdari, Schlumberger	
13:00-13:20	SPE-SAS 605	Well Test Planning for First Deepwater High Pressure, High Temperature well in Saudi Arabia *Vikash Kumar, Hudson Lemes, Hisham Al-Bokhari, Wasim Azem, Schlumberger*
13:20-13:30	SPE-SAS 721	Development of Thin/Tight layers in a Giant reservoir Using Emerging Technology *Hammam AlGhamdi, Soha El-Hayek, Ahmed Alhuthali, Saudi Aramco*
13:30-13:50	SPE-SAS 694	First Successful Application of Limited Entry Multi-stage Matrix Acidizing in Saudi Aramco's Deep Gas Development Program – A Case History *Mahbub Ahmed, Hamoud Anazi, Ali Habbtar, Bandar Malki, Zillur Rahim, Saudi Aramco*
13:50-14:10	SPE-SAS-700	Holistic Approach Toward Optimum Optimization of MRC Wells *Feras Rowaihy, Saudi Aramco*
	*SPE-SAS-703	Systematic Assessment of Reservoir and Well Properties to Evaluate Gas Potential and Optimize Productivity – Field Example *Khaled Faleh, Zillur Rahim, Mustafa Basri, Rabah Mesdour, Saudi Aramco*
	*SPE-SAS-698	Well Performance Analysis for Deep High Pressure and High Rate Gas Fields in Saudi Arabia, Field Case Study *Farrukh Moid, Abdulrahman AlNutaifi, Mustafa Basri, Abdullah Utaibi, Saudi Aramco*
	*SPE-SAS-593	Strategic Development of Deep Gas Sandstone Reservoir in Saudi Arabia *Mohammad Al-Dhamen, Meftah Tiss, Saudi Aramco*

Session 6 **Monday, May 20** **Session Room-B**

Reservoir Characterization & Geophysics 12.35 - 13:55

Session Chairpersons: Nezar Talha, Saudi Aramco
Mohammed Khalifa, Saudi Aramco

12:55-13:15	SPE-SAS 684	High Resolution Electrical Imaging While Drilling Enables Accurate Well Placement in Carbonate Reservoirs *Kamran Khan, Derick Zurcher, Baker Hughes; Richard Palmer, Saudi Aramco*
13:15-13:35	SPE-SAS 664	Low Frequencies Matter *Peter Pecholcs, Saudi Aramco; Victor Aarre, WesternGeco*
13:35-13:55	SPE-SAS 555	Fault Detection and Characterization Using A 3D Multidirectional Sobel Filter *Saleh Al-Dossary,Saudi Aramco;Khalid Al-Garni,Saudi Aramco*
	SPE-SAS-665	Diffraction Imaging of Sediment Drifts in the Canterbury Basin, New Zealand *Salah Al-Hadab, Saudi Aramco*
	*SPE-SAS-609	Fluid Capacity of Gas Reservoir with Derivation from Sonic Scanner and Dual-Density Log for Initial Study *Chin Loong Seah, Schlumberger*
	*SPE-SAS-617	Improved Characterization of a Permian Aeolian Gas Reservoir using New Seismic Acquisition Technology *Ali Al-Gawas, Brian Wallick, Saudi Aramco*

Session 7 — Monday, May 20 — Session Room-A

New Emerging Technologies In Upstream Oil & Gas (1) — 14.25 - 15:50

Session Chairpersons: Suresh Jacob, Saudi Aramco
Khalid Naimi, Saudi Aramco

14:25-14:50	**Keynote Speaker:** Brandon Least, Halliburton	
14:50-15:10	SPE-SAS 686	Real Time Data: An Automatic and Dynamic Software Structure for Validating Massive Data Streams *Danah AlSana, Majed Awajy, Abdel Abitrabi Ballan, Abdullah Bar, Faisal Aboudi, Muhammad Ehsan, Saudi Aramco*
15:10-15:30	SPE-SAS 580	Safe Operation, Time Saving and Maximizing the Well Production in New Generation ICD System Installation *Mohammed Al-Madan, Saudi Aramco; Kousha Gohari, Roberto Vicario, Paolo Gavioli, Baker Hughes*
15:30-15:50	SPE-SAS-678	Innovative Three Phase Production Logging Operation Avails Accurate Surface Flow Rates and Other Essential Parameters *Abdulkarim Al-Mubarak, Karam Al-Yateem, Majed Al-Omrani, Saudi Aramco*

Session 8 **Monday, May 20** **Session Room-B**

Drilling Operations (2) 14.10 - 15:40

Session Chairpersons: Mohamed Khalil, Saudi Aramco
Bandar Malki, Saudi Aramco

14:10-14:30	SPE-SAS 715	Evaluation of Properties of Nano Particles Admixed Oil Well Cement under HTHP Conditions *Mobeen Murtaza, Abdulaziz Al Majed, King Fahd University of Petroleum and Minerals*
14:30-14:50	SPE-SAS 623	Successful Introduction of a New Wired CTD Drilling System *Malik Humood, Saudi Aramco; Luis Fuenmayor, Schlumberger*
14:50-15:20	SPE-SAS 629	Expanding the Drilling Envelope to New Horizons in Saudi Aramco Shaybah Operations *Ahmed Osman, Chandresh Verma, Dony Kuncahyo, Nadim Mikati, Schlumberger; Rami Saleh, Saudi Aramco*
15:20-15:40	SPE-SAS-639	Coring Optimization: Wireline Core Recovery in Saudi Arabia Using Standard Drill Pipe *Assaad Mohanna, National Oilwell Varco*
	*SPE-SAS-613	First Time a Floated Liner Run a Balanced Hydraulic Cylinder Liner Hanger in the Middle East *Abdullah Mohamed, Abdullah AlJamaan, Baker Hughes; Emmanuel Nwosu, Saudi Aramco*
	*SPE-SAS-652	Implementing Artificial Neural Networks and Support Vector Machines in Stuck Pipe Prediction *Islam Al-Baiyat, Saudi Aramco; Lloyd Heinze, Texas Tech University*

Session 9 Tuesday, May 21 Session Room-A

Reservoir Modeling & Simulation 08:00 - 09:30

Session Chairpersons: Tareq Zahrani, Saudi Aramco
Fatima Awami, Saudi Aramco

8:00-8:20	SPE-SAS 696	Predicting Conductivity Variances on Hydraulic Fracturing Treatments under High Stresses *Eduardo Pacheco, Amr Hassan, Eduardo Soriano, Halliburton*
8:20-8:50	SPE-SAS 590	A New Method to Predict Performance of Gas Condensate Reservoirs *Ali Al-Shawaf, Saudi Aramco; Mohan Kelkar, Mohammad Sharifi, The University of Tulsa*
8:50-9:10	SPE-SAS 724	Advanced Visualization for Reservoir Simulation *Badr Alharbi, Abdulaziz Al-Darrab, Osaid Hajjar, Ahmed Al-Zawawi, Khalid Al-Zamil, Saudi Aramco; Angela Myhre, Kongsberg*
9:10-9:30	SPE-SAS-654	Automatic Integration of Streamline Information in Finite Difference Simulator during Optimization to Enhance History Matching *Alan Siu, Ali Al-Turki, Ahmed Zawawi, Umar Al-Nahdi, Saudi Aramco*
	*SPE-SAS-558	Reducing Lateral Spacing Strategy: Impact on Hydrocarbon Recovery Using Giga-Cell Model *Hasan Nooruddin, Abdulaziz Nuaim, Mohammed Malki, Usuf Middya, Fatema Al-Awami, Saudi Aramco*
	*SPE-SAS-634	Complex Water Movement and its Impact on Reservoir Development Plans *Majed Al-Shammari, Mansour MohammedAli, Fatema Awami, Saudi Aramco*

Session 10 Tuesday, May 21 Session Room-B

Petrophysics And Formation Evaluation (2) 08:00 - 09:40

Session Chairpersons: Ahmed Muthana, Saudi Aramco
Ahmed Harbi, Saudi Aramco

8:00-8:20	SPE-SAS 608	Successful Application of a Novel Mobility Geosteering Technique in a Stratified Low-Permeability Carbonate Reservoir *Stig Lyngra, Salem Al-Suwaidi, Saudi Aramco; Iwan Roberts, Jihad Al-Hussain, Ihsan Pasaribu, Schlumberger*
8:20-8:50	SPE-SAS 543	New Insights into the Prediction of Capillary Pressure from Resistivity Measurements *Mohamed Mahmoud, King Fahd University of Petroleum & Minerals*
8:50-9:10	SPE-SAS 624	Characterization of Shale Gas Rocks Using Dielectric and Nuclear Magnetic Resonance *Khaled Hadj-Sassi, Mohammed Badri, Schlumberger; Anas Marzoug, Ahmed Al-Harbi, Saudi Aramco*
9:10-9:30	SPE-SAS-587	Frequency Dependent Magnetic Resonance Response of Heavy Crude Oils: Methods and Applications *Arjun Kurup, Henry Bachman, Andrea Valori, Martin Hurlimann, Lukasz Zielinski, Schlumberger; Jean-Pierre Korb, Ecole Polytechnique*
	*SPE-SAS-559	Electrical Properties of Carbonate Rocks during Drainage and Imbibition *Fabrice Pairoys, Ahmad Al-Zoukani, Schlumberger; Mark Ma, Ali Belowi, Saudi Aramco*
	*SPE-SAS-655	Heterogeneous Carbonate Reservoirs in Eastern Saudi Arabia: Case 1 – Mineralogy at Multiple Scales *Jimmy Ardila, Saudi Aramco*

Session 11 — Tuesday, May 21 — Session Room-A

Well Stimulation And Productivity Enhancement (2) — 9:40 - 11:20

Session Chairpersons: Rasim Rodoplu, Saudi Aramco
Daniel Kalinin, Schlumberger

9:40-10:00	SPE-SAS 668	A Successful Field Application of a New Chemical treatment in a Fluid Blocked well in Saudi Arabia *Nezar Ramadan, Ali Al-Yami, Saad Shamrani, Saudi Aramco*
10:00-10:20	SPE-SAS 697	Practical Considerations for Pressure Transient Analysis of Multi-Stage Fractured Horizontal Wells in Tight Sands *Zillur Rahim, Ismail Buhidma, Saudi Aramco*
10:20-10:40	SPE-SAS 637	Productivity Increases in Manifa Field Using Coiled Tubing Well Tractor to Enable Total Well Stimulation *Kristine Henriques, Haider Al-Khamees, Brian Sidle, Welltec*
10:40-11:00	SPE-SAS-669	Successful Oriented Hydra Jed Perforation and Fracture Stimulation of a Highly Deviated Tight-Gas-Producer *Nezar Ramadan, Francisco Gomez, Mohammed Asiri, Talal Aa- Mutary, Saudi Aramco*
	*SPE-SAS-714	Design and Evaluation of Hydraulic fracturing in Tight Gas Reservoirs *Mobeen Murtaza, King Fahd University of Petroleum and Minerals; Sami Alnaim, Saudi Aramco*
	*SPE-SAS-656	Modeling of Filter Cake Deposition in Horizontal Wells in Sandstone Reservoirs *Badr Bageri, Saleh Al-Mutairi*

Session 12 | Tuesday, May 21 | Session Room-B

Advances In Improved Oil Recovery (IOR) & Enhanced Oil Recovery (EOR) (1) 9:50 - 11:35

Session Chairpersons: Ali Al Yousif, Saudi Aramco
Abeer Olayan, Saudi Aramco

9:50-10:15	**Keynote Speaker:** John Edward, Schlumberger	
10:15-10:35	SPE-SAS 728	Minimizing Asphaltene Precipitation in Malaysian Heavy Oil Reservoir *Muhammad Ali Buriro, Muhannad Talib Shuker, Universiti Teknologi Petronas*
10:35-10:55	SPE-SAS 710	Brine Composition Effects on Polyacrylamide Viscosity and the Implications for Chemical Flooding *Abdulkareem AlSofi, Saleh Hassan, Saudi Aramco*
10:55-11:15	SPE-SAS 564	Economic Study of Miscible CO_2 Flooding in a Mature Waterflooded Oil Reservoir *Said Salem, Taha Moawad, King Saud University*
11:15-11:35	SPE-SAS-717	Wettability Alteration by Brine Salinity and Temperature in Reservoir Cores *Talal Al-Aulaqi, Quentin Fisher, University of Leeds*

Panel Discussion | Main Hall-1

The Upstream Technology Engine; Keeping the Wheels of Innovation Turning 11:30 - 13:15

Moderator: Waleed Al-Mulhim, Manager, SRMD, Saudi Aramco

Panelists:
Tom Tilton, Chief Technology Officer, Weatherford
Samer Al-Ashgar, Manager, Expec ARC, Saudi Aramco
Rustom Mody, Vice President, Technology, Baker Hughes
Greg Powers, Vice President, Technology, Halliburton

Session 13 | Wednesday, May 22 | Session Room-A

Production Operations (2) 8:00 - 9:40

Session Chairpersons: Jassim Mulla, Saudi Aramco
Majed Omrani, Saudi Aramco

8:00-8:25	SPE-SAS 690	Utilizing Chelating Agent System Fluid to Remove Scale Buildup from Stuck ESP in Offshore Saudi Arabia *Ahmed Al Zahrani, Saudi Aramco*
8:25-8:50	SPE-SAS 650	High Expansion Technology provides Greater Flexibility and Economy When Installing Temporary Downhole Gauges and Samplers *Meflah Al-Murit, Rondall Zbitowsky, Saudi Aramco*
8:50-9:15	SPE-SAS 708	Zero Oil Flaring Concept and Implementation in Saudi Aramco Offshore Fields *Abdulrahman Al-Jamal, Karam Yateem, Iskandar Riza, Khaled Kilany, Yaseen Bokamseen, Saudi Aramco*
9:15-9:40	SPE-SAS-660	A Coiled Tubing Perforating Solution Incorporating a Gun Deployment System and Dynamic Underbalance Technique Improves Well Production *Hasan Al Jubran, Saudi Aramco*
	*SPE-SAS-683	Energy Savings from Stabilizer Bottoms Pump – A Success Story from khCPF Operational Excellences *Ahmad Saif, Ashiff Khan, Saudi Aramco*
	*SPE-SAS-663	Production Logging Evaluation in Gas Wells in Saudi Arabia: Risks, Limitations and Special Considerations for Optimum Data Acquisition *Hasan Al Jubran, Saudi Aramcoi*

Session 14 | **Wednesday, May 22** | **Session Room-B**

Well Stimulation And Productivity Enhancement (3) 8:00 - 9:30

Session Chairpersons: Ahmad Baqawi, Saudi Aramco
Khalid Mohanna, Saudi Aramco

8:00-8:20	SPE-SAS 541	Dealing with Uncertainty of Reservoir Heterogeneity and Pressure Depletion to Optimize Acid Placement in Thick *Albertus Retnanto, Curtis Lynn, Edin Orellana, Schlumberger*
8:20-8:40	SPE-SAS 692	First Field Trial Test of a Compartmentalized Acid Matrix Completion Technology in a Carbonate Gas Well *Mohammed Alulait, Saudi Aramco*
8:40-9:00	SPE-SAS 583	Bull-Heading Acid Stimulation for Horizontal PWI well - Case Study Success Story *Bangkong Sabut, Abdullah Alghamdi, Mohammad Otaibi, Saudi Aramco*
9:00-9:20	SPE-SAS-561	Iron Sulfide Scale Dissolvers: How Effective Are They? *Qiwei Wang, Hassan Al-Ajwad, Tawfiq Al-Shafai, Jack Lynn, Saudi Aramco*
9.15-9:30	*SPE-SAS-618	Pressure Drop Reduction of Stable Emulsions: Role of Aqueous Phase Salinity *Mohammed Al-Yaari, Ibnelwaleed Hussein, King Fahd University of Petroleum & Minerals, Abdel Salam Al-Sarkhi, Mustapha Abbad, Stephen Dyer, Schlumberger; Basel Abu-Sharkh, Idea-Net*

Session 15 **Wednesday, May 22** **Session Room-A**

Well Completion 10:10 - 11:30

Session Chairpersons: Ibrahim Arnaout, Saudi Aramco
Abdullah AlMulhem, Saudi Aramco

10:10-10:30	SPE-SAS 674	Multiple Injection Nozzle Matrix Acidizing Technology Boosts Production from Massive Gas Carbonate Reservoir in Saudi Arabia *Majed Al-Rabeh, Saudi Aramco; Wael El-Mofty, PackersPlus; Stuart Wilson, Schlumberger*
10:30-10:50	SPE-SAS 636	Application of ICD Completion Diagnostics Using Log Data and ICD Modeling *Majed Alrabeh, Saudi Aramco*
10:50-11:10	SPE-SAS 603	Integrated Completion Systems to Overcome Field Production Challenges in an Unconsolidated Sandstone Reservoir *Nami Al-Amri, Karam Yateem, Sauid Aramco; Mahmoud Abd El-Fattah, Schlumberger*
11:10-11:30	SPE-SAS-644	Completing a Thick, High Pressure and Quality Carbonate Reservoir with Pre-Perforated Un-Cemented Liner *Haas, Michael , Meftah Tiss, Sebastian Lopez Saavedra, Abdullah Utaibi, Abdulrahman AlNutaifi, Tariq Mubarak, Saudi Aramco*
11.30-11:50	SPE-SAS-750	Smart Well Completion Utilization to Optimize Production in MRC Well – A Case Study *Nashi Otaibi, Saudi Aramco*
	*SPE-SAS-670	A Practical Method of Predicting Chemical Scale Formation in Well Completions *Syed Hamid, Haliburton; Carlos Magno, Ronaldo Izetti, Hardy Pinto, Petrobras; Enrique Droguett, UOL*

Session 16 Wednesday, May 22 Session Room-B

Reservoir Engineering & Management 9:45 - 11:05

Session Chairpersons: Majed Rabeh, Saudi Aramco
Ajmal Wardak, Haliburton

9:45-10:10	**Keynote Speaker:** Brett Bouldin, Saudi Aramco	
10:10-10:30	SPE-SAS 687	Building a True Intelligent Field *Abdulrahman Al-Johar, Rajesh Jalan, Saudi Aramco*
10:30-10:50	SPE-SAS 588	Upgrading Multistage Fracturing Strategies Drives Double-Success after Success in the Unusual Saudi Gas Reserves *Mohammed Al-Ghazal, Saad Al-Driweesh, Abdulaziz Al-Sagr, Saudi Aramco*
10:50-11:10	SPE-SAS 630	Optimizing Well Design in Gas Shale Wells by Integrating Geomechanics and Drilling Practices *Safdar Khan, Anurag Yadav, Schlumberger*

11:15-12:30	**Keynote Luncheon Speaker:** Scot Evans, Halliburton
	Lunch & Prayer Break
	Luncheon Generously Sponsored by Halliburton

Session 17 **Wednesday, May 22** **Session Room-A**

Drilling Operations (3) 12:35 - 13:50

Session Chairpersons: Mahdi Balhareth Saudi Aramco
Hattem Ghannam, Saudi Aramco

12:30-12:50	SPE-SAS 596	Expandable Solutions for 21st Century Drilling Problems *Ali Al-Herz, Roberto Duran,;Ali Al-Shaikh, Saudi Aramco*
12:50-13:10	SPE-SAS 628	Successful High CCAP Repair for Gas Wells in Saudi Aramco *Abdul Halim Ab Hamid, Khalifah Amri, Shaker Al-Khamees , Mohamed Khalil, Luani Alfonzo, Saudi Aramco*
13:10-13:30	SPE-SAS 556	Innovative Self-Adapting Damping Of Downhole Vibrations *Mark Hutchinson, APS Technology*
13:30-13:50	SPE-SAS-635	Drilling Agitator Tool: Effective Friction Breaking in Horizontal Applications *Assaad Mohanna, National Oilwell Varco*
	*SPE-SAS-612	Advanced Drilling Analysis Tool *William Contreras, Ramzi Al-Ghamdi, Mohammed Hazzazi, Murtadha Hubail, Saudi Aramco*
	*SPE-SAS-616	New 16" PDC Bit Design with Improved Cutter Technology Deliver High Rate of Success and Increased Rate of Penetration Drilling *Mehdi Djaoui, Paul Teasdale, Sri Markandeya, Mehdi Djaoui, National Oilwell Varco; Octavio Alvarez, Saudi Aramco*

Session 18 **Wednesday, May 22** **Session Room-B**

Advances in Improved Oil Recovery (IOR) & Enhanced Oil Recovery (EOR) (2) 12:35 - 13:55

Session Chairpersons: Sunil Kokal, Saudi Aramco
Abdulkarim Sofi Saudi Aramco

12:35-12:55	SPE-SAS 602	Numerical Simulation of Improved Heavy Oil Recovery by Low-Salinity Water Injection and Polymer Flooding *Hassan Alzayer, Saudi Aramco; Mehran Sohrabi, Heriot-Watt University*
12:55-13:15	SPE-SAS 676	Synthesis and Performance Evaluation of Date Pit Based Surfactant for Enhanced Chemical Flooding *Jimoh Adewole, Abdullah Sultan ,King Fahd University of Petroleum & Minerals*
13:15-13:35	SPE-SAS 581	Effects of Brine Composition on Wettability Alteration of Carbonate Rocks in the Presence of Polar Compounds *Wael Abdallah, Schlumberger; Hasan A Al-Hashim, Mohammad Jabbar, King Fahd University of Petroleum and Minerals*
13:35-13:55	SPE-SAS-725	Phase Behavior and Interfacial Tension Properties of an Amphoteric Surfactant for EOR Application *Alhasan Fuseni, Ming Han, Adel Al-Mobith, Saudi Aramco*
	*SPE-SAS-584	Study of Polyacrylamide/Cr (III) Hydrogels for Conformance Control in Injection Wells to Enhance Chemical Flooding Process *Saleh Hassan, Ming Han, Xianmin Zhou, Dimitrios Krinis, Badr Zahrani, Saudi Aramco*

Session 19 Wednesday, May 22 Session Room-A

Production Operations (3) 14:00 - 15:20

Session Chairpersons: Ammal Anazi, Saudi Aramco
Mohammed Atwi, Saudi Aramco

14:00-14:20	SPE-SAS 720	The Optimum Design of Horizontal Water Shut-offs – What Have We Learned So Far? *Muhammad Javed, Mesfer Alghahtani, Mohammed Bawareth, Saudi Aramco*
14:20-14:40	SPE-SAS 542	Prediction of Two Phase Flow through Chokes using Artificial Intelligence: Choke Size Prediction *Mohammad Khamis, King Fahd University of Petroleum and Minerals*
14:40-15:00	SPE-SAS 633	Prediction of Two Phase Flow through Chokes using Artificial Intelligence: Flow Rate Prediction *Mohammad Khamis, Abdulaziz Abdulraheem, King Fahd University of Petroleum and Minerals*
15:00-15:20	SPE-SAS-567	Application of Neural Network for Two-Phase Flow Through Chokes *Mohammed Al Khalifa, Saudi Aramco; Mohammed Al Marhoun, King Fahd University of Petroleum and Minerals*
	*SPE-SAS-730	Successful Implementation and Utilization of Multi Phase Flow Meters (MPFM) in The South Ghawar Area *Ayedh Al-Shehri, Saudi Aramco*
	*SPE-SAS-557	A Simple Method for predicting Gas/Oil Ratio (GOR) of Electric Submersible Pumping (ESP) Oil Wells *Said Salem, King Saud University*

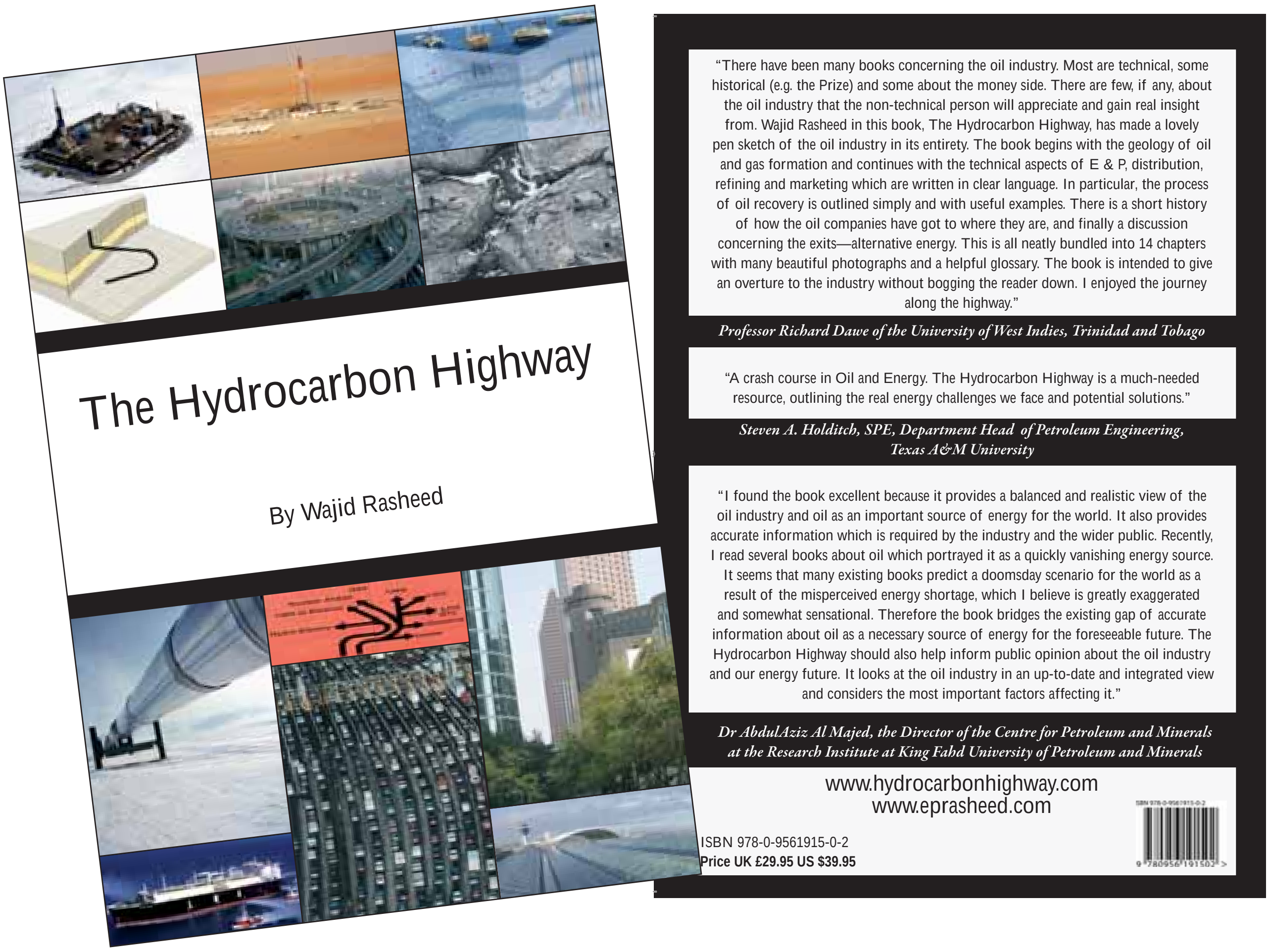
Session 20 Wednesday, May 22 Session Room-B

Reservoir Engineering And Management (2) 14:05 - 15:25

Session Chairpersons: Jaime Rabines, Saudi Aramco
Badr Harbi, Saudi Aramco

14:05-14:25	SPE-SAS 709	Optimal Interwell distances for a large Gas Condensate Reservoir *Joel Lehman, Abdullah Thuwaini, Ali Habbtar, Bandar Malki, Adnan Kanaan, Saudi Aramco*
14:25-14:45	SPE-SAS 621	Enhancing Reservoir Understanding by Utilizing Business Intelligence Workflows *Ali Al-Taiban, Tareq Al-Ghamdi, Badr Al-Harbi, Ahmed Al-Zawawi, Fouad Abouheit, Saudi Aramco*
14:45-15:05	SPE-SAS 642	Pushing Maximum Reach Contact Applications to New Limits in Tight Facies: A Case Study of Middle East's Highest Reservoir Exposure *Majed Al-Suwailem, Abdulaziz Nuaim, Hassan Nooruddin, Chandresh Verma, Saudi Aramco*
15:05-15:25	SPE-SAS-640	Integrated Technologies Yield Five Years of Excellent Performance: A Unique Field Case Study *Orji Ukaegbu, Essam Alyan, Saudi Aramco*
	*SPE-SAS-688	Well Testing Considerations and Tight Gas Reservoir Performance *Rabah Mesdour, Ahmed Al-Zayer, Mustafa Basri, Abdullah Utaibi, Abdulrahman Al-Nutaifi, Saudi Aramco*
	*SPE-SAS-739	Best-in-Class Methods for Unlocking Thin Stringer Potential: A Case Study *Fahad Al-Fassam, Mustafa Lutfallah, Saudi Aramco*
	*SPE-SAS-679	Integrated Reservoir Management Approach to Improve Injection Efficiency in a Low Transmiss. Sec. of a Giant Carbonate Reservoir *Muhammad Almajid, Lajos Benedek, Ahmed Alhuthali, Razally Ali, Saudi Aramco*

Pipelines and Tankers



Transportation of oil and gas is a key factor affecting the industry. Only rarely are oil or gas fields conveniently located next to consumers. This chapter looks at how oil, gas and products reach consumers.

Gas, which requires a huge distribution infrastructure, is particularly affected. Only recently have such solutions as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) tankers allowed many countries to export their natural gas. Qatar, Nigeria and Trinidad, for example, produce far more natural gas than their domestic market requires. The best solution for these countries is to convert their gas to LNG which can be transported to a variety of markets in the world by ship.

Pipelines are the most common forms of transporting crude oil, natural gas, refined products, derivatives and ethanol. They are highly efficient and this is

> Although pipelines are recognised as one of the safest forms of hydrocarbon transportation and distribution, they require a high degree of monitoring and management.

a major reason that oil and gas is such a popular energy source. In fact, pipelines are so efficient that coal companies have tested their use for transporting coal. The coal is ground up into small particles that are pumped within a liquid slurry from the mines to their principle destination, power generating stations or large industrial complexes.

Pipelines extend from oil and gas producing fields, which in turn receive oil and gas from many wellheads. The delivery point can be refineries, liquefaction facilities, petrochemical plants or ports for tanker shipping. Before transportation can occur, however, a complex network of pipelines and associated infrastructures must be in place. Pipelines range from small-diameter field flow lines and gathering lines to huge transcontinental lines.

Oil companies use complex software to visualise, plan, route and monitor pipelines.

While this allows routes to be visualised, any relevant geological and geotechnical features of the route will be subject to local inspections and using a 3D visualisation model developed from aerial photographs and topography data processing. Nowadays, where the use of technological innovation allows capturing, storing and processing a large amount of information, the features visualised on flat paper can be brought to life in 3D forms. Principal considerations range from socio-environmental factors to pipeline design and sizing, data transmission, control systems and leak detection[1].

Socio-Environmental Factors

Achieving a balance between transporting crude oil, natural gas and its derivatives and acting in a socially responsible manner is not easy. Although pipelines are recognised as one of the safest forms of hydrocarbon transportation and distribution, they require a high degree of monitoring and management. Such care is not only restricted to the oil company, but also encompasses the community that may be affected by the construction of a pipeline. In cases where this occurs, participation of communities that live near the pipeline is vital. If communities participate fully at the planning stages, recommendations can be made regarding the use of land that surrounds the pipeline. This contributes to maintaining harmonious relationships between operators and host communities and reduces the risk of conflicts developing years later. The aim is to maintain a positive co-existence between

> "Achieving a balance between transporting crude oil, natural gas and its derivatives and acting in a socially responsible manner is not easy."

the populace, host communities and the pipeline network[2].

Pipeline Design and Construction
This involves new-build pipeline projects where designs aim to reduce costs, minimise environmental impact and ensure the safe operation of the pipeline. Often this involves the mapping and registration of any existing buried or submerged pipelines as well as the analysis of any likely structural problems. Pipelines installed in unstable geological areas must undergo geotechnical surveys to determine the risk of soil movement or formation collapse. The interaction between the soil and the pipeline is constantly assessed in order to guarantee the structural integrity of the line. For buried pipeline applications, new technologies are being developed and applied to improve safety and these include 3D visualisation and monitoring systems as well as the evaluation of the soil-pipeline interaction[3].

In order to guarantee the structural integrity of the pipelines installed in these areas, it becomes necessary to survey and map all the unstable areas and study soil mass movements. Creep movements usually involve extensive areas and present slow speed. In general, they are difficult to detect through visual inspection. Natural subsidence, or compaction of shallow sediments, can cause extreme stress on buried lines that can result in damage or rupture.

Types of Pipelines

Oil and gas pipelines are often welded together in the case of steel pipes or specially connected in the case of composite materials. Inner diameters can reach 48 inches (121 cm) and pipelines may stretch for many miles onshore and offshore. Onshore pipelines may be placed within trenches a few feet below ground or they may be suspended off the ground using steel supports. Offshore, pipe laying vessels such as barges are required to trench and lay pipelines. Pipelines may be created on site with pipe joints welded together on the vessel. Alternatively, pipe joints are often welded together on land into a continuous pipeline unit which is then floated out to the site for layout saving time and money.

The oil and gas is kept mobile within the pipeline by pumping and compressor stations which are carefully spaced along the pipeline according to mobility requirements.

> The oil and gas is kept mobile within the pipeline by pumping and compressor stations which are carefully spaced along the pipeline according to mobility requirements.

Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline. Usually in multi-product pipelines, there is no physical separation between the different products. Some mixing of products occurs, creating an interface which is removed from the pipeline at receiving facilities and segregated to prevent contamination. If fluids are to be completely segregated from one another, a device called a 'pig' is inserted in the line between the two liquids. Pigs are pliable plugs that can be pumped through the line for long distances. They can negotiate bends in the line and are retrieved by a 'pig trap' that operates like an air-lock at the destination end.

Remote Operations and Control Compressor Stations

Compressor stations along natural oil and gas pipelines are often remotely operated. System and equipment status as well as any alarm data are exchanged with a Control and Supervision Centre (CSC) through a Supervisory Control and Data Acquisition (SCADA) system.

Supported by the SCADA software, operators receive immediate detailed information about what is happening in the pipelines. By monitoring the levels of flow, pressure and temperature of the oil and gas and, at the sign of any abnormality, the system allows for pumps to be switched on or off and valves to be opened or closed within any segment of the entire pipeline. This helps operators avert leakages, blockages and maintains the safe and productive operation of the pipeline.

Such systems can perform a range of control actions such as starting and stopping compressor units and stations as well as remotely setting pressure and flow control points[4]. In addition, most compressors and line pumps are instrumented with sensors and associated telemetry that monitors their 'health' status around the clock.

This can provide an early warning of dangerous operating conditions or impending failures and enable operators to take timely action.

Storage

Demand cycles particularly affect the gas industry. Gas, used primarily for home heating, sees widely fluctuating demand between summer and winter. Building a

"A system is needed that could accept a steady stream of natural gas all year long, storing it at the terminal end during the summer months against peak demand during the subsequent winter."

pipeline large enough to handle wintertime demand would be a waste of money because it would only be used efficiently for a few months each year. A system is needed that could accept a steady stream of natural gas all year long, storing it at the terminal end during the summer months against peak demand during the subsequent winter. Storing the huge volumes of gas in surface tanks was impractical and uneconomic so companies created gas storage fields. These consist of storage wells that access depleted oil or gas reservoirs, or large aquifers. Gas is pumped down into these wells in the summer and then produced into the distribution network in winter. Alternatively, large caverns can be leached into salt domes to form huge subterranean storage chambers.

Pipeline Systems

Pipeline rated operating pressures will be dictated by several factors including hydrocarbon type, pipeline length, pipeline integrity and others. Often stations are located along the pipeline and will typically use reciprocating compressors driven by gas engines. To provide efficient outflow of large volumes, pipelines with greater diameters and higher pressure ratings are required. Increasing steel burst strength by specifying different alloys means thinner pipe can be used. The benefits include saving steel by weight reduction, thereby reducing the costs of pipe purchasing, pipe construction and assembly[5].

Remote Data Transmission

This involves the monitoring of all operating parameters and events of station equipment and systems. Typically this includes:

- Operating data such as pressure, temperature, power consumption and flow rates, and
- Fire and leak detection with remote signalling.

All the data mentioned above has to be available as continuous, real-time information to CSC operators[6].

SCADA

This system is made up of two basic sub-systems: the control and supervision centre and the local operation station. The components of the control and supervision centre are described below:

- Real-time database server: All the current data is stored on redundant servers which continuously communicate with the local database on the compressor stations to receive process data and send operator commands
- Historical database server: These servers receive data from real-time servers, storing process data on hard disk and tape cartridges
- Human-machine interface: This is used by operators to supervise and control the pipeline. From these stations, data can be accessed via real-time servers, historical servers and an advanced functions station

> By preventing corrosion-related failures, corrosion management technology increases operational reliability standards, reduces environmental damage and extends the lifespan of the pipeline network.

• Engineering station: This station is used for developing and testing purposes
• Advanced functions station: This workstation runs the pipeline simulator. Additionally, there are three software modules for pig tracking, inventory calculation (line-pack) and leak detection
• Very Small Aperture Terminal (VSAT) communication system: This system comprises a personal earth station at the CSC, a hub station at the provider's installations, and a personal earth station at each compressor station
• INMARSAT communication system: This is used for communication with the city gates where natural gas from a pipeline enters the smaller diameter distribution network. This system does not communicate continuously. The operation is periodic (every four hours) and by exception (from the city gates to the CSC)
• Leased lines: These lines are used as backup for the VSAT system at the compressor stations, and
• Global Positioning System (GPS): These systems are used to maintain each compressor station synchronised with the CSC.

The components of the local operation station, which is provided at each compressor station, are described below:

• Local database and operation station: This redundant server has the function of continuously gathering data from the programmable controllers, and sending data for the real-time database server at CSC. These stations can be used to operate the compressor station in case of communication problems with the CSC
• Programmable Logic Controller (PLC): The PLC is used for process control and interlocking. There is a PLC for each turbo compressor and one redundant Central Processing Unit (CPU) for utilities such as generator sets, switchgear, fuel gas systems, compressed air systems, etc.
• VSAT communication system: As described above for CSC
• Leased line: As described above for CSC, and
• GPS: This is used for time synchronisation between the compressor station and the CSC.

Operational stations continuously communicate with the CSC servers. From these stations, it is possible to access all the operational and maintenance data from the area of responsibility of each operational division[7].

Corrosion Management

By preventing corrosion-related failures, corrosion management technology increases operational reliability standards, reduces environmental damage and extends the lifespan of the pipeline network[8].

Systems Capable of Detecting Leaks

Oil companies can detect leaks more efficiently by pin-

Figure 1 - Modern Pipeline, Shipping and Product Remote Operations Centre (Saudi Aramco)

pointing oil, gas or other derivative leaks in pipelines. Overall, this improves profitability by reducing the loss of hydrocarbon products and any environmental impacts. Leak detection technology is used in oil and gas to minimise product losses with a consequent reduction in the environmental impact as well as the costs. A flow and leak detection simulation system for multi-purpose pipelines can be employed by the oil company for this purpose[9].

Rehabilitation of Pipelines

The reason for rehabilitating pipelines is to make the best use of existing resources and to minimise the need for new builds. This, however, requires integrity criteria to be met which will extend the lifespan of the pipeline network. Hydrostatic test methodologies, certification criteria and commonly available repair techniques are all employed. Oil companies are benefitting through higher pipeline utilisation factors, more flexible and economic pipeline repairs, reduced maintenance costs and enhanced safety. To repair in-service pipelines, welding of in-service pipelines and the use of composite materials are commonly used[10].

Pigging Technology

'Pigs' play a vital role in keeping the pipelines operational. Pigs are instrumented battery-powered devices that can be pumped through the pipeline to inspect for corrosion, cracking or buckling both internally and externally. Their usage helps ensure the integrity of the pipeline and keeps the flow of products going. Pigs also help reduce the risks of environmental damage and avoid emergency shut-downs. Both onshore and offshore pipelines can be inspected using pigs.

Pipeline Material Technology

By using advanced materials, operators can reduce costs, increase reliability and extend the life of a pipeline. High-strength steel has been developed for use in large pipelines in order to increase operational safety and reduce the costs of building new pipelines. Models for the simulation of pipeline structural behaviour are also used extensively in order to identify defects and their repair needs.

Coiled tubing can also be used as an effective tool for pipeline applications. This includes the transportation of pigs, removing organic deposits and hydrate plugs or sand and placing a patch or liner to repair minor leaks.

Transfer Systems

These solutions help ensure optimal production flow and supply to the oil and product markets. Studies and tests for the application of friction reducers are carried out for oil product pipelines and this has shown to be viable in various types of pipelines, especially those with utilisation factors close to capacity. The next challenge is the development of proprietary additives to further enhance transfer; for example, to facilitate the transport of heavy crude from the oilfields of Venezuela to the port terminal on the Caribbean Sea, a solvent is added to the crude to reduce its viscosity. This solvent is subsequently separated and retrieved at the terminal end and pumped back to the source to be re-used.

Figure 2 - The Baku-Tbilisi-Ceyhan Pipeline is 1,099 miles (1,768 km) Long (Courtesy of BP)

Tankers

Crude oil tankers make up many of the world's largest ships, hence the common term 'supertanker'. Vessels are classed as Ultra Large Crude Carriers or ULCCs (a handful of which are able to carry more than three million barrels [MMbbl] of oil) and Very Large Crude Carriers or VLCCs (which may carry approximately two MMbbl of oil).

Another fleet class exists at the one MMbbl mark and refers to ships that serve smaller ports where larger counterparts cannot berth[11]. Refined oil products are carried by far smaller vessels carrying half a MMbbl of oil to storage depots or other facilities. These vessels begin the distribution process of moving oil from the refineries to the tanks in consuming countries, from where the oil cargoes are fed by road, rail, pipeline and coastal tankers and inland tank barges to power stations and depots close to where the products are consumed.

Tankers are advantageous over pipelines as they can respond to market fluctuations much more quickly. Cargo can be distributed to any destination in the world that has berthing facilities. However, they are limited to carrying capacity and potential delays in delivery.

Modern tankers are usually built with a lattice construction and double hull to enhance safety. Tankers are often filled using onshore pumps, but are discharged using the tankers' own pumps.

LNG Tankers

LNG tankers must be specially designed to meet the needs of LNG transportation. Special needs are generated by the very low temperatures that must be maintained to keep gas at a pre-determined liquefied state.

LNG companies mostly build LNG ships for a specific project, then own and operate them thereafter. Construction costs have dropped from US $280 million in 1995 (for a 138,000 m^3 capacity ship) to US $150 to $160 million in 2004. This is still more than double the cost of a crude oil tanker. Most added costs relate to the construction of insulated tanks[12].

LNG shipping costs vary based on the ship's operating and amortisation costs, the size of the cargo, and the distance transported. The costs of building and operating receiving terminals, unloading, storage, and re-gasification facilities vary by site. In the US, new onshore terminals built on existing designs are expected to cost US $400 million or more[13]. The cost of constructing offshore LNG facilities is substantially higher. LNG is transferred from the production facility to the tanker's storage tanks using specially constructed booms and pumps. Specially configured loading pipes are designed to withstand the very low temperatures necessary for liquefaction.

The two main designs are the membrane and spherical tanker type. The former has multiple tanks with linings made from thin nickel steel alloys capable of withstanding extreme temperatures. These tanks are integrated into the hull of the ship.

The spherical design tanker has characteristic circular containment tanks that are structurally supported by beams in the hull of the ship[14].

We have seen that the main ways to transport oil and gas are pipelines and tankers. But what happens to crude oil once it has been transported? What needs to be done to prepare the oil and gas for the end customer? How do we take crude oil and turn it into useable products? This is where refining fits in and turns crude into products and feedstock. Refining is core to delivering all the products that oil and gas has to offer; in other words, releasing its commercial value.

References

1. RP 1111 Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines 3rd Edition / July 1999.

2. This includes animal and plant life surrounding the pipeline.

3. Projects and Construction of New Oil and Gas, Pipelines in Brazil, Breno de Souza e Silva & Ney Passos—Petrobras Engineering.

4. Pipeline Integrity Program, Paulo de Tarso Arruda Correia—Petrobras Transport.

5. Improving pipeline performance The PRODUT program helps Petrobras improve operational reliability, increase capacity, and maintain environmental safety. By Ney Passos, Petrobras Brasil S.A., Rio de Janeiro, Brazil.

6. RP 1113 Developing a Pipeline Supervisory Control Centre September 2007.

7. Transpetro´s gas pipeline network, By Marcelo Renno, Natural Gas Director of Transpetro.

8. API RP 5UE Recommended Practice for Ultrasonic Evaluation of Pipe Imperfections.

9. Improving pipeline performance, PRODUT.

10. Pipeline Integrity Program, Paulo de Tarso Arruda Correia—Petrobras Transport.

11. Joe Evangelista (Winter 2002). “Scaling the Tanker Market”. Surveyor (American Bureau of Shipping).

12. UNCTAD 2006 Price for new vessel in 2005 in US $ Millions.

13. UNCTAD 2006 Five year old ship in 2005 in US $ Millions.

14. Comparison of Spherical and Membrane Large LNG Carriers in Terms of Cargo Handling, Kiho Moon et al Hyundai Heavy Industries, Gastech Bilbao 2005.

Figure 3 - The Trans Alaska Pipeline (BP)

Figure 4 - Ultra-Large Crude Carrier (Saudi Aramco)

Figure 5 - The Nilza Tanker (Petrobras)

Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com

Contribute to Saudi Arabia Oil & Gas during 2013

EPRasheed is looking for editorial submissions on the topics outlined in the editorial calendar. This can provide your company with the opportunity to communicate EP technology to the wider oil and gas community.

Please send abstracts or ideas for editorial to **wajid.rasheed@eprasheed.com**

Preference is given to articles that are Oil Company co-authored, peer reviewed or those based on Academic research.

Editorial 2013 Calendar

Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec
Ad Closing: 1 Jan 2013 **Materials Closing:** 8 Jan 2013	**Ad Closing:** 15 Feb 2013 **Materials Closing:** 8 Feb 2013	**Ad Closing:** 15 April 2013 **Materials Closing:** 8 April 2013	**Ad Closing:** 3 July 2013 **Materials Closing:** 10 July 2013	**Ad Closing:** 29 August 2013 **Materials Closing:** 30 August 2013	**Ad Closing:** 5 October 2013 **Materials Closing:** 12 October 2013
• New Stimulation Technology • Advances in Drilling Technology • Smart Reservoirs • Deep Diagnostics & Reservoir Mapping • Geosciences • E&P Software Solutions for Asset, Field and Well Management	• Intelligent Fields • Oil Field Automation and Optimization • Extreme Reservoir Contact • Wide Azimuth • Near Surface Resolution • Technology Innovation to Secure Future of Energy Supply Middle East	• Successful Innovation from Paper to Prototype • Accelerating and De-risking New Technologies • Real Time Operations • I Field • Drilling Automation • KSA Upstream Research & Development • KFUPM Techno Valley	• Deep Water Red Sea Challenges • Assessment of KSA & IOCs Gas Exploration Initiatives • Shale Gas • Tight Gas Developments • Tight Gas Technology Development	• KSA Offshore Gas Development Projects (Karan, Wasit, Arabia, etc....) • Smart Water Chemistry in Carbonate Recovery • Development of Unconventional Gas	• Maximizing Sweep Efficiency in Heterogeneous Carbonate Reservoir Using Advanced Intelligent Completion Technology • Red Sea Salt Challenges
Issue 30 *'Deep Diagnostics'*	**Issue 31** *'Transforming the Energy Future'*	**Issue 32** *'The Upstream Innovation Spark, Lighting Our Way To A Better Tomorrow'*	**Issue 33** *'Red Sea Challenges'*	**Issue 34** *'Offshore Gas'*	**Issue 35** *'Maximising Sweep Efficiency'*
BONUS CIRCULATION					
	SPE/IADC Drilling Conference 5-7 March 2013 Amsterdam The Netherlands **18th Middle East Oil & Gas Show and Conference** 10-13 March 2013 Manama Bahrain **6th International Petroleum Technology Conference** 26-28 March 2013 Beijing, China	**Offshore Technology Conference** 6-9 May 2013 Houston Texas USA **SPE SAS Annual Technical Symposium & Exhibition** 19-22 May 2013 Khobar Saudi Arabia **75th EAGE Conference & Exhibition** 10-13 June 2013 London UK		**Offshore Europe** 3-6 September 2013 Aberdeen UK **SPE Annual Technical Conference and Exhibition** 30 September - 2 October 2013 New Orleans USA **SPE/IADC Middle East Drilling Technology Conference & Exhibition** 7-9 October 2013 Dubai UAE	
SPECIAL PUBLICATIONS					
	** Official Saudi Magazine	* Official Technical Magazine			* Media Partner