Brazil Oil & Gas, tt_nrg and Norway Oil & Gas

EPRASHEED
signature series

2010 – Issue 16

Saudi Arabia oil & gas

Saudi Arabia Oil & Gas (Print) ISSN 2045-6670
www.saudiarabiaoilandgas.com
Saudi Arabia Oil & Gas (Online) ISSN 2045-6689

Inside


OPEC Celebrates 50 Years


EXPEC Advanced Research Center


Dhahran Techno Valley R&D Center


SRAK in the Rub Al Khali

مدينة الملك عبدالعزيز
للعلوم والتقنية KACST
Oil and Gas Research Institute

Seismic Analysis Center

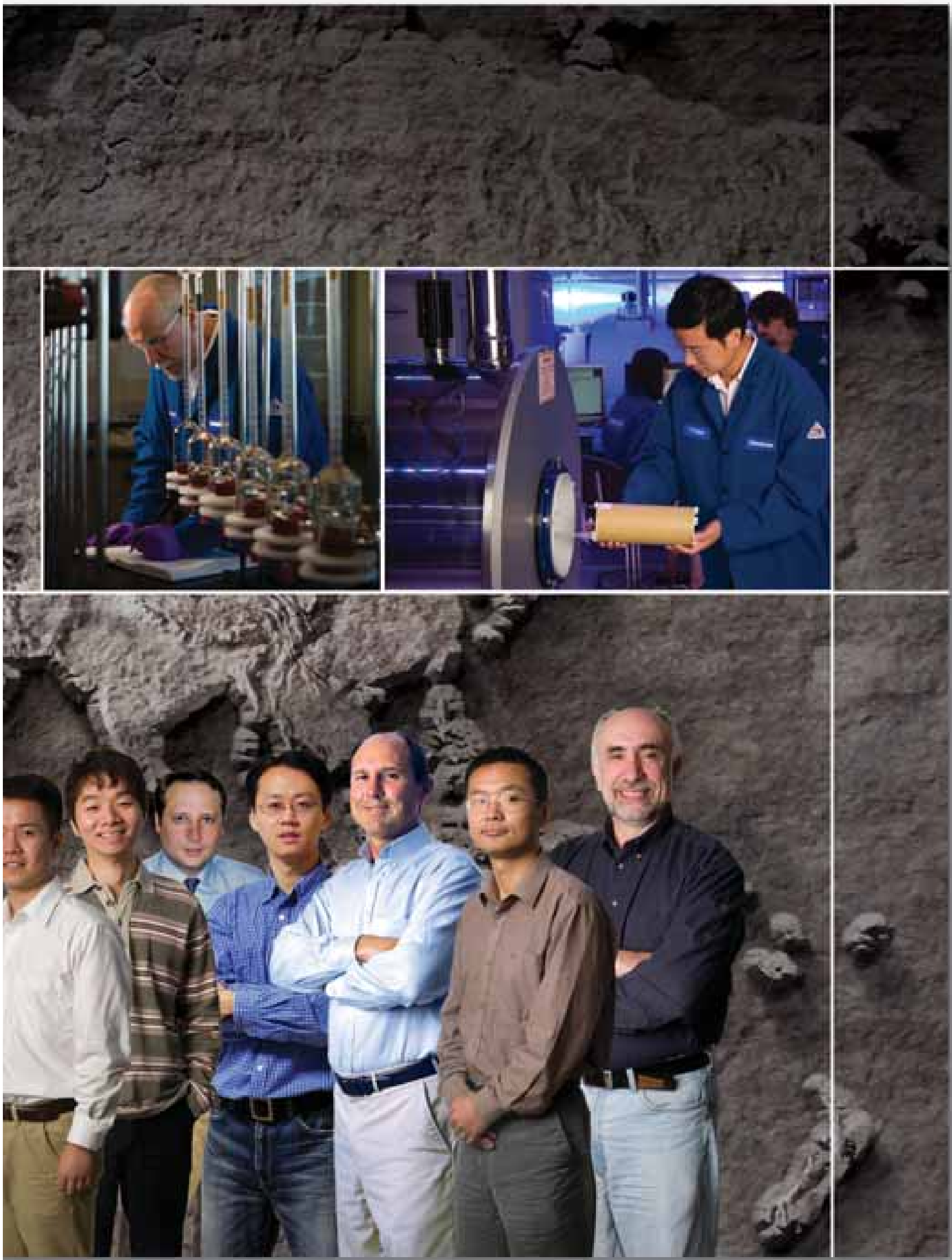
Our Vision Is to be the leading soultion provider for seismic processing and imaging in the arabian peninsula

SAC - KACST - P.O. Box. 6086 Riyadh 11442
Tel. : +966 1 4814324 - FAx : +966 1 4814314

www.sac.edu.sa


LOGGING WHILE DRILLING
In deep water, now you can get samples in hours, not days. And all on LWD.
Until now, retrieving formation fluid samples during drilling couldn't be done. Perfect for deep water, the GeoTap® IDS sensor not only provides truly representative fluid identification and sampling on LWD, it can save you millions in hidden NPT costs routinely incurred with wireline sampling.
What's *your* deepwater sampling challenge? For solutions go to Halliburton.com/geotap.
Solving challenges.™
HALLIBURTON
Sperry Drilling
© 2010 Halliburton. All rights reserved.

Carbonate Advisor



Schlumberger

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

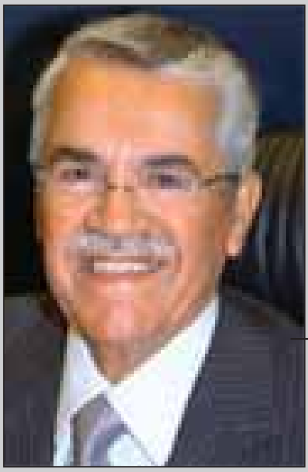
www.kacst.edu.sa

EPRASHEED
signature series

2010 – Issue 16

Saudi Arabia oil & gas
www.saudiarabiaoilandgas.com

Contents



Contacts

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

Editors
Majid Rasheed
Mauro Martins

Design
Sue Smith

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

Brian Passey
brian@bspmedia.com

Sally Cole
sally@bspmedia.com

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

Houston
David Jones
david.jones@eprasheed.com
Tel: (1) 281 793 4314

William Bart Goforth
william.goforth@eprasheed.com
Tel: (1) 713 304 6119

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

SPE International Saudi Arabia Section

SPE | DGS
ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION
15-18 MAY 2011 | KHOBAR, SAUDI ARABIA | SEEF CENTER

2011 ATS&E ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION

Tackling Upstream Challenges:
Fueling the World

Safely

Reliably

and Cost-Effectively

The Society of Petroleum Engineers (SPE) Saudi Arabia Section and the Dhahran Geoscience Society (DGS) are pleased to invite you to submit a paper proposal for the 2011 SPE/DGS Annual Technical Symposium and Exhibition (ATS&E) to be held on **May 15-18, 2011**, at Seef Center in al-Khobar, Saudi Arabia. The ATS&E is the largest gathering for petroleum professionals in the Kingdom and is heavily attended by international professionals as well.

The technical program committee accepts abstracts under Exploration and Production (E&P) as well as Geosciences highlighting: new technologies, case histories, fundamental research, field applications and new field development.

The ATS&E covers a wide range of E&P technical categories including:

- **Reservoir Engineering and Management**
- **Drilling Operations**
- **Reservoir Geology and Geophysics**
- **Unconventional Resources**
- **Improved Oil Recovery and Enhanced Oil Recovery (IOR/EOR)**
- **Reservoir Simulation**
- **Well Completion**
- **Offshore Fields Exploration and Development**
- **Well Stimulation**
- **Reservoir Characterization**
- **Developments in Geological and Geophysical studies**
- **Non-Seismic Geophysics**

The ATS&E is a great chance to share your knowledge, experience and latest technology advancement. I look forward to receiving your abstracts by December 20, 2010. Submissions can be made online by visiting the event website at **www.atse2011.org**. Authors will be notified of acceptance by January 30, 2011.

Dr. Ghaithan A. Al-Muntasheri, Chairman
2011 SPE/DGS Annual Technical Symposium and Exhibition
E-mail: ghaithan.muntasheri@aramco.com

Collaboration Produces Novel Intepretation Tool

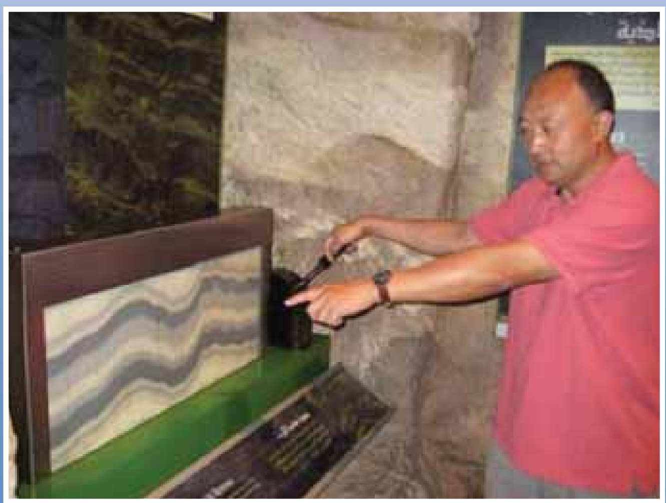
DHAHRAN, October 20, 2010 – The EXPEC Advanced Research Center (EXPEC ARC), in collaboration with the Colorado School of Mines, has completed the first industry application of a novel automated seismic interpretation tool. The seismic image flattening method simplifies the tedious work routinely performed by seismic interpreters by delivering better data control and instant visualization of stratigraphic features.

The theoretical framework was initially developed at the Colorado School of Mines earlier this year and enhanced by a Saudi Aramco team led by EXPEC ARC senior geophysical consultant Yi Luo.

Before the method was developed, geophysicists spent many hours selecting geologic shapes in the seismic 3D volume using the computer or even manually in order to transform particular layers into a flattened appearance.

"This deformation flattening technique has already provided valuable return to our company," said Panos Kelamis, chief technologist of the EXPEC ARC Geophysics Technology Team. "Our seismic interpreters are able to now quickly – and quite effortlessly – obtain more accurate images for their analyses, which is critical in exploring for stratigraphic traps."

Yi Luo points out how the deformation flattening technique automatically flattens the geologic structure.



Yi Luo points to an image of the current earth structure, after millions of years of geologic deformation.

> We now have a reliable way to instantly reveal critical geological features, which could lead to discoveries of new hydrocarbon reservoirs and more efficient production of existing ones.

Seismic image flattening is a standard procedure in geophysical interpretation. When a geologic layer is isolated and viewed in its entirety, it is easier to recognize stratigraphic features and understand how they relate to the search for hydrocarbon deposits. Due to changes in geologic structure over time (folding, fractures, uplifts, etc.), the geologic layers of today are no longer flat and neatly ordered as they were at the time of deposition, millions of years ago. Seismic image flattening reverses the effects of geologic processes by removing geologic structure.

The flattening technique provides many benefits and is already in high demand. It reduces interpretation time by eliminating hand-picking and reduces human bias during picking, and more importantly, the technology can flatten the entire 3D image at once – not just a single layer.

“We now have a reliable way to instantly reveal critical geological features, which could lead to discoveries of new hydrocarbon reservoirs and more efficient production of existing ones,” said geological specialist Schuman Wu. “This technology will raise the success rate of proposing new exploration and production wells.”

OPEC a Half Century Old

RIYADH, October 27, 2010 – The Organization of Petroleum Exporting Countries (OPEC) this year celebrates 50 years of helping member countries make the most of their non-renewable oil resources. The anniversary celebration came to Saudi Arabia from October 18-20 during the International Energy Symposium here.

"Fifty years ago, when OPEC was set up in Baghdad, there were some who predicted that the organization would not last long," said OPEC Secretary General HE Abdalla S. El-Badri of Libya in an address to symposium participants from OPEC countries and energy industry groups. "Fifty years on, however, that initial small group of developing oil producing countries has evolved into a group of 12. These come from across the world and have brought more strength and diversity to the organization."

In an interview, HE Ali I. Al-Naimi, Minister of Petroleum and Mineral Resources, spoke of the central role the Kingdom and, especially, former Minister of Petroleum and Mineral Resources the late Abdullah Al-Tariki played in establishing the organization.

"The Kingdom worked throughout the years to ensure that the organization stayed well-focused on its main mission and that it also remained cohesive," Al-Naimi said. "It has advocated moderation in the decision-making during the posted oil-price and the market-determined price eras. It championed dialogue between producers and consumers and called for the organization to

> "The founding of OPEC was a commitment based upon the need to safeguard their legitimate national interests and to ensure order and stability in the international oil market."

HRH Prince Abdulaziz ibn Salman, Deputy Minister of Petroleum and Mineral Resources for Petroleum Affairs, looks on while HE Ali I. Al-Naimi takes questions from reporters during a 2004 OPEC meeting in Vienna.

Abdullah Al-Tariki, center, head of the Saudi delegation, takes part in a formative conference in Cairo in 1959.

be involved and proactive in the various global environmental and economic forums."

OPEC's creation made a big difference in the global petroleum market and economy, he said. "It has done the same for its member countries as well." The organization's negotiations with the major international oil companies allowed the members to get fair returns for this "precious resource" in the early years and to "produce and market the resource at reasonable prices in subsequent years."

That was a boon to those countries' economies, he said. "We in Saudi Arabia – being the major producer and exporter within the organization and due to the role of oil in our gross domestic product, government finances and balance of payments – have contributed to and benefited from the achievements of OPEC throughout the years."

In his address, El-Badri spoke of the organization's history. "It has certainly not been an easy task to advance the organization's standing and influence," he said, "particularly given the nature of the oil industry at the time of its establishment. As I am sure you are all aware, the main catalyst for its birth came in 1959, when a group of international oil companies – the Seven Sisters – unilaterally reduced the posted prices of the crude they supplied."

Those companies dominated the oil market at the time and derived the greatest benefits from every aspect of the industry, from exploration to distribution, El-Badri said. "They controlled the quantity of oil extracted and sold, to whom it was sold and at what price. And decisions were made without ever consulting host governments of oil-producing countries."

That's when, in 1960, Iran, Iraq, Kuwait, Saudi Arabia and Venezuela came together. Since then, Qatar, Libya, the United Arab Emirates, Algeria, Nigeria, Ecuador and Angola have joined. "The founding of OPEC was a commitment based upon the need to safeguard their legitimate national interests and to ensure order and stability in the international oil market," El-Badri said. "It was about gaining full sovereignty over exhaustible nonrenewable natural resources.

"Over the years, this cooperation has grown stronger as the organization has evolved and become an established and respected member of the global energy community. In the years ahead, OPEC's dedication to the welfare of its member countries, the international energy market and the global economy will, of course, continue."

In another interview, HE Dr. Majid Al-Muneef, the Saudi governor at OPEC, stressed the many challenges ahead. When the organization was created in 1960, its announced reserves were at 300 billion barrels. Despite the fact that 400 billion barrels have been produced by member countries, reserves are now estimated at 1 trillion barrels, 77 per cent of the world's proven reserves. "Which means," Al-Muneef said, "member countries were producing and expanding their reserves at the same time." And that bodes well for the next 50 years.

The symposium's main topics were the Kingdom's relationship and role in OPEC, relations between OPEC and other relevant global organizations, and OPEC's influence on global markets.

Partnership to Create New R&D Center

By Aref M. Younis.

DHAHRAN, November 03, 2010 – A new Research and Development Center (R&DC) was the object of a memorandum of understanding signed Oct. 8 at King Fahd University of Petroleum and Minerals (KFUPM). Representing the two parties were KFUPM rector HE Dr. Khalid Al-Sultan; and Herman Rosen, president of the Rosen Group.

The center would be built at Dhahran Techno Valley and recognized as the first oil and gas downstream investment in the valley. There, KFUPM, Saudi Aramco and Rosen professionals would work side-by-side with students getting hands-on development in mechanical and chemical engineering.

The center would pioneer pipelines research by introducing new technologies, carrying material and spare parts for specialized tools and conducting research in order to manufacture extended-life materials.

The center also would cover new inspection technologies related to electrical and civil industrial structures. Saudi Aramco would offer a place for the newly developed technologies and material to be tested at an industrial scale.

Al-Sultan said students and experts would work on joint and independent projects in the oil and gas industry. Saudi Aramco's Khalid G. Al-Buainain, senior vice president of Refining, Marketing and International, commended the Rosen Group for establishing its first Middle East research center in Techno Valley, which he called a clear testament to KFUPM's academic excellence and Saudi Aramco as a business partner of choice.

Seated, from left, H.E. Dr. Khaled S. Al-Sultan, Khalid G. Al-Buainain and Herman Rosen sign the memorandum of understanding aimed at building a Research and Development Center at Dhahran Techno Valley. Looking on are other representatives of KFUPM, Saudi Aramco and Rosen.

The project would pursue state-of-the-art technologies that have been recently embraced by Rosen Group.

"Rosen's new facility is very much in line with the Kingdom's long-term goal to become a knowledge-based economy," said Rosen, whose company supports the oil

> Significantly, through the contribution made by Saudi employees – who today are over 58 percent of our work force in Rosen Saudi Arabia – and with the completion of this center, Rosen will be able to provide innovative solutions to its customers in the Kingdom and worldwide.

and gas industry with inspection, integrity services, rehabilitations and products. "Rosen will do its part to prepare the Kingdom's young generation to be responsible participants in the future. For more than 15 years, we at Rosen are privileged and honored with the exceptional relationship with Saudi Aramco."

Rosen said one of the first areas to explore would be nondestructive testing, which would directly benefit Saudi Aramco. "Significantly, through the contribution made by Saudi employees – who today are over 58 percent of our work force in Rosen Saudi Arabia – and with the completion of this center, Rosen will be able to provide innovative solutions to its customers in the Kingdom and worldwide."

Rosen Group operates four R&DCs – in Germany, Switzerland, the United States and Colombia. The Saudi Arabia site would be its fifth.

Also present were Nasir K. Al-Naimi, executive director of Pipelines, Distribution and Terminals; and Muhammad A. Trabulsi, general manager of the Pipelines Department.

The Kingdom Celebrates its 80th Birthday

By Aref Younis and Rick Snedeker.

Prince Mansour ibn Miteb ibn 'Abd al-'Aziz (first from the right) attends the National Day activities that took place at the Saudi Arabian Pavilion at the 2010 Shanghai Expo in China. Also seated is Joa Han Min, Vice President to the Political Advisory Congress of Peoples' Republic of China in Shanghai.

Two girls dress in white and green, the Kingdom's national colors, in observance of the Saudi National Day.

Saudi revellers salute passers-by as part of their celebrations for the Saudi National Holiday on September 23.

Eastern Province Harley Davidson's Club members lead the National Day Procession, with as many as 400 vehicles adorned in the national green and white colors.

DHAHRAN, September 29, 2010 – Saudi Aramco joined the rest of the country on September 23 in celebrating Saudi Arabia's National Day, which included massive parades, fireworks and official observations, along with a general national party mood.

The company also observed the patriotic day with special events in various cities around the world where it conducts business activities.

The day, officially celebrated only since 2005, commemorates the 80th anniversary of the founding of Saudi Arabia in 1930, and the formal unification of the Kingdom on September 23, 1932, under the country's founding monarch, King 'Abd al-'Aziz ibn Al Saud.

In The Hague, capital of the Netherlands, the King Abdulaziz Center for World Culture, being developed by Saudi Aramco, was on display for over 300 special guests of the Saudi ambassador, Abdullah bin Abdulaziz Al-Shaghroud, at his residence.

The exhibition, held in conjunction with National Day, featured a scale model of the center as well as a miniature cinema that played a 3D film about the center and its mission of inspiring creativity, education and cross-cultural engagement. The center is slated for completion in 2012.

Ahmad Al-Zayyat, Managing Director of Aramco Overseas Company, an affiliate of Saudi Aramco based in The Hague, said the exhibition could be the first of many throughout Europe, given the level of interest shown.

"There is an opportunity here to add a cultural dimension to Saudi Aramco's already-robust relationship with its European business partners," Al-Zayyat said.

In Houston, key representatives of Aramco Services Company (ASC) joined the Saudi Council General Dr. Abdurrahman Al Shaye'a, in commemoration of Saudi National Day. Saudi Aramco was well represented at the ceremony by executive management and employees of Houston-based ASC. A number of Saudi students from U.S. colleges and universities attended the event, wearing Saudi dress as a reflection on life in the Kingdom.

In Hong Kong, a Saudi National Day celebration was held on September 21 at the Four Seasons Hotel and attended by officials of the Saudi Consulate of Hong Kong and Donald Tsang, the Honorable chief executive of Hong Kong. The evening's highlight was Tsang's visit to the Saudi Aramco booth.

Mansour ibn Miteb ibn 'Abd al-'Aziz, Saudi Minister of Municipal Affairs, attended National Day celebrations at the Saudi Arabian Pavilion at the 2010 Shanghai Expo Center.

Also attending were Saudi Ambassador to China Yahya Bin Abdulkarim Al-Zaid and Dr. Yusuf Bin Tarad Al Saadoun, under-secretary of Economic Affairs and cultural ambassador, as well as key company representatives from Aramco Overseas Co. regional offices in addition to a delegation of culture and information personalities from Saudi Arabia.

"There is an opportunity here to add a cultural dimension to Saudi Aramco's already-robust relationship with its European business partners."

> The increasing momentum of modern achievement in the Kingdom today is a demonstration of continuous development over the arenas of economics, construction, education and many other fields.

Saudi Aramco management attending included Nabeel A. Al-Jama‘, acting executive director, Saudi Aramco ` Affairs, accompanied by Khalid K. Al-Mulhim, manager, Public Relations Operations Department.

Al-Jama‘ said, “The increasing momentum of modern achievement in the Kingdom today is a demonstration of continuous development over the arenas of economics, construction, education and many other fields.”

National Day celebrations in the Kingdom itself were nothing short of jubilant. In the Eastern Province, where Saudi Aramco’s Dhahran headquarters is located, a long cavalcade of more than 1,000 cars, buses and motorcycles, including more than 60 participants astride Harley-Davidson motorcycles, drove along the Arabian Gulf seafront from the town of Dammam to al-Khobar.

The impressive procession included 200 well-preserved classic cars of the late King ‘Abd al-‘Aziz, several of which belong to Prince Mohammed bin Fahd, governor of the Eastern Province, and several were brought in the neighboring Gulf countries such as Qatar.

One young National Day reveler in al-Khobar, Nasser Ahmad Al-Oraifi, told the English-language *Arab News*, “We are the sons of Saudi Arabia, and we feel proud to be Saudi. Today is the day of celebration!”

Other Gulf countries that participated in the festivities included Kuwait, Bahrain and the United Arab Emirates.

In Riyadh, Prince Sattam ibn ‘Abd al-‘Aziz, acting Governor of the Central Province, attended an evening reception held by the Embassy of the People’s Republic of China in honor of National Day. The Prince was welcomed by the ambassador of China to the Kingdom, Yang Honglin, who noted the depth of relations between his country and the Kingdom in many fields, and lauding the efforts of King Abdullah in the development of relations between the two countries at all levels.

A colorful parade of cars and motorcycles was held on National Day evening in Makkah, followed by a ceremony at the Sports City with a variety of cultural programs, such as folk dances and an operetta in which 200 people, including children, participated.

In Jiddah, the Ministry of Culture and Information organized a ceremony in Obhur, in coordination with the municipality, at which Saudi actor Fayez Al-Malki opened the festivities and urged Saudis to work hard to make the Kingdom one of the advanced countries of the world. To mark the event, the people of Jiddah prepared a huge Saudi flag, 30 meters in length.

SPE International
Saudi Arabia Section

YP&SO

INFINITE POTENTIAL

2011 Young Professional Technical Symposium

Call For Papers

Abstract submission deadline: January 15, 2011
Acceptance notification: January 31, 2011

The Young Professionals and Students Outreach committee of the Society of Petroleum Engineers – Saudi Arabia section is delighted to invite you to submit your paper abstract for the **2011 Young Professionals Technical Symposium**. The symposium will be held in Dhahran, Saudi Arabia on March 14-16, 2011.

The YP Technical Symposium is an annual event that provides an exceptional venue for regional and international SPE young professionals to share technical experiences and exchange ideas. The symposium programs include technical and poster sessions, and a panel discussion. The technical sessions cover the following technical categories:

- **Drilling, Workover and Well Completion**
- **Production Enhancement and Operations**
- **Reservoir Engineering and Management**
- **Reservoir Characterization and Simulation**
- **Health and Safety**

For submission, please send your abstracts to
Saud Al-Dawsari at **Saud.Dawsari@aramco.com**

Msalli Al-Otaibi
YP Technical symposium chairman

Al Falih at the Inauguration of

Saudi Aramco CEO/President, Mr. Khalid Al Falih and members of his team visited Prince Mohammad Bin Fahd University (PMU) to mark the inauguration of "Geoscience Club". The University is committed to providing its students with opportunities that help to enrich their personal growth, character, and leadership development, and encourage them to participate in a variety of activities and functions through myriad clubs and societies.

"PMU Geoscience Club" at its inauguration, recruited 14 students. The main attraction for students to join the club was to take part in field trips that the Dhahran Geoscience Society (DGS) organizes. The club greatly benefits from the various activities conducted and organized by the Dhahran Geoscience Society. The club thanks the DGS for offering free membership to student's community. While Mr. Khalid Al Falih visited the Goescience Club booth, He expressed an enormous appreciation for the efforts of the PMU Division of Student Affairs and the professional displays of the clubs and societies presented at this day. He advised that the PMU Geoscience Club should work closely

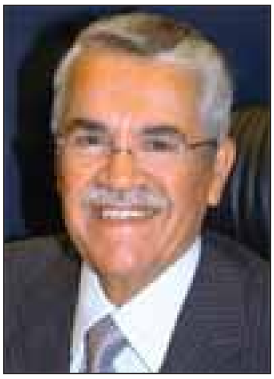
the PMU Geoscience Club

with the DGS, and the students must be proactive in the various programs being organized. The programs that are organized by DGS, certainly give the youth a wide spectrum for learning, leadership skills, personal development, technical lectures, and on-site field trip experiences.

Mr. Mohammed Asgharuddin Ahmed, a sitting member of the DGS and an advisor to the PMU Geoscience Club, appreciated Mr. Kahlid Al-Falih for his concerns towards the youth development. He is thankful to him for his time at the Geoscience Club exhibition.

The Role of Petroleum in the True Smart Energy Economy

By Ali I. Al-Naimi, Minister of Petroleum and Mineral Resources, Kingdom of Saudi Arabia.



Singapore, November 01, 2010

"Your Excellencies, distinguished guests, ladies and gentlemen – good evening.

I would like to express my sincere appreciation to His Excellency Mr. S. Iswaran, Senior Minister of State for Trade & Industry and Education, for his kind invitation to take part in Singapore International Energy Week.

This summit affords a venue for the timely exploration of best practices, policies and solutions for a smart energy platform, bringing economic development, energy security, and environmental and financial sustainability into balance.

I welcome this opportunity to share Saudi Arabia's perspectives.

And as ever, it is a great pleasure to return to Singapore. Today I can see a tremendous difference in Singapore's physical and economic landscape from even a few short years ago. It is inspiring to note that with this dramatic growth, Singapore has preserved and enhanced its beautiful gardens, parks and nature reserves, remaining both vibrant and green.

This year's International Energy Week theme, "Fueling the Smart Energy Economy," responds to a fast-changing energy scene that demands our readiness to meet fast-growing demand, within the smart-energy criteria of supplies that are adequate, available, affordable, and in line with environmental imperatives.

Of course, the main driver in this transformational energy scene is structural: the movement of most of the world's economic growth to Asia. We need look no farther than Singapore, one of Asia's fastest-growing economies, for a cosmopolitan emblem of the dawning Asian Century. Singapore's emergence as a key global financial center, its prominence in the dynamic pharmaceutical and electronics sectors – and very significantly, its swift emergence from the global downturn – are representative of Asia's increasing clout.

Energy demand is projected to grow by 40 percent within the next two decades, as more people attain higher levels of prosperity and need more energy to power their improving lifestyles.

In contrast to the West's mature, industrialized economies, phenomenal growth is taking place throughout Asia's emerging economies, especially China, India and the Middle East, where nascent middle classes are newly acquiring cars, traveling, and buying more consumer goods.

This new energy demand will also be fed by the energy aspirations of the developing world, and the phenomenal growth of global population by another 2 billion in the next 20 years.

So while the immediate symbol of Asia's new energy intensity may be the greater number of cars on the roads in Shanghai, the impact of this higher consumption is manifested in both dramatic and subtle ways. Twenty years ago, considerably fewer Asian peoples, especially in rural areas, routinely owned private transportation.

Today, we see Asia's energy consumption ranging from Singapore's global debut of the luxurious Airbus A380

> "With new middle and upper classes' purchasing parity, as seen in greater business and tourism travel, greater private transportation and more extensive goods consumption, Asia will account for 60 per cent of global energy growth through 2030."

super-jumbo jets – which incidentally claim the world's cleanest turbofan engines – to China's emerging status as the world's biggest energy consumer. With new middle and upper classes' purchasing parity, as seen in greater business and tourism travel, greater private transportation and more extensive goods consumption, Asia will account for 60 per cent of global energy growth through 2030.

Thus, to put a human face on this structural shift, we have only to consider the magnitude of hundreds of millions of people in Asia who now have a better situation through upward mobility, or who hope to emerge from energy poverty.

This new economic and social reality underscores the need for a smart energy policy, as around the world, government directives and public interest seek to reconcile consumption with sustainability. This dual approach is logical: finding more energy, and deriving the greatest possible use from it, are two sides of one coin.

There is a lot to like about smart energy. Beyond the inherent wisdom of balancing consumption and stewardship, smart energy boasts the intuitive marriage of hardware and software for an optimal power grid; the genius of innovative meters and appliances for more efficient use; and the potential contributions of renewable energies. A word of caution is in order, however, to temper our exuberance with realism about the readiness of newer energies to carry the day.

Premature enthusiasm for the benefits of renewables puts us at risk of equating smart energy with "new" energy. In this view, the smart energy concept specifically marginalizes fossil fuels as "old" energy. Indeed, some governments, as a matter of policy, are emphasizing green energy as a means of seeking energy independence and weaning away from fossil fuels.

Such a narrow focus un-levels the playing field, where policies, resources and public sentiment favoring alternative energies inhibit fossil fuels' ability to compete and contribute. It also creates undue risk that these newer energies may not have sufficiently developed to the point of payback on considerable investments of time

> So if smart energy is about deriving the greatest resource value, we would have to agree that any kind of energy that lets us weigh those qualifying criteria and tick the reliability and sustainability boxes off our checklist will apply.

and money. Fossil fuels must bridge the gap, until green energy consistently lives up to its name, and overcomes affordability and infrastructure hurdles.

Simply put, an either-or approach ultimately will catch us short-handed.

So if smart energy is about deriving the greatest resource value, we would have to agree that any kind of energy that lets us weigh those qualifying criteria and tick the reliability and sustainability boxes off our checklist will apply.

Saudi Arabia does agree that every kind of energy has a role to play. We acknowledge that fossil fuels, primarily oil, will shoulder the biggest burden in meeting global demand, and that renewables will complement them. Thus, our aim is to deliver the petroleum that powers the world's economic and social engines; leverage technology and innovation to make its use cleaner; and develop renewables so that they can contribute meaningfully to the energy mix.

With that in mind, let's look at petroleum through the smart energy lens.

From the smart-energy fundamentals of adequacy and reliability, the world will depend on fossil fuels for the next 50 years. Of the dramatic 40 per cent increase in world energy demand that we will be seeing over the next 20 years, 85 per cent will be met primarily by fossil fuels. From the perspective of Saudi Arabia alone, the smart energy supply fundamentals are well served.

As the world's leading supplier of oil with 264 billion barrels of proven oil reserves, at current production levels the Kingdom could continue to supply crude oil for another 80 years, even if we never found another barrel.

However, we're finding those new barrels.

In fact, even though we produced 62 billion barrels of oil between 1990 and 2009, our reserves have not decreased. Through new discoveries and improved recoveries, we are adding as much oil as we are producing every year. And we have been doing this for the past 20 years.

Ladies and gentlemen, given the urgency of growing global demand, it is projected that some $26 trillion in energy investments must be made – and resource stewards like Saudi Aramco, the Kingdom's oil enterprise, are expending funds to make additional supplies available.

Last year, Saudi Aramco completed the largest capital program in company history at a cost exceeding $100

> Aided by science and technology advances, producers are stewarding these supplies so that strides are being made in such areas as better recovery, less invasive practices, emissions reduction, and improved fuel efficiency.

billion and spanning mega-projects in oil, gas, natural gas liquids, refining and petrochemicals. The oil and gas components of this project slate have enabled the Kingdom to raise its maximum sustainable crude oil production capacity to 12.5 million barrels per day. That's a capability unmatched in the industry. More importantly, that's good news for energy security.

Turning from the adequacy criterion to the sustainability factor, petroleum continues to pass the smart energy test. Aided by science and technology advances, producers are stewarding these supplies so that strides are being made in such areas as better recovery, less invasive practices, emissions reduction, and improved fuel efficiency.

The cornerstone of smart energy is R&D; the same is true for oil. Making the footprint of petroleum operations and products lighter is a major industry thrust. Just as we are investing in supplies, we are also allocating massive investments toward improving petroleum's sustainability – a broad umbrella that encompasses efficiency, affordability, safety and environmental protection. Some of the most significant environmental innovation is aligned with petroleum's leading use in transportation.

In Saudi Arabia's case, we are focusing on cleaner-burning fuel formulations and clean-engine technologies. On a domestic level, we are implementing a plan to reduce the sulfur content of various grades of fuel used in the Kingdom.

Complementing innovation, knowledge leadership is an emerging energy sustainability focus. Think-tanks like King Abdullah Petroleum Studies and Research Center, whose mission is global energy and environmental research and policy studies, are contributing useful perspectives and insights to global energy tracking.

Having shown how petroleum checks off those smart energy boxes, I have one more strategy to define in the Kingdom's smart-energy approach: the development of alternative energies.

Far from dismissing alternatives, Saudi Arabia is committed to researching, commercializing and manufacturing promising sources. This energy diversity is reflected in the newly established King Abdullah City of Atomic and Renewable Energy, a cooperative program for the investigation of those sources.

Solar, however, is a core development interest in Saudi Arabia. The Kingdom's transition to a knowledge economy that leverages our extensive energy expertise and resources is evident in R&D-focused investments, such

> "... the ultimate bottom line for smart energy solutions is that they must be sufficiently robust and resilient to shoulder a fast-growing energy burden."

as King Abdullah University of Science and Technology. The mission of this new graduate institution for global solutions includes a broad solar energy focus, and its centerpiece is the Solar and Alternative Energy Engineering Research Center, dedicated to making solar commercially viable through lower costs.

My friends, what I hope to convey from these examples of in-depth and inclusive scientific scrutiny is this: while being forward-looking and innovative are smart – being pragmatic, even cautious, may be even smarter.

While renewables must be brought along to contribute meaningfully to a diverse energy mix, let us be realistic. Today, renewables' portion of the energy pie is just 2 per cent, and their share is expected to reach 4 per cent by 2030. Even if their current portion developed faster, doubling in those two decades, that would be a good advance – however, we would be looking at just 8 per cent. And while solar and wind must be tied to the energy mix, their intermittent nature means they must augment the tried and true as they, and other alternative energies, are brought along to full maturity and viability.

Thus, Saudi Arabia's stance is not to curb fossil fuel use, thereby drastically limiting economic and social growth. Instead, our aim is to supply the market with oil to enable economic growth and prosperity; improve petroleum's environmental performance through sustainability-driven R&D; and contribute to energy diversity by developing renewable energies. We, and other energy resource holders, welcome smart energy and renewables as part of a vital mix.

Perhaps this optimal energy utilization aim is best illustrated in Saudi Arabia's positioning of solar as a means of fuel flexibility in the Kingdom. By introducing solar for some energy needs, we can ultimately reduce domestic oil and gas consumption, thereby having more hydrocarbons to export to our customers in Asia and elsewhere in the world.

Ladies and gentlemen, the ultimate bottom line for smart energy solutions is that they must be sufficiently robust and resilient to shoulder a fast-growing energy burden. To acknowledge another economic game-changer for Singapore, the integrated resort and casino, the smart bet would be to put the money on petroleum as a vital, and rightful, part of the smart energy mix.

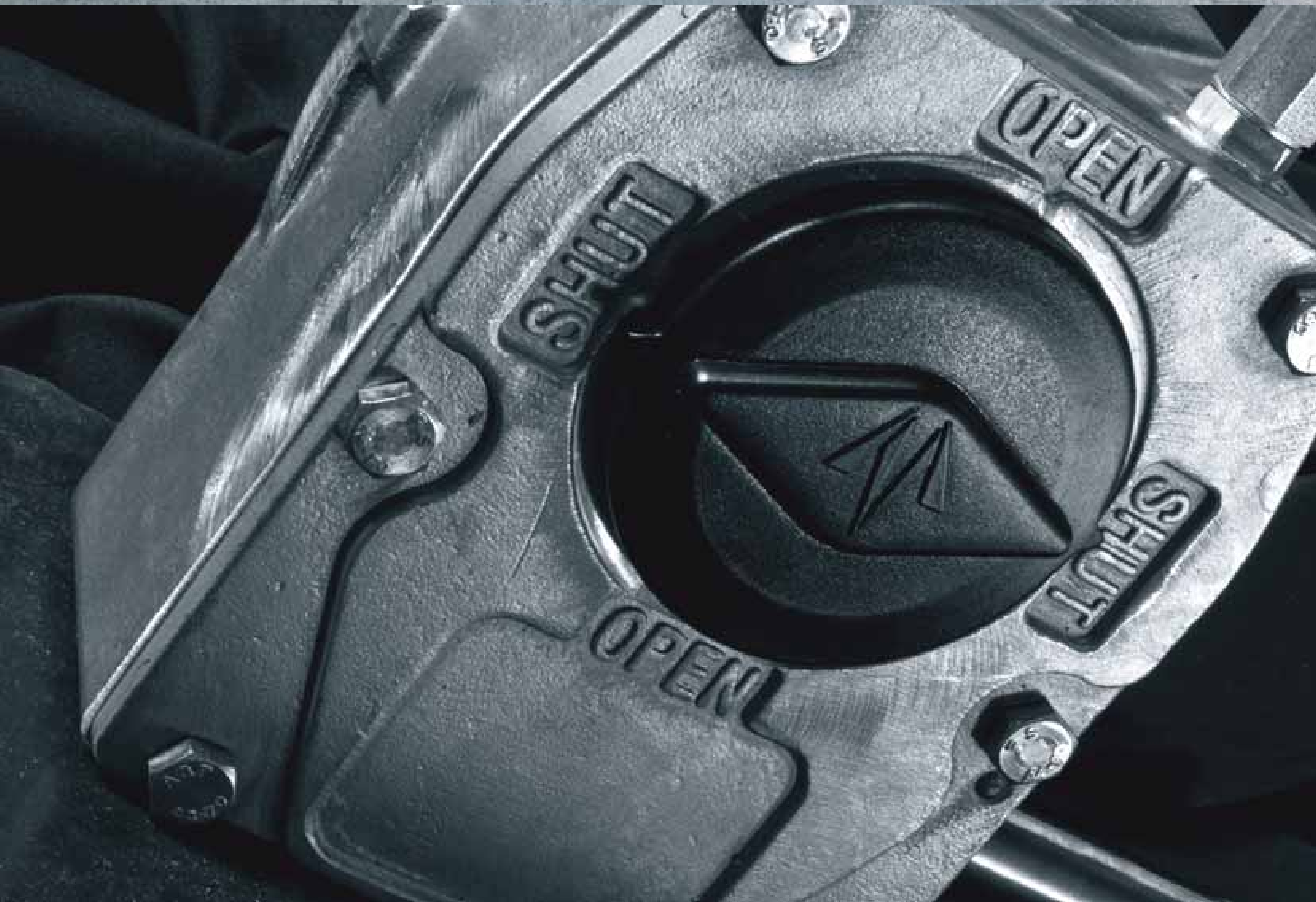
Emerging and evolving energies and exciting new solutions for energy efficiency, like smart grids and smart appliances, assuredly have a role to play, but the known and proven must be given place with the pioneering. If we do otherwise, my friends, the risk of being unprepared for the future is simply too great.

If producers and consumers recognize that all viable energies have a role in meeting future demand; commit to improving the availability, accessibility and sustainability of all; and use energy prudently and efficiently, I am confident that energy's smartest days – and thus, the best days for all people, here in Asia and everywhere – lie ahead.

Thank you for your kind attention."

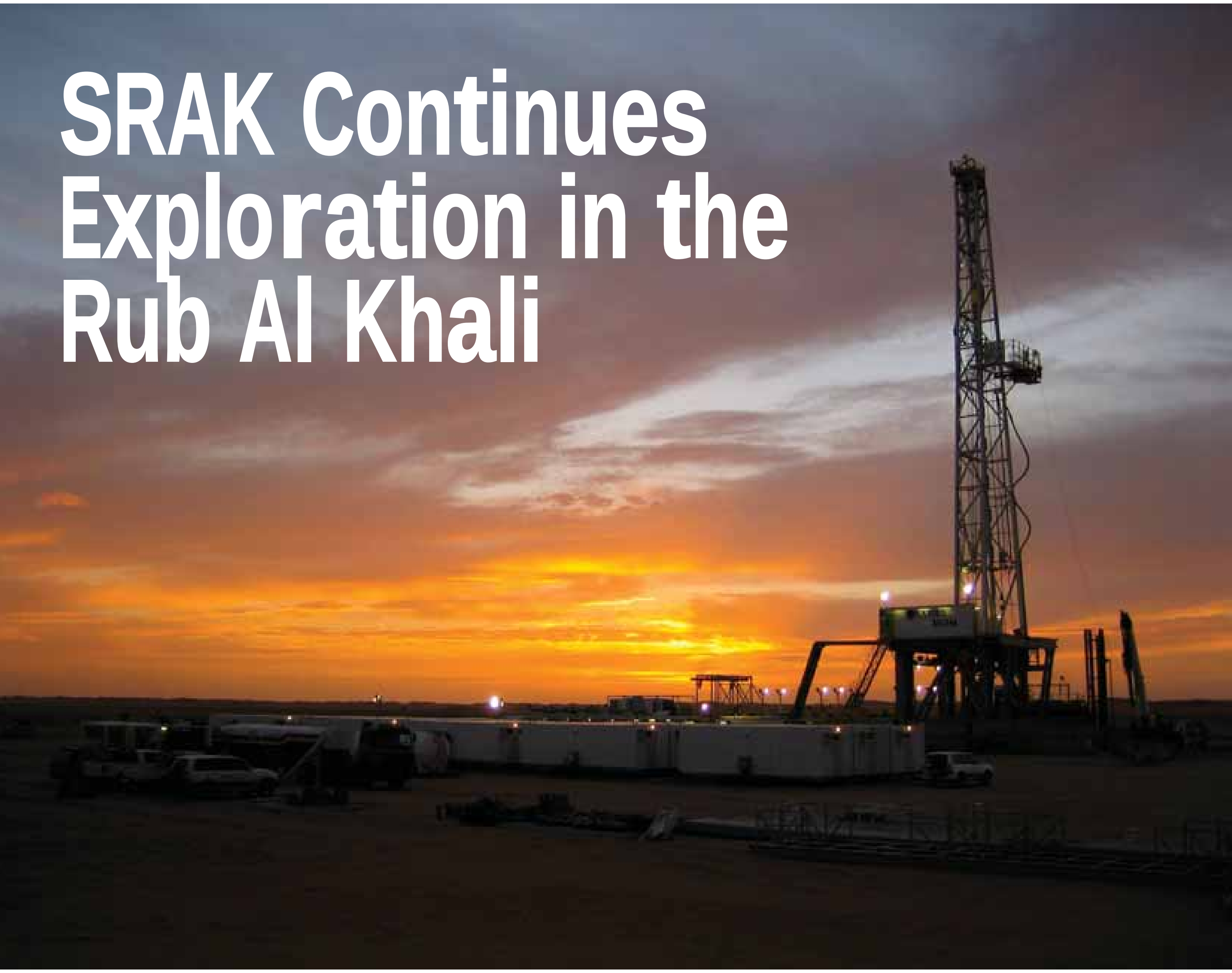
MASTERGEAR UK

The **Stainless Steel** Gearbox Range.



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

www.mastergearworldwide.com



SRAK Continues Exploration in the Rub Al Khali

By SRAK Staff.

The South Rub Al Khali Company Limited (SRAK) is pleased to announce that it has successfully concluded its First Exploration Period and embarked on the Second Exploration Period as of July 26 2010 in the Rub Al Khali in the Kingdom of Saudi Arabia.

SRAK completed all of its commitment for the First Exploration Period in May 2010. This comprised the drilling of seven exploration wells, acquisition of approximately 25,000 kilometers 2D seismic data and the acquisition of 750 square kilometers of 3D seismic data.

SRAK is also pleased to announce that the company and its contractors achieved over seven million man-hours and about three years of operations without any lost time injury.

The evaluation of the data acquired over the First Exploration Period led SRAK to retain its Contract Area 1 in the Rub Al Khali. During the Second

Exploration Period thre wells are planned to be drilled in this area, in addition to the acquisition of about 3,600 square kilometers of 3D seismic data and 3,000 kilometers of 2D seismic data.

SRAK will also submit to the Government of the Kingdom of Saudi Arabia an appraisal plan for Kidan area.

SRAK is a joint venture between Saudi Aramco and Shell with equal equity holding. The purpose of exploring for and the production of non-associated gas in the South Rub Al Khali.

Top: Seismic Camp. Above: Saudi Woestijn Rig 35. Facing page, bottom: T 79 on Al-Mirtan.

Accessibility and Acceptability: Striking the Balance for an Optimal Energy Future

By Khalid A. Al-Falih, Saudi Aramco President and Chief Executive Officer.

Montréal, Canada, September 13, 2010

"Honorable delegates, distinguished guests, ladies and gentlemen: good morning. Allow me to begin by thanking the World Energy Council and Christoph Frei for giving me the opportunity to share my views with you.

The themes of this Congress go to the heart of many of the issues facing the energy sector, though I have elected to look in particular at two key challenges identified by the Council.

I would like first to look at the accessibility challenge, before turning my attention to issues of stakeholder acceptance.

Then, I would like to look at the complex interplay of those two imperatives, and the ways in which we at Saudi Aramco seek to achieve a sustainable balance between them.

Allow me to begin by focusing on access to energy.

My friends, as we gather here in one of the most advanced and most affluent nations on the planet, we run the risk of unintentionally reducing energy accessibility to an abstract problem rather than something which shapes the lives of real human beings.

It's worth remembering that today some two billion people have no access to modern forms of energy, while another two billion only enjoy limited access.

Aside from the considerable human toll of energy poverty, there are also dire environmental impacts, particularly the deforestation and pollution resulting from the burning of crude forms of biomass.

Certainly none of us would begrudge the extension of greater prosperity to these disadvantaged individuals and families – and in fact hundreds of millions have in recent decades enjoyed prosperity that was once unimaginable, but which has been enabled by modern energy.

However, these more affluent and more energy intensive lifestyles mean global demand for energy will expand steadily, and when you consider that our planet's population is set to grow by roughly yet another two billion people by the middle of this century, it's clear that demographics will also contribute significantly to the growth of our energy needs.

Consequently, we will have to meet the world's increased energy needs, and must do so in the most responsible manner. So how do we best address the challenge of ready access to affordable energy?

The short answer is that the world will continue to rely on traditional fossil fuels for most of its energy needs for the coming decades.

> "... it's no good driving a zero-emissions electric car if the juice for the batteries comes from an outdated, inefficient, coal-fired power plant somewhere over the horizon, which simply increases emissions and transfers them from vehicle tailpipes to power plant smokestacks."

In fact, these energy sources – namely coal, oil and natural gas – are expected to account for about four out of every five units of energy that mankind will consume for the foreseeable future.

In addition, even though the share of fossil fuels in the energy mix may decline over the longer term, the absolute quantities of energy from these sources will continue to rise simply because total energy demand is set to expand so significantly.

At the same time, alternative sources of energy should grow – and indeed must grow – in order to play their part in meeting that rising demand.

Certainly we should encourage the development of both renewables and more energy efficient end-use technologies, though we need to avoid the temptation of market-skewing cross-subsidies among fuel sources.

However, the growth of such sources is likely to be slow and uneven due to a range of daunting technological, economic, environmental, infrastructure and consumer acceptance issues, and given that the scalability of these energy sources remains a major challenge.

Furthermore, we need to make a complete and rational assessment of alternatives, including their realistic deployment rates, the comparative economics of various energy sources and technologies, and their totalenvironmental impact.

For example, prospects for many biofuels have been dimmed by rising food prices, high carbon emissions

> "The high cost and intermittent nature of wind and solar means they must be part of a broader and more stable system utilizing conventional energy sources..."

over their life-cycle, and ethical concerns over using land, water and energy to grow crops for fuel rather than food.

The high cost and intermittent nature of wind and solar means they must be part of a broader and more stable system utilizing conventional energy sources, and when it comes to nuclear, there are lingering concerns regarding plant safety and the safe disposal of spent fuel.

Similarly, plug-in hybrid and electric vehicles must still overcome issues related to battery charging time and driving range, initial vehicle cost, and the need to draw their electricity from environmentally sound and sustainable sources.

Ladies and gentlemen, it's no good driving a zero-emissions electric car if the juice for the batteries comes from an outdated, inefficient, coal-fired power plant somewhere over the horizon, which simply increases emissions and transfers them from vehicle tailpipes to power plant smokestacks.

We must also consider the roughly one billion motor vehicles currently on the road, as well as the massive existing industrial, commercial and residential equipment and facilities based on proven petroleum technologies—meaning that even when alternatives do become viable, it will take a long time to displace this existing base.

Furthermore, the devil is often in the details:

If we look at just transportation, electric propulsion systems are being envisaged for light passenger vehicles. But heavier vehicles like buses, trucks, trains, planes and ships – which account for a significant proportion of the energy used for transportation and whose energy demand is set to grow faster than light vehicles – have no such prospects on the horizon.

Ladies and gentlemen, let me summarize my view of the accessside of the energy equation by reiterating three simple conclusions:

One, for the foreseeable future the world will continue to rely primarily the same conventional energy sources that have generated an unprecedented century of progress and prosperity.

Two, the contribution of alternatives will grow but only gradually.

> "... there are significant opportunities to make petroleum more environmentally friendly, including cleaner burning fuel formulations, carbon capture and sequestration, and a host of other advanced technologies that are still in their infancy – and I believe it is incumbent on our industry to do its utmost to realize those enhancements."

And three, the role of alternatives in various energy sectors is likely to expand unevenly: more and faster in electric power generation but slower in transportation.

That means that even as we pursue promising new alternatives – as we should – we must continue to invest in efforts to both increase access to hydrocarbons and improve their performance, given their predominant role in the foreseeable future.

This brings me to the issue of acceptability, and what i consider to be our industry's "public permit" to operate as petroleum enterprises. Let me first look at environmental considerations.

From my perspective, there are significant opportunities to make petroleum more environmentally friendly, including cleaner burning fuel formulations, carbon capture and sequestration, and a host of other advanced technologies that are still in their infancy – and I believe it is incumbent on our industry to do its utmost to realize those enhancements.

I would also stress that simply by concentrating on more efficient vehicles, equipment and plants, the world can reduce significantly its emissions of carbon as well as conventional pollutants.

In addition, this approach offers a win-win solution, as it not only reduces emissions but also cuts costs and conserves energy – or viewed another way, enhanced energy efficiency is yet another way of providing increased access to energy which is already being produced but otherwise would be wasted.

But we should not single out the transportation sector as the only venue for substantial action on greenhouse gas emissions.

> I view the issue of acceptability as transcending environmental considerations, and encompassing the safety, dependability and affordability of energy supplies.

In fact, a McKinsey study entitled "Pathways to a Low Carbon Economy" analyzed the significance and cost of various methods of abating greenhouse gas emissions, and concluded that the most substantive prospects exist in power, forestry, various industries, agriculture, buildings, and then transport, in that order.

In my view, simply directing more natural gas supplies to the power generation sector could substantially reduce carbon emissions, given that gas emits less than half the carbon of an equivalent unit of power derived from coal.

These conclusions make clear the need to examine the whole spectrum of energy use when it comes to environmental protection and preservation.

However, I view the issue of acceptability as transcending environmental considerations, and encompassing the safety, dependability and affordability of energy supplies.

All of these help to ensure reliability, which in turn helps to ensure responsibility – a connection made clear by this year's tragedy in the Gulf of Mexico and its lingering aftermath.

Ladies and gentlemen, the petroleum industry's safety record is better than the images of the last several months would lead the public to believe, and today it is more capable, the technological tools at its disposal are more sophisticated, and the petroleum supply chain is more robust than at any point in the oil industry's long history.

But it would defy both logic and experience if any of us claimed that a similar incident could never happen again.

For that reason, we need to understand how such incidents could be prevented, and how their serious human, environmental and economic consequences could be better mitigated.

We may also need to look again at the possible impacts of other massively cataclysmic events that – like the incident in the Gulf – once seemed unimaginable.

> ... perceived energy security concerns seem to be driving some nations to discriminate against select energy sources, as we have seen in the case of oil.

Other sectors – such as commercial aviation, space exploration, nuclear power, chemicals, and pharmaceuticals – have faced similar catastrophes, and emerged stronger and more capable as a result of absorbing the right lessons from such disasters. I believe our industry now has a similar opportunity for learning and growth.

If nothing else, this incident reminds us of a few basic truths:

First, we operate in an inherently risky business, and oil producers undertake a tremendous amount of liability as a result;

Second, ours is a technically demanding business that requires a high degree of collaboration across a wide range of institutions and disciplines;

And third, operational excellence, including the maintenance of health, safety and environmental standards on the job, is indispensable not only to corporate efficiency and productivity, but also to public acceptance.

Tragedies such as this also underscore the need for senior management to clearly set priorities, and to ensure that the drive for profitability and shareholder value does not undermine a strong culture of operational excellence, environmental stewardship, and safety.

But ladies and gentlemen, if it is to be workable, our understanding of acceptability must include considerations beyond just the environment and safety.

This becomes strikingly clear if we look at the actual growth trends in the consumption of two key conventional energy sources: coal and oil.

On the whole, global coal consumption remained relatively flat during the nineties, but this decade, worldwide coal consumption grew at an unusually high rate of four-and-a-half percent per year on average. During those same two decades, oil consumption grew at a much slower rate of approximately one-and-a-half percent per annum.

What is most striking to me is that this acceleration

"... we also need to recognize the complex interplay between the imperatives of access and acceptability, since actions designed to impact one side of the equation invariably have some consequence on the other."

in coal demand came even as attention to climate change was also on the increase, and at a time when global warming was becoming a fixture on the global agenda.

These statistics are not only troubling with regard to increased carbon emissions, but are also indicative of a contradiction between stated objectives and the real-world results I just illustrated.

In addition to environmental concerns, the actual consumption of various energy sources is clearly driven by the interaction of economic growth, the resource endowments of individual nations, the economics of competing energy sources, and a range of energy and environmental policies, amongst others.

Furthermore, perceived energy security concerns seem to be driving some nations to discriminate against select energy sources, as we have seen in the case of oil.

This leads me to believe that we need to address stakeholder acceptance using a multi-faceted framework which better captures the practical reality of acceptability.

By the same token, we also need to recognize the complex interplay between the imperatives of access and acceptability, since actions designed to impact one side of the equation invariably have some consequence on the other.

Just as it is irresponsible to tackle issues related to energy supply without assessing their potential safety risks or impact on the natural environment, we must also evaluate the viability and ultimate benefits of environmental protection measures in light of the increasing global need for energy.

Balancing access and acceptability is something we have taken to heart at Saudi Aramco.

In terms of enhancing access to energy, our oil reserves of about 260 billion barrels represent roughly a fifth of the world's proven reserves, and at our current production rate, these reserves are enough for more than 80 years of production.

Yet we expect that over time those reserves will grow by an additional 40 percent, and are working to raise the rate of recovery from our major oil fields to 70 percent, or twice worldwide average.

On the gas side, our existing proven gas reserves of 276 trillion cubic feet are the fifth largest in the world, and growing. In fact, over the last five years we've added more than 45 trillion cubic feet of gas to our reserve base, even as our natural gas production increased.

Furthermore, our future gas exploration programs target growing those reserves from deep offshore, sour gas, shale gas and tight gas reservoirs in addition to conventional onshore gas.

All of those efforts ensure that we will continue to provide vital petroleum energy to the world for generations to come.

In terms of providing oil to the market today, and in keeping with the Kingdom's policy, we maintain large surplus production capacity at considerable cost to us.

This surplus capacity, which currently approaches four million barrels per day, has helped assure market stability, providing additional supplies whenever unforeseen events such as natural disasters or manmade strife and conflicts have struck.

Furthermore, we are making large investments in expanding our refining capacity, and are also integrating world-class petrochemical facilities with some of our major refineries.

In fact, over the next five years we are undertaking perhaps the most ambitious capital program in the petroleum industry, with the lion's share of those funds directed to the gas and downstream oil sectors.

Our capital program is designed to allow us to continue to play our role vigorously and responsibly in furthering the reliable supply of vital hydrocarbons to the world, and I am confident the positive impact of these massive investments will continue to be felt for many decades.

But as I noted, at Saudi Aramco we are also heavily engaged in addressing acceptability issues, including environmental stewardship.

To that end, we have been steadily boosting our environmental investments, and capital funding for our Environmental Master Plan has risen to nearly five billion dollars today.

As part of this plan, we are concentrating on producing cleaner fuels from our refineries, and enhancing the protection of our land, air and water resources – aside from our research into cleaner fuels and advanced engines, the reinjection of well cuttings, and gas flare recovery.

We're also devoting hundreds of millions of dollars to a CO_2 enhanced oil recovery demonstration project, which boosts oil production by injecting into the reservoir CO_2 that otherwise would have been emitted into the atmosphere.

Thus the technology not only protects the environment through carbon capture, but also boosts access to energy by enhancing ultimate recovery rates from oil reservoirs.

These, ladies and gentlemen, are the kind of win-win solutions we like to pursue, and which will enhance our industry's ability to supply energy to future generations, reliably and responsibly.

In addition, we have placed operational excellence at the top of our corporate agenda, and although we are very proud of our safety record, we are determined to make Saudi Aramco the global leader in industrial safety.

That longstanding commitment to performance, coupled with our massive infrastructure and technology investments and our surplus production capacity, helps address issues of acceptability in the holistic framework I outlined earlier – including the stability of global petroleum markets and a range of concerns related to energy security perceptions.

Ladies and gentlemen, allow me to close today by saying that the best way to achieve a truly sustainable balance between accessibility and acceptability in all their complexity is to engage in a frank and constructive dialogue among all stakeholders.

Only by working together can we better understand the complex issues in play; trace the alternative energy paths the world has available for the future; assess the real potential of these alternatives over time; concurrently examine both environmental and economic imperatives; and finally, recognize the various interests at stake in both the developing and developed worlds.

The World Energy Council plays a vital role in furthering that dialogue, and I applaud its continued efforts to bring energy issues to the forefront of the public agenda worldwide.

At the end of the day, we must each act decisively in the short term while also considering the long-term implications of those actions, and do our level best to attain an optimal balance between access and acceptance which achieves the best possible results for the greatest number of people.

Thank you."

Saudi Aramco RTOC, Collaborative, Safe and Effective Delivery of Wells from Start to Finish

By Musab M. Al-Khudiri, Naser A. Naser, Majid A. Al-Shehry, AbdulMohsin A. Al-Nassir and Hani K. Mokhtar.

Reprinted courtesy of Saudi Aramco JOT.

Abstract

The objective of this article is to discuss Saudi Aramco's drilling Real-Time Operating Center (RTOC) experience in developing personnel, establishing process workflow and acquiring technologies to deliver wells safely and effectively. The article starts by describing the IT infrastructure that facilitates rapid information flow from drilling sites to the RTOC. Then it discusses the process workflow, which includes pre-drill collaborative planning, real time predictive modeling, and 24/7 monitoring services to provide accurate response to real time trends for successful management of drilling risks, and therefore reduction of nonproductive time (NPT). Finally, overall achievements of 2008-2009 and a case study of one monitored and optimized well are presented.

Introduction

In January 2008, Saudi Aramco opened the Drilling & Workover RTOC, a state-of-the-art well visualization and real-time monitoring command center, to plan, drill and complete wells in the safest, efficient and cost-effective manner. The RTOC involves three critical components: People, Process and Technology. We found that understanding each component role is crucial to develop collaborative environment that helps to promote the RTOC values.

Saudi Aramco's RTOC was opened with a lot of challenging objectives. To meet the drilling management expectations, these phases were divided.

Phase 1

The initial RTOC objective was to operate the center on critical wells, mainly offshore wells to reduce occurrence of tight hole, stuck pipe, borehole collapse, sidetracked bottom-hole assemblies (BHAs) and borehole instability problems.

Phase 2

The next step was to improve drilling optimization and efficiency for the monitored wells. One of the techniques used was to monitor and implement the "Mechanical Specific Energy (MSE)" to optimize drilling parameters. Another main goal at this phase was to reduce the NPT for the monitored wells by monitoring the rig activity.

Phase 3

At this phase in the process, the RTOC might recommend the bit selection to increase rate of penetration (ROP). A main goal at this phase was to optimize hydraulics, hole cleaning and equivalent circulating density (ECD) for extended reach drilling (ERD) wells, BHA design, monitor drill string mechanics and BHAs to prevent damage and reduce well control incidents.

Saudi Aramco RTOC

The RTOC consists of a main room that is equipped with 10 main consoles; two of them are reserved for supervisors. These computers are connected to large screens on the wall to display monitored wells' real-time data. A collaborative room for day-to-day meetings is equipped with plasma screens and a PC. Another collab-

Fig 1. Overview of the RTOC.

orative room is equipped with video conferencing tools to communicate with other teams in the company and the outside world as needed. Figure 1 shows an overview of the center.

Drilling engineers nominate their wells based on how critical they are for the operation and potential challenges for the drilling activity. Once approved, the team starts by collecting and preparing required data for that well and the offset wells in the area from various sources. By using different tools and mechanisms, we predict the wellbore stability and monitor it in real-time, automatically generate targets and optimize platform placement and incorporate uncertainty. This work is being done in real-time using data coming from the surface and downhole tools. The communication is established between RTOC engineers with others using phone calls and embedded chat sessions to assist in better and faster decisions. We internally have designed our key performance indicators (KPIs) as described in the IT section to monitor the results of the RTOC and follow-up on what we have achieved so far.

Alerts are classified into two levels: Low and high levels. The low level alerts for any possible problems. Examples of cases with low level alert responses: loss of real-time data, weight on bit (WOB) deviations, reaming of stands while drilling, over pull while reaming, connection gas, low circulating time prior to pulling out of hole (POOH), low circulating rate to achieve hole cleaning, change in torque and drag trends, variation in expected hook load while running casing and deviations from program/procedures.

The high level alerts are for problems that need immediate action and response. At this level, the RTOC engineers notify drilling engineers verbally. If the drilling engineer can't be reached, the foreman is contacted directly. Then a follow-up summary is sent with real-time data capture to the drilling engineer.

Examples of cases with high level alert responses: sudden drop in standpipe pressure, sudden increase in standpipe pressure, sudden loss of string weight, flow out rate variations, alarms (washout, kick, loss circulation), erratic or sudden increase in torque while drilling, high over pulls while picking up on connections, high over pulls while POOH, and a sudden increase in drag while tripping pipe or casing and stuck pipe.

RTOC Staff

Since its first day, the RTOC began operating 24/7. It started with eight employees as follows:

RTOC Supervisor, Saudi Aramco

The RTOC Coordinator, is a senior person in both industry and Saudi Aramco, and has the overall responsibility for the RTOC activity and crew. He establishes and coordinates the levels of monitoring according to Saudi Aramco requirements and data availability.

Three Petroleum Engineers (Specialists), Saudi Aramco

These engineers are responsible for preparing the subsurface pore pressure/geomechanical model. Also, they will prepare downhole calculations for torque and drag, swab/surge and hydraulics.

One Senior Drilling Surveillance Specialist, Drilling Consultation Services

He is second in command to the RTOC Coordinator. The Senior Drilling Engineer, responsible for job activity and crew, issues a Daily Report at 6 a.m., and a Weekly update and Monthly Activity Review. He is mainly responsible for communications with Saudi Aramco personnel and he attends meetings as required and directs activity in the RTOC.

Two Staff Drilling Surveillance Engineers, Drilling Consultation Services

They ensure continuous Earth Mechanical Model build-up and update the models already built. They build and maintain mechanical and hydraulic models using complementary software. Each one works 12 hour shifts with 24/7 coverage.

Two Associate Drilling Surveillance Engineers, Drilling Consultation Services

Compare and record differences between pre-drill estimated performances with real-time data received. Main-

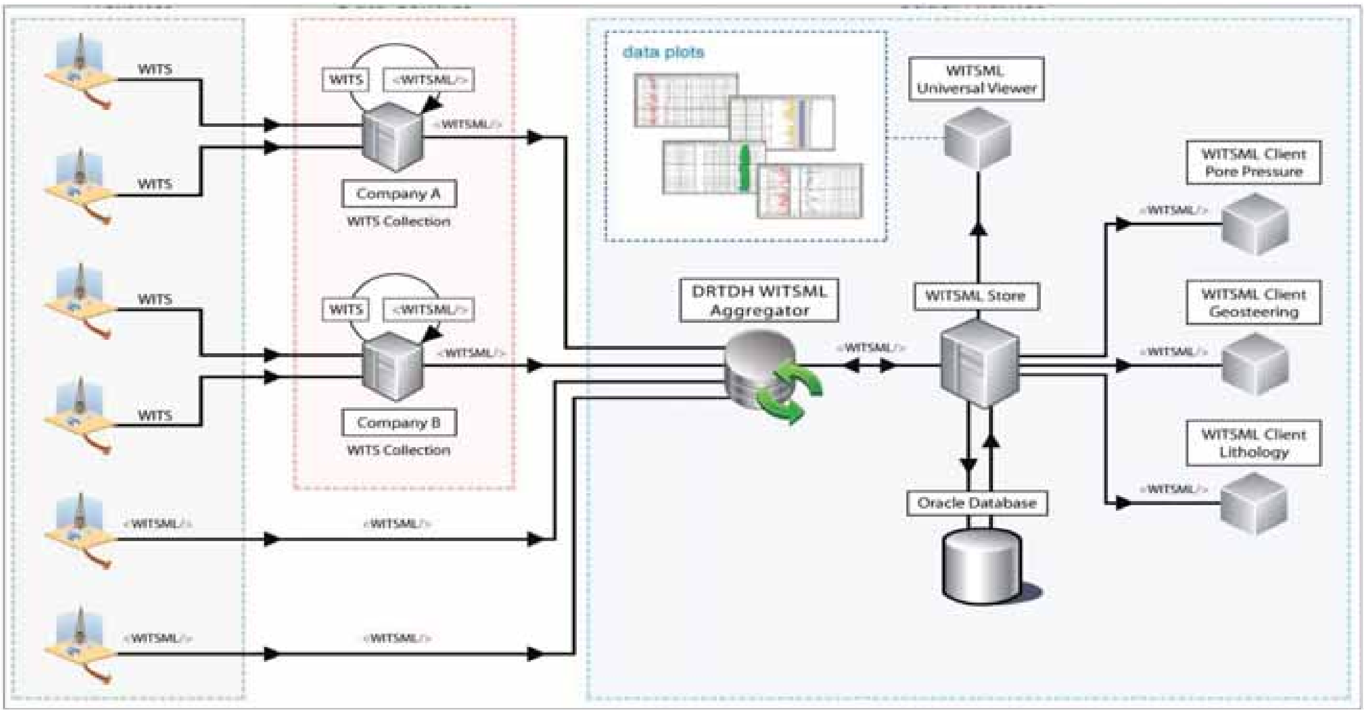


Fig 2. Current real-time well site data flow at Saudi Aramco.

tain an open communication channel with all parts involved in the project: Drilling Engineer – Geosteering Team – RT Provider – Rig Supervisor. Each one works 12 hour shifts with 24/7 coverage.

Two Technical Computer Support, Saudi Aramco
Provide offset well data available in Saudi Aramco databases. Troubleshoot network problems. Ensure required access to Saudi Aramco proprietary applications. Each one works during the daily office hours, and is on call 24/7.

IT Infrastructure

Saudi Aramco uses many different service organizations to deliver its global drilling and completions agenda. Applying a common approach to information access on a global basis has enabled us to streamline our operations and make wider use of emerging analysis, monitoring and collaboration technologies.

In early 2007, Saudi Aramco implemented new data architecture for real-time drilling and completions (D&C) information. This new architecture has enabled us to make wider use of our monitoring and collaboration centers through a common approach. It also allows us to leverage the evolving Well site Information Transfer Standard Markup Language (WITSML) standard more effectively in our drilling operations. Figure 2 shows the current real-time well site data flow at Saudi Aramco.

The WITSML is a continually developing industry standard for the transmission of real-time, historical and contextual drilling and completions information. The WITSML standard is managed by Energistics on behalf of the members. Saudi Aramco is a contributing member of Energistics and has been a member of the drilling WITSML Special Interest Group (SIG) since January 1, 2008. It is the most active user of the WITSML standard worldwide[1].

The RTOC uses different tools to collect data in real-time. These tools vary from downhole parameters measuring while drilling/logging while drilling (MWD/LWD) tools to surface parameter tools. These tools are unmanned and just need to be setup at the beginning of the job. The tools are provided by different providers, and they are based on WITSML standards. Data are collected from different rigs and sorted in Saudi Aramco's drilling real-time data hub (DRTDH)[1].

Real-time technologies have been utilized to capture, monitor and analyze drilling data from rig sites so that critical decisions can be made in real-time to help reduce and eliminate borehole problems, thereby reducing nonproductive time (NPT). This includes high-tech rigs, business continuity solutions for real-time information, collaboration tools and real-time data visualization systems.

Predictive Modeling

The RTOC runs a complete geopressure and geomechanics solution that improves drilling success. It includes all the tools needed to achieve new levels of risk reduction, cost savings, and drilling performance. This includes leading geopressure analysis, 3D visualization and analysis, seismic velocity correction, seal integrity and compartment analysis, uncertainty analysis, and fully integrated wellbore stability analysis. Figure 3 shows predictive model get feeds by real-time data.

Mechanical Specific Energy

Real-time MSE surveillance as described by a previous SPE paper[2] provides calculations to monitor changes in the efficiency of the drilling operation. It measures the calculated work that is being performed to destroy a given volume of rock. A MSE calculation helps to identify the best drilling parameters and justify any design changes, such as bit selection, BHA design, markup torque, directional target sizing and motor differential ratings. The MSE depends on the fact that the input energy from the rig (RPM, WOB, torque and pump pressure) is equivalent to the output energy (vibration and ROP). Vibration must be minimized to optimize the ROP. The following equation has been defined to calculate MS:

$$MSE = \frac{480 \times Torque \times RPM}{Dia^2 \times ROP} + \frac{4 \times WOB}{Dia^2 \times \pi}$$

To make our analysis more accurate, we have chosen to calculate and display the adjusted MSE by including an efficiency factor:

$$MSE_{adj} = MSE \times EFF$$

where EFF= 0.35 (Efficiency factor).

To apply MSE optimization, we have applied optimal drilling parameters to collect realistic MSE data and trend on two pilot wells for each lithological formation. The recommended parameters were passed to the bit specialist to apply them at the well site while drilling. During the drilling operation, the MSE from recommended drilling parameters were recorded for future MSE analysis against recommended drilling parameters for the next well(s). Bit specialists at the well site are a key performer for ROP optimization by utilizing MSE. Figure 4 shows a sample of how MSE curve is displayed in a real-time data viewer after calculating its value based on the MSE equation.

Drilling Simulation Systems

Work is in progress to implement advanced real time modeling, diagnosis, visualization and simulation systems. The systems will utilize real-time data acquired from surface and downhole sensors to simulate the drilling activities through 3D interactive visualization techniques. The systems will assist the engineers in looking forward to downhole problems, provide recommendations and develop scenarios while drilling to avoid operational risks and speed up drilling.

Measuring RTOC Value

A system was developed to help the RTOC management in defining and measuring progress towards the RTOC's main goals. The goals are to reduce NPT, to optimize drilling operations and to improve safety in drilling activities. Figure 5 shows different snapshots of the KPIs charts.

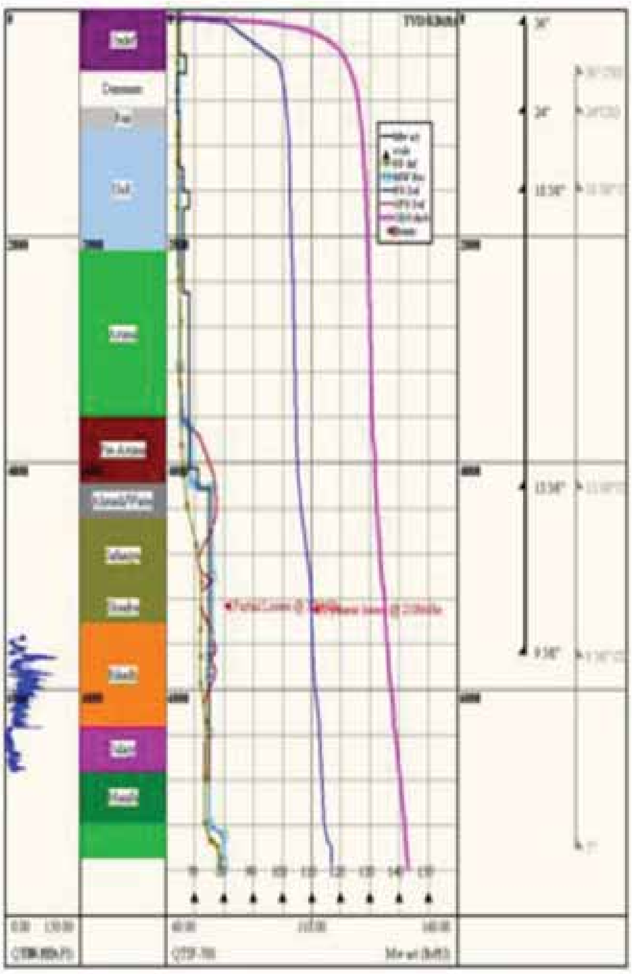


Fig 3. Predictive model fed by real-time data.

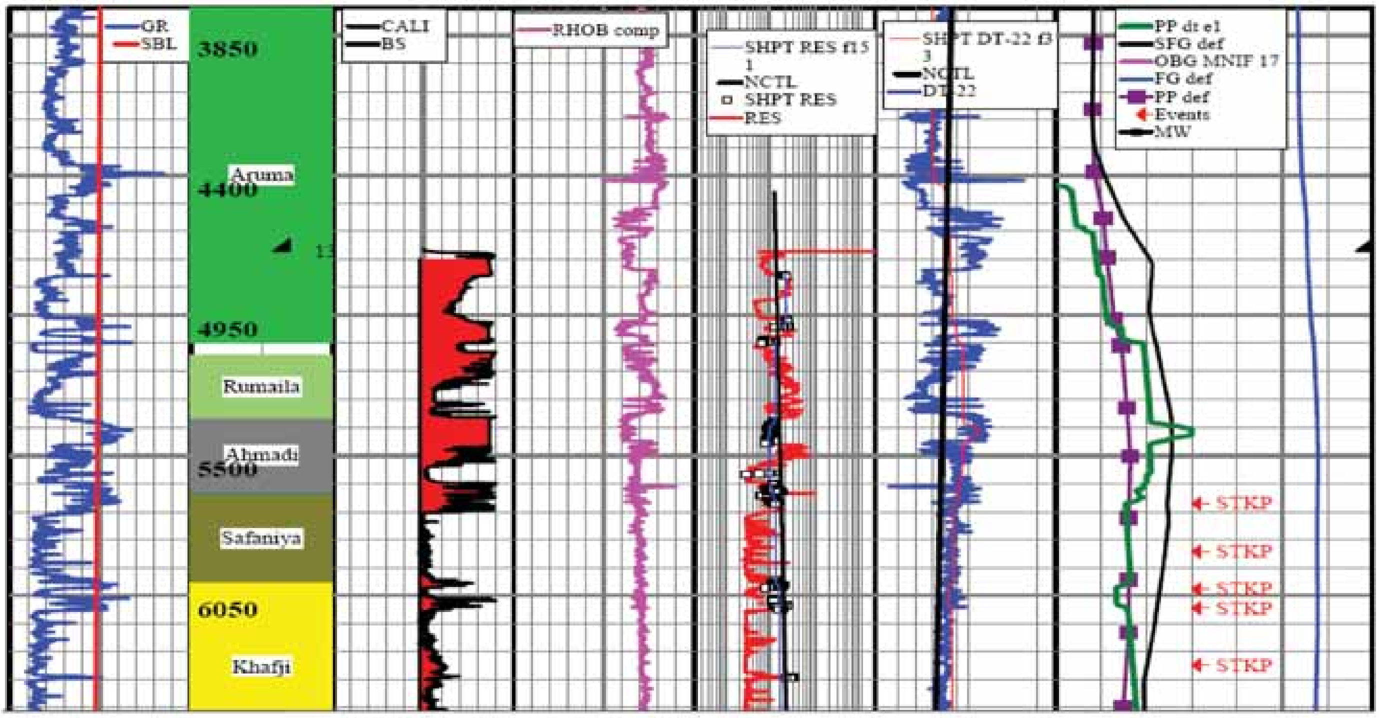


Fig 4. Displaying MSE as a curve along other logs in real-time.

So far the RTOC team has identified the following KPI definitions to be calculated:

• Average total operation time and average total lost time in RTOC vs. non-RTOC wells in the same field.
• Percentage of wells that had specific trouble (e.g., stuck pipe) per year.
• Percentage of drilling troubles per field.
• Total lost time per operation code.
• Compare how many feet per day were drilled in the RTOC and non-RTOC wells.

The first six months of operation in the RTOC has paid back the cost of the center.

A total of 90% of the stuck pipe issues were monitored and prevented. Some of the RTOC statistics reported in August 2009 are:

Total monitored sections = 232
Total alerts raised = 115
Total recommendations = 335

Challenges and Solutions

1. Many drilling engineers are not aware of what the RTOC can provide to them. Aggressive technical marketing of the RTOC is needed among the drilling engineers with the supervisor's assistance. Many training sessions were held for drilling engineers and rig foremen to overcome this challenge.

2. To enforce data analysis every 12 hours per shift to determine "a totally independent technical critique" of drilling activities. Every 12 hours, analyze real-time data and make recommendations to the drillers offshore on how to respond when parameters change, to ensure wellbore viability and bring forward what we call "Practices worth replicating" to the next phase of execution.

3. In the RTOC, we refined the process and the procedures on monitored wells like using a traffic light system for the monitored rigs. Green means the RTOC is tracking the well, amber means slight deviation from the plan executed and red means stop operations. This is to ensure the interaction between the rig and the RTOC follow clear protocol.

4. To improve collaboration with the Geosteering Operation Center (GOC), petrophysics and senior well engineers. There are some initiatives to implement a real collaborative environment between the two centers.

5. To automate rig activity detection, and to optimize and award merit based bonuses to enhance rig activity. This is needed to monitor NPT/Invisible lost time (ILT) and to create best practices and lessons learned.

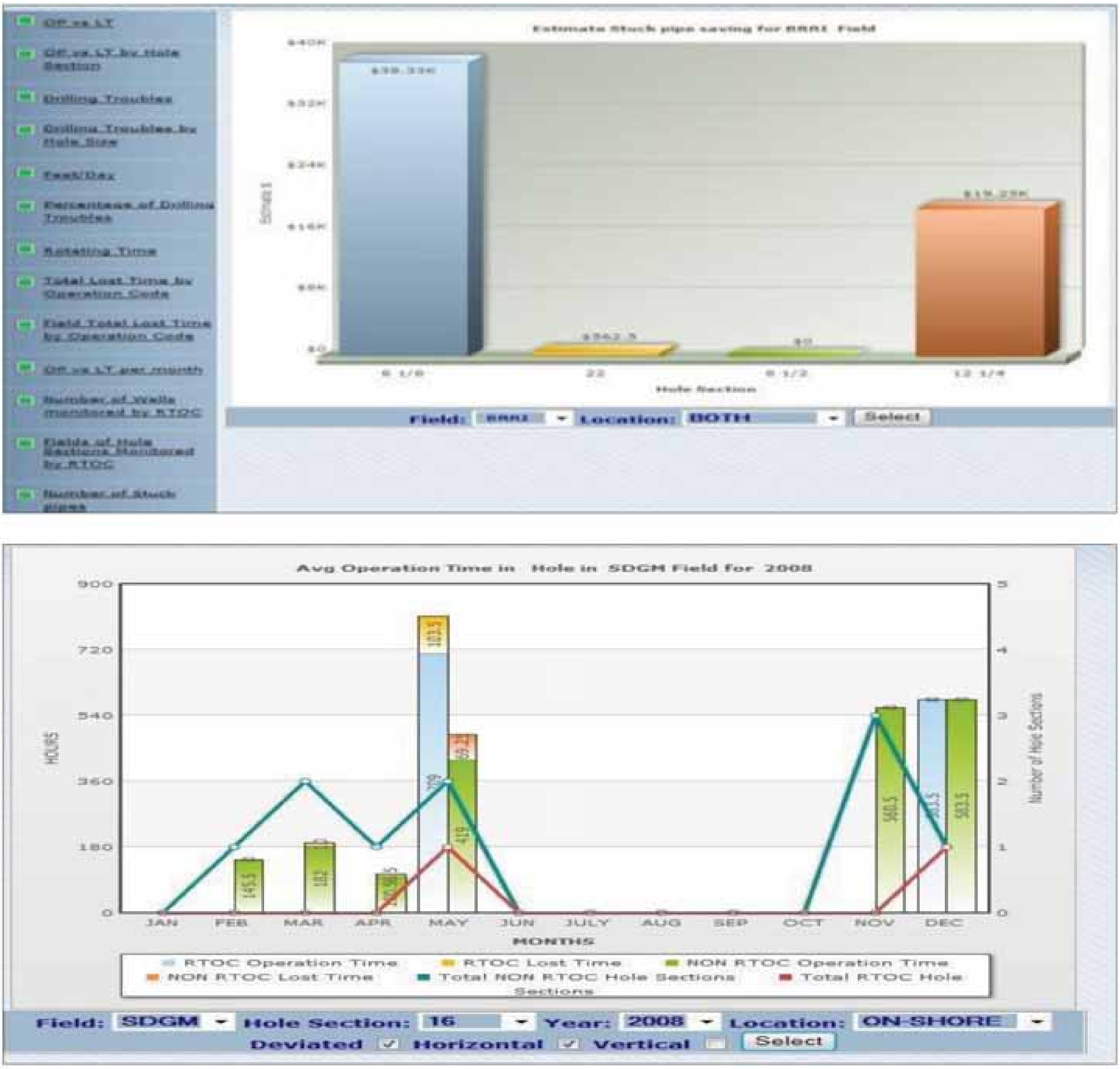


Fig 5. Snapshots of KPI charts.

Futuure Plans

Drilling Real Time Applications Gateway

Implement an interactive Applications Dashboard for drilling applications. The system is a business and operations management dashboard platform that can be customizable for user roles (Command Centers Manager, Drilling Supervisor, Drilling Engineer, Geologist, Geosteering Supervisor, etc.) or departmental functions (drilling geosteering, IT, etc.).

Saudi Aramco Interactive Drilling Solution (S-IDS)

Overhaul the Saudi Aramco Drilling Knowledgebase (SADK) framework to encompass real-time data, drilling simulation data and planning data in addition to the existing operation data. The morning reports and other reports will be interactively driven by the planning data and real-time data updates. SADK was developed five years ago and has been growing ever since. It is time now to build a new framework to capitalize on the introduction of new workflows as real-time data gathering and automation of drilling programs.

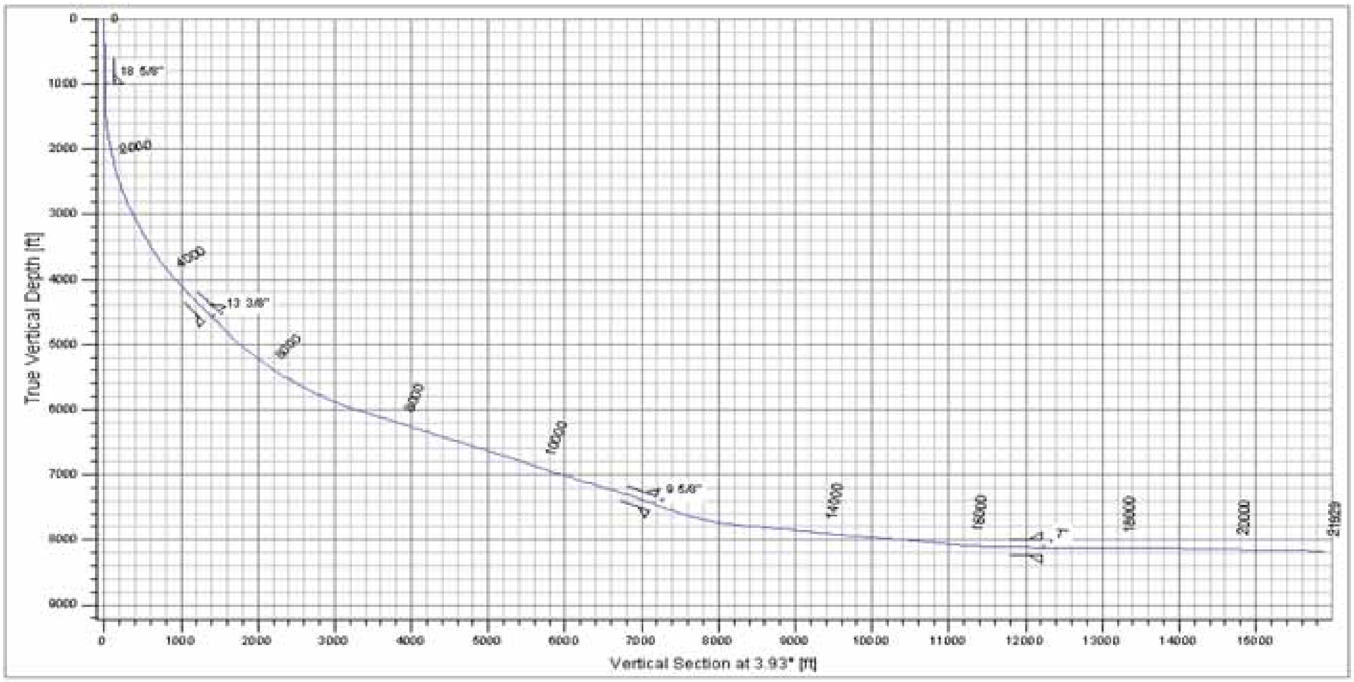


Fig 6. Well A deviation profile..

A CASE STUDY FOR WELL A WITH 8½" AND 6¹/₈" SECTIONS

Introduction

During the well planning phase, drilling engineers identified potentially difficult sections of the well based on offset well data and drilling difficulties experienced in previous well drilled. A request to monitor the well/sections in Well A is submitted to RTOC. Well A was designed as an ERD well. See well deviation profile in Fig. 6.

The RTOC team, in collaboration with the drilling engineer, identified the potential drilling problems for both sections, see Tables 1 and 2.

Pre-drill Modelling Work done by RTOC

Pre-drill models are generated by the RTOC team for optimum monitoring of Well A. These models include a Drillworks Predict Model; Torque and Drag Models; Hydraulics Model; etc. The Drillworks Predict Models simulates the expected maximum pore pressures, shear failure gradient and fracture gradient. All of these suggest to the engineer the required minimum mud weights for hole stability and minimum expected fracture pressures.

Torque and Drag Models are the main method to listen for "wellbore healthy" by monitoring torque and the hook load (HKLD) during drilling or tripping operations. By plotting the real-time HKLD on the Torque and Drag Model, effects on "wellbore healthy" would be presented in a form of friction experienced between the drilling strings and the wellbore.

The Hydraulics Models simulate the required circulation parameters needed to clean the hole based on the ROP, amount of cuttings generated, and the wellbore profile to evaluate the optimum flow parameter required to eliminate cutting beds, and compare ECDs with or without a cutting effect to avoid potential hole problems.

Real-Time Monitoring

Real time surface parameters logging data was continuously being transferred from the rig and monitored continuously in the RTOC. While drilling was going on, real time observations were made by the RTOC team and recommendations were made to avert potential drilling hazards that could jeopardize the objectives of the well. Corrective actions either suggested by the RTOC team or thought out by the Engineering team were made to avert these hazards and the well was successfully drilled

Formation	Prognosis Depth (MD)	Actual Depth (MD)	Potential Hole Problems
Buwaib	12,415 ft		
9⅝" Casing	12,790 ft		
Yamama	14,810 ft		Potential of mud losses, hole cleaning and stability.
Upper Ratawi	15,680 ft		Hole cleaning, Geometry.
Base Upper Ratawi	18,132 ft		Hole cleaning. Borehole Geometry.
Lower Ratawi Reservoir	18,723 ft		Stability, Torque and Drag, Stuck Pipe, H_2S and/or CO_2 influxes.
7" Casing Liner	20,237 ft		

Table 1. Potential hole problems for the 8½" section.

Formation	Prognosis Depth (MD) and TVD	Actual Depth (MD)	Potential Hole Problems
Lower Ratawi Reservoir			
7" Casing Liner TE	20,237 ft 8,106 ft TVD		
Lower Ratawi Reservoir-B TD	23,482 ft MD 8,106 ft TVD		Possible borehole cleaning. Excessive torque and drag. Loss circulation and stuck pipe. Possible H_2S. Induce losses.

Table 2. Potential hole problems for the 6⅛" section.

to TD. See examples below of the format of recommendations and alerts raised with the drilling engineers.

High Stick-Slip in the 8½" Hole

Consequences

High stick-slip may cause drill string torsion failure and downhole tool failure.

Remedies Suggested by RTOC

RTOC recommended changing the drilling parameters (optimize drilling parameters), increase the lubricity of mud, proper bit selection, and installing a soft torque dampening system.

RTOC Recommendations

RTOC recommended increasing RPM and/or reducing WOB and picking up off-bottom (to release stress from string). If the above actions did not help, to prevent and reduce stick-slip, circulation with pills and the increase of mud lubricity should be considered.

Results

By applying recommendations from RTOC, potential string failure was averted.

Stationary Drill String, for Long Time Periods, During Repeated Attemps to Record Pressure Points in the 6⅛" Hole

Consequence

Having a stationary drill string, for long time periods, during repeated attempts to record pressure points in the 6⅛" hole could lead to differential sticking.

RTOC Recommendations

To prevent differential sticking, RTOC recommended reciprocating the string full stand between two pressure points or in a repeat attempt at the same point.

Results

By applying recommendations from RTOC, sticking incidents did not occur.

Lessons Learned

1. While tripping in and out of the build section, it is critical to clean the hole completely before POOH. This may take three or four bottoms up cleanings, and shakers must be clean to avoid the string becoming stuck.

2. To demonstrate the hole is clean, the pipe must be pulled without rotation or pumps.

3. Back reaming in certain fields and reservoirs gives a false indication of the hole condition. This may cause lost time when running casings.

4. Raise awareness of good hole cleaning practices with rig personnel.

Involvement in the Planning Stage to Help Drilling Engineers

1. Designing the optimum directional trajectories to minimize torque, drag, improve ROPs and improve BHA design for critical well designs.

2. Modeling torque and drag to improve future well designs and to provide information to optimize drilling parameters for future wells.

3. Modeling hydraulics and ECD to optimize flow rates for hole cleaning and ROP. This is planned to be done in real time.

4. To provide input into decision making regarding running annular pressure while drilling (APWD) tools in critical wells.

5. Providing inputs and assisting in casing design based on the bore pressure prediction software results.

Involvement in Operation Stage

1. Attending daily morning meeting to discuss the recommendations for further improvement of operations.

2. To attend planning meetings and conducting post well/event meetings to add learning from the RTOC.

3. To be part of the team in planning future well designs.

Acknowledgements

The authors wish to thank Saudi Aramco management for their support and permission to present the information contained in this article.

References

1. Khudiri, M.M., Shehry, M.A. and Curtis, J.D.: "Data Architecture of Real-Time Drilling and Completions Information at Saudi Aramco," SPE paper 116848, presented at Abu Dhabi International Petroleum Exhibition and Conference (ADIPEC) in Abu Dhabi, U.A.E., November 3-6, 2008.

2. Dupriest, F.E. and Koederitz, W.L.: "Maximizing Drill Rates with Real-Time Surveillance of Mechanical Specific Energy," SPE paper 92194, presented at SPE/IADC Drilling Conference in Amsterdam, the Netherlands, February 23-25, 2005.

Proactive Geosteering in Thin Reservoir Bounded by Anhydrite in Saudi Arabia

By Abdralrasool A. Al-Hajari, Adeyinka Soremi, Dr. Shouxiang M. Ma, Ali H. Julaih, Troy W. Thompson, George Saghiyyah, Amr Lotfy, Mohammed Bayrakdar, Dr. Michael Bittar and Roland Chemali.

Thin reservoirs of a few feet in thickness present a clear challenge to well placement. Drilling out of the target is a real possibility, and plugging back and reentry can be extremely difficult. Clearly, the best solution is to avoid exiting the target reservoir by detecting approaching boundaries as early as possible, and by remaining at an optimal distance from the boundaries. This practice is known as "proactive geosteering." In recent developments, wave resistivity logging while drilling (LWD) and azimuthal wave resistivity sensors have been shown to effectively facilitate proactive geosteering. Their abilities to scan laterally several feet, up to more than 10 ft, around the wellbore and then to identify the relative azimuth of approaching boundaries have been instrumental in recent successes. The challenge posed by the subject reservoir in this study is the combination of the thinness of the reservoir, approximately 3 ft, and the high resistive environments of the boundary, zero-porosity anhydrite formations, as well as the oil reservoir containing a low porosity dolomite layer. The challenge was met by carefully selecting the most appropriate measurements to send to the surface, interpreting them in real time, and using multi-boundary inversion. A series of pre-well simulations were run using offset wells. The simulation results showed that for the most likely scenario, shallow azimuthal wave resistivity curves and images provided the highest sensitivity to the approaching boundary. Medium and deep resistivity curves were less active and of lower resolution, but they contributed to the inversion for dual boundaries. Newly generated high resolution electric and density reservoir imaging and petrophysical logs were also interpreted in real time to assess the relative dip and provide finer control of the well angle. They helped to verify that the well remained within the reservoir through nearly its entire span, i.e., that the well was successfully placed with a high net-to-gross in a very thin reservoir in resistive environments.

Introduction

Drilling a horizontal well and maintaining it within the best section of the reservoir presents multiple and diverse challenges. For very thick reservoirs, large errors in well placement may not affect the initial production, but the overall sweep efficiency during the life of the field and the ultimate recovery of hydrocarbon are likely to be affected[1]. In general, the optimal location for a well in a thick reservoir is selected on the basis of future performance. The preferred well path is often defined with reference to geological boundaries, including overlaying conductive or resistive boundaries (such as shale, anhydrite, and oil-water contact). As a result, geosteering methods in thick reservoirs have consisted of monitoring the distance between the well path and a reference boundary, and adjusting the well direction to maintain that distance within prescribed limits[2].

For thin beds, the challenges generally consist of remaining within the boundaries of the reservoir and of experiencing as few exits as possible. When they occur, reservoir exits should be short with a rapid return to the pay zone, but severe doglegs must be avoided. Doglegs interfere with drilling, running completion including screens or casings, and conducting reservoir surveillance. Clearly, every interval drilled out of the reservoir rock is a nonproductive interval. In many cases, out of zone intervals, such as shales, are also less mechanically competent than the reservoir rock, giving rise to drilling problems. If an exit cannot be avoided, it is important to rapidly define a return path into the reservoir.

Proactive geosteering strives to anticipate reservoir exits and alter the well path ahead of time to remain within the best portion of the reservoir[3]. By detecting approaching boundaries long before they cross the well path and by changing direction appropriately, it is possible to remain in the zone through a large portion of the producing interval. In the reservoir considered for this publication, the producing interval is limestone, only a few feet thick, and bounded above and below by anhydrite. From geological information gathered in nearby wells, the thickness of the producing interval is estimated to be as thin as 3 ft in places. The geosteering challenges are to maintain the drillstring in the zone in a particularly thin interval, to identify the direction and distance of approaching boundaries, and to perform these tasks in a resistive environment that is unfavorable to wave resistivity measurements. The expected signal levels for anhydrite, being highly resistive, are much weaker than in the more traditional situations in which the hydrocarbon-bearing interval is contained between two less resistive layers, typically shale above and water bearing below. This expectation was demonstrated by an early study in an adjacent field[4].

Geosteering in Thin Bed Reservoirs in the Presence of Highly Restrictive Resistive Adjacent Formations

The sensor selected for proactive geosteering is the azimuthal deep resistivity sensor, Fig. 1[5,6]. With tilted receiver antennas and real-time modeling capability, the azimuthal geosteering signal for the azimuthal deep resistivity array tool described in the following paragraphs is capable of recognizing laterally approaching formations from several feet away. Multiple spacings and frequencies each provide a phase reading and an attenuation reading; the azimuthal deep resistivity sensor yields multiple measurements at different depths of investigation. The shallowest measurement comes from the 16" spacing, with phase operating at 2 MHz; the deepest measurement comes from the 125 KHz attenuation resistivity of the 112" spacing. Figures 2 to 4 show several modeling results that illustrate the advantages and limitations of various spacings. Because of the limited bandwidth of mud pulse telemetry, only a small number of these measurements are accessible in real time for steering the well.

Measurements from the azimuthal deep resistivity tool generally considered for geosteering are broadly classified into two families. The first family is the azimuthal resistivity itself for each of the transmitter-receiver pairs and for each of the frequencies. Azimuthal resistivity is naturally binned along 32 sectors around the circumference of the wellbore. For ease of represent-tation, the azimuthal values are often mapped as deep resistivity images. The second family is the suite of geosteering

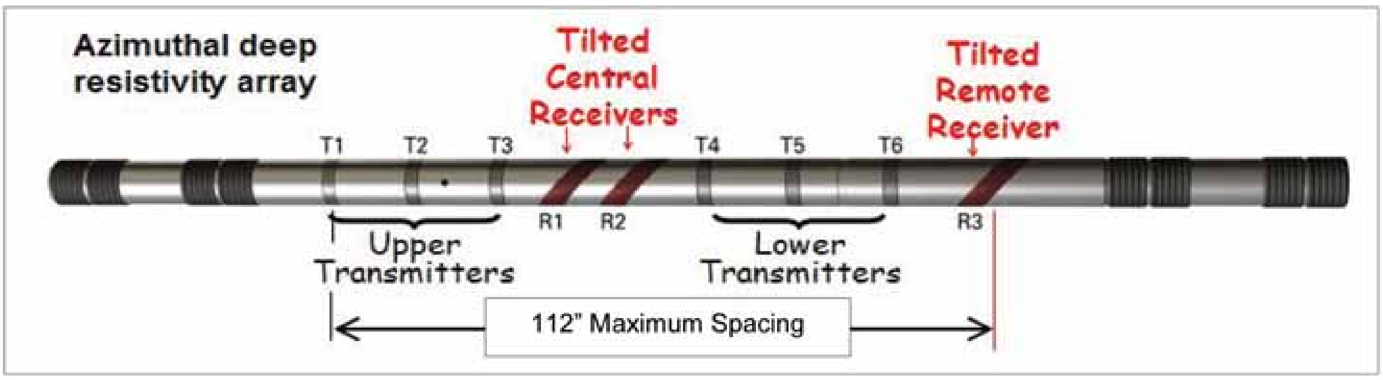


Fig. 1. Measurements at multiple depths of investigation are generated by the azimuthal deep resistivity sensor array. As the BHA rotates, the resistivity measurements scan the formation surrounding the wellbore into 32 azimuthal bins, providing images of the formation at varying depths of investigation. The longest transmitter-receiver spacing is 112" and the shortest is 16".

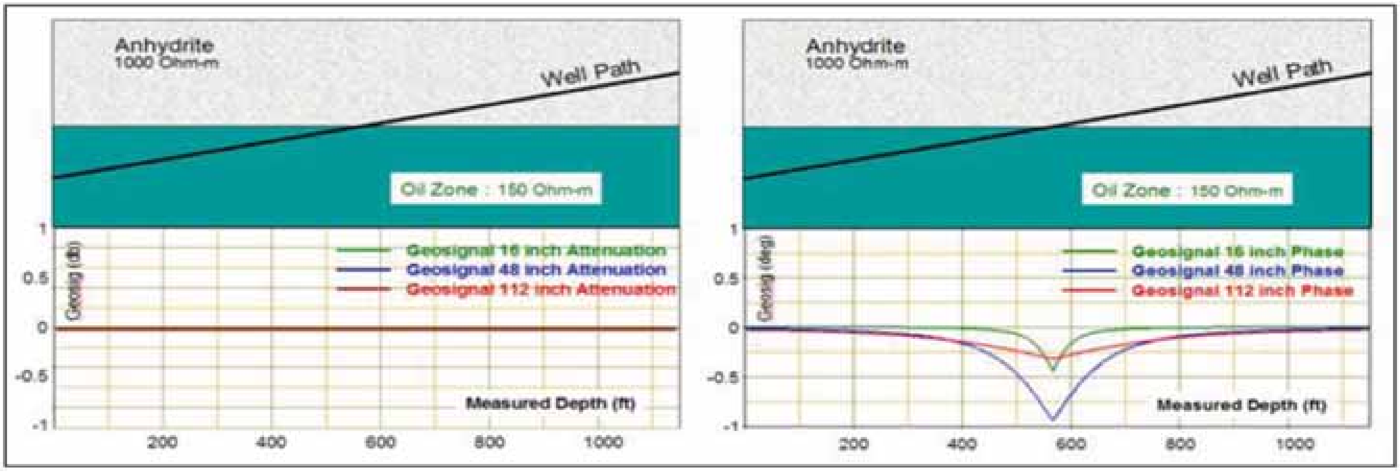


Fig. 2. Given the high resistivity of oil zone and surrounding anhydrite, a simple model is run to verify the applicability of the various measurements from the Azimuthal Deep Resistivity tool. The attenuation clearly exhibits little sensitivity to the reservoir boundary and the phase shows adequate sensitivity. The geosignal points toward the less resistive formation.

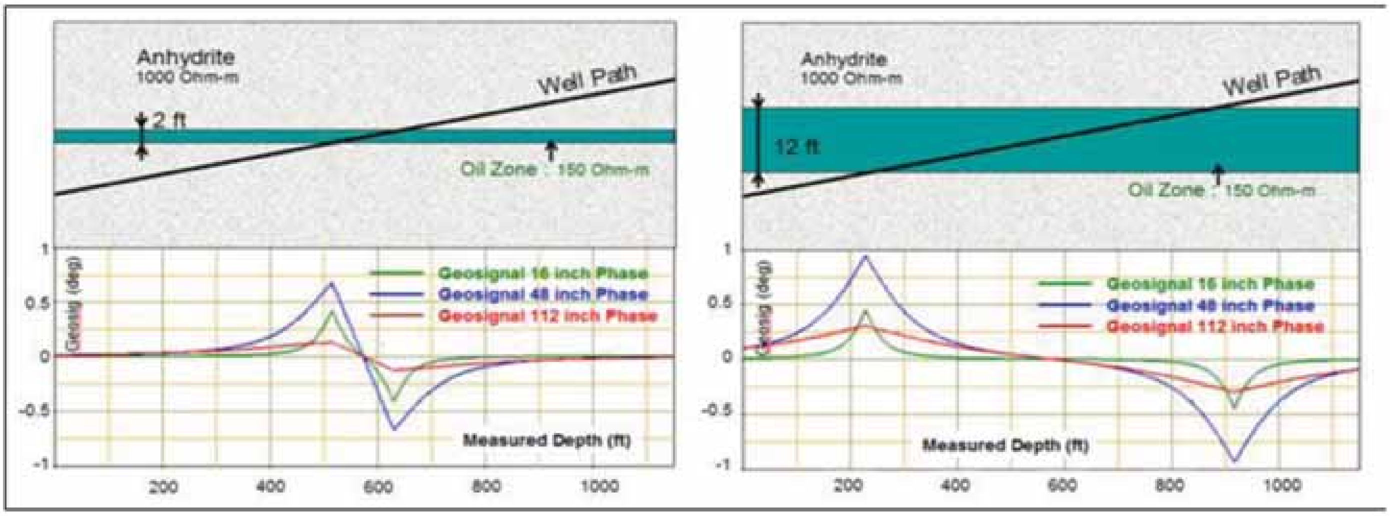


Fig. 3. In a very thin reservoir surrounded by anhydrite, the modeling suggests that the shorter spacing of 16" and 48" are more likely to be able to resolve the reservoir boundary than the longer spacing, such as 112".

signals, which are also called geosignals[7]. Geosignals feature a vastly enhanced sensitivity to non-axisymmetrical events, including side-approaching boundaries. Typically, one measurement from each of the two families is pulsed in real time to the surface.

The geology of the reservoir in this case study presents two main challenges. Special care must be given to planning the geosteering operation and configuring the sensor to address both challenges.

The first challenge is unique to the geology, in that the oil reservoir and the surrounding media are very resistive, which precludes the use of the attenuation geosignal. Figure 2 shows a simple geological configuration in which the target resistivity is 150 Ohm-m and the resistivity of the overlaying formation is 1,000 Ohm-m. The attenuation-based geosignals for short and long spacing are nearly zero, remaining totally insensitive to the boundary, even as the well path crosses it. This phenomenon occurs only when all formations within the reach of the signal have high resistivity. By comparison, the phase based geosignal shows more character in the same simple geological model, Fig. 2. The response to the boundary is weak, but measurable. As expected, the longer spacing of 112" anticipates the boundary long before it is met by the wellbore.

The second challenge is the thinness of the reservoir. Under normal circumstances, the petrophysicist would

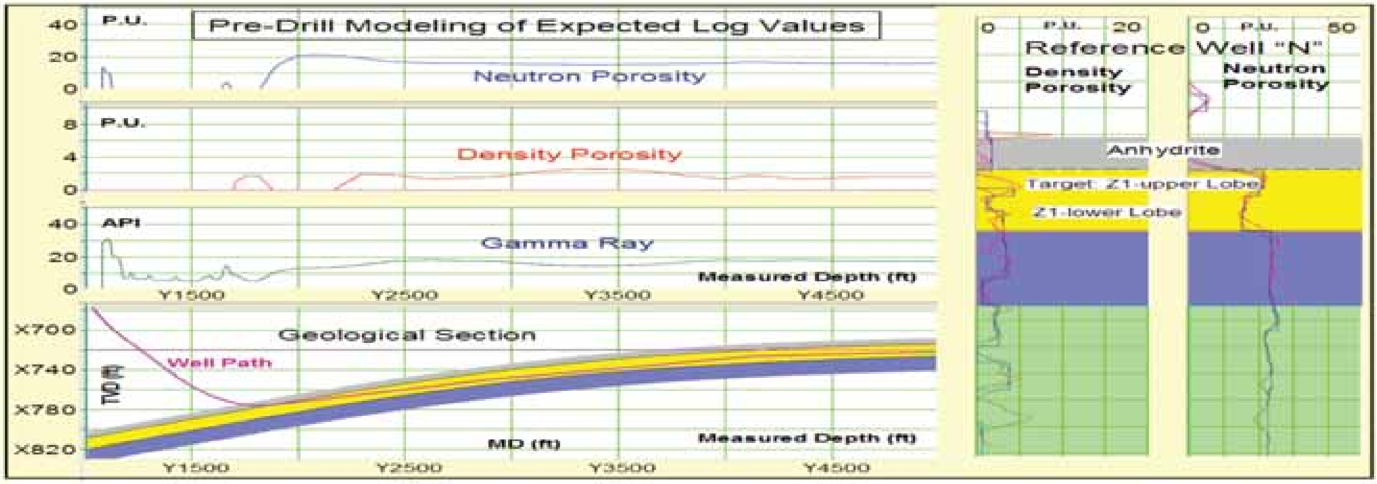


Fig. 4. Pre-drill simulations were computed by convolving the geological model with log information from three nearby wells. The graph uses neutron porosity, density, and gamma ray logs from Well N, which is nearest to the projected location.

select the deepest reading spacing (i.e., 112") to reach laterally as far as possible. In this case however, the response of the longest spacing is too smooth and does not provide the required resolution. The models shown in Fig. 3 suggest that the shallower spacing of 16" and 48" are suitable to locate the well within a thin reservoir and to resolve the boundary with enough accuracy.

Given the thinness of the reservoir, wave resistivity measurements may not be used for quantitative formation evaluation. They are affected, to a large extent, by the polarization horns attributable to adjacent beds. A laterolog measurement is better suited for this application8. In the following example, an azimuthal focused resistivity is added to the bottom-hole assembly (BHA) for electrical imaging and to deliver a laterolog type resistivity measurement[9].

Pre-Drilling Modeling and Planning of the Geosteering Operation

In preparation of the geosteering operation, a series of pre-drill simulations were run based on a geological odel, generated from the areal seismic and geological studies. The pre-drill simulations convolve the geological model with the resistivity, density, gamma ray, and neutron porosity logs from nearby wells. The objective is to map in advance the expected log responses for the projected well. Should the actual logs acquired while drilling depart from the pre-computed ones, petrophysicists would update the model to achieve as close a match as possible between pre-computed and measured values. In the case subject of this article, three nearby wells were initially considered. After the simulations corresponding to these three wells were studied in detail, only those results from the nearest well (Well N) were retained for the geosteering operation. Figure 4 shows the pre-drilling simulations for density, neutron porosity, and gamma ray derived from Well N. The target, Z1-upper Lobe, is a thin layer of limestone formation overlaying the Z1-lower Lobe, a low porosity, high resistivity, dolomitic limestone.

The pre-drill modeling of the azimuthal deep resistivity included several variations of the calculations, Fig. 2 and Fig. 3. The proactive aspect of the geosteering occurs during drilling and includes looking for markers and boundaries, and adjusting the well path accordingly to avoid exiting the reservoir. Of all available resistivity measurements and images available from the azimuthal deep resistivity, only those from phase measurements from the shorter spacing were retained. Specifically, traditional non-azimuthal resistivity measurements from the 16", 32" and 48" were programmed for the mud pulse telemetry, as well as the azimuthal resistivity and geosignal measurements from the 16" spacing.

Another important aspect of the proactive geosteering includes computing the distances to upper and lower boundaries through inversion in real time[1]. Trends in either distance help to guide steering decisions.

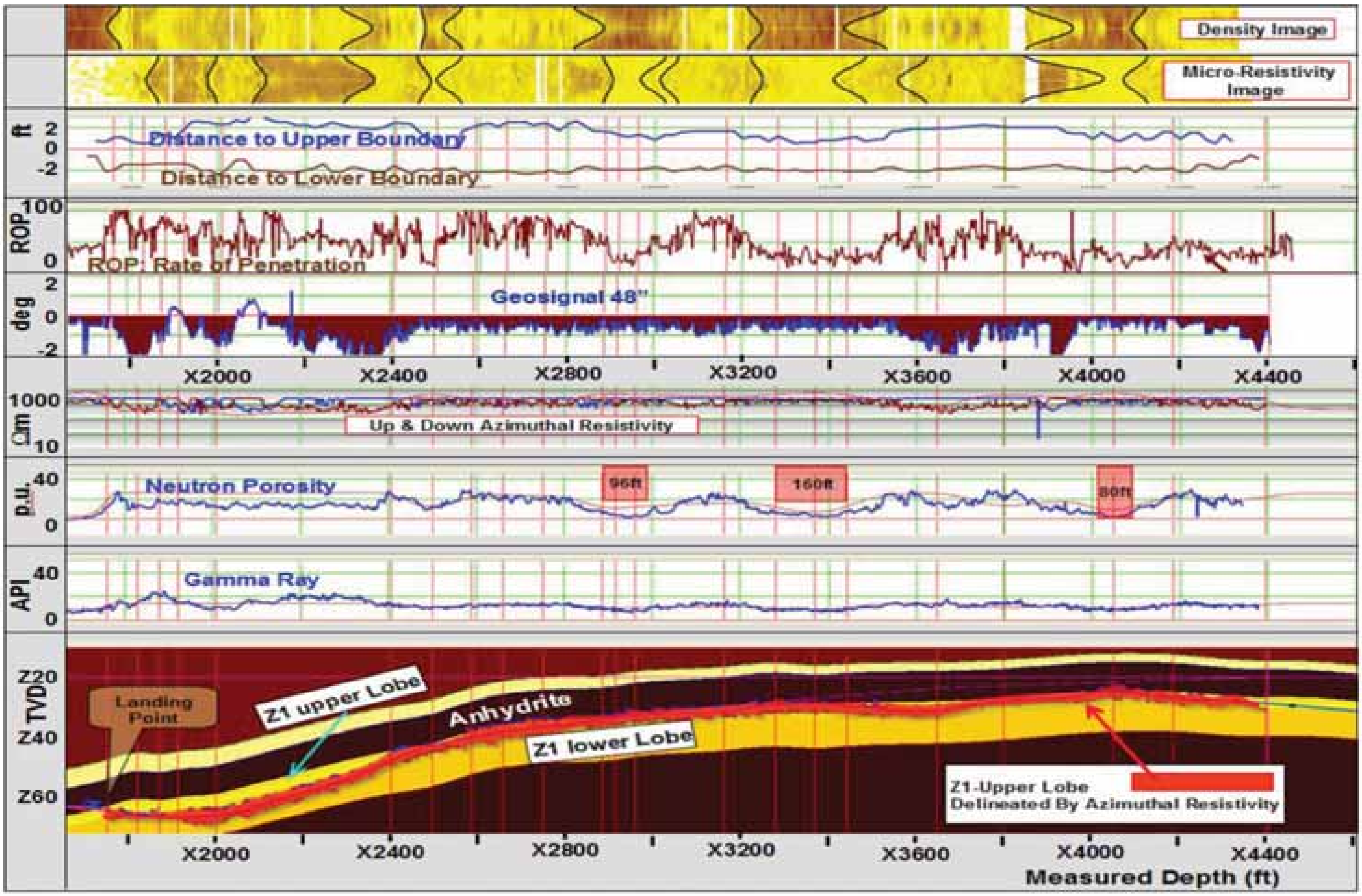


Fig. 5. Real-time logs and images help to steer the well within the thin Z1 upper Lobe target. Computations of distances to upper and lower boundaries re-delineate the target from the original layer-cake to the actual geometry shown by the red and peach colors. Neutron porosity logs and micro-resistivity images identify the short intervals where the well encountered the anhydrite roof.

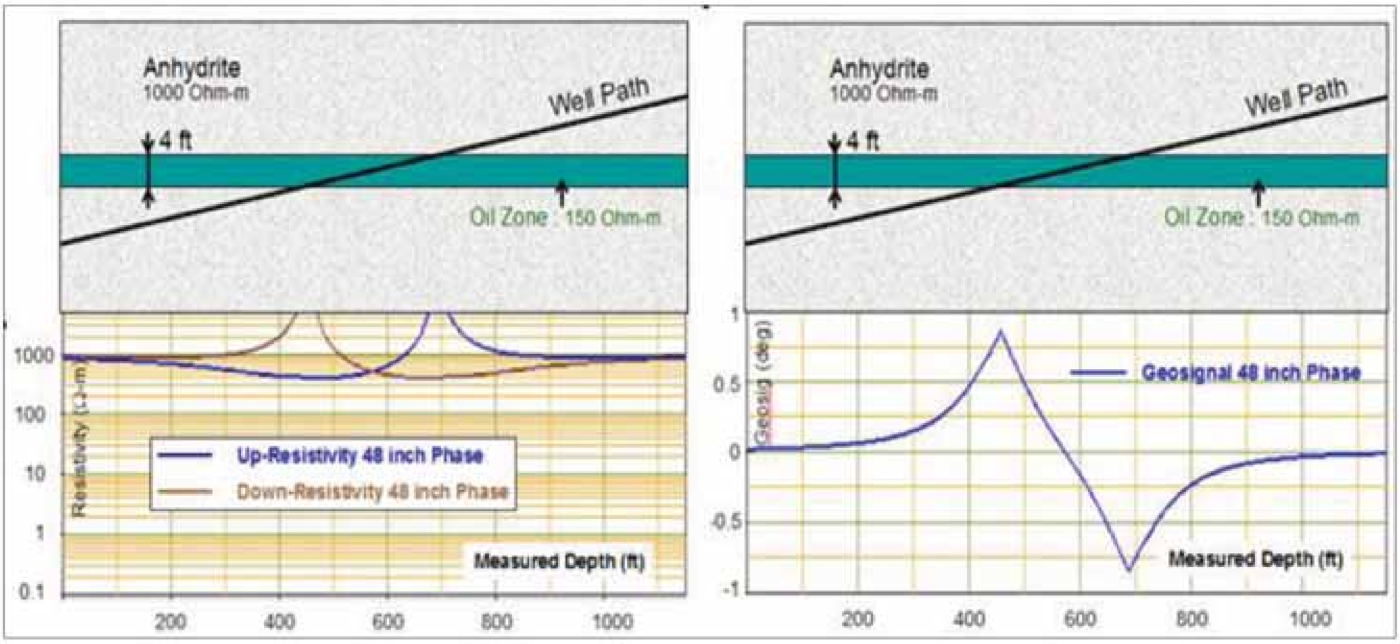


Fig. 6. Modeling of azimuthal deep resistivity helps to understand the azimuthal resistivity logs as the well moves between the upper and lower boundaries. The upward curve criss-crosses with the downward curve (left Fig.). Similarly, the geosignal changes sign as the well moves from the lower portion of the reservoir to the upper portion of the reservoir (right Fig.).

> "When the well briefly leaves the reservoir, density images exhibit the characteristic sinusoidal pattern that can be interpreted in terms of relative dip angle and azimuth."

Geosteering with Geosignal, Images, Azimuthal Resistivities and Distances to Boundaries

A comprehensive set of real-time measurements and images were pulsed to the surface and continuously scrutinized to guide geosteering decisions in a timely manner. The unusually thin target requires definite decisions be made in nearly real time.

Density images distinguish between anhydrite and carbonate since the density of anhydrite (2.96 g/cc) is significantly higher than the reservoir rock. Density images also provide enough resolution to distinguish between the target limestone rock of the Z1-upper Lobe and the denser, less desirable dolomitic limestone rock from the Z1-lower Lobe. When the well briefly leaves the reservoir, density images exhibit the characteristic sinusoidal pattern that can be interpreted in terms of relative dip angle and azimuth[10]. A "smiling" pattern confirms that the exit is through the roof into the anhydrite.

The non-azimuthal neutron porosity helps to identify at a glance whether or not the well has left the reservoir and entered the anhydrite. The reservoir interval is characterized by a porosity value ranging between 15 p.u. and 20 p.u. By contrast, the anhydrite registers negative neutron porosity.

The wave resistivity is highly affected by the presence of resistive adjacent beds, anhydrite on top and tight dolostone below. The two beds are only 2 ft to 5 ft apart from one another, and create a compounded polarization horn that makes it nearly impossible to determine whether or not the well is within the target.

The geosignal from the azimuthal deep resistivity is quite sensitive to the distance-to-bed boundary. It provides the earliest indications of impending reservoir entries and exits. Geosignals from two shorter spacing (16" and 48") were pulsed to the surface. The shallower reading geosignal from the 16" spacing showed the highest level of activity and proved to be the most useful. The deeper reading geosignal was applied in the inversion for

> “Because the reservoir is in reverse contrast (compared to the more common shaly sand reservoirs) from the surrounding media, the petrophysicists had to undergo a certain amount of reconditioning.”

distance-to-bed boundary calculations. Because the reservoir is in reverse contrast (compared to the more common shaly sand reservoirs) from the surrounding media, the petrophysicists had to undergo a certain amount of reconditioning. In the more common case, in which the surrounding formations are less resistive than the reservoir, the geosignal generally points to the boundary. In this reverse contrast instance, the geosignals consistently pointed toward the less resistive reservoir.

The geological section of Fig. 5 shows the well path and the estimated size of the target. The large brown and yellow colored layering corresponds to the originally postulated geology. As the well progressed and the data from azimuthal deep resistivity was inverted, the actual thickness of the target Z1-upper Lobe was updated to the shape shown by the red and peach colors.

The well path was computed from the navigational sensors on the BHA. The landing of the well was immediately confirmed by the neutron porosity near depth, 1,900 ft. The measured neutron porosity rapidly increased from near 0 p.u. to approximately 17 p.u. The density image exhibited the characteristic sinusoidal “frowning” pattern, mapping the entry in the reservoir. At a depth of 2,200 ft, the geosignal warned of the proximity of the anhydrite roof. The decision was made to steer the well downward, dropping the angle to keep the well within the target.

Along the interval between 1,900 ft and 2,900 ft, additional sinusoidal patterns on the density image and the microresistivity image suggested that the well went through subtle layering, barely identifiable, with no noticeable change in the neutron porosity log readings. In that interval, the reservoir thickness, computed by inverting the azimuthal resistivity logs, varied between 2 ft and 4 ft. Only at the point near 2,500 ft did the well meet the anhydrite roof. The rate of penetration (ROP) exhibited an abnormal drop, suggesting that the bit entered the anhydrite formation.

> "Modeling studies showed deeper reading measurements to be less sensitive and not nearly as useful, given the unusually high resistivity of the reservoir and of the adjacent formations."

Following the well span from 2,900 ft to 3,500 ft, three intervals were identified where the well probably partially entered the anhydrite. These three intervals are marked by a box with pink shading superimposed on the neutron log. The first interval was estimated to be 96 ft long. The second was identified as 160 ft long and the third one was estimated to be 80 ft long. The surprising event in the second interval was the lack of activity of the geosignals. A strong negative geosignal should have appeared at a depth of 3,300 ft, similar to the one seen previously at a depth of 2,200 ft.

The upper and lower bins from azimuthal resistivity are designated as "up-down resistivity." In this formation, both curves showed little character except when the well migrated from an area near the lower boundary to an area near the upper boundary, and vice versa. This phenomenon occurred through the depth interval of 1,900 ft to 2,500 ft. In most of the remaining sections, the well path is near one of the boundaries, generally the upper one. The polarization horns bring the readings to near or above 1,000 Ohm-m. The simulation of Fig. 6 shows the crisscrossing of the up and down resistivity curves as the well crosses the midpoint in the reservoir.

The coincidence of the two curves occurs near the geometrical midpoint at a distance known as the "electric midpoint[11]."

Summary and Conclusions

The challenge of placing a horizontal oil producing well within a thin reservoir and maintaining it within boundaries was successfully met through a combination of complementary logging while drilling (LWD) technologies and modeling capabilities. First, LWD sensors capable of measuring deep-resistivity azimuthally were used to identify approaching boundaries, including the reservoir roof and floor, as early as possible. In addition, dedicated pre-job modeling helped to select the best measurements from the azimuthal array to perform the task. Because of the thinness of the producing interval, shallow reading geosignals were found to be preferable. Modeling studies showed deeper reading measurements to be less sensitive and not nearly as useful, given the unusually high resistivity of the reservoir and of the adjacent formations.

The deep images are complemented by shallow reading density and microresistivity, and by neutron porosity to unequivocally recognize the crossing of geological boundaries. In summary, deep resistivity images and logs are farsighted, whereas traditional density, neutron porosity, and microresistivity images and logs are nearsighted. By using them in combination, the highly challenging subject well of this article was drilled with an estimated 87% reservoir contact.

Acknowledgements

The authors wish to thank Saudi Aramco management for their support and permission to present the information contained in this article. We also wish to acknowledge the contributions of our colleagues at both Saudi Aramco and Halliburton Sperry Drilling, including Mostafa Badawy, Ian Johnstone and Jeremy Combs.

References

1. Chemali, R., Bittar, M., Hveding, F., Wu, M. and Dautel, M.: "Integrating Images from Multiple Depths of Investigation and Quantitative Signal Inversion in Real Time for Accurate Well Placement," SPE IPTC paper 12547, presented at the International Petroleum Technology Conference, Kuala Lumpur, Malaysia, December 3-5, 2008.

2. Iversen, M., Fejerskov, M., Skjerdingstad, A., et al.: "Geosteering Using Ultra Deep Resistivity on the Grane Field, Norwegian North Sea," paper 2003-J, presented at the SPWLA 44th Annual Logging Symposium, Galveston, Texas, June 22-25, 2003.

3. Seydoux, J., Tabanou, J., Ortenzi, L., et al.: "A Deep Resistivity Logging-While-Drilling Device for Proactive Geosteering," OTC paper 15126, presented at the Offshore Technology Conference, Houston, Texas, May 5-8, 2003.

4. Mudhhi, M., Ma, S., Al-Hajari, A., et al.: "Geosteering with Advanced LWD Technologies – Placement of Maximum Reservoir Contact Wells in a Thinly Layered Carbonate Reservoir," IPTC paper 10077, presented at the International Petroleum Technology Conference and Exhibition, Doha, Qatar, November 21-23, 2005.

5. Bittar, M., Klein, J., Beste, R., et al.: "A New Azimuthal Deep-Reading Resistivity Tool for Geosteering and Advanced Formation Evaluation," SPE paper 109971, presented at the SPE Annual Technical Conference and Exhibition in Anaheim, California, November 11-14, 2007.

6. Seifert, D., Al-Dossary, S., Chemali, R., et al.: "Deep Electrical Images, Geosignal and Real Time Inversion Help Guide Steering Decisions," SPE paper 123940, presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, October 4-7, 2009.

7. Bittar, M.: "Electromagnetic Wave Resistivity Tool Having a Tilted Antenna for Geosteering within a Desired Payzone," U.S. Patent 6,476,609, November 5, 2002.

8. Bourg, L., Decoster, E., Klein, J. and Gipson, L.: "Resistivity Logging in Horizontal Wells in the Orinoco Heavy Oil Belt: Laterolog or Dielectric Propagation LWD Tools?" paper 2007-QQQ, presented at the SPWLA 48th Annual Logging Symposium, Austin, Texas, June 3-6, 2007.

9. Prammer, M., Morys, M., Knizhnik, S., et al.: "Field Testing of an Advanced LWD Imaging Resistivity Tool," paper 2007-AA, presented at the SPWLA 48thAnnual Symposium, Austin, Texas, June 3-6, 2007.

10. Ballay, G., Al-Ali, H., Amos, S. and Debnnis, B.: "In the Driver's Seat with LWD Azimuthal Density Images," IADC/SPE paper 72282, presented at the IADC/SPE Middle East Drilling Technology, Bahrain, October 22-24, 2001.

11. Wang, T., Chemali, R., Hart, E. and Cairns, P.: "Real Time Formation Imaging, Dip, and Azimuth While Drilling From Compensated Deep Directional Resistivity," paper 2007-NNN, presented at the SPWLA 48th Annual Logging Symposium, Austin, Texas, June 3-6, 2007.

Abdalrasool A. Al-Hajari is a Supervisor at the Reservoir Description Division of Saudi Aramco. He has 27 years of experience in sand-shale and carbonate petrophysics, including work in several different areas of petroleum engineering, drilling, production and reservoir management. Abdalrasool has authored and coauthored several papers in petrophysics and well monitoring logging. He has B.S. degree in Petroleum Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia.

Dr. S. Mark Ma is a Petroleum Engineering (PE) Consultant at the Reservoir Description Division and the E&P Petrophysics Professional Development Advisor responsible for petrophysics curriculum and course development at the Upstream Professional Development Center, Saudi Aramco. Before joining Saudi Aramco in 2000, he worked at New Mexico Petroleum Recovery Research Center, Western Research Institute, and Exxon Production Research Company. Mark currently serves as a mentor at the PE's Technologist Development Program. He is a member of the Society of Petroleum Engineers (SPE), the Society of Petrophysicists and Well Log Analysts (SPWLA) and Society of Core Analysts (SCA). Mark is a technical editor for the Journal of SPE Reservoir Evaluation & EngineeringandJournal of Petroleum Science & Engineering.He received his Ph.D. in Petroleum Engineering from New Mexico Tech, Sorroco, NM in 1992 and has published more than 50 technical papers on log and core analyses for formation evaluation, well placement, and reservoir surveillance.

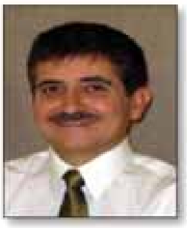
Ali H. Al-Julaih has worked with Reservoir Description, Production Engineering and Reservoir Management. Currently, he is working with Shedgum Reservoir Management as a Reservoir Engineer, and is heavily involved in development programs of exploiting thin targeted zones in a fractured carbonate reservoir. In 2005, Ali received his B.S. degree in Petroleum Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia, and is currently pursuing a M.S. degree in Petroleum Engineering, also with KFUPM.

Troy W. Thompson is a Geological Specialist with Saudi Aramco. He has over 20 years of oil industry experience as a Developmental Geologist and Workflow/Applications Specialist. Troy is a lead Field Geologist for Saudi Aramco and has been involved with horizontal well placement for the previous 5 years. Troy received both his B.S. and M.S. degrees in Geology from Florida State University, Tallahassee,

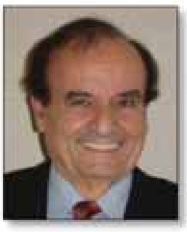
FL. George Saghiyyah is a Senior Petroleum Engineer with Saudi Aramco in the Reservoir Description Division located in Dhahran, Saudi Arabia. He joined Saudi Aramco in 2007, where he specializes in log interpretation and applications, as well as monitoring of logging operations. George has previously worked for Baker Atlas and Wood Group Logging Services and is currently a member of the Society of Petroleum Engineers (SPE) and the Society of Petrophysicists and Well Log Analysts (SPWLA). He graduated with a B.S. degree in Mechanical Engineering in 1994 from Lehigh University in Bethlehem, PA.

Amr Lotfy is the Petrophysics and Geosteering Lead for Halliburton-Sperry Drilling Services, Saudi Arabia. He received a B.S. degree in Physics from the American University in Cairo, Egypt. Amr has coauthored multiple national and international publications. He is an active member of both the Society of Petroleum Engineers (SPE) and the Society of Petrophysicists and Well Log Analysts (SPWLA)

Mohammed Bayrakdar is a Petrophysicist and Geosteering Coordinator for Halliburton Sperry Drilling Services, Saudi Arabia. He received his B.S. degree from the American University in Cairo, Egypt. Mohammed is currently an active member of both the Society of Petroleum Engineers (SPE) and the Society of Petrophysicists and Well Log Analysts (SPWLA). He has coauthored several publications on geosteering and electrical imaging.



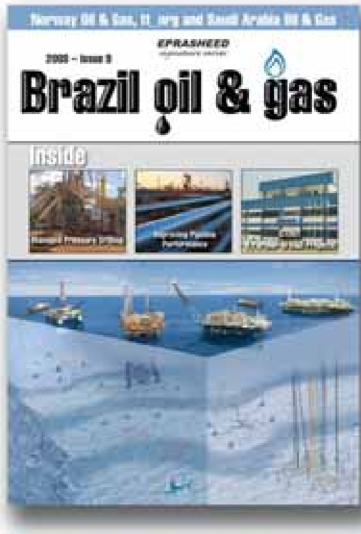
Dr. Michael Bittar is Director of Formation Evaluation Technology for Halliburton Drilling and Evaluation. He joined Halliburton through Sperry-Sun Drilling Services in 1990. Michael has contributed to the advancement of logging while drilling (LWD), wireline resistivity and logging sensor technology and interpretation, most recently as the Sensor Physics Manager for Sperry Drilling Services and Wireline and Perforating Services. He led the team that developed the InSite ADR sensor. Michael received his B.S., M.S. and Ph.D. degrees, all in Electrical Engineering, from the University of Houston, Houston, TX in 1983, 1986 and 1990, re-spectively. He has more than 20 patents and is the author of more than 20 publications. In 2006, Michael received the Society of Petrophysicists and Well Log Analysts (SPWLA) Technical Achievement Award.

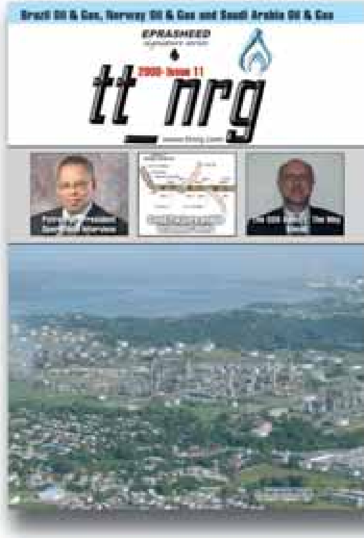


Roland Chemali is Chief Petrophysicist for Halliburton-Sperry Drilling Services. He has coauthored multiple papers and patents on formation evaluation, including geosteering high angle wells, magnetic resonance and formation pressure measurement while drilling. In 1997, Roland received the Technical Achievement Award from the Society of Petrophysicists and Well Log Analysts (SPWLA), and in 1988 he received the Technology Innovation Award from Petroleum Engineer International. Roland was also the Distinguished Member of the Technical Staff at Halliburton in 1991 and the SPWLA Distinguished Speaker in 2005 and in 2008. He received an Engineering degree in 1966 from the Ecole Polytechnique of Paris, France and a Petroleum Engineering degree in 1967 from the French Petroleum Institute (IFP), Rueil Malmaison, France. Roland also received his M.S. degree in Mathematics in 1969 from Louisiana State University, Baton Rouge, LA..


EPRASHEED
signature series
Increase Sales
Do You Want Your Advertising Message To Reach Oil Company Buyers And Decision Makers?
ADVERTISE IN EPRASHEED MAGAZINES NOW!
www.eprasheed.com
sales@eprasheed.com


Brazil Oil & Gas, tt_nrg and Norway Oil & Gas
EPRASHEED
Saudi Arabia oil & gas
Inside
GEO 2008


EPRASHEED
Brazil oil & gas
Inside


EPRASHEED
tt_nrg


Norway oil & gas
EPRASHEED
Inside

Optimized Field Development of an Offshore Carbonate Reservoir in Saudi Arabia

By Dr. Sarfraz A. Jokhio, Carl T. Dismuke, Hassan K. Mubarak and Anas A. Shuaibi.

Abstract

A relatively large carbonate reservoir, Arab-D, located off -shore of Saudi Arabia was developed over the last several years to augment Berri field's production capacity. Theobjective was to raise the field's oil production capacity by an additional 25% to help offset downtime occurring on existing production platforms due to workover and facility upgrading operations. In this article, the development project's scope, implementation, simulation, use of technology and drilling activities that resulted in a successful implementation of th edevelopment plan for the Berri field Arab-D reservoir, as well as the initial results, will be discussed.

The development was placed on a fast implementation schedule and was carried out during a high oil demand period (2006-2009) that placed large constraints on delivery of new equipment and platforms, however, the production increment was successfully brought onstream within a 3 year time frame. The development plan included the installation of three platforms for both oil production wells and power water injectors as well as several sidetracks to add sustainable production capacity. Keywells were equipped with permanent downhole monitoring systems (PDHMSs) to monitor reservoir pressure performance in real time, and the newly drilled producers were completed with electrical submersible pump (ESP) lift systems. In addition, the first application in Saudi Aramco of a distributed temperature sensor (DTS) system was deployed in an injector to obtain realtime flow profiles along the entire wellbore section.

The overall development project utilized a number of existing assets to minimize the development cost and trial testing of the innovative applications, such as using existing wells for on platform water injection that consists of a water supply well and an injection well combination. Both are located on the same platform, with an inverted ESP assistedwater injection lift system.

Reservoir simulation studies were used to optimize the wellbore placement and indicated the oil production plateau of 85 thousand barrels per day (MBPD) could be sustained for 10years.

Introduction

he development of the Arab reservoirs (A, B, C and D) in Berri field has been deferred historically due to the field's ability to continuously maintain production at target rates by producing primarily from the two main reservoirs, Hanifa and Hadriya. The Arab reservoirs have been produced throughout the 40 year history of the field; however, their resources have not been developed to their full capacity. Tofurther increase production from the field, full development of the Arab-D reservoir was initiated between 2006-2009 with the drilling of seven additional new production wells, six reentry workovers and eight new power water injection wells. The requirements included one additional production platform and two injection well platforms. Subsequently, an additional drilling slot was added to one existing injection platform, and an injection flow line was extended to an existing production platform so that one well could be drilled as an injector. During the initial ramp-up phase of the development, short-term spare capacity of approximately 20 thousand barrels per day (MBPD) was included to offset the anticipated platform downtime during the implementation of future Arabian Light production. This spare capacity provision is necessary since many of the older platforms in the field require significant upgrades to accommodate electrical submersible pumps (ESPs) due to limited deck space available. Also note that during the development phase-in of production from the Arab-D reservoir, new recompletion opportunities (when existing deeper completions in mature reservoirs water out) will arise from time to time and will be taken advantage of and incorporated into the plan for further optimization.

Geological Description

Berri field is located on the Eastern edge of Saudi Arabia, near Jubail City in water that is up to 90 ft deep, Fig. 1. The field structure is a north-south trending anticline approximately 40km long and 20 km wide. All eight reservoirs are of Jurassic age. The Jurassic period of Saudi Arabia constitutes a major cycle of carbonate deposition that started with a transgression of the sea over a broad platform, followed by the deposition of mostly shallow to moderate depth limestone, and closed with the regression of the sea and the deposition of thick evaporates. Eight major Jurassic intervals were formed in the area of the field by these regressive and transgressive cycles. The major development of the Berri field structure occurred in the Cretaceous period prior to the migration of oil, which occurred in the Tertiary period. This article will discuss the development of the Arab-D reservoir only. The Arab-D reservoir falls within the productive limits of the other majorr eservoirs in Berri field and covers an area of approxi mately180 square km. Figure 2 illustrates the Arab-D structure and current well locations.

The Arab-D has a smaller areal extent and contains a thinner vertical oil column than the two primary reservoirs in the field. It is underlain mostly by water throughout the field. The reservoir has major intervals of grainstones across the upper portion of the reservoir with porosities between 18% -30% and permeability between 80 millidarcies (mD) - 1,200mD. The porosities and permeabilities are generally better over the crest. The reservoir seal is made up of an anhydrite that resulted from a shallowing of the seas in an arid sabkha, or a supratidal to hypersaline environment.

Petrophysical Description

The four Arab reservoirs are limestone and have a predominantly grainstone texture, with some having packestone

Fig. 1. Location of Berri field in and along the Arabian Gulf shoreline.

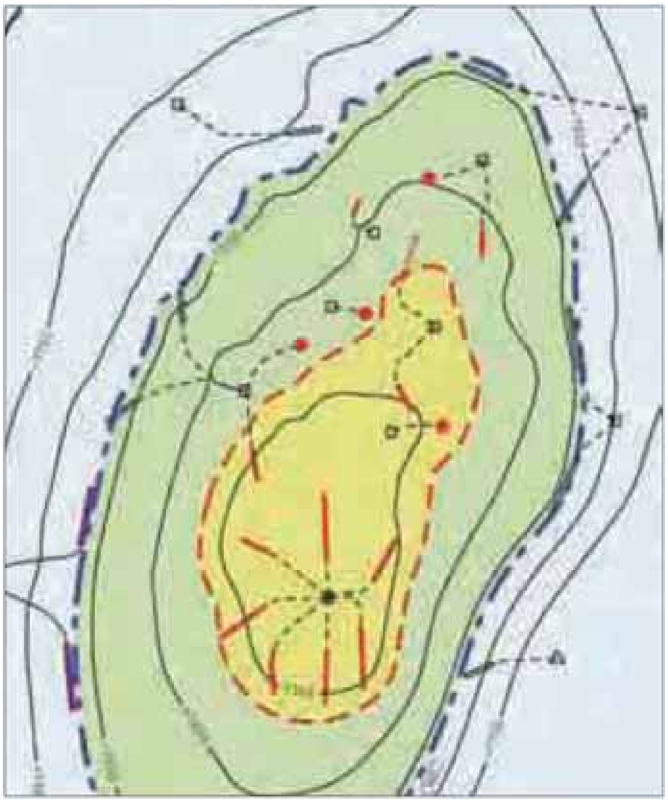


Fig. 2. Arab-D reservoir structure map.

and algal (plant or plant like) boundstone textures. Calcite dissolution of the matrix and grains has produced a diagenetic grainstone texture in the limestone having an original packestone and packestone/grainstone tex-

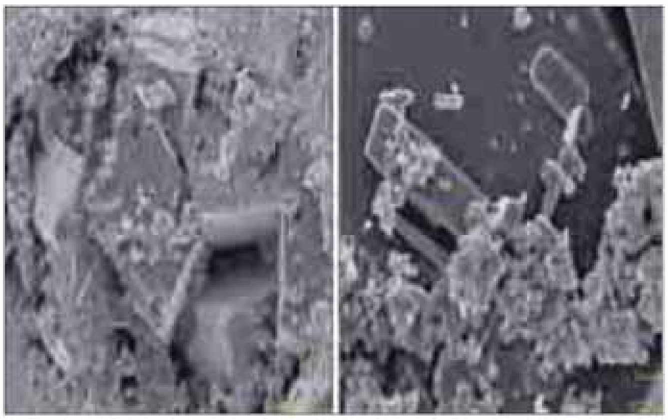


Fig. 3. Thin section descriptions (SEM) of Arab-D reservoir. This sample was taken from tight portions of the reservoir.

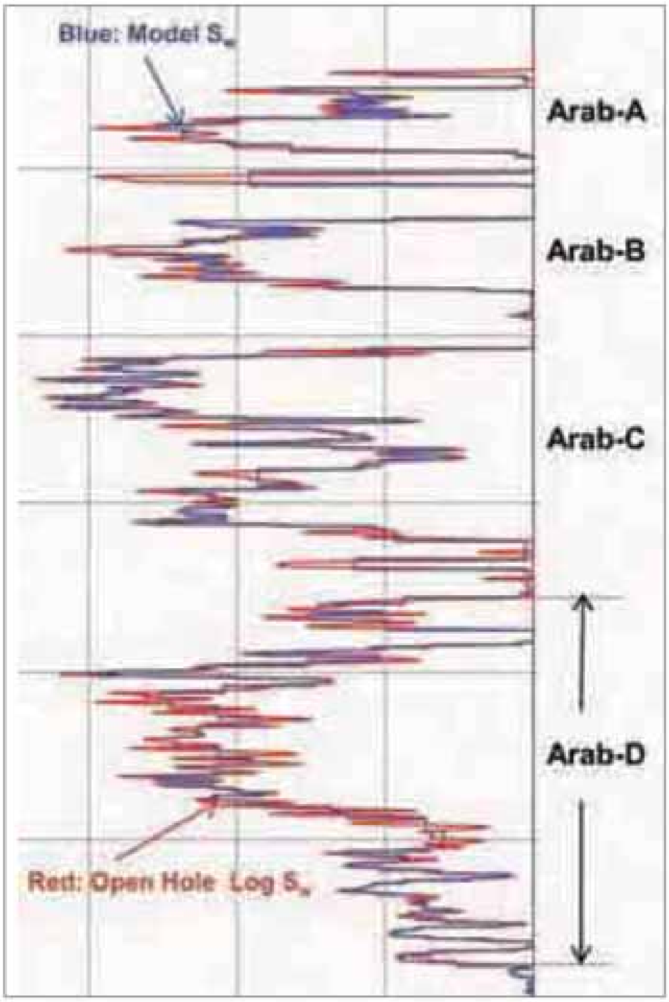


Fig. 4. The excellent match of Swin the Arab reservoirs model, including the Arab-D reservoir. The red line illustrates the open hole log calculated Sw as compared to the Sw initialized in the simulation model.

ture. The most common allochems are micritic to algal boundstone intraclasts, algal grains, peloids (bacterial), ooids (sand) and skeletal fragments; many grains have micritized margins. Diagenesis is the main cause of the secondary porosity, and compaction and the micritic matrix, Fig. 3, are the main causes of the reduction of the primary pore volume[1]. Dissolution of calcitic grains and the matrix (often accompanied by neomorphism and dolomitization) has generated secondary pores.

Cementation is generally light in most core samples taken from Arab reservoirs. Dolomite is slightly more common in the Arab-C and Arab-D where it cements 0% to 7% of the limestone. Pore types and reservoir quality are largely controlled by diagenesis. Dissolution of limestone is a significant contributor to the best reservoir quality. The best porosity and permeability values come from the ooid-dominated grainstones that have well developed interparticle and oomoldic pores. Compaction of grainstones and packestones, without significant calcite dissolution, results in poor reservoir quality. The pore systems in the limestone consist of primary and secondary interparticle mesopores, moldic pores and common micropores in the algalgrains. The pore system also includes small intraparticle pores,minor amounts of isolated intraskeletal pores and small amounts of fracture pores.

Reservoir Simulation

In 2007, a detailed reservoir simulation study[2] was started to plan the development drilling of the Arab reservoirs. The purpose of the study was to optimize the well and facility requirements, and to establish the optimal depletion rate for the Arab reservoirs. The model included a stacked geology and grid to incorporate all of the Arab reservoirs, since some zonal communication was suspected based on static pressure data observed over the years. The geologic model[3] constructed utilized all wells that have penetrated the four reservoirs during the past 40 years for the sequence stratigraphy and geological properties modeling. The final geology contained 121 stratigraphic surfaces with 39 within the Arab-D reservoir. Each of the reservoirs was then broken into sub-zones as required, which resulted in a geological model description containing over 7 million cells. Reservoir properties (e.g., permeability, porosity, water saturation, etc.) were distributed in 205 layers using a total of eight petrophysical rock types (PRTs) based on mercury injection capillary pressure data. Reservoir permeabilities were calculated using aneural network methodology and combined with the PRTs derived from Thomeer parameters. Properties were distributed

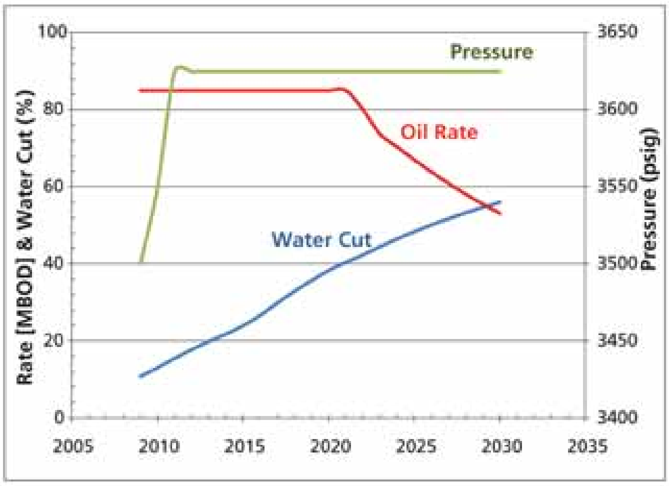


Fig. 5. Simulation forecast showing oil rate, pressure and water cut.

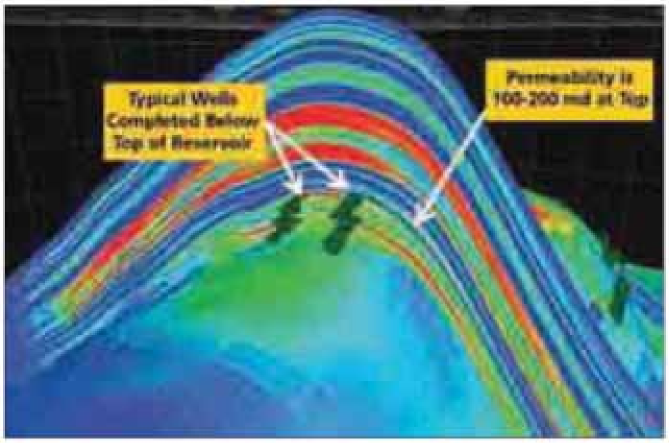


Fig. 6. West to East permeability cross section of the Arab-D reservoir.

based on ordinary kriging and co-kriging methods, and the model was upscaled using a technique developed by Saudi Aramco[4, 5]. The final geological model used for the reservoir simulation model contained approximately 3.4 million gridblocks.

The water saturations in the 3D geological model were calculated and distributed as a reservoir property using a unique methodology involving the use of Thomeer parameters, along with additional formation properties, to calculate and upscale the properties to the correct cell size[6]. This saturation was validated by a direct comparison of the calculated bulk oil volume (BOV) to the actual open hole logs across the field, which were found to have excellent agreement. The initialization of water saturation (Sw) in the model was performed using J-functions. Figure 4 shows an example of its excellent match with Sw from the open hole logdata that was obtained in a typical Arab reservoir well in Berri field.

Once the history match was obtained, simulation forecasts were performed utilizing the planned well locations. The simulation results as well as material balance studies indicated that a plateau of 10 years at a daily rate of 85 thousand barrels of oil per day (MBOPD) can be maintained, Fig. 5, however, pressure must be raised and maintained through continued injection.

Sensitivities on the horizontal well completion intervals were also analyzed and resulted in a slanted well that penetrates the formation from 30 ft true vertical depth (TVD) below the top of the Arab-D formation. Based on model water encroachment forecasts, a high permeability zone at the top of the reservoir would likely result in very early water breakthrough and was isolated behind casing, Fig. 6.

Further optimization was conducted to determine the need for artificial lift over the life of the wells. Based on the model forecast, initial target rates could be achieved after drilling, but the pressure decline in the first 2-3 years would result in rates dropping below the required rate planned for the development wells. The decision to install ESPs was made to guarantee that the production capacity was achieved, and the platform was ordered with the required specifications to accommodate the ESP surface facilities.

The well design called for running the ESPs in a 958 production casing with 4½ tubing. The completion also incorporated a Y-tool to allow access for coiled tubing assisted logging operations for reservoir monitoring.

Long-term simulation runs also revealed that the plateau period and oil recovery would not be optimized unless additional pressure support was supplied. The decision was made to install a peripheral water injection system that utilizes mainly horizontal injection wells. The new wells were again drilled as horizontal wells, approximately 30 ft TVD below the top of the Arab-D reservoir at the oil-water contact (OWC) to avoid the high permeability zone, and slanted through the formation to the base of the reservoir to evenly distribute the injection water across the entire thickness. The completion interval contained a 618 open hole with about 7,000 ft of reservoir contact.

Development Plan and Challenges

New facilities included one production platform and two injection platforms that would be integrated into the overall Berri field infrastructure. The major challenges included: 1)Integrating a high potential platform into an existing gathering system without adversely im-

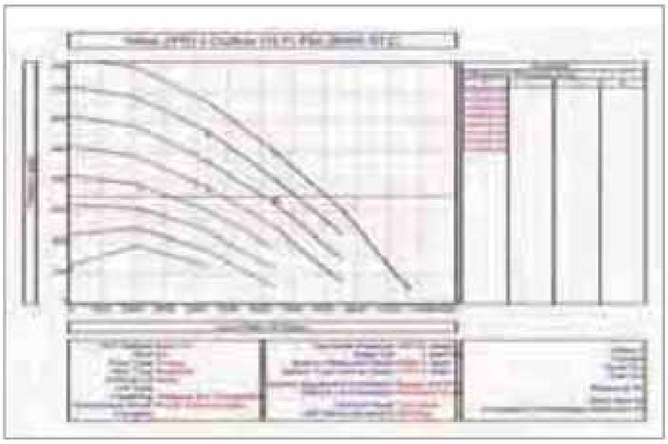


Fig. 7. Outflow performance curves showing that the well would underperform with no water production at 2,900 psig average pressure. Planned target production rates ranged from 6 MBOPD - 10 MBOPD.

pacting the performance of other wells in the system, 2) Constructing and installing the new platforms, and 3) Completing the drilling operations within a 3 year time frame so that production could be onstream by mid 2008.

Detailed surface facilities and a production system model analysis were performed to evaluate the performance of the gathering system under existing conditions and while producing the Arab-D reservoir at a high rate. In addition, our production facilities engineers looked for options to utilize the existing pipeline configuration to determine the most optimal location to connect the platform to the gathering system. Based on their analysis, the most cost-effective solution was to lay a new flow line to an existing tie-in platform and utilize an existing mothballed trunk line to transport the crude oil to the gas-oil separation plant (GOSP). By doing this, the average backpressure on the wells tied to the pipeline network would not be affected.

The installation of seven ESPs in the new wells was also required. Based on our analysis, it was determined that sustainable rates at our target levels could not be maintained without artificial lift due to the expected pressure drop in the reservoir after start up. Analysis showed that with a 400 psi -500 psi drop in average reservoir pressure at datum, the wells would begin to die without artificial lift. Justification for theinstallation of ESPs is illustrated in Fig. 7, showing the outflow performance calculation at a pressure of 2,900 psig and no water production. The wells would become unstable or dead even with a modest drop in average pressure (300psig) in the drainage area. A small increase in water cut would definitely kill the wells without artificial lift. Forecasts of average pressure in the drainage area of the new platform suggested that the reservoir would approach these pressures within a couple of years after production start up. In addition, the negative impact of the Arab-D reservoir fluid properties, namely low solution gas-oil ratio (GOR) and higher oil viscosity, would also reduce well production performance. Therefore, ESPs utilizing variable speed drives were required at the start up for the platform. This would be the first platform designed in Berri field that had the needed space to accommodate the ESP surface facilities which were constructed during the fabrication of the platform.

The use of ESPs on the new platform wells from the beginning provides an additional benefit to field operations since the spare capacity generated will aid in offsetting downtime, thereby enabling the overall field to maintain its target rates during peak work periods when other platforms are shut down for maintenance.

Drilling and Facilities Coordination

During the 2005-2008 time frame, the industry faced a largechallenge to increase deployment of facilities due to the highdemand resulting in rapidly increasing oil prices. In 2006, theBerri field team implemented a plan to speed up the platforminstallation and drilling by drilling the wells at the same timethat platform construction continued so as to optimize the rigmovements among the three platforms.

The decision therefore was taken to install a drilling support structure (DSS) to accelerate the drilling of the wells. The DSS was set approximately one year after placing the request, and drilling commenced shortly afterwards. The platform deck would continue to be fabricated while drilling continued. All seven wells on the production platform were drilled prior to the deck installation. Consequently, at the time the platform deck module (PDM) was scheduled for installation on the two injection platforms (PF-A and PF-B), rig operations were still ongoing on PF-B. Coordination between the Saudi Aramco drilling department, contractors, marine operations department and reservoir management resulted in an optimized plan to minimize loss of rig time while ensuring a smooth platform deck construction and installation schedule. Due to the tight construction schedule and contractor commitments in other offshore fields in the Kingdom, a delay in this installation would create a major disruption in project work throughout the offshore operating areas. The estimated time required was 5 days for each PDM.

The plan called for the construction barge to go to the available platform (PF-A) and proceed with a normal installation of the PDM. During this time, the wells on the other platform (PF-B) would be suspended and secured for safe topside operations. Following the well suspensions, the drilling rig was moved to an anchorage area for a couple of hours as the construction barge was moved over from PF-A to PF-B. The drilling rig then proceeded to move from anchorage to PF-A to initiate drilling on the second injection well platform. Once the three wells on PF-A were completed, the drilling rig then returned to PF-B to complete the drilling of the suspended wells on the first platform.

The successful installation of the three platforms and the drilling of the 13 new wells were the result of effective coordination between all parties involved. The loss of rig operational time amounted to just several hours.

Reservoir Development Plan

To develop the reservoir at a sustainable rate of 25% above current field production capacity while minimizing cost, the reservoir management team studied various options that included both reentry workovers of watered out producers and drilling new wells. Based on the model previously described, it was determined that an additional seven new horizontal producers located at the crest of the field would provide sufficient production to meet production goals. The targeting of the horizontal wellbores was based on geological modeling and later by reservoir simulation, although Arab reservoirs have some aquifer (non-potable water) support, Fig. 8, all injection wells would be drilled at the OWC and drilled horizontally, targeting the main pay interval of the Arab-D reservoir. The designed target injection rate was set to a maximum of 10 thousand barrels of water per day (MBWPD) - 12 MBWPD.

Rigorous well performance simulation work was done to determine the open hole wellbore section length (reservoir contact) to optimize production and reduce cost. Using 1 km, 2km and 3 km well spacings, well performance was simulated under various wellhead operating conditions and water cut scenarios. It was found that the first few thousand feet of well length have a large impact on the well capacity, however, as the length increases, no significant increase in the rate is observed.If the well length is kept constant, the well capacity decreases as the well spacing is increased. Therefore, it was concluded that 3,000 ft was the optimum well length in the Arab-D reservoir, if you take into account the reservoir rock and fluid properties and pressure distribution, Fig. 9.

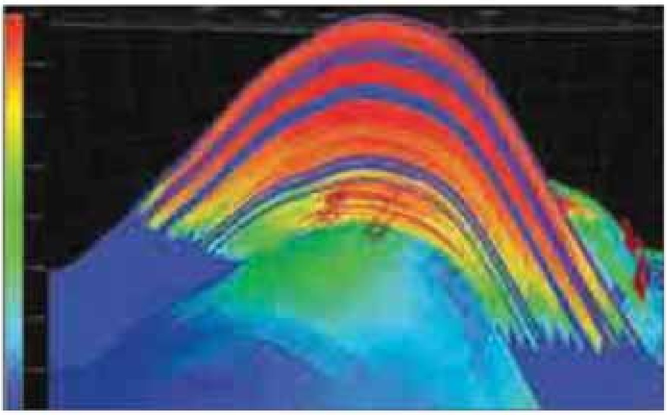


Fig. 8. West to East cross section showing oil saturation distributions in the Arab reservoirs at initial conditions. Note that the Arab-D is the lowest zone shown and is mostly underlain with water, shown in blue.

Pressure support was also studied in detail to develop an optimized injection strategy and the design of the injection facilities. The material balance and reservoir simulation studies indicated that a subsurface injection -production ratio of 1.2 must be maintained to raise the average reservoir pressure to a level where target production can be sustained for longer periods of time, taking into account the expected losses to the aquifer that are inherent in peripheral injection.

Reservoir Surveillance

The Berri field Arab-D reservoir has the largest transition zone and contains almost half of its reserves, Fig. 2. Several wells are planned for sidetracking in this area in the future. Surveillance activities are also focused in this area to monitor water encroachment. There is enough well control across the entire reservoir due to a large number of completions into deeper reservoirs, which are utilized to monitor fluid movement. The Arab-D wettability ranges from intermediate to oil wet with a mobility ratio of 2. Therefore, a shorter water fingering breakthrough time is expected as compared with the two main reservoirs, where the mobility ratio, 0.5, is more favorable.

Actual Well Performance

After the completion, all seven new wells on the new production platform showed 56 MBPD restricted capacity when flowed back on limited choke sizes, Table 1. It is estimated that with all ESPs running, the platform

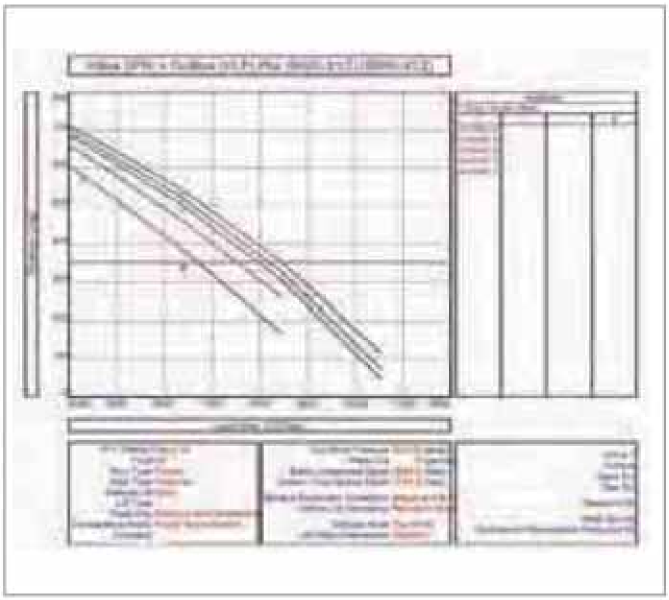


Fig. 9. Effect of well length on well performance.

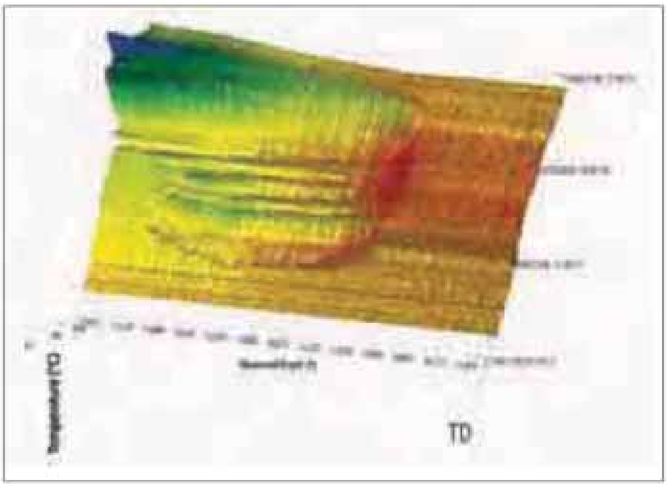


Fig. 10. DTS survey showing a temperature decease due to cooling by the cooler injected acid. The last 1,000 ft does not show any change, implying that either the acid was spent or it did not reach TD.

Well	Test Results		
	Choke	WHFP	Rate
	1/64	psig	MBOPD
1	32	740	6.3
2	44	650	7
3	44	560	6
4	36	720	6.6
5	44	720	11
6	44	800	11
7	44	520	8.5
		Sum	56.4

Table 1. Rate test results of seven newly drilled horizontal wells in the Arab-D reservoir.

will produce over 70 MBOPD. The wells have exceeded this target production.

Technology Trial Testing

The Arab-D reservoir development was complemented by several new concepts and unconventional technologies, such as a fiber optic distributed temperature sensor (DTS), an inverted ESP and on platform water injection using ESPs.

Fibre Otpic DTS Applications in a Power Water Inection Well

The seafloor on the east flank of the field is silty and poses barge jack up problems. This has resulted in a backlog of data acquisition in this area since it requires a special barge to conduct logging operations. Keeping this in mind, a water injection well on the east flank was selected for trial testing of the fiber optic DTS application. This is the first water injection well in Saudi Arabia to be equipped with the fiberoptic DTS system. The DTS provides the intake profile along the entire wellbore, thereby eliminating the need for running flow scanner logs. Figure 10 shows the temperature after acid treatment of the well. It is very clear that approximately the last 1,000 ft of the well either did not take the injected acid or the acid was spent before reaching total depth (TD). The well is in service, and data will be downloaded and compared between the flowing and shut-in periods, thereby indicating which portions of the well are taking the water.

On Platform Water Injection Source

To provide a cost-effective and independently operating solution to injection needs, the "On Platform Water Injection Source" concept was applied, which is where the water source and injection pressure are made available on the same platform. This has several benefits over the centralized water injection system: 1) It does not need to have capital intensive long injection lines laid to the platform where the injection wells are located, and 2) In case of failure, only one injection well shuts down with minimum injection loss, as compared with the centralized injection system where a leak in the flank requires several wells to be shut-in, and results in significant injection loss over a very short period of time. Sometimes,

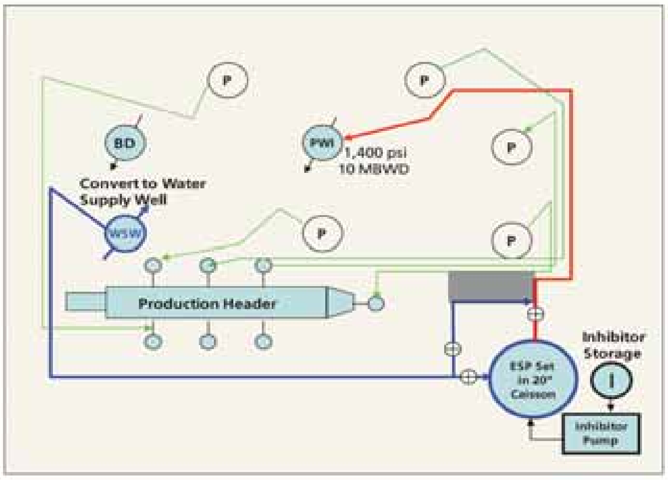


Fig. 11. Well layouts for the on platform water injection source concept showing water supply, caisson and injection well.

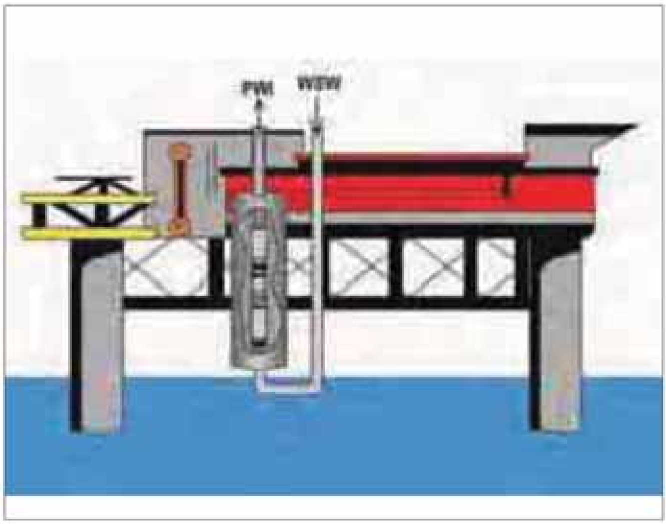


Fig. 12. Caisson ESP configurations for the on platform water injection source concept showing water supply, caisson and ESP.

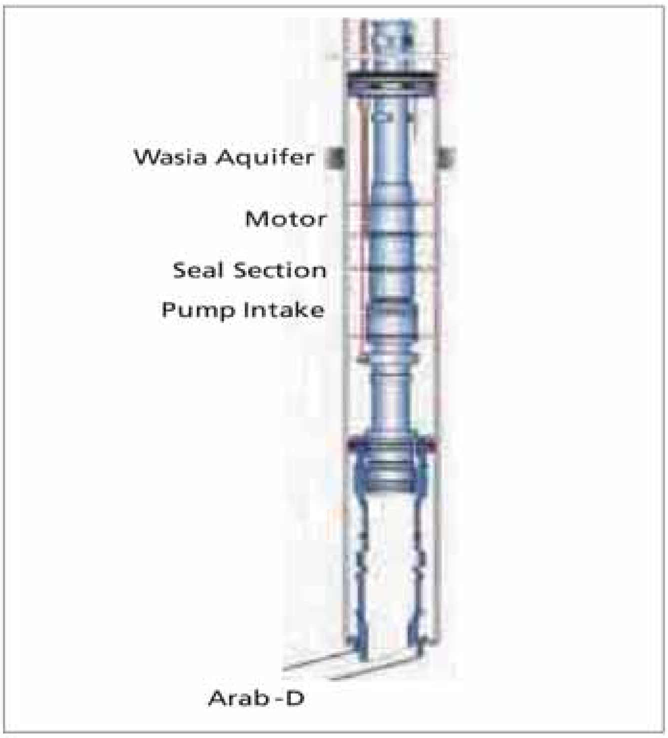


Fig. 13. Completion diagram showing the Wasia aquifer, inverted ESP unit and Arab-D reservoir at the bottom.

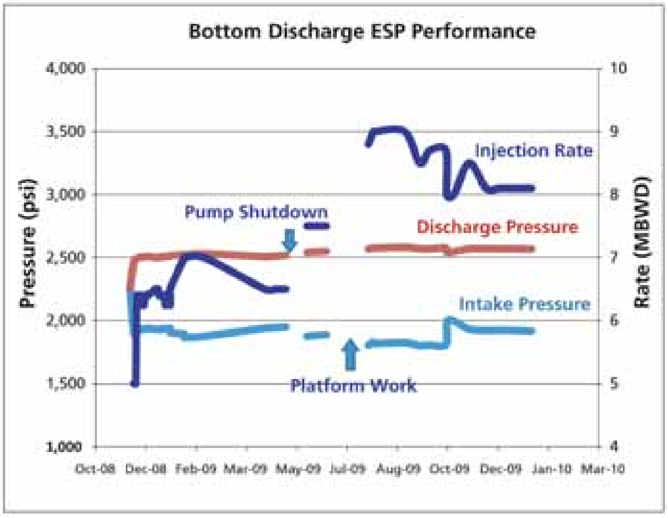


Fig. 14. Bottom discharge ESP performance

a significant portion of the flank needs to be isolated and all the down stream injection wells need to be shut down to repair the pipeline.

One well in a deeper reservoir was converted into a water supply well that produces from the Wasia aquifer (non-potable water) located at a shallower depth, while another depleted well was sidetracked as a power water injector into the Arab-D reservoir. Desired injection pressure is achieved with an ESP installed inside a caisson or a container hanging on the PDM, Figs. 11 and 12. This type of installation was also chosen for its simplicity that allows rigless well intervention for changing or repairing the pump. The expected injection rate in this system is 10 MBWPD - 12 MBWPD. The water supply well tested 28 MBWPD and is capable of feeding several injection wells on the platform. After its successful testing, the system will be implemented on a new platform designed to accommodate the ESP facilities, and both the water supply well and multiple injection wells designed for maximum water supply and injection capacity. A single water supply well will feed four to six injection wells, while only one ESP, designed to deliver 50 MBWPD - 60 MBWPD at adequate surface injection pressure, will be used.

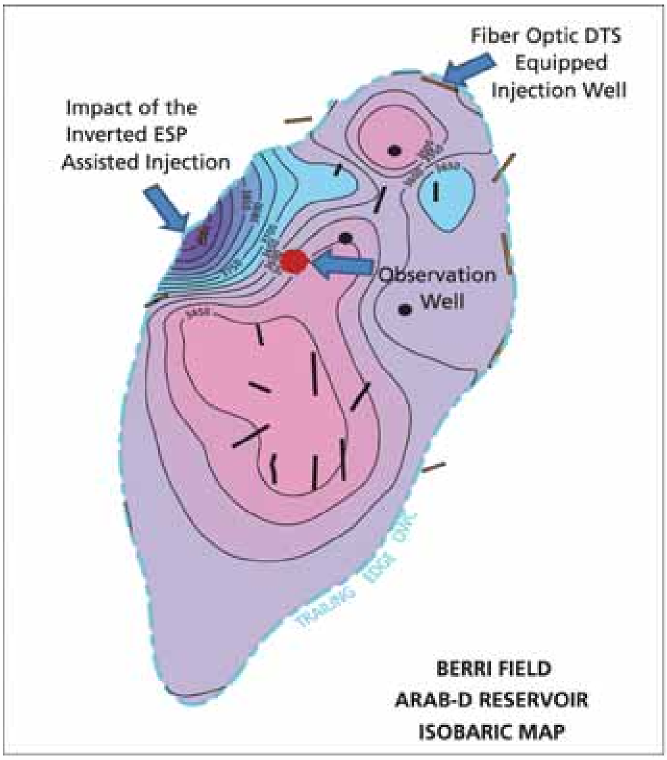


Fig. 15. Arab-D isobaric map showing the pressure increase around the inverted ESP injection well.

Bottom Discharge ESP Injection System

Another example of innovative water injection was the use of a sidetracked well located at the Arab-D reservoir periphery as a power water injector. The well was completed with a bottom discharge ESP equipped with a dual pressure temperature sensor, capable of reading intake and discharge pressure measurements. Again, the source of the injection water is the Wasia aquifer, Fig. 13, perforated in the same well. Water dumps from the aquifer and the inverted ESP boosts pressure to the desired injection pressure. The system has been in service since December 2008, has performed well, Fig. 14, and has significantly impacted the pressure in the area. An offest observation well, located approximately 3 km away from the injection well, showed a 100 psi pressure rise in one year due to inverted ESP assisted injection. One more bottom discharge application is planned in 2011 in the Arab-D reservoir at its southwest periphery.

Conclusions

Based on the work implemented today, the Berri field Arab-D reservoir development has met all of its initial goals with the following major conclusions:

Detailed geological and simulation work has captured the reservoir properties and production mechanism for the Arab reservoirs in Berri field.

Drilling and completion operations for all injection and production wells were completed smoothly and without major incidents due to the detailed planning for the newly drilled wells.

Close coordination of the drilling department, contractors, and marine operations resulted in a flawless installation of the PDMs during the drilling phase of the project.

The perfomance of the new horizontal wells has met the targetted initial rates.

Acknowledgements

The authors would like to thank the management of Saudi Aramco for permission to publish this article and E.J. Pavlas of the Reservoir Simulation Division for his contribution and support that resulted in the published work.

References

1. Core Laboratories Inc.: "Advanced Core Analysis Study, Saudi Aramco Project OOK-12/05-Berri Field Analysis of Various Formations," Saudi Aramco internal document, March 16, 2007.

2. Pavlas, E.J.: "Berri Field Arab Reservoirs, POWERS Full Field Model," Saudi Aramco internal document, 2009.

3. Siddieqy, Y.A.A.: "3D Geological Model, Berri Field Arab Reservoirs," Saudi Aramco internal document, 2007.

4. Thomeer, J.H.M.: "Introduction of a Pore Geometrcal Factor Defined by a Capillary Pressure Curve," *Petroleum Transactions*, AIME, Vol. 219, T.N. 2075, 1960, pp. 354-358.

5. Clerke, E.A.: "Beyond Porosity-Permeability Relationships – Determining Pore Network Parameters for the Ghawar AG Resrvoir Using the Thomeer Method." *GeoFrontier*, Vol; 1, Issue 3, 2003.

6. Buiting, J.J.M.: "Fully Upscaled Saturation Height Functions for Reservoir Modeling Based on Thomeer's Method for Analysing Capillary Pressure Measurements," SPE paper 105139, presented at 15th SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, March 11-14, 2007.

Dr. Sarfraz A. Jokhio joined Saudi Aramco in June 2005 and is currently a Senior Reservoir Engineer in the Reservoir Management Department. He is responsible for the reservoir management activities of Berri field, including business planning, reservoir monitoring, water flooding and field appraisal planning. Sarfraz's previous work experience includes work as a Reservoir Engineer with Schlumberger, Houston, from 2003-2005, a Post-doctoral Research Fellow and Lecturer atthe Mewbourne School of Petroleum and Geological Engineering, University of Oklahoma, Norman, OK, from 2002-2003, an ESP Application Engineer at Woodgroup ESP, Oklahoma City, OK, from 2000-2002, and a Field Engineer with Dowell, Schlumberger, Hobbs, NM, from 1998-1999. His technical interests include ESP and jet pump sizing, single and multilateral well performance modeling, including MRC and fishbone completions, CO_2 rich and gas-condensate reservoir and well performance modeling, transient pressure test analysis and integrated reservoir management. In 1989 Sarfraz received his B.S. degree in Petroleum Engineering from Mehran University of Engineering andTechnology, Jamshoro, Pakistan. He received his M.S. degree in 1997, and in 2002 Sarfraz received his Ph.D. degree, both in Petroleum Engineering and from the University of Oklahoma, Norman, OK. He has authored and coauthored 19 Society of Petroleum Engineers (SPE) and non-SPE papers.

Carl T. Dismuke recently retired as a Petroleum Engineering Consultant with the Reservoir Management Department after more than 17 years of service with Saudi Aramco. He worked as a Reservoir Engineer and Supervisor on Berri field, where he specialized in reservoir management and field development planning. Prior to joining Saudi Aramco, Carl worked with Amoco Production Company in Tulsa, OK, and Houston, TX, where he participated in CO_2 miscible gas project evaluations and simulations. In addition, he worked for Qatar Petroleum and Miller and Lents, Ltd., as a Senior Reservoir Engineer. In 1980, he received his B.S. degree in Mechanical Engineering from Texas A&M University, College Station,TX, and has been a licensed Professional Engineer in the State of Texas since 1987..

Hassan K. Mubarak works as a Reservoir Management Supervisor for the AFK fields. He has also supervised

Berri and Shaybah fields, and has been with Saudi Aramco for the last 25 years. Hassan received his B.S. degree in Petroleum Engineering from the University of Southwestern Louisiana, Lafayette, LA, in 1986. He has authored and coauthored over 10 technical publications, mainly in the area of horizontal welltechnology.

Anas A. Shuaibi joined Saudi Aramco in August 2006 and works as a Reservoir Engineer in the Northern Area Reservoir Management Department. He is responsible for the reservoir management activities of Berri field. In 2006, Anas received his B.S. degree in Petroleum Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia.

Why participate?

You may have questions about an interesting design or process that mathematics can help you with giving quantitative or qualitative answers, but you are unsure how to formulate the problem mathematically or do not have the resources for analysis and inferring optimal design decisions. Study Groups provide you with access to experienced researchers who, for the duration of the meeting and possibly afterwards, will bring their skills to bear on your problem.

The problems presented at Study Groups vary in nature, and include those where:

- the underlying processes are well understood, but your specific application requires substantial and novel computation,
- the general processes are understood, but analysis is required to determine dominant forces, parameter sensitivity, optimal design, and other key dependencies,
- the underlying mechanisms are not understood, and you wish to model the basics.

Study Groups are a resource that offers:

- clarification and formulation of a proposed or existing process,
- methods to solve problems of interest in industry,
- links with applied mathematicians and scientists from top universities and national laboratories,
- access to advanced computing solutions and environments,
- highly cost-effective consulting,
- fresh input of new ideas.

Contact details

If you are interested in con
would like to learn more ab
please contact:

Dr Kamel Bentahar | Tech
bentahar@maths.ox.ac.uk

For the local academic orga
please contact:

Dr Ibrahim Hoteit | Assis
Earth Sciences and Enginee
Mathematics and Computa
ibrahim.hoteit@kaust.edu.s

tributing a problem or
oout Study Groups then

nology Translator for OCCAM

nization

stant Professor
ering Applied
tional Science
sa

search/ResearchEvents.html

Industry Collaboration Program

Global Collaborative Research

OCCAM
Oxford Centre for Collaborative Applied Mathematics

Study Group in MATHEMATICS FOR INDUSTRY

23 - 26 January 2011

King Abdullah University of Science and Technology
Thuwal, Kingdom of Saudi Arabia

http://www.kaust.edu.sa/research/ResearchEvents.html

KAUST has teamed up with Oxford University's world-leading mathematics-in-industry researchers for the first Study Group in the Region. Academic participants will be drawn from Oxford's large international network so as to bring relevant expertise to bear on your problem.

What is a study group?

Study Groups are collaborative problem-solving workshops where applied mathematicians tackle real life problems brought by companies. They help to rapidly determine the key scientific issues and mathematical challenges to be confronted.

On the first morning of the meeting, the companies present their problem to the whole mathematical audience.

The academics then form problem-solving teams which work collaboratively with the industrial presenters. The teams formulate their ideas in an accessible way in order to realize the benefits from modelling, analysis and computation.

At the end of the meeting, the academics present the results of their investigations, and outline the possible future work that can be done.

Please check http://www.maths-in-industry.org for examples of Study Groups around the world over the past number of years.

This Study Group will be preceded by a symposium on "The Impact of Applied and Computational Mathematics in the 21st Century" on January 22nd, 2011.

Administration

The academics are not paid
However, a standard fee of
is requested, except for com
for small or medium sized en

Please contact the industri
to discuss your contributio

For the best results from th
companies are asked to have
present or available for dis
Study Group.

The Study Group will help
travel and accommodation.
participants will be covere
from the industrial sponsor
KICP) and OCCAM.

Experience has shown that the best
achieved when the proposed proble
refined prior to the Study Group. If
in presenting a problem at the Stud
contact Dr Bentahar, who will, if ne
formulate it appropriately for the w

Experience has also shown that alm
problem can be presented and tack
disclosing proprietry information.

l a consultancy fee.
$5000 per problem
npanies in KICP. Reductions
terprises may be negotiated.

al organiser, Dr Bentahar,
n.

he event, the presenting
e at least one representative
scussion throughout the

academics with their
. Subsistence for all of the
d by a mixture of funds
rship, KAUST (GCR and

t results are
em is discussed and
you are interested
ly Group, please
cessary, help you
vorkshop.

most any industrial
led without

Experience

Mathematical Study Groups have proved to have been a key tool for delivering the underpinning discipline of mathematics to dificult problems for more than forty years, and many mathematicians from all over the world take part in these events regularly. See *http://www. maths-in-industry.org*

The meeting provides opportunities for bridging the gap between academics and scientists from industry, and encourages technology transfer from one another.

Study Groups have a track record of success in 20 countries in all 5 continents.

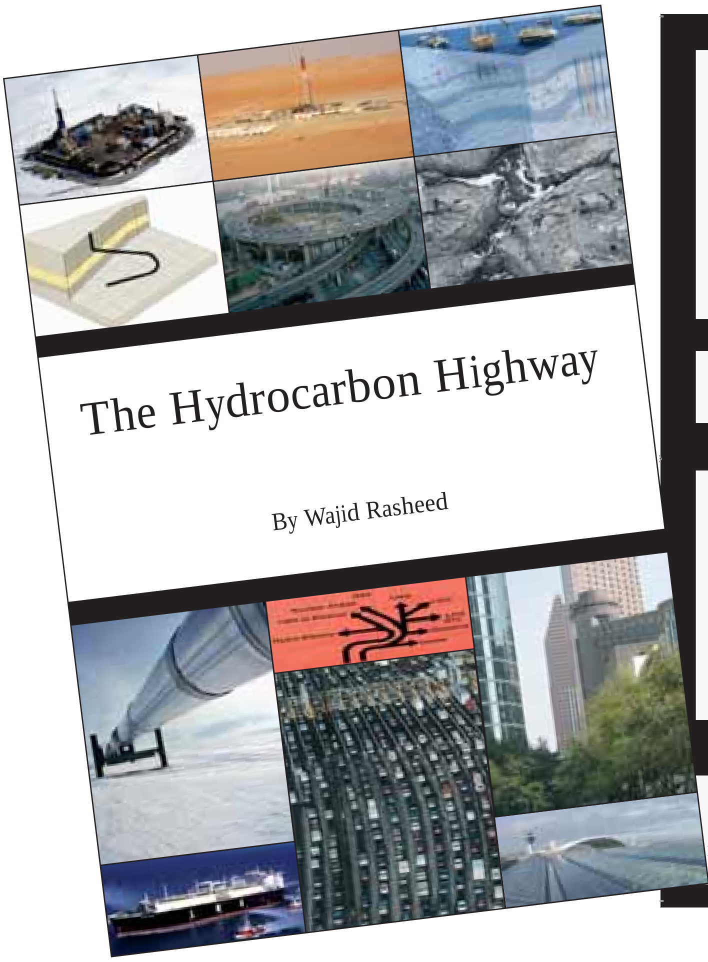
Benefits

As well as revealing new scientic insights of practical value, the benefits to industry include:

- discovering exciting new solutions,
- learning about new methodologies via close interactions with academics,
- working with world-class mathematicians to obtain a better quantitative understanding of industrial problems of all kinds,
- recruitment opportunities and inspiring students.

Most participating companies find the Study Group experience of great value, especially for the perspectives that then emerge from the discussion sessions.

Mature Fields



"There have been many books concerning the oil industry. Most are technical, some historical (e.g. the Prize) and some about the money side. There are few, if any, about the oil industry that the non-technical person will appreciate and gain real insight from. Wajid Rasheed in this book, The Hydrocarbon Highway, has made a lovely pen sketch of the oil industry in its entirety. The book begins with the geology of oil and gas formation and continues with the technical aspects of E & P, distribution, refining and marketing which are written in clear language. In particular, the process of oil recovery is outlined simply and with useful examples. There is a short history of how the oil companies have got to where they are, and finally a discussion concerning the exits—alternative energy. This is all neatly bundled into 14 chapters with many beautiful photographs and a helpful glossary. The book is intended to give an overture to the industry without bogging the reader down. I enjoyed the journey along the highway."

Professor Richard Dawe of the University of West Indies, Trinidad and Tobago

"A crash course in Oil and Energy. The Hydrocarbon Highway is a much-needed resource, outlining the real energy challenges we face and potential solutions."

Steven A. Holditch, SPE, Department Head of Petroleum Engineering, Texas A&M University

"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. It also provides accurate information which is required by the industry and the wider public. Recently, I read several books about oil which portrayed it as a quickly vanishing energy source. It seems that many existing books predict a doomsday scenario for the world as a result of the misperceived energy shortage, which I believe is greatly exaggerated and somewhat sensational. Therefore the book bridges the existing gap of accurate information about oil as a necessary source of energy for the foreseeable future. The Hydrocarbon Highway should also help inform public opinion about the oil industry and our energy future. It looks at the oil industry in an up-to-date and integrated view and considers the most important factors affecting it."

Dr AbdulAziz Al Majed, the Director of the Centre for Petroleum and Minerals at the Research Institute at King Fahd University of Petroleum and Minerals

www.hydrocarbonhighway.com
www.eprasheed.com

ISBN 978-0-9561915-0-2
Price UK £29.95 US $39.95

Inevitably, all producing fields reach maturity one day, so the importance of mature field technology is set to grow as greater numbers of assets enter maturity. This chapter provides an overview of Enhanced Oil Recovery (EOR) and Improved Oil Recovery (IOR), as well as several practical field applications.

Pumps, polymers and permanent seismic are just a few of the technologies used to enhance and improve production in mature assets. Mature fields are challenging as they exhibit a decline in hydrocarbon rates, increased water production as well as the responsibility of decommissioning platforms, wellheads or pipelines[1].

For our purposes, a field is defined as mature once its natural reservoir drive mechanisms—gas drive, water-drive or gravity drainage—are incapable of sustaining production. Consequently, hydrocarbons must be artificially swept from the reservoir and be able to travel through production tubing, the wellbore and to surface installations[2].

Figure 1 - Nodding Donkey Or Rod Pump (EPRasheed)

Reservoir Drive

Reservoir pressure curves correlate directly with reservoir production rate curves. As long as reservoir pressure is greater than bottom-hole pressure, the differential pressure will result in production. Pressure differentials can be created by reducing bottomhole pressure or by increasing reservoir pressure, either of which will increase hydrocarbon production[3].

Following the development of low-hanging fruit, most mature assets have traditionally been distributed onshore; however, the trend now shows extensive numbers of shelf and deepwater assets entering maturity. Already, several notable offshore fields are classified as mature assets; for example, Brent and Troll in the North Sea, and Marlim in offshore Brazil.

Pump Up Production

Primary or artificial lift methods to increase production include the nodding donkey or rod pump, Electrical Submersible Pump (ESP) or a gas-lift system. During primary recovery, only a small percentage of the initial hydrocarbons in place are produced, typically around 10% for oil reservoirs and 15% for gas reservoirs[4].

Secondary production (IOR) of hydrocarbons is achieved when a fluid such as water or gas is injected into the reservoir through injection wells. Injectors are carefully drilled into formations so that fluid communication or flow pathways can be made to production wells. The purpose of secondary recovery is to increase reservoir pressure and to displace hydrocarbons toward the production wellbore[5]. As a consequence of prudent reservoir management, wells may be converted from producers to injectors or new injector wells may be drilled. The trick is to consider the entire field as a 'production unit' and manage all wells with the objective of increasing overall production. This can be a very complex and contentious issue when several landowners are involved. Imagine an oil company telling a farmer that the prolific oil well on his property that is returning him a handsome revenue in royalties is about to be converted into a water injection well.

Normally, gas is injected into the gas cap and water is injected into the production zone to sweep oil from the reservoir. The mechanics of gas and water injection are complex and include consideration given to directional injectors and multi-phase flow. A pressure maintenance programme can begin during the primary recovery stage, but it is still considered a form of enhanced recovery. The secondary recovery stage reaches its limit when the injected fluid (water or gas) is produced in considerable amounts from the production wells and the production is no longer economical. For some fields this could be 50%, while for others it could be as high 80%. In Oman, wells are currently producing economic volumes of oil with over 90% water cut. The successive use of primary recovery and secondary recovery in an oil reservoir produces about 15% to 40% of the original oil in place[6]

Tertiary recovery (EOR) not only restores formation pressure, but also seeks to improve reservoir flow characteristics. With greater numbers of mature assets, oil companies target mature onshore and offshore oil fields worldwide in order to extract maximum value from sunk costs. Tertiary oil recovery applications are internationally recognised and this area of production engineering covers most categories of crude oil with American Petroleum Institute (API) grades varying from 13° to 41°. The industry adopted a broad ranging methodology, which enabled pilot testing to commercial/field applications using steam injection, carbon dioxide (CO_2) injection and polymer flood. EOR methods range from chemical flooding (alkaline or micellar-polymer based), biological flooding (microbial or bacterial based), miscible displacement (CO_2 injection or hydrocarbon injection), and thermal recovery (steam flood or in-situ combustion)[7].

Sometimes these methods are accompanied by additional stimulation services, such as hydraulic fracturing, or by drilling sidetrack lateral wells from the main wellbore to access stranded oil.

A thorough characterisation of reservoir heterogeneity and the nature of reservoir fluids is required for a mature field production strategy and only after extensive analysis of the application can a particular method be chosen. The application process can be split into three basic stages: modelling future behaviour, field data analysis and corrective correlation of the model[8].

Typically, data maybe collected from permanent seismic (time-lapse or 4D) or downhole equipment that monitors production. The objective is to draw up a reservoir management strategy that will address:

- The effect of recovery methods on reservoir fluids
- Migration and production of oil and gas
- Communication with adjacent reservoirs
- Sealing faults
- Fracturing
- Induced pathways due to modified permeability
- Scale formation
- Hydrogen Sulphide (H2S) mitigation, and
- Water disposal.

Analysis will include:

- Reservoir temperature
- Pressure
- Depth
- Net pay
- Permeability and porosity
- Residual oil and water saturations, and
- Fluid properties such as oil, API gravity and viscosity[9,10].

Seismic

A major goal for oil companies is to improve recovery factor for mature fields. A key method is to use imaging as a way of identifying stranded hydrocarbons and improving the efficiency of water injection. This helps mitigate the problems associated with water production, such as souring and scaling, and thus decreases the lifting costs of old fields. By using 4D seismic, and examining the differences between subsequently acquired seismic images, production geophysicists can: map reservoir drainage patterns; identify flow barriers such as faults or unconformities that are below the resolution of direct seismic imaging; and, plan the location of future injector wells.

Mature Field Applications

Water Injection

Water management is a major challenge associated with

> To ensure smooth transition from lab technology to field application, oil companies run pilot programmes; for example, a pilot water re-injection programme would handle say 5% of actual water volumes produced from the reservoir and re-inject this to maintain reservoir pressures.

mature fields. Besides handling increasing volumes of water at surface, the challenge is to increase recovery by improving the sweep or production of hydrocarbons through water injection. This requires the correct evaluation of reservoir drainage patterns. In order to meet water management and environmental needs, oil companies are shifting from water injection to water re-injection. To ensure smooth transition from lab technology to field application, oil companies run pilot programmes; for example, a pilot water re-injection programme would handle say 5% of actual water volumes produced from the reservoir and re-inject this to maintain reservoir pressures. Water injection is easily applicable offshore where the entire ocean is available, but recently land operators have had problems finding water to inject. Farmers object to the use of aquifers for obvious reasons.

Accordingly, operators have figured ways to re-inject unwanted water produced in conjunction with the oil. This recycling solves two problems at once: it is an elegant way to dispose of the unwanted saline water that is not suitable for irrigation or drinking, and it augments oil production. Now, even offshore operators are recycling produced water because it is unlawful to dump it into the sea because of its high saline content and because it contains traces of residual oil.

To get an idea of the volumes manipulated, Petrobras handles an average water injection volume of two million barrels of oil per day (MMbbl/d) half of which come from produced water. This accounts for approximately 1.87 million barrels (MMbbl) of oil which is an average water cut of 50%. Petrobras plans to construct a system for ‘raw’ water injection which would be placed over the seabed and used to capture and filter water prior to injection. This has a good application on mature fields or fields whose small platforms are often space-limited[11].

H_2S in Mature Fields

The term ‘souring’ describes various sour gas and H_2S management strategies. The Health, Safety and Environmental (HSE) implications of water injection are well understood as injection has been ongoing in certain areas since 1978. In Brazil's Offshore Campos Basin in the Marlim field, water injection begun in 1994 and a H_2S breakthrough occurred in 2003. Injecting nitrate to mitigate the problem and to simulate the reservoir behaviour of H_2S generation processes helps to define, for the fields under development, which strategy to adopt. This approach is dependent on the forecast of how much H_2S is involved and when it will be produced[12].

If only trace H_2S volumes are expected, there is no need to act; if there are medium levels, metallurgical improvements may be selected. In addition, sulphate removal for scaling treatment may help to mitigate some of the souring problems. If levels are high, nitrates must be injected. Field pilots usually test the effectiveness of nitrate injection by having one pilot re-inject reservoir water and another pilot inject seawater. It should be noted that both would be using nitrate. These technologies are developed in conjunction with service and research companies, which are performing lab tests to help determine the simulation parameters of H_2S generation in the reservoir[13].

Salt and Scale

Offshore operations also create salt and scale problems. This can occur anywhere between surface and sub-surface equipment. Remote operations have been used successfully to perform interventions such as well cleaning and squeezing of scale inhibitors into the formation. Satellite wells using subsea Christmas trees are employed in all Brazilian deepwater fields, and remote handling avoids incurring high rig costs for intervention. The problems of corrosion and its effects on subsea installations need to be carefully considered[14].

Steam Onshore Fields

Onshore fields have seen good results from EOR using cyclic or continuous steam injection, as is demonstrated by the production of a total of 20,000 barrels per day (bbl/d). Applications in the Fazenda Alegre, onshore Espírito Santo Basin, have seen production rates improve in horizontal wells due to the introduction of ther-mal recovery methods. Several research projects are testing theories and feasibility of in-situ combustion. Petrobras is also considering variations of in-situ combus-tion and steam injection. The old vertical injector – vertical producer scheme – is being substituted by innovative geometries; for example, a vertical well to inject and a horizontal well to produce. Another alternative is to associate steam with solvents. This technology was recently applied in a field in the Espírito Santo Basin to mobilise oil which had not responded to steam injection alone.

Steam Assisted Gravity Drainage (SAGD) is an enhanced oil recovery technology for producing heavy oil. It involves the parallel drilling of a pair of horizontal wells spaced apart a few metres. Pressurised steam is continuously injected into the upper wellbore to heat the oil and reduce its viscosity, causing the heated oil to drain into the lower wellbore, where it is pumped out.

In all thermal recovery processes, the cost of steam generation and the availability of water will play a major part in determining whether the cost of oil production is commercially viable.

Microbial Applications

Another EOR front uses microbial applications based on water and bacterial interaction to increase production. The water and bacteria are pumped down and this is followed by nutrients. The bacteria develop a biomass that clogs the porous medium and subsequently increases the viscosity of water and diverts flow along new pathways to increase production. Biopolymers, generated by the metabolic process of the bacteria, clog the water pathways of higher permeabilities. Continuously injected water displaces the remaining oil from the lowest permeability zones. This process has been tested by Petrobras' Carmópolis field in the Sergipe Basin[15]. Alternatively, microbes are used to 'eat' clay particles that clog pore throats, thus improving permeability. A limitation to the use of microbes is their relative temperature limit. Ongoing research seeks to breed colonies of microbes that are more temperature resistant.

Modifying Relative Permeability

A neat application is the use of chemicals to control water. Water shut-off control in more than 200 wells has been achieved with the injection of a patented polymer called Selepol, which is a relative permeability modifier. Several formulations were attempted with the more recent based on tiny pieces of hydrophilic gel[16].

Drilling in carbonates or tight sands is another area of interest where stimulation technology plays a central role. There have been five fractures in a well drilled in the Enchova field, a shallow water, low permeability, light oil-bearing carbonate.

A new exploratory approach may bring into focus a new family of reservoirs of this kind, previously thought to be marginal in Brazil[17].

> In all thermal recovery processes, the cost of steam generation and the availability of water will play a major part in determining whether the cost of oil production is commercially viable.

A novel gas management programme was designed to characterise gas reservoirs, principally for the tight sandstone Mexilhao field in the Santos Offshore Basin. The development of a gas-producing province at the Santos Basin, south of Campos, is a major goal for Petrobras and the company is focusing on stimulating flow in low permeability porous media[18,19].

Steam Injection

In the late '70s, following the discoveries of heavy oil reservoirs in the onshore part of the Sergipe-Alagoas and Ceará-Potiguar Basins, cyclical steam injection was introduced into Brazil. These first successful projects were later expanded and commercialised[20]. Subsequently, continuous steam injection was applied to a total of 15 cyclical and continuous steam injection projects covering a broad range of oil viscosities. Steam is responsible for virtually all tertiary recovery production, estimated to be presently 3% of Brazil's total oil production. In the Fazenda Alegre field, located in the onshore Espírito Santo Basin, extremely low API grade oil is being cold-produced using steam injection and horizontal wells completed with slotted liners and stem rod pumps[21].

In-Situ Combustion

Two in-situ combustion pilots were performed in the '80s in the Buracica and Carmópolis fields, and in the Recôncavo and Sergipe-Alagoas Basins respectively. The best results were obtained in the Buracica pilot, which was characterised by a low temperature oxidation process; however, sand production and well surface facility corrosion were major operational problems. Additionally, oxygen breakthrough interrupted the project due to the risk of well explosion. The Carmópolis pilot showed poorer results, despite the fact that it generated the best combustion efficiency. Poor reservoir characterisation was the main reason for losing control of the combustion. Electrical heating was tried in two heavy oil reservoirs in the Potiguar Basin as an alternative to steam injection. Results showed that the electrical heating process cannot replace steam, but can be useful in areas where steam is not applicable. Further electrical heating and water injection techniques have been applied in a pilot project conducted in the Canto do Amaro field[22].

Polymers

The first polymer injection project was implemented in 1969 in the Carmópolis field. After operating for some years, the project was interrupted but evaluations showed that an additional oil recovery of 5% could be credited to polymer injection. Besides the technical success of this project, the drop in the costs of polymers and the increasing ease with which polymer could be handled and prepared offered new opportunities to apply this technique. Currently, there are three polymer projects in course, one in the Carmópolis field and the other two being carried out in the Buracica field, Recôncavo Basin and in the Canto do Amaro field in the Potiguar Basin[23].

Water Management in Petrobras Fields and Treatment of Subsea Xmas Tree Wells

Water Flooding

Flooding is the main recovery method used in Brazil in both onshore and offshore fields. Offshore operations in the Campos Basin are responsible for a daily output of roughly 75% of the total country's output. The volumes of water injected exceed 800,000 bbl/d and the water production reaches values of over 350,000 bbl/d[24].

Due to the importance of water injection for the Petrobras fields, water management has become a major priority. Problems associated with water injection and production has been the focus of several important projects developed in the past few years.

It is worth emphasising that 'simple' problems in onshore fields, such as the stimulation of injector wells that have lost injectivity, become more complex offshore. Many wells located in deepwater areas are completed as satellites; therefore, workovers are extremely expensive due to the need for a floating rig. For such scenarios, remote operations are performed as a way of decreasing intervention costs.

A major factor in managing water is the rate of water injection that is required. The injection decline curve for injector wells must be precisely drawn in order to evaluate the economics of two options: to perform effective water treatment that requires fewer workovers or to inject lower quality 'water' that requires more frequent workovers.

Petrobras has been injecting seawater in offshore fields for twenty years. Water quality has been monitored using an index which covers parameters involved in water treatment such as injection and disposal volumes, corrosion risk, bacteria, solids and oxygen content. Irrespective of the quality of the injection programme, there is an ultimate loss of effectiveness over time. Some remote treatments using acid to remove damage in injection wells have been performed and have yielded very good results[25].

Remote Acidisation

This technique has been performed in the Marlim field which is a giant complex of oil fields located in water depths that vary from 1968 ft (600 m) to 3,445 ft (1050 m). It produces 600,000 bbl/d from high permeability turbidites. To maintain reservoir pressure, an equivalent amount of water is injected daily. Despite excellent reservoir properties, injector wells lose effectiveness after a few months of water injection. Conventional acid treatments cannot be performed due to high rig costs. The solution, therefore, is to pump acid from the production platform which is often several kilometres away from the subsea Xmas tree wells. Careful laboratory tests are needed before field operations can begin to ensure that the treatment does not damage subsea equipment such as injection lines, well heads and injection columns[26].

To date, only vertical or slant cased wells have been treated. The challenge is to perform remote pumping in horizontal wells completed with slotted liners.

An alternative that may help guarantee effective water injection is to inject low quality water at pressures high enough to keep fractures open. Safe water injection requires extensive modelling of reservoir sweeps, geometry and fracture propagation[27].

Flow Assurance

Flow can be interrupted or halted altogether due to inorganic scale formation caused by seawater and reservoir water mixing together; therefore, the prediction, prevention and corrective treatment of scale is fundamental to ensure the flow of oil. The Namorado field was the largest Brazilian offshore field in the '80s and suffered from scale formation. Interventions to squeeze scale inhibitors into the rock formation were performed and oil production was maintained without interruption.

As some deepwater fields contain horizontal, uncased satellite wells, scale treatments are more difficult to

> The injection decline curve for injector wells must be precisely drawn in order to evaluate the economics of two options: to perform effective water treatment that requires fewer workovers or to inject lower quality 'water' that requires more frequent workovers.

perform. Nevertheless, some excellent results were achieved in the Marlim field using a special chemical process developed by Petrobras. Oil production increased by more than 13,000 bbl/d after the treatment. Again, the challenge for the next few years is the application of these treatments in horizontal uncased wells[28]. Sea floor water separation and re-injection are techniques under development[29].

Polymers

The use of polymers to control water is another potential solution and Petrobras has performed more than 170 well treatments in onshore fields. The rate of success for such treatments is in excess of 65%. The process modifies the relative permeabilities of the oil-water-sandstone system, retaining water in the wellbore vicinity. Higher seawater salinities, higher temperatures, higher permeabilities and higher produced volumes, as compared to onshore conditions, are the main challenges to be overcome offshore[30].

Water Disposal

Once large amounts of produced water cannot be avoided, disposal becomes the priority. The focus is on treating water to remove oil (this can be difficult due to space restrictions on platforms) in an environmentally acceptable manner so that re-injection into the reservoir or disposal in non-productive formations can be achieved[31].

Trends in Reservoir Geophysics

The challenge for seismic contractors is to increase the quality and resolution of seismic data, not only in exploration, but also in mature applications. New acquisition and seismic processing parameters oriented to reservoir characterisation and monitoring are helping improve seismic quality and resolution. With this new data set, reservoir geophysicists can potentially better understand external reservoir geometry, the internal heterogeneity of turbidite reservoirs and monitor the fluid flows. Historically, reservoir geophysicists have been using the same sequential process normally used

> "Due to the increasing number of brown fields worldwide, 4D seismic applications have increased substantially; however, as seismic is a recent technology, there are relatively few processes available to evaluate it."

in exploration. Nowadays, oil companies are applying new techniques such as 4D seismic adapted to reservoir needs[32].

Mature Field Seismic

In the following applications, we look at the benefits of seismic in brown fields owned by BP, Petrobras and StatoilHydro. These oil companies have successfully used the latest 4D and time-lapse seismic to maximise the life of the reservoir, characterise stacked and thin-bed reservoirs as well as monitor water injection in deepwater reservoirs. This has helped these companies reach bypassed payzones, extend production and even change the definition of what was once considered economic.

Reservoir Studies of BP's Mature Fields in the Columbus Basin, Trinidad

4D seismic accompanies the lifecycle of an oil and gas asset and can provide valuable production monitoring information. This is because, as with all technology, seismic is subject to constant improvement. Seismic shot 20 or 10 years ago would have had limited 'vision' and likely only located 'shallow' reservoirs. Today, opportunities exist to find deeper reservoirs in mature fields, which were once characterised by 2D (early less sophisticated seismic). This can be seen in the new frontiers or deep gas plays, which are being explored in the Gulf of Mexico (GOM) and in the Columbus Basin[33].

This has tremendous value in shaping decisions as to the peaking of production rates and decline curves. Usually, a cost-benefit analysis is conducted which measures costs and attributes the value gained. This exercise can be difficult as the value gained may often be indirect. 4D seismic is used mainly to better manage reservoir production across the lifecycle of a field. Due to the increasing number of brown fields worldwide, 4D seismic applications have increased substantially; however, as seismic is a recent technology, there are relatively few processes available to evaluate it[34].

In 2004, BP in Trinidad and Tobago faced the challenge of valuing a number of seismic survey options over the Greater Cassia Complex in the Columbus Basin, Trinidad. In Southern Greater Cassia, several trillion cubic feet (tcf) of gas reserves are located under shallow gas reservoirs, which often blur seismic visualisation. Development of these reserves is complicated

Figure 2 - Offshore Vessel in the Troll Field

> Oil companies commonly apply dual geoscience programmes of seismic for reservoir characterisation and also 3D geological modelling.

by the presence of 27 stacked reservoirs with reserves trapped in over 100 separate segments[35].

BP had to identify and value the style of survey required to improve seismic visualisation over the southern half of the complex, which was affected by shallow gas imaging problems, and value the benefits that 4D seismic could offer for reservoir management and future well placement. This required consideration of expensive 4D Ocean Bottom Cable (OBC) seismic acquisition options. Additional benefits from 4D seismic for monitoring dynamic reservoir performance could be foreseen with a permanent installation. Here BP developed several research programmes to ascertain which 4D acquisition option was the best solution. The integration of these results, along with other elements, helped support decisions for a seismic strategy for the 'Life of the Cassia Complex'[36].

Mature Field Seismic Application in Petrobras' Deepwater Campos Basin, Brazil

Petrobras acquired its first 4D seismic in the Marlim field in 1997. In 1999, Petrobras started several 3D, reservoir-oriented seismic acquisition programmes covering former 3D surveys. These occurred in the South Marlim, Barracuda and Caratinga, Espadarte, Marimbá, and Pampo-Linguado fields in the Campos Basin.

Common seismic processing techniques were used to map reservoir turbidite systems and to reduce appraisal and production risk. Visualisation techniques were applied in 3D views of exploration and development projects[37]. From its initial evaluation of the 4D interpretation, Petrobras was able to re-locate the trajectories of 11 development wells planned for the Marlim Complex. In addition, the company was able to identify the need for nine additional wells to improve reservoir drainage efficiency. In short, the company realised a Return on Investment (ROI) of more than 40 times by saving US $1.6 billion by not drilling wells in the wrong place. It remains to be seen how much additional revenue the company will gain from drilling its development wells in the right place.

Geosciences

Oil companies commonly apply dual geoscience programmes of seismic for reservoir characterisation and also 3D geological modelling. Seismic for reservoir characterisation is a main issue. An acquisition project was started in 2005 with the objective of acquiring base 4D timelapse data of the whole Marlim Complex (Marlim, Marlim Sul and Marlim Leste fields). Petrobras has a '4D-room' where geologists and engineers can visualise geological phenomena[38,39]. At the time, Marlim was the largest seismic acquisition ever acquired both in terms of area and the amount of data acquired. The data amounted to 157 terabytes and required the continuous application of 12,000 processing units (9000 of which were located in Houston and 3,000 in Gatwick, UK).

Regarding the specific challenges that reservoirs create, modelling reveals such things as key depositional features and reservoir geometry which can help explain the gross size, volumes and channels of the reservoir[40].

Mature Field Application of 3D Seismic and Multilaterals in Norway's Troll Field

The Troll field is located approximately 50 miles (80 km) off the west coast of Norway in shallow seawaters. Troll's reserves are mainly gas (at one time it was considered to be a gas play only), but it also contains sizeable oil reserves and has produced more than one billion barrels of oil.

This oil, however, was distributed in hard-to-reach thin oil-bearing layers that were just 13 ft to 85 ft (4 to 26 m) thick and spread out over an area of approximately 173 square miles (450 sq km)[41,42].

A combination of multi-laterals and state-of-the-art geosteering drilling technology was required to drain the thinly dispersed pockets of oil. This included the latest rotary steerable systems in conjunction with reservoir imaging tools, which allowed the oil company to place the well in the best parts of the reservoir. This, however, was only half the story as state-of-the-art completion and production technology was required due to challenges such as Subsea sand and water separation.

In the late 1980s, it was the belief that the development of Troll oil would 'never' be economically feasible because its oil reserves were so thinly layered and the price of oil was US $10 per barrel; however, with the creative use of technology, Troll became one of the largest oil producing fields in the North Sea. The success of this drilling and production approach led to its application in even thinner oil layers measuring just 23 ft to 46 ft (7 to 14 m) thick[43].

The Troll story is one of realising the potential of the field by: applying modern drilling technology; placing well trajectories within a very difficult and challenging reservoir; and keeping sand and water production to a minimum to achieve maximum production.

These successful field applications illustrate the immense financial and technical risks faced by the oil companies in reaching their prize, and show how challenges can be overcome to realise added profit and extended reservoir life.

We have seen how technology in Extreme E & P and mature field applications has extended Hubbert's peak into a plateau. With the powerful combination of technology and knowledge we are producing from reservoirs once thought to be unproduceable and improving overall recovery rates.

But how does the oil and gas from wells reach consumers?

References

1. Enhanced Oil Recovery, Textbook Vol. 6. by Don W. Green and G. Paul Willhite ISBN: 978-1-55563-077-5, Society of Petroleum Engineers 1998.

2. For details of reservoir gas injection and wellbore artificial lift see Petrobras Technology Harts E & P June 2003.

3. These are general figures and are illustrative only. Significant variations occur in practice.

4. Case Study based on information sourced from SPE papers written by Farid Shecaira, Eduardo Faria and other Petrobras sources.

5. Reservoir Engineering Aspects Of Waterflooding Monograph Vol. 3 ISBN: 978-0-89520-202-4 Society of Petroleum Engineers.

6. Thermal Recovery Monograph Vol. 7 by Michael Prats ISBN: 978-0-89520-314.4 Society of Petroleum Engineers, 1986.

7. Modelling future behaviour covers data entry.

8. Fluid samples will be as representative as possible of the reservoirs.

9. This can be an ongoing process accompanying the lifecycle of the field.

10. Petrobras E & P Technology June 2003 Harts.

11. See PRAVAP Petrobras Advanced Oil Recovery Program.

12. Petrobras E & P Technology June 2003 Harts.

13. SPE 65589 Remotely Acidizing Satellite Wells by E. P. Da Motta, C. C. M. Branco, F. S. Shecaira, Petrobras Source SPE International Symposium on Oilfield Chemistry.

14. SPE 69474 Using Tracers to Characterize Petroleum Reservoirs: Application to Carmopolis Field, Brazil by Maria Aparecida de Melo, Carlos Roberto de Holleben, Alcino Resende Almeida, Petrobras R & D Centre.

15. Variations on hydrophilic gel include mechanical inflow control devices with hydrophilic membranes.

16. Both from a light oil and carbonate reservoir perspective.

17. Petrobras presentation on development strategy.

18. Tight gas reservoirs have become a major front in the US and Canada.

19. See Petrobras PRAVAP.

20. SPE 112160 The Fazenda Alegre Journey into Intelligent Energy—Lessons Learned From a Successful Holistic Approach of People, Process, and Technology Aligned to Business Strategy and Results Author W.L. Vinturini, G.B. de Castro, and J.H.S. Crespo, Petrobras, and J.R. Albernaz, M.A.S. Lopes, and A. Valadares, Accenture.

21. Petrobras E & P Technology Harts June 2003.

22. SPE 94898 Evaluation of Polymer Injection Projects in Brazil. Authors M.A. de Melo, C.R.C. de Holleben, I.P.G. da Silva, A. de Barros Correia, G.A. da Silva, A.J. Rosa, A.G. Lins and J.C. de Lima, Petrobras.

23. Petrobras E & P Technology Harts June 2003.

24. Idem.

25. Reservoir Engineering Aspects Of Waterflooding Monograph Vol. 3 ISBN: 978-0-89520-202-4 Society of Petroleum Engineers.

26. See Pravap.

27. Petrobras E & P Technology Harts June 2003.

28. Idem.

29. Reinjection is the ideal solution.

30. This is the Life of Complex Seismic (LoCS).

31. Value of Information for a 4D-Seismic Acquisition Project by P.R. Ballin, SPE, G.S. Ward, C.V. Whorlow, and T. Khan, BP Trinidad and Tobago LLC Source SPE Latin American and Caribbean Petroleum Engineering Conference, 20-23 June 2005, Rio de Janeiro, Brazil.

32. SPE 99948 Integrated Multizone Low-Cost Intelligent Completion for Mature Fields H.L. da C.P. Pinto, M.F. Silva Jr., R.G. Izetti, and G.B. Guimarães, Petrobras.

33. SPE 94705 Produced Water Reinjection in Petrobras Fields: Challenges and Perspectives Author C.J.A. Furtado, A.G. Siqueira, A.L.S. Souza, A.C.F. Correa, and R.A. Mendes, Petrobras.

34. SPE 104034 New Life for a Mature Oil Province via a Massive Infill Drilling Program J.G. Flores, SPE, and W. Gaviria, SPE, Schlumberger, and J. Lorenzon, SPE, J.L. Alvarez, and A. Presser, Petrobras Energia S.A.

35. Petrobras EP Technology Supplement Brazil Oil and Gas Issue 7.

36. Idem.

37. Petrobras EP Technology Supplement Brazil Oil and Gas Issue 7 Seismic throws up array of applications.

38. Most oil companies have similar seismic visualisation rooms.

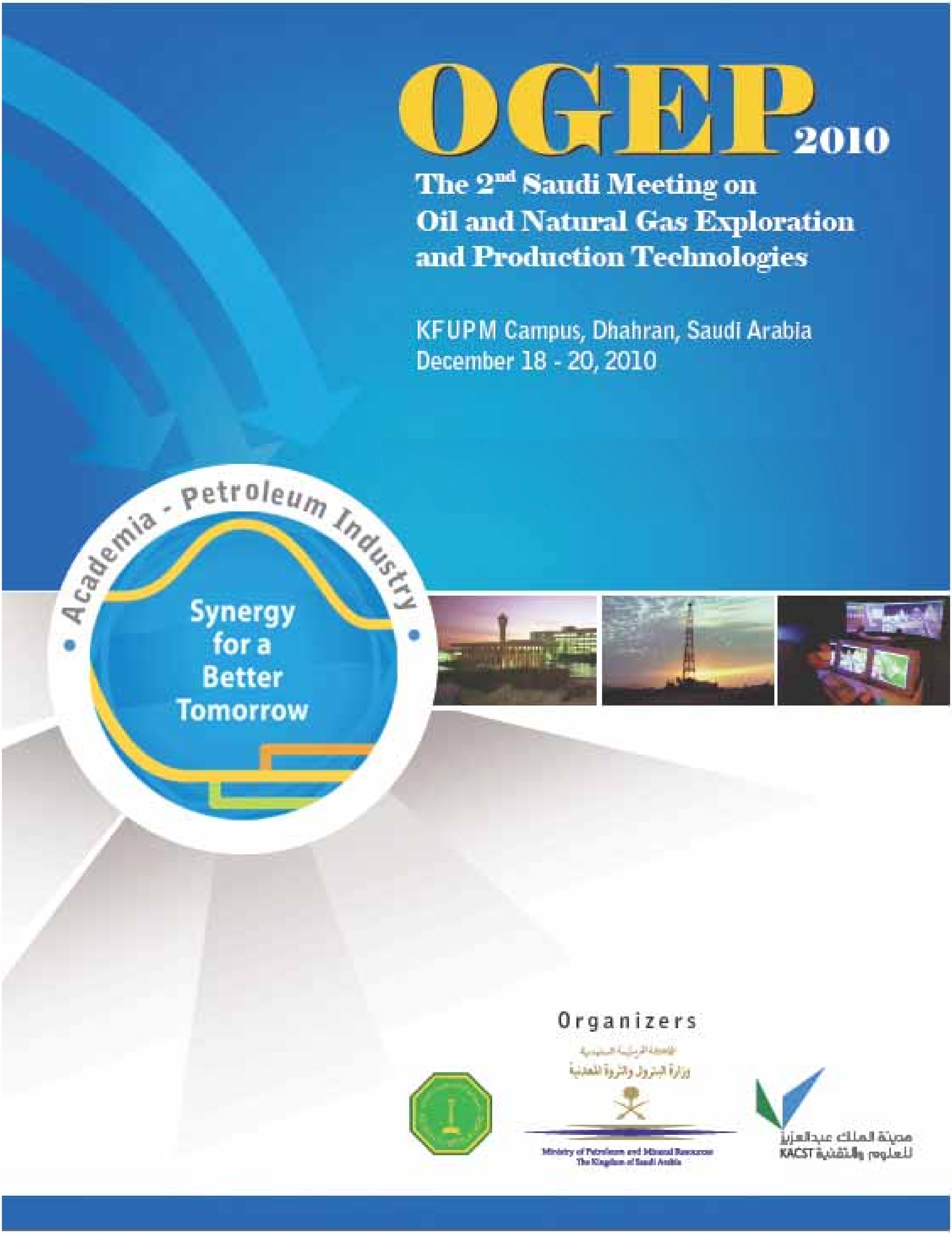
39. At the time Marlim was the largest acquisition.

40. The models are corrected and validated with field data.

41. Cost Effective Horizontal Drilling in the Troll Field Through use of State of the Art Technology and Optimal Operations by Henriksen, N., Storegjerde, D., Norsk Hydro A/S SPE/IADC 1997.

42. Idem.

43. Troll West Oilfield Development—How a Giant Gas Field Became the Largest Oil Field in the NCS through Innovative Field and Technology Development by Richard Dyve Jones, StatoilHydro AS, Erland Saeverhagen, Arve K. Thorsen, and Sveinung Gard, SPE, INTEQ IADC/SPE 2008.


OGEP 2010
The 2nd Saudi Meeting on
Oil and Natural Gas Exploration
and Production Technologies
KFUPM Campus, Dhahran, Saudi Arabia
December 18 - 20, 2010
Academia - Petroleum Industry
Synergy
for a
Better
Tomorrow
Organizers
المملكة العربية السعودية
وزارة البترول والثروة المعدنية
Ministry of Petroleum and Mineral Resources
The Kingdom of Saudi Arabia
مدينة الملك عبدالعزيز
للعلوم والتقنية KACST

Invitation

The Ministry of Petroleum and Mineral Resources, King Fahd University of Petroleum & Minerals (KFUPM), and King Abdulaziz City for Science and Technology (KACST) cordially invite you to participate in the 2nd Saudi Meeting on Oil and Gas Exploration and Production Technologies (OGEP 2010). The Meeting will be held at the KFUPM Campus in Dhahran, Saudi Arabia, on December 18-20, 2010, under the auspices of His Excellency Ali Naimi, the Minister of Petroleum and Mineral Resources.

The theme of the meeting is "Academia Petroleum Industry: Synergy for a Better Tomorrow." The theme was selected to focus on enhancing the collaboration between academia and industry in research and development and to prepare a competent workforce for the future.

The OGEP 2010 will include technical sessions covering both oral and poster presentations, invited speakers, panel discussions, young professionals session, student paper contest, and an exhibition covering the latest advances in oil and gas exploration and production technologies.

The meeting is designed to provide a forum for discussion of a broad range of topics relevant to academia and E&P industry, including business relationships between academia and industry, human resources, exploration, production, drilling, reservoir, health, safety & environment, economics and energy. We particularly encourage the presentation of case histories, innovative ideas, challenges, and new technologies, as this is an excellent platform to exchange actual experiences and/or showcase new and innovative solutions with participants from local and regional academia as well as industry leaders from National and International Oil Companies (NOC/IOC) like Saudi Aramco, Chevron, and Shell as well as leading service providers such as Baker Hughes, BJ Services, Halliburton, Schlumberger, and Weatherford.

On behalf of the Technical Committee, I would like to invite you to participate in the OGEP 2010 through submittal of abstracts. I also ask for your support in distributing this announcement to colleagues and friends.

Chairman of the Technical Committee
Abdulrahman S. Al Jarri, PhD
Saudi Aramco

Co-Chairman of the Technical Committee
Abdulaziz A. Al-Majed, PhD
King Fahd University for Petroleum and Minerals

Objective

The meeting is organized for the academic community and the petroleum industry to discuss and collaborate on oil and natural gas exploration and production technologies. The meeting will provide a unique opportunity for professionals, experts, scientists, and faculty members in these fields to discuss and exchange their views and experience, with an emphasis on synergy between academia and the industry on relevant topics including human resources, research and development.

Topics

The technical program will cover numerous topics relevant to academia and oil and natural gas exploration and production including (but not limited to):

- Academia and Industry Business Relationships
- Human Resources
- Exploration Technologies
- Petroleum Geology and Reservoir Characterization
- Reservoir Related Technologies
- Production Technologies
- Drilling Technologies
- Health, Safety, and Environment
- Economics and Energy

Details of areas of interest are in the attached table.

Panel Discussions

The OGEP 2010 will include three panel discussions with the following tentative subjects:

• Academia and the Petroleum Industry: working together to supply future workforce
• Partnering Technologies for a Better Tomorrow: Academic and Industrial Prospective.
• Economic Exploration, Exploitation and Development of Tight Gas

Exhibition

The venue of the Meeting will host an exhibition, to take place at the same time as the conference. The exhibition will showcase the latest technologies available in the market for oil and natural gas exploration and production including hardware, software and services. An announcement for the exhibition will follow.

Young Professionals' Session

The Technical Committee is delighted to introduce a Young Professionals Session in the OGEP 2010. This session will be fully dedicated to participation by young professionals who are less than 35 years in age. The main objective is to create a network that allows young professionals to share their experiences, discuss career issues, ideas, events, and best practices in the petroleum industry. The Technical Committee encourages and seeks participation of young professionals through submittal of extended abstracts for presentation from local, regional and international institutions and companies.

Student Paper Contest

A student paper contest will also be held during the OGEP 2010. This is to attract students from various colleges and universities in the Gulf and the Middle East region. More information is available in the attachment on the website.

Field Trip and Tours

A half-day field trip covering some geological landmarks of the Eastern province will be planned and there will be tours to operating and R&D centers in the area.

OGEP 2010 Students Contest Information

Contest Objective

To allow graduate and undergraduate students from local and Middle East Universities to propose, on a competitive basis, innovative ideas, design concepts and new enabling technologies that are relevant to the E&P industry. The contest consists of selected students or teams (undergraduate, master, and PhD divisions from participating universities). The work of each student or team will be judged for content and presentation by a panel of experts according to the guidelines below. The contest will take place during the OGEP 2010 to be held in Dhahran, on December 18-20, 2010.

Contest Participants

Interested universities from Saudi Arabia and GCC (or Middle East) countries are invited to promote the contest through participation of their graduate & undergraduate students. Each university department is entitled to present one student (or team) from each division. Accordingly, university departments (Petroleum Engineering and Earth Sciences) are encouraged to screen potential representatives internally before suggesting one for the competition. Nominees could be composed of undergraduate and graduate students. Participation of PhD students is allowed up to one per team. Each participating student or team will be supervised by one or more university professors who also act as "Student/Team Advisor(s)." Each team should have a "Team Leader" student who will also act as the main contact person for the contest.

Contest Topic

Participating universities may wish to choose any topic that is relevant to E&P Industry. However, when choosing topics, 'out-of-the-box' thinking is encouraged.

Contest Format

Participating students or teams will present their papers to a panel of judges during the OGEP 2010 in Dhahran. Papers are to be reviewed and judged for content and presentation in accordance with the selection criteria as per the scoring sheet prepared by the OGEP 2010 Technical Committee. The highest scoring student paper shall be recommended for the award. Where two (2) papers receive the same total score, the proposal which has the highest score in the highest weighted criteria shall be recommended by judges from Industry and/or Academia for the particular award. Where this is not possible to separate equally scored papers, a joint award shall be recommended.

Contest Award

An Award consists of a certificate, a trophy, and a monetary prize (SR 10,000 for the first, SR 5,000 for the second, or SR 7,500 each for joint award). The Award is for the winning student or to be shared amongst all members of the team and it will be presented by the OGEP 2010 Technical Committee Chairman.

OGEP 2010 Technical Committee Members

Chairman: Dr. Abdulrahman S. Al-Jarri, Saudi Aramco
Co–Chairman: Dr. Abdulaziz Al-Majed, KFUPM

OGEP 2010 Participants

It is expected that several local and international organizations shall participate in the OGEP 2010. One of the major factors contributed to the success of OGEP 2008 was the participation of various organizations.

The following organizations participated in the OGEP 2008 technical program:

- Saudi Aramco
- King Abdulaziz City for Science & Technology
- King Fahd University of Petroleum & Minerals
- King Saud University
- Schlumberger
- Halliburton Services
- Shell
- Chevron
- Total
- South Rub Al-Khali Company LTD (SRAK)
- SAUDI ARABIA OIL AND GAS MAGAZINE
- EniRepSa Gas Ltd.

Technical Categories

1. Academia and Industry Business Relationships
- Academia versus Industry Perspective: Bridging the Gap
- Strategic Partnership for Maximum Returns
- Industry Oriented Academic Curriculum
- Training and Development
- Research and Technology Transfer
- HR capital
- University & High Institutes
- Internship
- Students Outreach
- Alliancing & Partnering
- Evolving Relationship between Academia & Industry
- Small & Medium Business Enterprise
- Applied Research to Commercial Development

2. Human Resources
- Coaching & Mentoring
- Education & Knowledge Sharing
- Outsourcing
- Practical Training, Development & Continuing Education
- Professionalism &Accountability
- Professional Certification
- Recruitment & Retention
- Succession Planning
- Technology Transfer
- Advances & Learning Techniques/Tools
- HR Development for E&P

3. Exploration
- Advances in Exploration Technology
- Geological Modeling and Basin Studies
- Deepwater Exploration Strategy
- Unconventional Reservoirs
- Tight Oil/Gas Reservoirs
- Fractured Reservoirs
- Applied Non Seismic Methods
- Case Studies

4. Production Optimization
- Artificial Lift
- Gas Lift, ESP, Beam, Pump, etc.
- Automation - Unmanned Platforms. Downhole Sensors Remote Well Surveillance, etc.
- Deliquification
- Integration: From Reservoir to Facilities
- Intelligent Pigging
- Modeling Gas Network
- Nodal Analysis
- Water & Gas Shut-Off Treatments
- Well Conversion
- Multiphase Metering & Pumping
- Debottlenecking

5. Drilling Technology
- Cementing
- Coring Technology
- Drilling and Casing
- Drilling with Casing
- Eliminating Drilling Surprises
- Fluids & Bits
- Slim hole, Coiled-tubing & Other Methods
- Underbalanced /Managed Pressure Drilling
- Well Control
- Wellbore Geomechanlcs
- Wellbore Stability

6. Completion Technology
- Completions
- Completion Fluids, etc.
- Expandable Tubular
- Formation Damage Management
- Intelligent Wells
- Monobore & Big Bore
- Sand Prediction & Control
- Stimulation
- Well Perforating

7. Offshore Technology
- Completions
- Development Options
- Drilling
- Flow Assurance
- Production Facilities
- Production Issues
- Subsea Completion
- Well Intervention

8. Extended Reach, Horizontal and Multilaterals
- Candidate Selection
- Drilling & Completion Methods
- Geo Steering
- Intervention
- Performance Prediction & Control

9. Petroleum Geology & Reservoir Characterization
- Reservoir Characterization Technologies
- Reservoir Modeling
- Geostatistics
- Geo-steering & Real Time Answers
- Rock Mechanics / Well Stability
- Core Analysis
- Fracture Characterization
- Pore Volume Assessment
- Rock Physics and AVO
- Case Studies

10. Formation Evaluation
- Petrophysical Technologies
- Carbonate/Clastic Petrophysics
- 3D Earth Models
- Advances in Well Testing
- Open, Cased & Slim Hole Measurements
- Mud Logging Technologies
- Saturation Monitoring
- Borehole Seismic
- Core Analysis & Petrophysics
- Imaging Technology
- Low Resistivity Pay/Thin Pay
- Measurement & Logging While Drilling
- Open & Cased Hole Methods
- Overlooked/Bypassed Oil Zones
- Tracer Flow Tests
- Wireline Formation Testing & Sampling
- Low Permeability Reservoirs

11. Gas
- C02 Storage/Sequestration
- Gas-Condensate Reservoirs
- Gas Development & Marketing
- Gas Storage
- LNG
- Tight Gas
- Sour Gas

12. HSE
- Bioremediation
- Discharge Issues/Limitations
- Downhole Separation and/or Disposal
- Emergency Response Planning/Management
- HAZOP Studies/Risk Management/ Safety Case Requirements
- Safety Behavior
- Security Issues
- Social Responsibility
- Toxic Waste Management
- Water & Solids Treatment & Disposal

13. IOR (EOR)
- Chemical, Thermal, Miscible Injections &Others (Microbial, etc)
- Heavy Oil Production
- IOR Techniques
- Water flooding, Gas Injection, Vibro Seismic, etc.

14. Information Management and Real-Time Monitoring
- Collection, Transfer, Archival, Reporting. Quality Control & Assurance
- E-business applications
- How much data is enough?
- Near Wellbore Characterization
- Neural Networks
- Applications & Benefits
- Real-time Data Analysis & Control

15. Reservoir Engineering & Management
- Description & Characterization
- Forecasting Methods
- Material Balance, Simulation etc.
- Fractured Reservoirs
- Reserves Assessment & Booking
- Reservoir Compaction & Subsidence
- Reservoir Continuity & Drive Mechanism in Deepwater – Reservoir Geomechanics
- Multidisciplinary Approaches
- Onshore Operating Centre
- Performance Monitoring
- Pressure Maintenance

16. Developing Seismic Technology
- Acquisition/Processing/ Interpretation Techniques
- 3D & 4D Seismic
- Seismic Inversion
- Borehole Seismic Methods
- Rock Physics, Seismic Forward Modeling and AVO/AVA
- Cost Effective Seismic Acquisition and Processing Practices
- Application of Seismic Attributes in Exploration and Reservoir Development
- Advances in Seismic Interpretation
- Cross-well Seismic
- Multi-component, Multi Azimuth Seismic
- Ocean Bottom Seismic
- Pattern Recognition
- Time Lapse
- Passive Seismic
- Recent Acquisition Techniques
- Advanced Seismic Data Processing Methods
- Seismic Imaging
- Near Surface Seismic
- Multiple Suppression

17. Economics & Energy
- Reserves Assessment
- Field Development and Optimization
- World Energy Outlook (Supply and demand)
- Energy prices & Markets (Oil markets and Natural gas markets)
- Project evaluation and Real Options
- Risk and uncertainty
- Energy Management, Efficiency & Security related Studies

18. Field Development
- Assets Life Cycle Depletion Plan
- Development of Mature Fields
- Fast-Track Developments
- Heavy Oil
- Marginal Fields
- Subsea Development
- Virtual Reality Techniques

19. Integrated Technologies and Case Studies
- Case studies should demonstrate the design and implementation of schemes to create or increase value.
- While successes are great and are usually what get attention, cases demonstrating failures and why a failure occurred, and lessons learned are welcomed.

Members	Affiliation
Mr. Majed Hassan Badah	MinPet
Mr. Ameen A. Al-Humidi	MinPet
Dr. Abdullatif Al-Shuhail	KFUPM
Dr. Hassan Al-Hashem	KFUPM
Dr. AbdulAziz Loubon	KSU
Dr. Emad Al-Homadhi	KSU
Dr. Hassan Naji	KAU
Dr. Omar Almisned	KACST
Dr. Fahad A Al Ajmi	Saudi Aramco
Mrs. Hiba A Dialdin	Saudi Aramco
Dr. Hamoud A Anazi	Saudi Aramco
Dr. Mohammed G. Al Otaibi	Saudi Aramco
Mr. Matter J. Al-Shammery	Saudi Aramco
Dr. Patrick Allman-Ward	Shell
Dr. Paul Thompson	Chevron
Dr. Muhammed Badri	Schlumberger
Mr. Mike Hopkins	Halliburton
Mr. Jaafar Aluzri	Baker Hughes
Mr. Charles P. Kreuz	Weatherford
Mr. Jose Reyes	BJ Services
Mr. Abdullah S. Al-Muhaish	SRACO

- Baker Hughes Inc.
- GETECH
- Spectraseis Technologies
- Egyptian Petroleum Research Institute (EPRI
- The University of Texas at Austin
- Azerbaijan National Academy of Science
- GeoTomo LLC
- CGGVeritas
- University of Oklahoma
- ENI E&P Div.
- King Abdulaziz University
- University of Houston
- Colorado School of Mines
- Imperial College
- LUKOIL Saudi Arabia Energy Ltd.
- Petroleum Deveolpment of Oman
- Centrilift
- LUKSAR

Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com

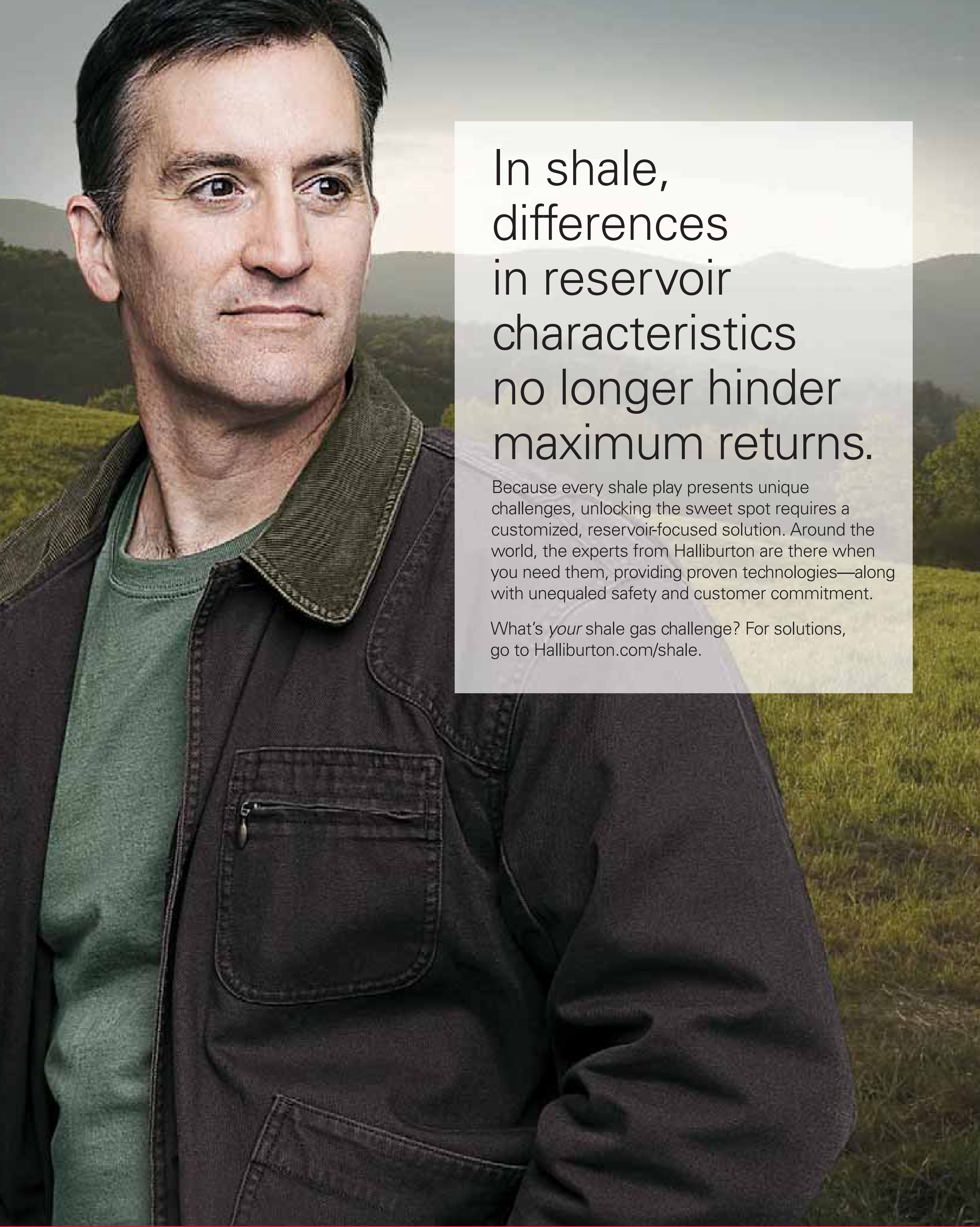
Contribute to Saudi Arabia Oil & Gas during 2011

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 2011 Calendar

Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec
• Saudi Aramco RTOC • Digitalization • While Drilling Technology • Telemetry • Production • Extended Seismic Feature (4D, OBC, Wide Azimuth)	• Khurais • Near Surface Modelling • Rotary Steerable & Motor Systems • Drill Bits and Underreamers • Complex Wells • Geophysical • Drill-Pipe Integrity	• Manifa • Remote Operation Centres • Drill-Bit Technology • Advances in Drill-Pipe • Zonal Isolation (incl. Packers, Multi-Zone Completions) • Carbonate Reservoir Heterogenity • Exploration Rub Al Khali	• Shaybah • Drilling Optimization • Formation Evaluation • Wellbore Intervention • Casing While Drilling • Multi-Laterals • Tubulars	• Khursaniyah • Passive Seismic • Expandable Completions • Tubulars • Logging and Measurement WD • Environmental Stewardship • Refining	• Hawiyah • Smart Completions • I field • Geosteering • GOSP • OGEP
BONUS CIRCULATION					
	9th Middle East Geoscience Conference & Exhibition 7-10 March 2010 Manama Kingdom of Bahrain **SPE/DGS Annual Technical Symposium & Exhibition** 4-7 April 2010 Seef Centre Khobar, Saudi Arabia	**7th Middle East Refining and Petrochemicals Conference & Exhibition** 23-26 May 2010 Kingdom of Bahrain **72nd EAGE Conference & Exhibition/SPE EUROPEC 2010** 14-17 Jun 2010 Barcelona Spain		**SPE Annual Technical Conference and Exhibition** 20-22 Sept 2010 Florence Italy	**SPE Middle East Health, Safety, Security and Environment Conference & Exhibition** 4-6 October 2010 Manama Kingdom of Bahrain **OGEP II Saudi Meeting on Oil and Natural Gas Exploration and Production Technologies** December 2010
SPECIAL PUBLICATIONS					
	• Official Magazine	• Official Magazine		Saudi Aramco Supplement	• Official Magazine


In shale, differences in reservoir characteristics no longer hinder maximum returns.
Because every shale play presents unique challenges, unlocking the sweet spot requires a customized, reservoir-focused solution. Around the world, the experts from Halliburton are there when you need them, providing proven technologies—along with unequaled safety and customer commitment.
What's *your* shale gas challenge? For solutions, go to Halliburton.com/shale.