Brazil Oil & Gas, tt_nrg and Norway Oil & Gas

EPRASHEED
signature series

2010 – Issue 14

Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com


Schlumberger Al Khafji Base Opens


Inside

New Technology in the Bakken Play


SPE/DGS Joint Technical Symposium


Shaybah Expansion Project

روابي القابضة
RAWABI HOLDING

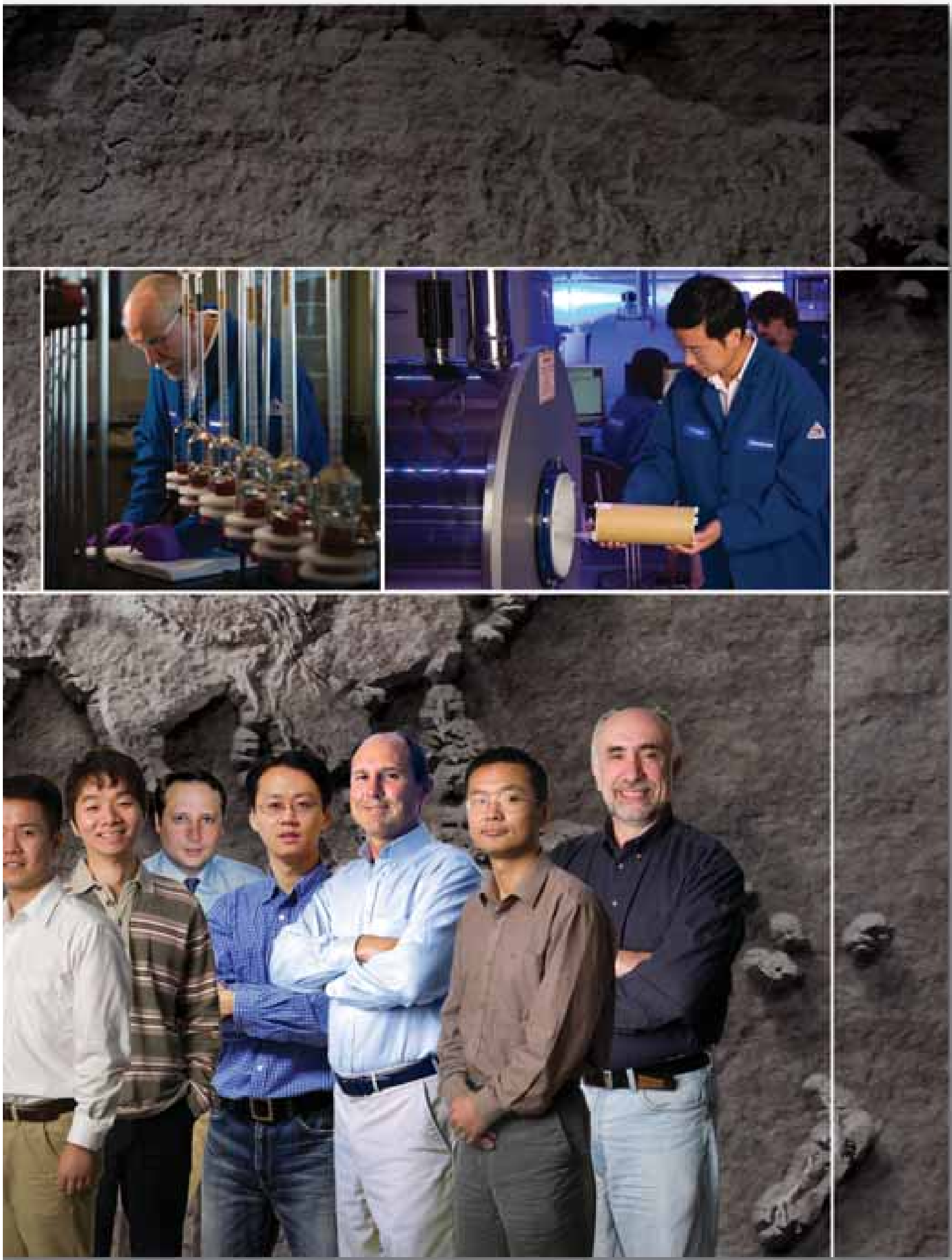
www.rawabiholding.com

Three decades of providing a diversified range of products and services to the region's oil and gas, petrochemical, construction and engineering, utilities, power and electrical, telecommunication and IT and manufacturing industries in Saudi Arabia and the Middle East, has made RAWABI Holding a leading industrial player. Customer focused, RAWABI builds strategic partnerships to develop a committed network of business relationships, working in a professional work environment that combines technical expertise to provide the very best in quality products and services.

P.O.Box 79800, Al Khobar 31952, Kingdom of Saudi Arabia
Tel: +966 3 865 7055 - Fax: +966 3 864 1943
e-mail: info@rawabiholding.com


Need rock-solid formation evaluation service?
Meet the advisors

Carbonate Advisor



Schlumberger

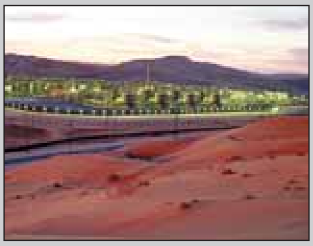
EPRASHEED
signature series

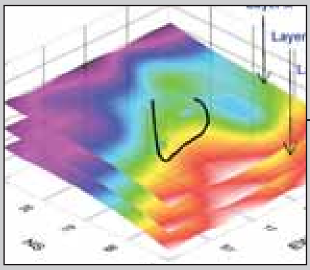
2010 – Issue 14

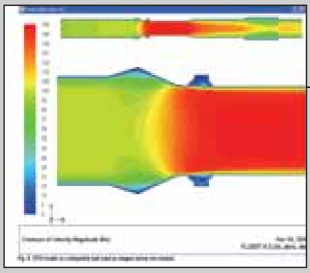
Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com

Contents







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

Editors
Majid Rasheed
Mauro Martins

Design
Sue Smith

Contacts

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

WELCOME MESSAGE FROM THE CHAIRPERSON

Welcome to the July 2010 issue of Saudi Arabia Oil and Gas. As the term of the current Executive Board is approaching its end, I would like to use most of this welcoming message to reflect on the section's accomplishments over the past year. 2009-2010 was a very successful year and remarkable in terms of accomplishments and members' participation.

The section grew significantly, with the addition of more than 500 members as a result of an extensive membership campaign conducted in numerous and outlying areas of Saudi Aramco and service companies. The section's technical program was remarkable this year, with a wide range of topics. The program comprised of dinner and distinguished lecturer meetings with renowned speakers. Workshops were also conducted to promote the dissemination and exchange of technical information. One great feature of our technical program this year has been the large turnout at almost every technical meeting. For the first time, we held a joint technical meeting with another section when our section visited the Egypt section during a social trip.

The Annual Technical Symposium was a resounding success which featured renowned keynote speakers, a strong technical program and a huge exhibition. The symposium was conducted for the first time with the Dhahran Geoscience Society and was well attended by local and international members. Our Young Professionals and Students Outreach activities were enormous and rewarding. The Young Professionals Technical Symposium was also a remarkable event, with outstanding participation from our young members. The first YP GCC paper contest was conducted and led by the young professionals of the section. The contest indeed opened new opportunities for collaboration and strengthened ties with other GCC SPE sections and YP committees. Saudi Arabia Oil and Gas magazine was useful as the Official Publication for the third year running and helped with publicizing the symposium.

The section newsletter Sand Rose is also one of the section accomplishments this year, with its new look and articles such as SPE 101, which were recognized internationally and shared with other sections. We have been very active socially, with large number of charitable events and trips, including Egypt, Shaybah, and Udhailiyah.

No doubt that your contributions and support are mainly behind those accomplishments. I have really enjoyed serving as the chairperson of the section and I hope that the officers and I have provided you with the quality service you expected. Finally, I would urge you to take a role in the section and serve as a committee member, which certainly will not only help the section but would also be a rewarding experience for you. I hope you enjoy this issue of Saudi Arabia Oil and Gas!

Ashraf Al-Tahini
Chairperson
SPE Saudi Arabia Section

Executive Appointments Announced

DHAHRAN, June 23, 2010 -- Saudi Aramco has announced the appointment of Khalid I. Abubshait as executive director of Saudi Aramco Affairs (SAA) and Nasir K. Al-Naimi as executive director of Pipelines, Distribution and Terminals Operations, effective July 1.

Khalid Abubshait joined Saudi Aramco in September 1970 in the first company Apprenticeship Program. In 1980, he started almost a decade of work and growth with Training and Career Development in Dhahran and Ras Tanura. He worked with Aramco Services Co. (ASC) as administrator, Career Development, in Houston for five years.

In September 1989, after returning from his ASC assignment, he was named manager of the SAA-Central Province Department in Riyadh. In 1993, he moved to Dhahran and worked as manager of the SAA-Eastern Province Department. He has also served as acting manager of the Public Relations Department and acting general manager of Government Affairs.

Khalid I. Abubshait.

Nasir K. Al-Naimi.

In 1995, he was selected by Minister of Petroleum and Mineral Resources Ali I. Al-Naimi to serve as the director general of the Minister's private office in Riyadh, and in 1997, Abubshait was promoted to general manager, special assignment.

At the end of 1999, after completing his four-year assignment with the ministry, he returned to Saudi Aramco as general manager of Government Affairs. He has also served as acting executive director of Saudi Aramco Affairs on several occasions. His new responsibilities cover Government Affairs and Public Affairs.

Abubshait holds a Bachelor's Degree in business administration from Hamline University in St. Paul, Minnesota, in the United States, and an Executive Master of Business Administration degree from King Fahd University of Petroleum and Minerals in Dhahran.

He has also completed the University Executive Program at the University of Virginia, as well as a number of in- and out-of-Kingdom developmental assignments.

Nasir Al-Naimi received his Bachelor's Degree from the University of Southern California in 1985 and began work in Professional Development in Petroleum Engineering.

He joined Petroleum Engineering's Professional Development Program in 1986 and went on an out-of-Kingdom development assignment in 1987.

He returned in 1988 and worked in Zuluf, Marjan and Manifa Producing and in the Safaniyah Production Engineering Unit in 1992. He also served as assistant superintendent of the Onshore-Offshore Well Services Division and in 1993 became senior operations adviser for Safaniyah Producing Operations.

He was superintendent of Oil Operations for Zuluf Offshore Producing Operations in 1994, of Northern Area Producing Well Services in 1995 and of Abu Ali Producing Operations in 1996 and 1997.

In 1997, he began working with Crude Oil Sales and Marketing and Product Sales and Marketing, where he worked until 2000, when he became senior marketing manager of Product Sales and Marketing and then of LPG, Naptha, Mogas and Middle Distillate.

He also took on several assignments as manager of Product Sales and Marketing until December 2001, when he became manager of Marketing Services for Saudi Petroleum International Inc. in New York.

He returned in 2003 as manager of the Marine Department, where he served until 2004, when he became manager of Mechanical Services Shops.

In 2007, he was made manager of the Terminal Department and took on several acting assignments as executive director of Industrial Services. In 2008, he was appointed general manager of Southern Area Producing in Udhailiyah, before his latest appointment as executive director of Pipelines, Distribution and Terminals Operations.

Al-Naimi took part in several leadership training programs, including the President's Leadership Challenge in 1998, the London Business School Senior Executive Program in 2004 and the Asia Business and Culture Program in 2008.

Partners with Techno-Valley

DHAHRAN, June 30, 2010 – Research and development, collaboration and technology transfer are strategic elements of a knowledge-based economy. Saudi Aramco has been supporting the country's leadership in creating the infrastructure required to diversify and strengthen domestic trends in science and technology.

The Dhahran Techno Valley (DTV) is one example of an initiative to expand R&D and technical innovation for the benefit of business throughout the Kingdom and the region. DTV is seen as becoming the Middle East's most influential industrial technology nucleus serving a range of industry applications.

Initiated by King Fahd University of Petroleum and Minerals (KFUPM) in 2003 and inaugurated by King Abdullah in 2005, DTV is a major undertaking as a center for excellence in science and technology. The valley also provides development, production and marketing support services to launch innovation that originates from academic research.

Saudi Aramco organizations such as New Business Development, Petroleum Engineering and Development (PE&D) and Engineering Services have helped attract tenants to DTV. The Schlumberger Carbonate Research Center was the first fully operational center at the valley, followed by Yokogawa. Many additional companies also are committed, including the upstream centers of service companies Halliburton, Baker Hughes and Weatherford.

"Having such R&D centers close to Saudi Aramco's operations and research activities will help expedite the development of technological solutions and human resources to tackle tomorrow's challenges," said Amin H. Nasser, senior vice president of Exploration and Producing.

"Interaction among world-class researchers in an easily accessible facility will be promoted in Dhahran Techno Valley," said Dr. Faleh Al-Suliman, vice rector for Developing Technology and Industrial Relations at KFUPM. "Saudi Aramco will benefit from the gathering of national and international research centers in one location."

"DTV, along with KFUPM research talent and Saudi Aramco's challenging business needs, will create a unique research culture that is conducive to investing in cutting-edge technologies," said PE&D executive director Mohammed Y. Al-Qahtani.

The EXPEC Advanced Research Center (EXPEC ARC) is working closely with the upstream R&D centers at DTV to help define and steer research programs to best address Saudi Aramco's upstream challenges. "The research collaboration among EXPEC ARC, KFUPM and DTV upstream centers creates a unique ecosystem where industry and academia can go and thrive," said EXPEC ARC manager Samer S. AlAshgar.

> "Saudi Aramco will benefit from the gathering of national and international research centers in one location."

Lab Earns Accreditation

Laboratory staff members pose with Southern Area management upon receiving accreditation for the division's technical competence

ABQAIQ, June 30, 2010 – The Southern Area Production Engineering Department (SAPED) recently received ISO 17025:2005 accreditation for its Southern Area Laboratories Division (SALD) from Deutsche Akkreditierungsstelle (DakkS), a German accreditation body.

Saad A. Al-Turaiki, vice president of Southern Area Oil Operation (SAOO), presented a certificate marking the accomplishment to SAPED manager Mohammed I. Al-Sowayigh. Al-Sowayigh congratulated the laboratory staff members for their achievement, which is a formal recognition of the lab's technical competence in producing laboratory data of the highest quality on par with internationally recognized standards. He added that accreditation is also a formal recognition of the technical competence of SALD staff, test methods, instruments and facilities.

SALD division head Yousef S. Al-Marzooq said ISO 17025 is an international quality standard specific to laboratory requirements. Assessment is by an independent third party. He said that this accreditation was just one step in the pursuit of excellence for the division.

"ISO 17025 is Commitment to Quality" was the theme of the function. Dawood O. Bukhari of SALD briefed participants about ISO 17025 standards and their benefits to customers.

A short video message from Dr. Kurt Ziegler, DAkkS managing director, was shown in which he recognized SALD for its professional internal audit controls, calibration system and technical competency of the staff.

The achievement is an example of the lab's commitment to excellence and meeting the highest international standards, said Al-Turaiki. He expressed his appreciation to division management and personnel and encouraged all to build on the achievement.

NOC Looks at Skill Shortage

By Laura Baker.

LONDON, July 07, 2010 -- "One of the major challenges our industry is facing is the shortage in skilled professionals," said Huda Ghoson, general manager of Training and Development, in her opening remarks at the World National Oil Congress held June 23 in London.

In her speech titled "Workforce Development: An Enduring Legacy," Ghoson called upon organizations to redouble their efforts to make the oil and gas industry attractive to young people.

She went on to address four challenges. "The world is more sensitive than ever before ... to the impact the oil industry can have on our fragile natural environment," said Ghoson of pressing environmental issues. She said Saudi Aramco has long been a leader in environmental stewardship.

The second challenge relates to oil resources and the fact that oil demand is expected to increase over the next two decades. "This means that the oil industry will be expected to develop additional production capacity," she said.

The third challenge focuses on integrating technology into business practices. "A significant portion of production will be coming from relatively small and mature fields that are also likely to have complex geology and production mechanisms" said Ghoson. She believes that "progress would be best made by sharing ideas and experiences, and making greater efforts in collaborative technology development." Through this, collaboration will help address the fourth significant challenge which is the shortage of a skilled and technologically agile work force.

"It is obvious that the business is best served by employees who possess the passion for continuous personal growth and development and lifelong learning, whatever their careers and professional interests may be," said Ghoson.

She concluded by saying, "With proper investments in technologies, partnerships and people, these challenges can be surmounted, as we have always done in the past."

Ghoson went on to share Saudi Aramco's integrated employment value proposition strategy, which enables Saudi Aramco to attract, develop and retain top talent. "The strategy combines three factors in a balanced approach starting from hire to retire," she said.

These three factors involve building on the solid reputation of the company; investment in training, development and management of people; and the total pay package designed to satisfy every stage of an employee's personal and professional growth.

Ghoson highlighted Saudi Aramco's talent management and development strategy, which is designed to provide a continuous flow of talent regardless of labor market conditions, skill shortages and swings in oil prices. The strategy uses blended learning to integrate various learning techniques and delivery methods such as technology simulations, knowledge sharing and online communities of practice in addition to standard instruction.

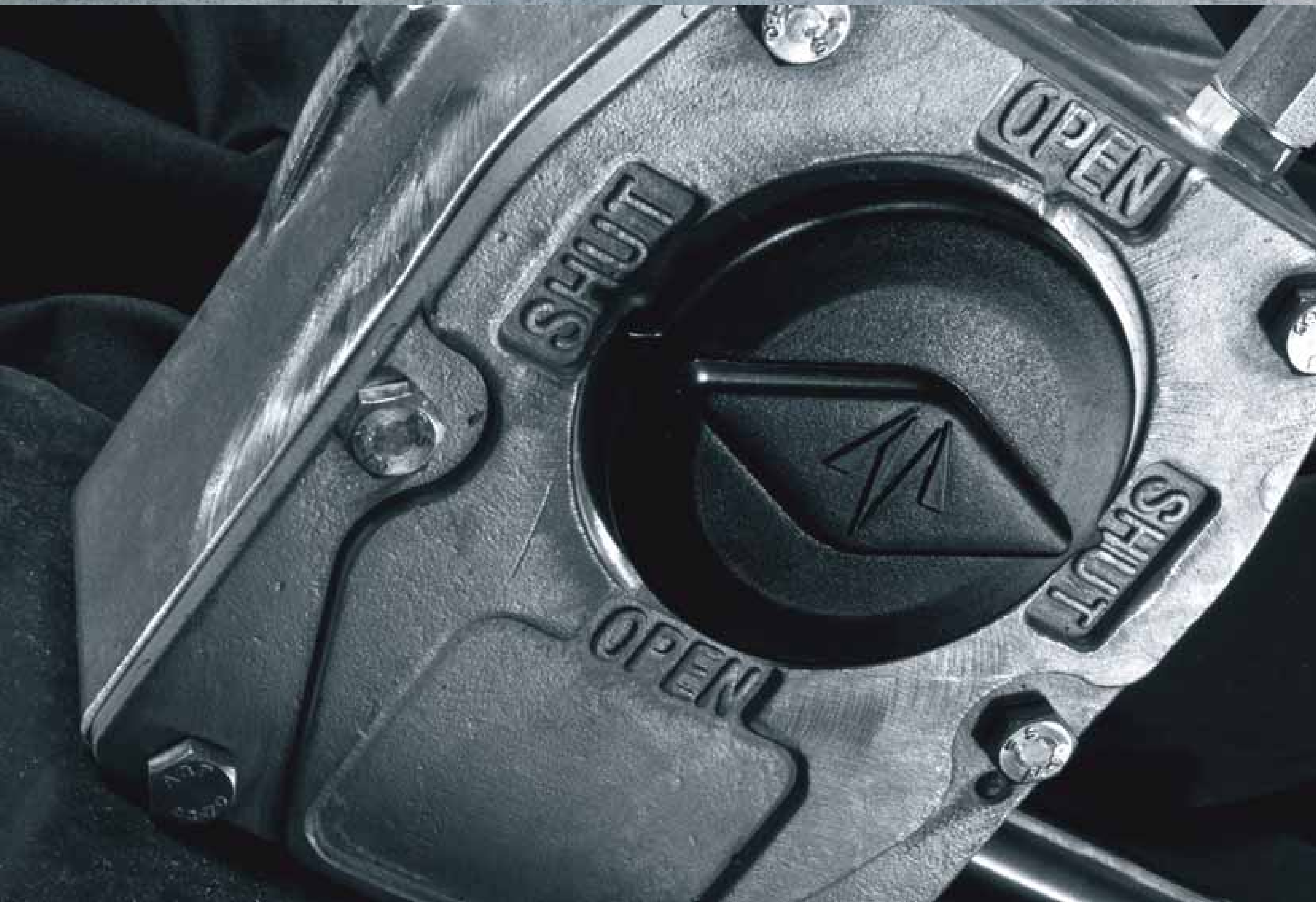
She mentioned that since Saudi Aramco draws 87 percent of its work force from Saudi Arabia, the company has a special relationship with students, educators and educational institutions throughout the Kingdom. To complement these relationships, Saudi Aramco also has partnerships with international universities, training companies, government agencies and private businesses around the globe.

"Together, they allow Saudi Aramco to share ideas, experiences and knowledge as well as ensure the skills of the next generation meet the business needs of today and tomorrow," she said.

Ghoson concluded by stressing the importance of the industry in providing energy to the world, "while protecting the environment, advancing research, sharing best practices and teaming with the community, education sector and governments to improve the social and economic well-being of people everywhere."

MASTERGEAR UK

The **Stainless Steel** Gearbox Range.



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

www.mastergearworldwide.com

Saudi Aramco and its Role in Saudi Arabia's Present and Future

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

Riyadh, Saudi Arabia, 2010

"Dr. Mohammed Bakr, thank you for your kind introduction. We admire your many achievements in business and public service and for your capable leadership as President of the MIT Club of Saudi Arabia. I wish to commend Massachusetts Institute of Technology and your many outstanding alumni for the transformative role that this great university and you as individuals have played in the Kingdom's development. Saudi Aramco is privileged to have many talented graduates of MIT in our professional ranks. It also is our privilege to be part of several collaborative projects with MIT, including the MIT Energy Initiative, the Sloan Engine Laboratory Industry Consortium, the MIT e-laboratory, and the Blended Learning Open Source Science or Math Studies (BLOSSOMS) program. Let me also acknowledge the presence of many distinguished guests of the MIT Club.

Today, I would like to address three main subjects:

First, I'll try to introduce Saudi Aramco to you in a manner such that you will be able to see it from up close, and then explain our main strategies; Second, I'll talk about how Saudi Aramco relates to the Kingdom in a variety of ways.

Lastly, I'll share some thoughts with you concerning the Kingdom's longer term challenges, a future economic perspective and what Saudi Aramco is doing in this regard at a strategic level.

A Look at Saudi Aramco from Up Close and its Key Strategies

As you know, Saudi Aramco is the world's largest producer and exporter of oil and is among the leading players in the global oil industry. For 20 years it has been ranked by Petroleum Intelligence Weekly as the number one oil company and is run as a modern international corporation, competing successfully with the best in the business; and it is this qualitative aspect of our standing in the global oil industry which is the focus of our efforts and the source of our pride. Equally important to the company is our critical obligation to support the Kingdom and its people. Looking from outside, Saudi Aramco may seem opaque to some of you, so I'll try to show you today who we are, what we do, and how we work.

We consider talent, technology and teaming to be the three most important success factors for Saudi Aramco and for any global energy enterprise, for that matter. Saudi Aramco comprises more than 57,000 men and women, 87 percent of whom are Saudi Arabs, with 13 percent expatriates employed in highly skilled professional disciplines; almost the entire management of the company consists of Saudis.

Our businesses range from exploration and production of oil and gas, oil refining, chemicals and shipping to sales and marketing and support in industrial, personnel, medical, finance, law and planning disciplines. We maintain world class expertise in all these areas.

We believe that talent will increasingly become a differentiating factor among more and less successful companies in the future.

Consequently, recruiting, developing and retaining talent is one of our key corporate strategies. We regard learning as a lifelong process and operate programs to enable this pursuit for our employees. We maintain one of the world's largest corporate training programs, having in-house training of operators, craftsmen and administrative staff. We currently sponsor more than 2,000 students for undergraduate and graduate degrees and specialized programs at more than 200 local and leading international universities.

Talent thrives only in an environment that rewards excellence, effort and achievement. Throughout its his-

> We not only attach great importance to governance and business ethics ourselves but demand the same of our employees as well as our business partners.

tory, Saudi Aramco has maintained a corporate culture which encourages individuals and teams to excel; where advancement is based on merit, skill and work ethic; and where employees have the opportunity to go as far as their expertise and drive will take them. That kind of working environment continues to be vital for our business success.

We also believe that technology is a great enabler of more efficient, more reliable, safer, lower cost and more profitable operations. Therefore, we utilize the world's best technologies in our operations. In fact, we are among the industry's leaders in deploying new, cutting-edge technologies in our operations. To remain among the leaders in technology, we have two advanced research and development laboratories: one for sub-surface called the EXPEC ARC and the other for surface facilities, the R&D Center. Many of our technologies are also developed collaboratively in partnership with service companies, technology developers and academic institutions. This partnering model sets the stage for a brief discussion of our Teaming strategy.

Teaming refers to our collaboration with partners, suppliers, customers, and other stakeholders. Whatever the extent of a company's capabilities, no company can or should go it alone these days, simply because the business is just too complex and too multifaceted for any single organization to excel at everything. We have pursued joint-venture partnerships with leading global petroleum companies and now with top-flight chemical enterprises. We also look at our dealings with suppliers, vendors, contractors and service providers as mutually beneficial partnerships. When it comes to teamwork, we look to partner with leading institutions which also take a strategic, long-term view of building capacity and capabilities, and whose strengths and expertise fit well with our own thus creating synergies.

Regardless of companies' past record of achievements and possession of talent and resources, bad governance can ruin company reputations and indeed put them into peril, as the examples of Enron and many others tell us. Such risks can be avoided only by strictly adhering to good governance, and practice of the highest business ethics. We not only attach great importance to governance and business ethics ourselves but demand the same of our employees as well as our business partners.

Oil and the Economy

Let us take a quick look at the situation of the world oil market today and into the future. Despite a lot of discussion in the media about the rapidly rising role of energy alternatives, we believe that alternatives are starting from a very small base and realistically speaking, their contributions will grow only gradually due to technology, economics, infrastructure and consumer acceptance issues.

Oil will continue to play a key role on the world's energy scene for the foreseeable future. We subscribe to the consensus view that oil demand will rise from about 86 million barrels per day currently to between 105 and 110 million barrels per day by the year 2030. Even if the share of oil and fossil fuels falls in the energy mix over the coming years due to alternatives gradually gaining ground, the demand for oil and fossil fuels is expected to rise in absolute terms.

To respond to the anticipated growth in oil demand, and taking a long- term view of the business, we have recently completed an upstream expansion program that brought our oil production capacity to 12 million barrels per day, with a spare capacity of roughly 4 million barrels per day. This spare capacity alone equals the exports of two typical large producers of oil, and helps assure oil market stability during unforeseen circumstances.

Oil is a volatile business. You saw this vividly during the past two years as the oil prices shot toward $150 per barrel; then fell below $35 as the world economy was hit by the financial and economic crises; and has since then recovered to exceed $80 per barrel. Oil exports remain the largest source of export revenue for the Kingdom. Depending on oil prices and our export volumes, oil still accounts for 80 to 90 percent of total revenue. This major dependence on a single commodity, oil, is not desirable. This is why it is imperative on all of us to work hard on diversification and indeed transformation of our economy.

However, economies take time to transform. Oil will continue to play a major role in the Kingdom's economy for the medium term, which I would consider to be the next several decades, while industrialization steadily increases and economic diversification grows.

While energy is a key enabler of the Kingdom's economic development and a major competitive advantage, we need to make sure that we use our precious oil and gas resources efficiently and wisely and minimizing waste. The total domestic energy demand is expected to rise from about 3.4 million barrels per day of oil equivalent in 2009 to approximately 8.3 million barrels per day of oil equivalent in 2028, or a growth of almost 250 percent.

We estimate that through improved efficiency, while maintaining the same economic growth, the increase in energy demand can be cut into half. This is a highly desirable goal because increasing domestic consumption of oil reduces the export availability. If no efficiency improvements are achieved, and the business is as usual, the oil availability for exports is likely to decline to less than 7 million barrels per day by 2028, a fall of 3 million barrels per day while the global demand for our oil will continue to rise.

Let us also look at the domestic energy use from another angle, that is, how much energy is required to produce one unit of GDP, indicating how productively energy is being consumed. For example, between 1980 and 2000, China's energy intensity in terms of BTUs of energy used per dollar of GDP generated fell by 67 percent. Over the same period, the US energy intensity index dropped by more than 33 percent. In comparison, energy intensity for the Kingdom increased by some 138 percent over the 1980 level, which is a serious source of concern. If the economy does not grow faster and if the Kingdom does not improve energy efficiency, by 2028 the intensity increase would reach 227 percent higher than the 1980 level.

The reasons for the increased intensity in the Kingdom include higher energy requirements for a rising population and expansion in the manufacturing sector, but the increase in energy requirements was not matched by an increase in GDP. This issue is receiving Government's urgent attention, and the focus by the business community would be equally useful and is highly desirable.

For our part, Saudi Aramco some 13 years ago undertook a rigorous examination of our own energy efficiency and productivity. We have acted upon all the areas where we learned we needed improvement; for example, we now are co-generating electric power, including process steam, at facilities where formerly we drew from the national electricity grid. Since the inception of Saudi Aramco's Energy Management Program in 2000, through 2008, the company alone has realized fuel savings equivalent to 71 thousand barrels of oil per day.

We welcome opportunities to share with others in the Kingdom the best practices we have learned in energy efficiency. There is much more that all of us could do, for example, in public awareness campaigns, in improving the energy efficiency of new residential and commercial buildings, in the energy efficiency of appliances and equipment, and in enhancing the mileage efficiency of the Kingdom's fleet of vehicles.

In our desert Kingdom, conserving energy also contributes to something as precious as life itself: the water supply. Saudi Arabia is the world's leading producer of desalinated seawater, the processing of which is particularly energy intensive. Any technological breakthrough that would reduce the BTUs consumed to desalinate water would be immensely valuable to our domestic economy.

The challenge of making desalination more efficient is one of the more exciting strategic opportunities for enterprising researchers. Another profoundly important aim for the long-term future of our sun-drenched land is developing our potential for solar energy. Both King Abdulaziz City for Science and Technology (KACST) and King Abdullah University of Science and Technology (KAUST) are now engaged in research on water desalination and solar power, and KACST recently announced a collaboration with IBM to build a solar desalination plant to serve 100,000 people in Al Khafji. With efforts such as these, we hope that the day is not too far away when we'll see breakthroughs in these fields. Moreover, the announcement of the establishment of the King Abdullah Nuclear and Renewable Energy City here in Riyadh adds yet another dimension to the Kingdom's determination to make the most of its energy potential.

How Saudi Aramco Relates to the Kingdom's Economy

Now let me turn to my second theme, which is how Saudi Aramco relates to the Kingdom's economy. The challenge to accelerate creation of high quality jobs in the Kingdom is tremendous. Six of every 10 Saudi citizens are under 25 years old. To absorb the influx of young people entering the labor market, Saudi Arabia will need to create nearly 4 million jobs over the next 10 years. The Kingdom's economy historically has grown between 3 percent and 5 percent, while to generate the number of well-paying jobs required for our youth, the economy needs to grow in excess of 8 percent. This is a tall order. Saudi Arabia's per capita GDP was $20,300 in 2009, about half of the US per capita GDP of $46,400. We'll need to increase our per capita GDP to close the gap with developed nations, or at least make sure that the gap does not open up further.

Saudi Aramco is well aware of this challenge, and is making a variety of efforts to contribute to the economy to grow more strongly. The company's activities have a major impact on the Kingdom's economy, well beyond providing a large share of export revenues.

Besides massive oil production capacity, Saudi Aramco contributes to the national economy by maintaining a world class Master Gas System that we are continuing to expand. This system supplies valuable sales gas, ethane and NGLs for national industrial development. Our raw gas production capacity, currently at 10.2 billion standard cubic feet per day (BSCFD) will be expanded to 15.5 BSCFD by 2015, by starting up gas increments at Khursaniyah (1 BSCFD, 2010), Karan (1.8 BSCFD, in stages from 2011-2013) and the Wasit Gas Plant (2.5 BSCFD, 2014).

Accordingly, our sales gas production potential will increase from 7 BSCFD to 9.3 BSCFD.

Ethane is a highly valuable feedstock. It will be increased from 800 million cubic feet per day to 1.2 BSCFD. Meanwhile, the world-scale production of natural gas liquids will grow from 937 thousand barrels per day in 2010 to about 1.2 million barrels per day in 2015.

Our refining capacity spread around the globe currently totals some 3.7 million barrels per day. The development of three new, grassroots refineries at Jubail, Yanbu and Jazan and the large expansion at Port Arthur in the United States will raise this refining capacity by about 1.5 million barrels per day.

Domestically, the fuels and feedstocks we provide power the electricity and water utilities, while feeding the chemical and mineral industries, especially the higher value phosphate fertilizers and aluminum industries being developed. Indeed, oil, chemicals and mineral products including high value fertilizers can become three pillar industries that will help us grow more rapidly over the medium term, while other industries complement this growth.

Our vision is nothing less than elevating the Kingdom's chemical and mineral industries from their current sound positions into world leaders in their enterprises, just as we are in oil. We are doing our best to assist these other two pillar industries by providing reliable and cost effective supplies of fuels and feedstocks.

While producing commodities in various industrial areas helps the economy, the real benefit comes when these commodities are converted into downstream and finished products that create and sustain well-paying jobs. Light manufacturing downstream by small-to-medium sized firms creates on average 15 jobs per million dollars invested, compared with less than one job created per million dollars invested in capital-intensive commodity industries. Saudi Aramco is building a large industrial park alongside its PetroRabigh refinery and integrated petrochemical project on the Red Sea shore to take petrochemical materials and turn them into downstream products.

Similar plans for refinery expansion and petrochemical and conversion industries are in the works on our Arabian Gulf coast.

We have put into place a large program to help manufacturers locally produce many of the materials and services we use in developing our projects, maintaining our plants and running our operations as well as those of other similar process industries. It is in our business plan to obtain more than 50 percent of our materials and services from local sources within the next five years. This will help boost industrialization in the Kingdom.

We have not only focused on Saudization within the Company but have developed a robust program to steadily increase Saudization in the workforces of our contractors. We are also working with the private sector to help train Saudi workers for contractor jobs.

Another way in which we are both thinking and acting locally is our program to evaluate small gas accumulations near small population centers. Gas supplies that could become available from such accumulations can help establish industries in small population centers as well as fuel power plants with capacity to meet local needs. This would assist in the better distribution of industrialization and job creation across the Kingdom, and obviate the need for people to move to larger cities to find employment. It also would make a positive contribution in the areas of energy efficiency and productivity.

Education, Personal Initiative, and the Knowledge-Based Economy

The Kingdom's long-term imperative is to become more and more a knowledge-based economy. While oil in particular, and chemicals and minerals in general, can help the Kingdom industrialize and grow over the medium term, looking strategically, it must be seen that nations do not sustainably raise their standards of living by only selling commodities. Wealth increases in nations that have been at the cutting edge of R&D, technology, innovation and knowledge in general.

In our country, the transition to a knowledge-based economy cannot happen instantly; it will take time – certainly decades and perhaps generations to take hold, the more reason we should start NOW. It will be an added challenge that other nations are ahead of us and moving faster towards the knowledge economy, but with commitment and dedication we can overcome these hurdles.

Clearly, high quality education is essential to lay the foundation for future growth in select knowledge based areas that can be targeted for investment. With four out of every 10 Saudi citizens 14 years old or younger, improvements must begin in primary school where a large proportion of our population needs to receive a high quality basic education before it is too late. And the improvements must continue at every stage through higher education.

A measure of the challenge before us is that Saudi Arabia has fewer than 500 engineers per 100,000 citizens. Jordan and Kuwait have about twice as many engineers per capita; the United Kingdom has about 10 times as many per capita. A comparison of 8th-grade math and science scores shows that Saudi Arabia lags badly behind the average of the top 20 countries in math and science rankings.

Fortunately, the Custodian of the Two Holy Mosques, King Abdullah bin Abdulaziz, is well aware of these gaps and is moving aggressively to promote his vision of high-quality and widespread education in the Kingdom, including the building of institutions of higher learning.

The Kingdom's new budget allocations for building schools and universities are unprecedented, including the Tatweer initiative which will bring a renewed focus on general education improvement including teacher training, math/science curriculum development, improvement in educational environment and increasing extra-curricular activities.

At Saudi Aramco, we are seeking to do our part to prepare the Kingdom's young people to be responsible participants in a future knowledge economy. Throughout its history, the Company has been a leader in building schools and providing quality education programs for our nation's young people. During the past year we adopted a new Corporate Citizenship Strategy to streamline and modernize our longstanding efforts in Corporate Social Responsibility. The Four Pillars of our strategy are: Economic Development, Community Support, Promoting the Kingdom's transition to the knowledge era, and Environmental Stewardship.

The Kingdom's young majority is the prime focus of the signature initiative of Saudi Aramco's new corporate citizenship strategy: the Youth Talent Development Program. Our goal for this is to reach 12,000 youth by 2012 and as many as 200,000 by 2020 through transformative and engaging programs. We will leverage Saudi Aramco's capabilities to provide young people with extra-curricular experience to develop the character and skills to excel in the 21st century.

Extra-curricular efforts are essential because Saudi students today up to age 18 spend 60 percent of their time in community or leisure activity and only 10 percent of their time in school. For children in the 10-12 age bracket, we will focus on additional learning opportunities to instill a love of the indispensable disciplines of math and science, skills in which the nation now suffers a serious deficiency. For adolescents in the age group 14–17, we'll concentrate on character education, critical thinking and moral reasoning.

The goal of many of Saudi Aramco's corporate citizenship programs is to make volunteerism a national character trait: to make it something people confidently recognize in our society. The culture of volunteerism dovetails with successful entrepreneurship, including the habits of decision making, taking initiative, teamwork, and follow-through.

> "As a pillar of our corporate citizenship strategy, we hold ourselves accountable when it comes to the issue of environmental stewardship, and the protection of natural ecosystems wherever we operate."

Saudi Aramco aims to help parents and educators instill in our young people a stronger appreciation for the dignity of work. Combating unemployment will be successful only if our younger citizens embrace a work ethic and employers accept responsibility for promoting employment of Saudis instead of expatriates in such sectors as wholesale and retail commerce, food service and hotel work, as well as the industrial and electronic technology sectors. Employing Saudis in the service industries is essential if we are to gain the 4 million new jobs we need.

In higher education, Saudi Aramco endows 10 professorships in energy-related chairs at Saudi universities. We sponsor numerous other student exchange programs, research collaborations and programs of technical and management advice for universities in the Kingdom and abroad, and we have established a University Relations Division for strategic management of our extensive efforts in support of higher education. The company is proud to have played a major part in developing our new national treasure, KAUST. Almost uniquely, this is an interdisciplinary university, without the barriers of traditional academic departments. It is a hive of research collaboration involving major corporate and university partners from around the world.

Related to Saudi Aramco's support for higher education is another effort in the realm of research, the King Abdullah Petroleum Studies and Research Center in Riyadh, and in the domain of culture, the company's 75th anniversary gift to the Kingdom, the King Abdulaziz Center for World Culture that will be built in Dhahran. With a library, museum and performing arts centers, this will be an unprecedented attraction, a resource for scholars, and a center for cultural education for younger students and the general public from both the Kingdom and other countries.

As a pillar of our corporate citizenship strategy, we hold ourselves accountable when it comes to the issue of environmental stewardship, and the protection of natural ecosystems wherever we operate. Within the Kingdom, we have invested billions in recent years to phase out lead in gasoline, produce low sulfur diesel, minimize sulfur emissions in exhaust gases from our plants and clean up the waste water before it is discharged. This commitment is nothing new – our first environmental policy statement dates back to 1963, well before green causes became fashionable.

My Saudi Aramco colleagues and I by nature are optimists, but our optimism is not a basis for complacency. The Kingdom's needs are pressing and urgent. At Saudi Aramco we want to collaborate and cooperate ever more effectively with each of you and our many other stakeholders in the Kingdom.

I am convinced that this is a moment the Kingdom can seize to leverage our current strength in petroleum to help our youth become world class participants in the global workforce, to diversify our economy, to improve energy efficiency and productivity, to accelerate and sustain economic growth, and to establish Saudi Arabia as the global leader in selected knowledge-based industries. These are not easy goals, but with hard work they can be attained. Just as today's Saudi Arabia has achieved prosperity and cultural development few could have imagined two or three generations ago, so too can we prepare the way for an even brighter and more exciting future for our nation."

"Thank you."

Shaybah Field – a History

By Julie Springer and Khalid Altowelli.

Decades ago, in April 1968, an untouched area of desert was thought to hold an untapped oil reserve.

It seemed improbable that the vast, rolling dunes of fine, red sand could produce any viable commodity. The climate was cruel and unforgiving, the landscape desolate and alarming. Temperatures soared to 60 degrees C in the summer. Dust storms were a daily occurrence, adding to the harshness of the climate.

The land was 547 kilometres from the nearest town and 386 kilometres from the closest road. This was, for all practical purposes, the harshest place on earth.

More than 30 years passed before the land was developed for production. And although the greatest challenge seemed to be the environment, it was technology that postponed development of the field. In 1995, and only after horizontal drilling and 3-D seismic surveys advanced, was the stage set to begin construction on the Shaybah Field.

Ultimately, the reservoir was tapped using 29 horizontal wells, and oil was extracted and transported to Abqaiq Plants.

In 1996, construction began, and the management team in charge of bringing the Shaybah Field on-stream was given an aggressive deadline. Asked to cut completion time by 25 percent, the team knew that in order to meet deadlines, a more modern organization was needed.

The decision was made to embed front-line supervisors into the management structure, establishing direct lines of communication. Decision-making authority was given to unit-level teams, decreasing the amount of time it took to get approvals. A team concept was implemented in which every stakeholder – including suppliers, agents, local officials and even employees' families – played a role in meeting the development and production goals. What resulted was a fine-tuned machine that acted and responded as a unit.

Thirty-six months later, the construction of the Shaybah facilities was complete and the field was placed in production. Fifty million work hours contributed to the Shaybah Field coming on-stream ahead of schedule and under the proposed budget. Additionally, the Shaybah Field set the benchmark for a more modern and systematic approach to construction and development and became one of the largest producing fields for Arabian Extra Light crude oil and natural gas.

In the process, it also became the model for future Saudi Aramco mega-projects.

Shaybah, in the Rub‘ al-Khali, or Empty Quarter, acts like a small town, able to thrive independently by producing its own desalinated water and electricity. The main facilities house three gas-oil separation plants (GOSPs), a gas compression plant and multiple utility plants.

Unlike 30 years ago, when it was a seemingly lifeless landscape, Shaybah is now a relative paradise to those who live and work there. More than 6,000 trees were planted to add colour to the topography.

Employees work two 12-hour shifts, and buses are used to transport employees to and from work. When not working, Shaybah residents enjoy myriad social and recreational activities. With the aid of the Dhahran library, the multipurpose library at Shaybah has an impressive collection of reading material.

There is a gymnasium, games room and swimming pool. Barbecue parties, trips to the desert and billiards add additional social outlets for residents.

Communication services such as Internet and telephones are provided as well.

Shaybah also boasts its own landing strip, bringing about 2,000 passengers in and out of Shaybah each week on 14 scheduled round-trip flights. While at the airport, visitors can enjoy a photo exhibit that was assembled to commemorate a decade of oil and gas production.

More than 920 men make up the work force at Shaybah, of which 557 are company employees and the rest contractors.

During Ramadan, the people of Shaybah gathered at sunset for fatoor and stories. Some stories were rooted in the past, some more current, others more personal. Among the 23 employees of the Shaybah Transportation Department, the majority of stories were about challenges and the perseverance in transporting goods and heavy equipment to the field, a feat once thought impossible.

Despite its remote location, Shaybah has hosted many VIP visitors, such as presidents, ministers and ambassadors of other countries. Shaybah employees Inad Hadif and Salim M. Al-Dossary believe Shaybah's size and location have contributed to the opportunity to meet interesting people.

Larger sites often make that kind of interaction nearly impossible, but residents here believe that is just another great benefit of living at Shaybah.

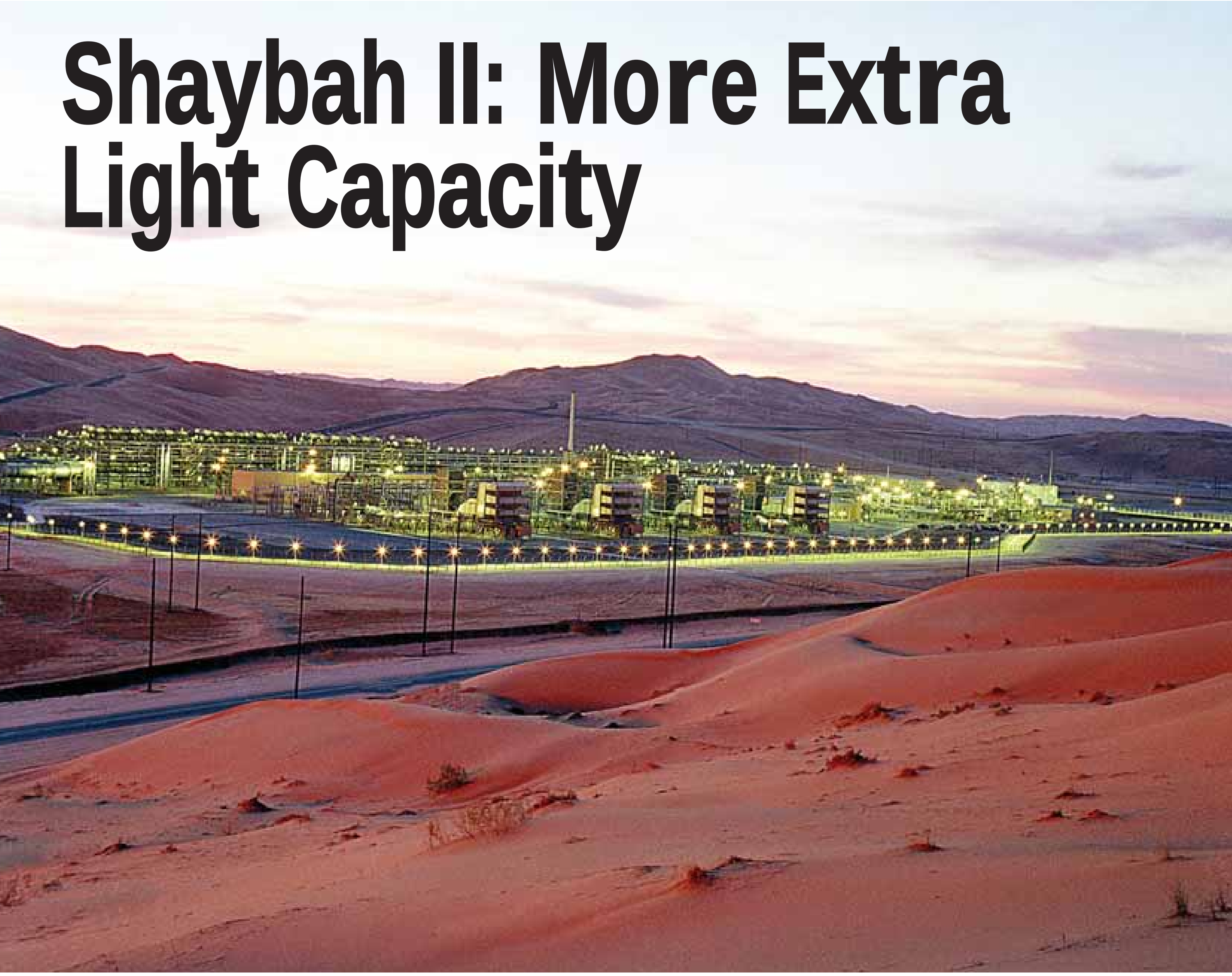
Talal H. Al-Marri, a chemical engineer, believes Shaybah offers more than just a pleasant landscape and life's simple pleasures. Al-Marri says that working in Shaybah and the expansion project offers young Saudis the opportunity to work with other professionals from other countries – Americans, Canadians, Russians, Koreans, Japanese and others – with diverse expertise, cultures and backgrounds.

A second expansion project is in the planning stage.

Hosam Maghribi and Abdullah Shanqaiti, two maintenance foremen, say the fact that they work together 12 hours a day and then socialize after working hours in the same community provides a unique atmosphere in which colleagues also become close friends. That, in turn, helps them work closely as a team.

"...working in Shaybah and the expansion project offers young Saudis the opportunity to work with other professionals from other countries – Americans, Canadians, Russians, Koreans, Japanese and others – with diverse expertise, cultures and backgrounds."

Shaybah II: More Extra Light Capacity



Once the finishing touches were applied to the Shaybah Expansion Project, the facility's Arab Extra Light oil production increased by a quarter-million barrels per day to 750,000 BOPD. The four-year construction project added a gas-oil separation plant (GOSP) and expanded gas compression injection facilities and power generation, as well as the pipelines to transport the crude.

"We started in 2005, and we faced multiple challenges, starting with the market conditions and the number of projects to be run at the same time – Khursaniyah, Khurais and Hawiyah," said Bader A. Dulaimi, general supervisor of the Capital Program Optimization Division, who earlier served as project manager for Shaybah.

The building boom required that the company seek innovative solutions. "We were challenged to find qualified contractors to run this project to our objectives and plans," Dulaimi said. Four new international contractors were introduced, but that meant bringing them up to speed on Saudi Aramco systems and expectations.

Dulaimi said the team's goal wasn't just to add to the existing facilities but to modernize them. "We didn't start from scratch. We took the old design and started to work with Operations and got their lessons learned from the day they started up the old plant to the day we started the new design," he said.

They devised solutions to all the issues faced in the old design, and they scoured the market for the latest technologies to improve processes. Among them were a new flaring system and a new, more efficient way to strip hydrogen sulfide gas, along with new communication technology.

Shaybah is spread over 130 subkhas, or salt flats, separated by massive dunes of red sand that tower above them, which can make communication difficult.

"The terrain at Shaybah is very challenging," said Abdulrahim M. Anwah, lead project engineer for communications. "Signals tend to fade or be obstructed by the sand dunes. That makes Shaybah very unique and difficult at the same time."

The transmission network was expanded to four times its previous scope. Three radio sites were placed on dunes, and a new radio-by-fiber-optic technology provided some subkhas with communication.

One enhancement that every Shaybah Producing employee will enjoy is expanded cellular-phone coverage, which until now has been available only in the Residential and Industrial Complex, Anwah said. It was extended to GOSP No. 4 and GOSP No. 2. "We have extended it so all four GOSPs have coverage. Now, if you lose radio for some reason, you also have the cell phones as a backup."

On any Saudi Aramco project, safety is as important as any schedule or deadline. To ensure the best results in the Shaybah Expansion, safety considerations extended far beyond the construction sites.

"Here in Shaybah it is truly remote. You have to take a plane or drive from 12-14 hours to get here," said Zaki S. Hallaq, who served as safety engineer for the project. "We did whatever it took to get (workers) to rest and be able to be stress-free so they could have a good attitude and enjoy their time after work."

Capitalizing on Shaybah's existing recreation facilities and common areas, construction workers had a variety of after-work activities from which to select, including weekend soccer and basketball tournaments, exercise rooms and majlis rooms, where friends could join to watch big-screen televisions.

Internet connections were provided, and dozens of television channels offered programs from around the globe.

"We provided these things, and it was interesting to see how the workers would adapt them and make them fun. The workers would look forward to the weekends because there were choices about things to do. If you have a boring weekend, you're likely to have a boring week; if you have a good weekend, you're more likely to have a good week," Hallaq said.

Construction traffic also required project managers to look at Shaybah's road grid and the long, desolate highway that links the facility to the rest of the world. "When the contractors started to mobilize and truck deliveries started, we had to look at the roadways," Hallaq said. "We widened roads between the contractor camps and the new GOSP and installed lighting."

Self-contained, solar-powered streetlights were employed to light the way, Anwah said. "Now I'm getting a lot of calls from other projects that are considering the lighting for their areas."

All of these factors combined to form the basis of the Shaybah Expansion Project's completion and are a source of pride for the thousands of people whose work made it a reality.

"The way of constructing buildings and the value engineering we conducted for this plant resulted in tremendous savings and optimization," Dulaimi said. "What we did in Shaybah was nothing different than is done in other projects. Operations and other organizations supported us from Day One. They gave us their best."

"Projects in general are an exciting experience because you design something and get to see it built," said Nazeeh A. Kureea, a senior project engineer who later became project manager.

People worked long hours, even without being asked. That gave young engineers a chance to focus on the work and work alongside senior engineers. "The whole Shaybah society is so close that even after we worked together all day, we gathered at night and discussed the work," he said.

Kureea credited management for making sure workers were prepared and had the proper awareness to get the job done. "Whether you look at it from a safety perspective, quality, schedule or completing a project of this magnitude, the people who were involved in it were the reason for its success."

Schlumberger Al-Khafji Operations

By Schlumberger staff.

L-R: Mr Khalid Al- Saati, Schlumberger Al-Khafji Operations Manager, Mr Nizar M. Al-Adsani, Chairman, Joint Operating Committee, and Mr Mohammad A. Al-Shammary, President & Chief Executive Officer, Aramco Gulf Operations.

The Schlumberger Al-Khafji Operations Base has been officially opened by Corporate and Executive Management of Al-Khafji Joint Operations (KJO) and Schlumberger.

The facility, located in Al-Khafji City, represents an investment of more than 5M US$ and supports the full complement of Schlumberger services. The new base is built on 20,000m^2 of property generously provided and supported by KJO. It consists of workshops and maintenance laboratories as well as office space and an equipment storage yard that is designed to support current Schlumberger operations and future expansion-needs.

The state-of-the-art facility houses more than 300 employees and encompasses the full repair and maintenance of specialized oilfield technologies and equipment, in addition to engineering, planning and operations support expertise for the entire range of Schlumberger Oilfield Services during the life of an oil and gas reservoir.

The facility was officially inaugurated in an opening ceremony held under the patronage of Mr. Nizar M. Al-Adsani, Chairman, Joint Operating Committee, and Mr. Mohammad A. Al-Shammary, President and Chief Executive Officer, Aramco Gulf Operations Company, along with distinguished guests from KJO, the Al-Khafji

Base Officially Opened

Commemorating well #1, established in Al-Khafji in July 1959, just over 50 years ago. L-R: Mr Khalid Al-Saati, Schlumberger Al-Khafji Operations Manager, Mr Aaron Gatt, Schlumberger President Middle East, Mr Nizar M. Al-Adsani, Chairman, Joint Operating Committee, Mr Mohammad A. Al-Shammary, President & Chief Executive Officer, Aramco Gulf Operations, and Mr Sherif Foda, Schlumberger Vice President & Gen Manager, Saudi Arabia, Kuwait & Bahrain.

government; and Al-Khafji School directors. The new base is a symbol of 50 years of partnership and achievements between KJO and Schlumberger and marks the next phase of a successful relationship by enhancing collaboration to ensure service excellence across KJO upstream operations.

During the inauguration ceremony, Mr. Nizar M. Al-Adsani noted, "The base construction was modelled on best practices and workflows captured from other bases and facilities around the world and implemented according to the highest industrial standards with a focus on efficiency, integration and the workplace environment."

Commenting on the opening Mr. Aaron Gatt, President, Schlumberger Middle East, added, "Just over 50 years ago, in July 1959, we ran our first wireline log in Al-Khafji in well # 1. Since then, Al-Khafji has tracked our history as a company as well as our record in developing technology."

Following the opening ceremony guests were given a guided tour of the facility during which new technologies and integrated solutions relevant to KJO operations were showcased.

Saudi Oilfield Technology Rawabi Holding

Saudi Arabia Oil and Gas: Can you provide some detail on Rawabi's history?

Rawabi Holding: RHC was formed 30 years ago to provide services to the oil and gas industry. We began with three specialized companies in this sector.

Today RHC has expanded its operation to Power, Electric, Telecom, Construction and Industrial services. In the year 2000 RHC started institutionalizing and restructuring projects to prepare the group for the future and to be in a better position to face challenges.

Saudi Arabia Oil and Gas: What are the business areas of Rawabi in the upstream segment? What are the focus areas for technology i.e. Production, Completions, Drilling?

Rawabi Holding: Currently we cover almost all activities in the upstream and continue to partner with the leading internal service and technologies providers to transfer technology in the midstream and downstream.

Saudi Arabia Oil and Gas: How is Rawabi partnering with Organisations in and out of Saudi to research and develop such solutions?

Rawabi Holding: The vision of RHC is to invest inthe latest technology in all sectors, mainly in the oil and gas industry. We believe in transferring technology and in investing more and more in Research and Development.

RHC partner with strong and reputable companies to add value to its current operation and to provide an integrated service in the oil and gas industry.

Saudi Arabia Oil and Gas: What are the company's long term plans?

Rawabi Holding: Our long term plan is to turn Rawabi into an integrated service company in the oil and gas industry.

Rawabi Holding aims to add more companies in this sector to close the circle, and strives to partner with top international companies.

We ensure that Rawabi is providing an integrated service solution to the oil and gas industry and are copying the model of Schlumberger as a company which provides integrated services to Saudi Aramco.

We continue to focus on upstream activities while developing midstream and downstream sectors.

In addition, Rawabi Holding is investing in services related indirectly to oil and gas; i.e., NDT, Corrosion and Construction. Furthermore, we are investing in Electrical, Power and Telecom.

The Eastern Region is the hub of the oil, gas and petrochemical industry and our objective is to serve this industry.

"The vision of RHC is to invest in the latest technology in all sectors, mainly in the oil and gas industry."

The Race to Ultimate Recovery: People, Technology, and Beyond

By SPE Saudi Arabia Section.

Faisal Al-Nughaimish.

Opening Ceremony

For the first time, SPE Saudi Arabia section in association with Dhahran Geoscience Society (DGS) organized a joint technical symposium. "With 17 technical sessions, panel discussion, poster sessions, pre-event courses, field trips and exhibition, the 2010 SPE/DGS ATS&E offers one of its richest programs over more than 25 years of history," said Faisal Al-Nughaimish at the opening ceremony of the 2010 SPE/DGS Annual Technical Symposium and Exhibition. The symposium kicked off on April 4th, 2010 with the opening remarks starting at approximately 6:30 pm. Attendance of over 600 people was registered for the first day alone. Saudi Arabia Oil and Gas was the Official Magazine, and over 1,000 copies were distributed at the event.

Keynote Speakers

The keynote speakers for the opening ceremony were Society of Petroleum Engineers President Dr. Behrooz Fattahi, Shell International Vice-President Mr. Jeroen Regtien, and Ibrahim Al-Saadan on behalf of Aramco Exploration Vice-President Abdulla Al-Naim. Dr. Fattahi said, "We offer our congratulations to the technical committee for developing the outstanding programme – the Saudi Arabia Section's Annual Technical Symposium has a 25-year history of bringing together regional and international industry professionals to exchange knowledge and to promote the latest innovations and technologies."

Technical Exhibit

Saudi Aramco's Senior Vice-President, Amin H. Nasser, and Vice-President, Mohammed Y. Gahtani, were part of the opening ceremony for the exhibition.

The exhibition included the main exhibitors, Saudi Aramco, Weatherford, Schlumberger and Baker Hughes, while the other exhibitors included Halliburton, Gotech, Rawabi Holding, Shoaibi Group, Global, Saudi Geophysical, NPS, Restec, Ertikaz and SRAK.

Over the three day period, the attendance in the exhibition again was very impressive. Positive feedback was observed about the exhibition in comparison with last year's exhibition. Faisal was on point when he was quoted saying: "And for the second year in a row, capitalizing on our last year's success, we have nearly doubled the size of our exhibition to expand the portfolio of companies showcasing the latest technologies needed to boost the growth of the regional upstream industry."

Technical Sessions

17 technical sessions and invited speakers were able to complete the success of the symposium with their expertise in all the different disciplines of petroleum engineering. The technical program included sessions that discussed Drilling and Work-over Operations, Advances and Challenges in Reservoir Characterization, Completion Technology, Reservoir Simulation, Production Technology and Operations, Geophysical Analysis, Stimulation Technology, Reservoir Performance Management, Geology & Geophysics Case Studies, Field Development, Well Testing, Petrophysics and Fluid Flow Mechanics.

Panel Discussion

"Toward 70% Recovery Factor: Multiple Disciplines, Different Methods, One Goal" was chosen to be the topic of the panel discussion to tackle the theme of symposium which was "The Race to Ultimate Recovery". Dr. Mohammed Al-Saggaf, the Moderator, led the invited panelists, who included: Carlos Morales-Gill, Dr. Ganesh Thakur, Hussain Al-Otaibi, Omer Gurpinar, Cr. S.M. Farouq Ali and Waleed Mulhim. The panelists discussed case-studies, modern technologies and expertise to tackle the main issues regarding current and ultimate recovery factors. Prior to the sponsored lunch, a valuable discussion was held with questions between Dr. Saggaf, the panelists and the audience.

Field Trips

Two geological field trips were conducted in conjunction with the SPE-DGS Symposium on April 04, 2010. The first trip was held to study the Dammam Dome and was led by Dr. Wyn Hughes, a Saudi Aramco geological senior consultant, while the second one was conducted at the Half Moon Bay to analyze the sand dunes and sabkhas and was led by Saudi Aramco senior geological consultant Chris Heine and geological consultant Bob Lindsay. Each trip was attended by 30 participants representing Saudi Aramco, service companies within the area, and college students.

The Dammam Dome trip started at the discovery well Dammam 7 and a brief history was given. Then, the trip progressed through the three Tertiary formations that are exposed within the Saudi Aramco camp, which are Rus, Dammam, and Dam Formations. Dr. Hughes's experience about the Dammam Dome enriched the quality of the trip and added greater value and insight as he openly answered the questions of participants and shared his geological knowledge with them. A coffee break at the Gold Club in the Saudi Aramco camp was also a memorable moment for all participants.

The second field trip started inside the Saudi Aramco camp to look at the wind flutes cut in limestone and then proceeded to Half Moon Bay. Several stops were made at the dunes to compare them to the Unayzah

"A" Aeolian reservoir. The stops at the sabkhas were part of understanding the desert environment. Both Chris Heine and Bob Lindsay were instrumental in leading such a trip, given that many participants did not have a background in geology. The knowledge and expertise of both leaders made for an interesting and valuable trip that all participants learned from. Lunch was provided at the Saudi Aramco snack bar in Abqaiq on the beach. An excitement that was not missed by all participants at the end of the trip was learning how to push backward a bus that is stuck in the sands!

"We never thought that geological field trips could be so exciting!" That is a statement made by two students who participated in the field trips. Such a statement tells how these trips positively impacted on its participants. SPE and DGS definitely made successful field trips!

Courses

Baker Hughes facilitated courses on Tight Gas Geo-Mechanics, Engineering a Coiled Tubing Underbalanced Drilling (CT UBD) Well & Deep Gas Drilling Optimization at the pre-event session of the SPE Symposium on 4th of April, 2010. This was the first time the SPE decided to hold courses before the opening of the ATS&E with a view to providing an opportunity for the industry professionals and academia to learn and discuss the technical and operational challenges the industry faces with Tight Gas development, Deep Gas Drilling and CT UBD operations with the segment experts, and for academia to network with industry professionals and help them shape their future careers in the oil and gas industry. The response overall exceeded the expectations of the organizing committee, with more than the planned registrations received for all three classes. The feedback from the attendees was positive, with requests received for more sessions to be planned and conducted over the next few months. Pictured bottom left the instructors for the CT UBD class are shown receiving a token of appreciation from the SPE representative.

Pictured bottom right are the instructors from the Deep Gas Drilling Optimization session receiving their token of appreciation from an SPE representative.

Deep Electrical Images, Geosignal and Real Time Inversion Help Steering

By Douglas J. Seifert, Saleh M. Al-Dossary, Saudi Aramco; Roland Chemali, Dr Michael Bittar, Amr Lotfy, Jason Pitcher and Mohammed Bayrakdar, Halliburton.

Reprinted with kind permission of Saudi Aramco Journal of Technology Winter 2009 issue.

ABSTRACT

Early production, as well as ultimate oil and gas recovery from a reservoir often depend on the timeliness and the accuracy of geosteering decisions, i.e., exiting the reservoir during drilling results in costly nonproductive intervals. Even staying within the reservoir, but in a non-optimal location, eventually leads to early water breakthrough while leaving behind valuable oil. In recent years, azimuthal deep resistivity measurements have been recognized as beneficial to real-time steering decisions. Because of their deep investigation, azimuthal deep resistivity measurements anticipate exits from the reservoir well before such events occur. In addition, their azimuthal sensitivity clearly points to the direction of preferred evasive actions.

Azimuthal wave resistivity measurements assume multiple embodiments and involve multiple characteristics and multiple depths of investigation. The best results are achieved by jointly interpreting several of these measurements according to workflows that are specific to the particular applications. In the simplest case, the up-down resistivity curves can exhibit an unexpected behavior that has proven valuable both to petrophysicists and to geosteering specialists. When approaching conductive overlaying shale, for example, the up-curve tends to read the resistivity of the reservoir while the down-curve exhibits amplified horns beneficial to reservoir navigation. Resistivity images feature bright spots whose progression with an increasing depth of investigation facilitates the avoidance of unwanted boundaries. A new measurement, designated as a geosignal, features strong lateral sensitivity. The geosignal from the deepest spacing is best suited to provide an early indication of the approaching boundary, with a near-exponential dependence on the distance to the boundary. Quantitative inversion based on a subset of the azimuthal resistivity logs and the use of limited local knowledge helps to quantify the distance to the reservoir boundaries and their rate of approach.

This article presents some of the most commonly used interpretation methods as demonstrated on computer models, and then applied to various wells, with applications varying from thick reservoirs to interbedded sand-shale sequences.

INTRODUCTION

Geosteering is beneficial in many types of reservoirs, from thin sands of sub-seismic thickness to large permeable formations with high oil saturation. In a thin sand reservoir, geometrical steering is not accurate enough to ensure that extended reach wells remain within the designated area. Well surveys include inherent errors that often surpass the dimension of the target. Even if the accuracy of the surveys were dramatically improved, the very dimensions of the bed of interest may not be known with enough detail to plan the well path with certainty. In a thick oil reservoir with a water drive, one of the most critical challenges is to place the well to ensure optimized sweep of the oil in place throughout the life of the field. This requirement corresponds in general to placing the well near the top of the reservoir[1], Fig. 1. When there is a gas cap, however, the well must be placed far enough below the gas-oil contact to avoid gas coning. In cases of a gas drive, the well must be placed near the oil-water contact, but high enough away to avoid water coning, Fig. 1. Other types of reservoirs present differ-

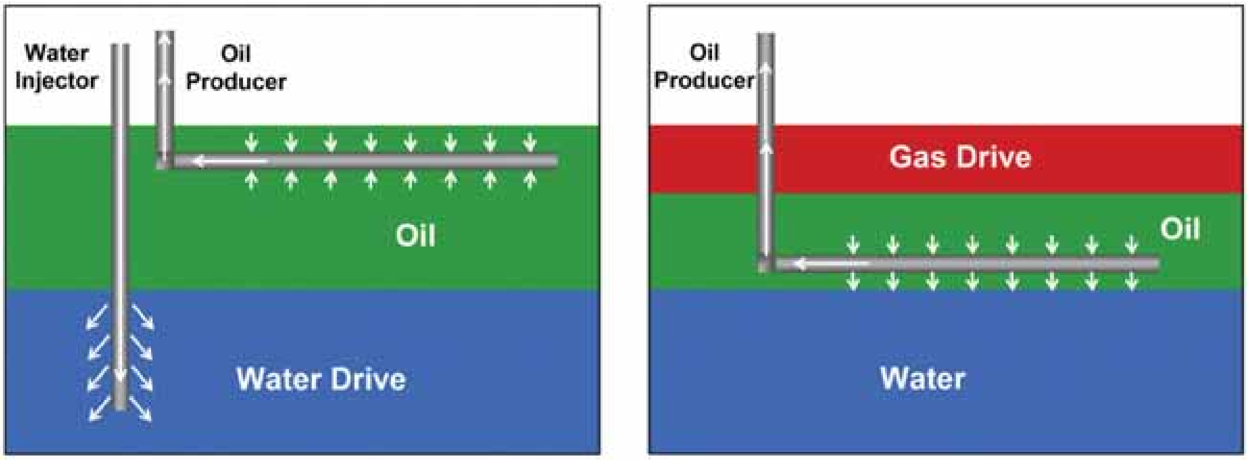


Fig. 1. Two conceptual well positioning requirements. In a massive water drive reservoir (left), the producing well must be placed near the roof for efficient sweep of the oil in place. In a gas drive reservoir (right), the producing well must be placed near the oil-water contact.

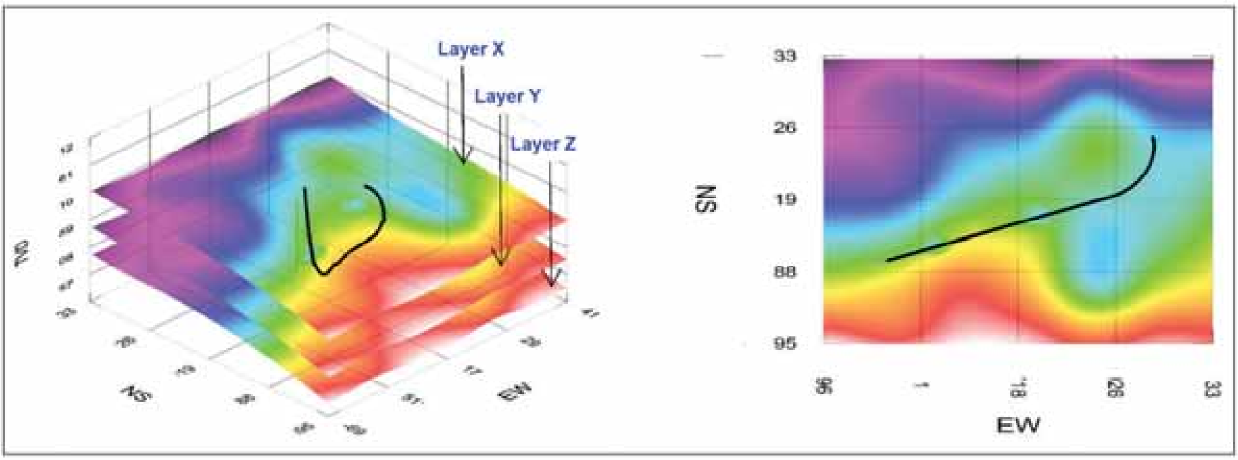


Fig. 2. The main target here is the upper sand of Layer Y. Its nominal thickness is 10 ft. In case of an unexpected pinch-out, the well is to be directed toward the secondary objectives, the lower sand of Layer Y or Layer Z. The top view shows the projected well curving northward in the reservoir.

ent challenges, but most geosteering challenges require maintaining a prescribed distance from the boundaries of the reservoir, and if exiting by accident, being able to rapidly return to the reservoir.

Successful geosteering has positive implications on nearly all phases of the life of the well. First, during the drilling operation, a well path contained within the reservoir often helps to avoid wellbore stability problems; in many instances, the reservoir rock is mechanically more competent than the surrounding shale. Completing the well is also much less risky when the well has a smooth profile, with limited doglegs. Early production, the next phase of the life of the well, benefits from successful geosteering. Clearly, high reservoir contact will result in greater initial and sustained production rates. In many instances, successful geosteering results in reservoir contact in excess of 90%. Finally, in the later years of the life of the well, optimal well placement delays water entry or unwanted gas breakthrough, yielding an optimal sweep of the reservoir.

GEOSTEERING CHALLENGES

Geosteering challenges vary with the reservoir geology, the size of the reservoir, its drive mechanism and the economic parameters of the project.

Two types of geosteering challenges are considered in this article. The first type of challenge is to place the well in a thin reservoir whose exact thickness is variable. Based on offset well data and seismic studies, the primary target formation for the subject well averages 7 ft in thickness. In practice, the thickness varied in the most favorable case from 20 ft or more to 0 ft in the

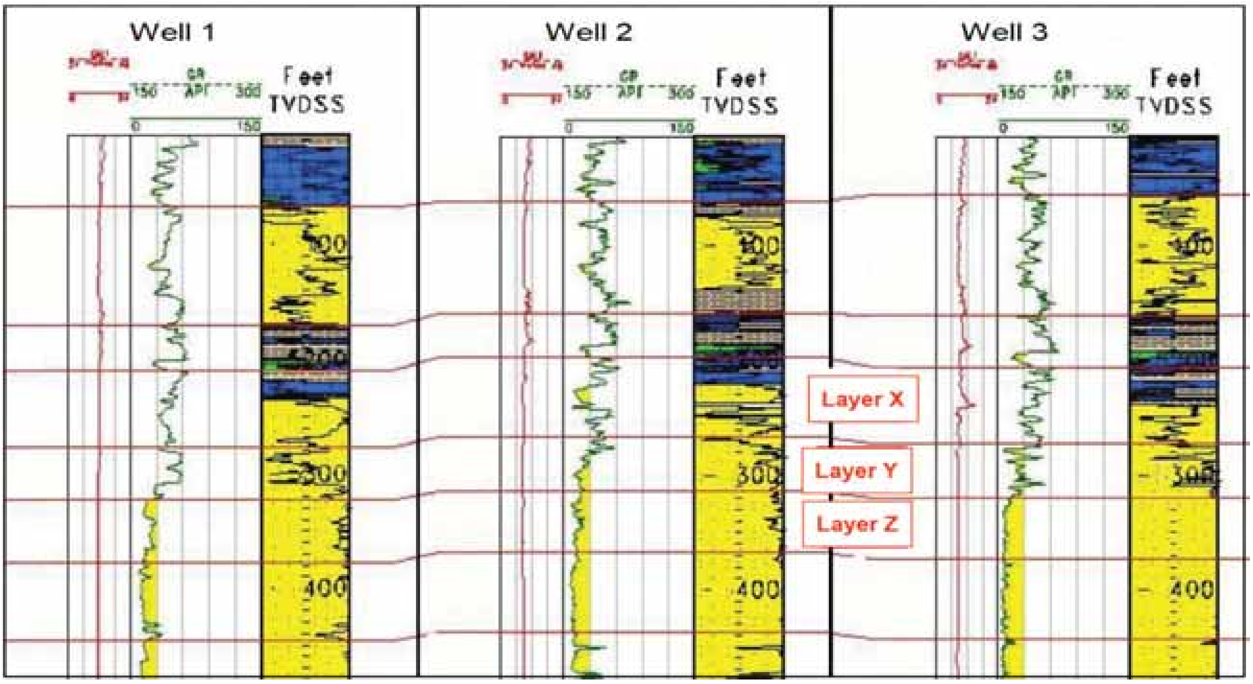


Fig. 3. Three offset wells, Wells 1, 2 and 3, are correlated in this cross section. Used with seismic information, the well data form the basis for the model used to compute the expected response of the LWD sensors before drilling. The targets for this particular development phase of the field are the thin intervals shown across the three wells.

case when a pinchout was encountered. Because of the limited resolution, seismic inversion cannot map the layers with the degree of accuracy needed. The real-time measurements must be processed and interpreted by the geosteering engineer in terms of distances to approaching reservoir boundaries. Steering the well requires the following: determining the formation thickness in real time, identifying pinchouts, updating the geological model as the well progresses and acting upon the information in a timely manner.

The second type of challenge arises when the well can no longer be maintained in the primary target. This occurs when the bed thickness is reduced to such a thickness that it is no longer possible to remain within the bed, or when the bed pinches out. Even if it were feasible to continue to geosteer within the thin section of the original target, moving to a secondary target often will significantly increase the economic value of the well. This situation arose in the subject well discussed in this article. In this well, the quality of the sand deteriorated at the same time that the formation pinched out. The decision was made to leave the primary target and to rapidly go to the secondary target. In the subject formation of this article, the primary target is the upper sand in Layer Y, Fig. 2; the secondary targets are the lower sands of Layer Y and possibly Layer Z.

The geological model of the case study subject was built by combining seismic data and logs from nearby offset wells, Fig. 3. Three neighboring wells were used to develop the geological model and to compute a pre-well model for the planned well path in the primary target. When the well plan was changed to aim for the secondary target, the pre-well model was immediately updated and used to land and steer the well in the secondary target.

Proactive geosteering was used for this subject formation[2]. If the well is to avoid exiting the reservoir, bed boundaries must be detected in advance and avoided. With currently available technology, only wave resistivity sensors offer this capability. These sensors can detect approaching boundaries before they intersect the well path. Azimuthally sensitive wave resistivity sensors have the added benefit of indicating, in real time, the relative azimuth of the approaching boundary, and consequently, the proper direction in which to steer the well

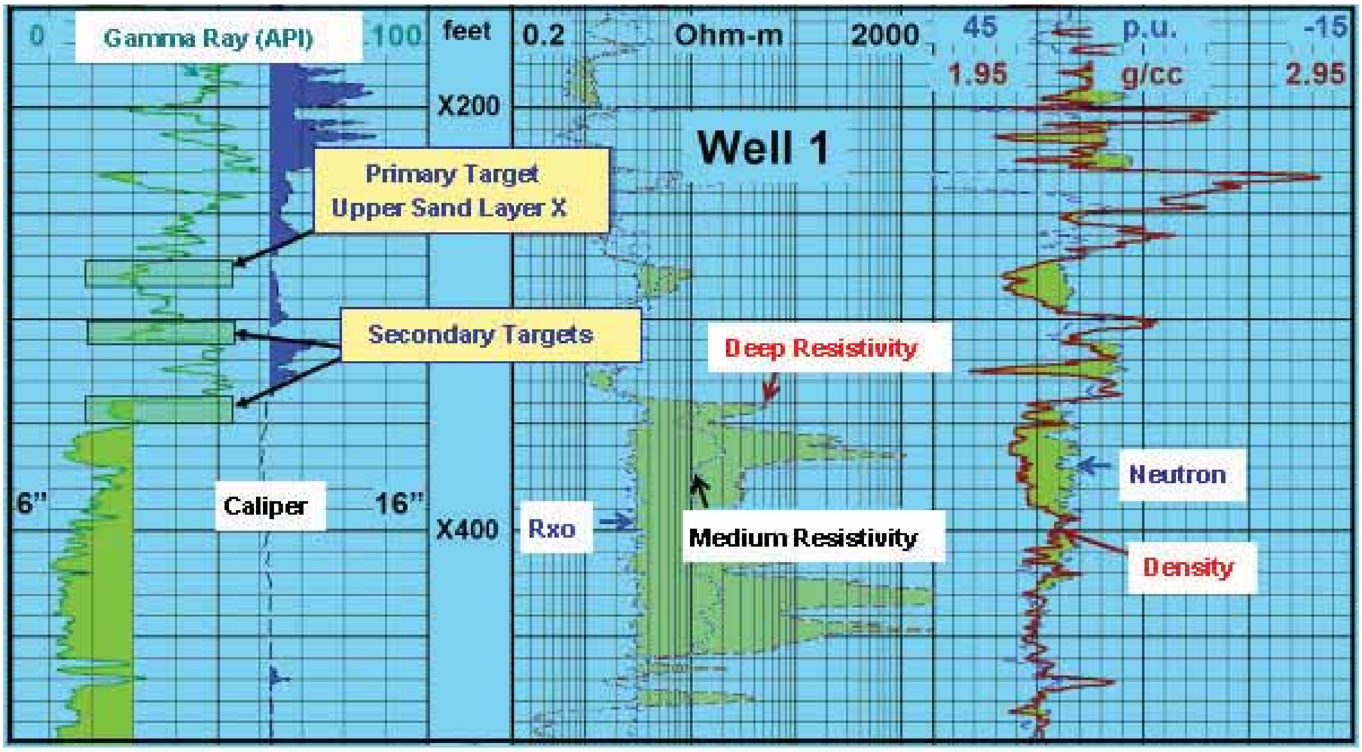


Fig. 4. Well 1 intersects the primary target at measured depth X270. The thickness of the formation is approximately 15 ft to 20 ft.

to avoid exiting the reservoir[3]. A detailed description of the technology used for this application is given in the next section. Proactive geosteering was complemented by reactive geosteering using borehole imaging. Real-time borehole images helped to identify reservoir exit and entry as they occurred, and to compute the true and relative dips of the boundaries being crossed.

Figure 4 shows the primary and secondary targets. Both targets are relatively clean sand with resistivity reaching 10 Ohm-m. In some of the wells, the sand splits into "upper sand" and "lower sand." Because the location of the horizontal well to be geosteered is nearest to Well 1, the upper sand was chosen as the primary target, and the lower sands were selected to be secondary targets. Where the planned well is to intersect the upper sand of Layer X, the thickness of the primary target is approximately 20 ft. Other offset wells show it to be thinning to less than 5 ft.

A resistivity model was built based on the data from Well 1, Fig. 4, with the understanding that the variability observed between the wells is very likely to occur along the length of the subject well of this study. Given the requirement for proactive geosteering in this thin reservoir and the need to identify boundary crossings as soon as they occur, the geosteering program was designed around the use of an azimuthal deep resistivity sensor and azimuthal density borehole imaging. Real-time data from the azimuthal resistivity is inverted to compute instantaneously the distances to the nearest boundaries. The azimuthal density sensor provides real-time images of the formation surrounding the wellbore. The density images are used to recognize reservoir exits when they occur and to compute the relative angle between the well path and the reservoir boundary[4].

AZIMUTHAL DEEP RESISTIVITY SENSOR ARRAY AND CAPABILITIES

Figure 5 shows the azimuthal deep resistivity sensor array[3, 5, 6]. The tool consists of three pairs of transmitters arranged symmetrically with respect to the middle of the array. The transmitters emit a series of electromagnetic wave trains from three different spacings at three different frequencies: 2 MHz, 500 KHz and 125 KHz. A pair of receivers located at the middle of the transmitter array measures the phase difference and attenuation of the electromagnetic waves. This is common to many

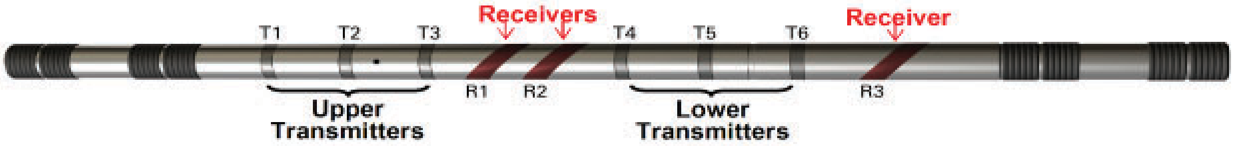


Fig. 5. The azimuthal deep resistivity array features tilted receiver antennas. As the BHA rotates, the resistivity measurements scan 32 discrete azimuthal sectors. If the well is far from all reservoir boundaries, all azimuthal readings are equal; when a boundary approaches from one direction, azimuthal readings exhibit characteristic dissymetries forewarning of an impending reservoir exit.

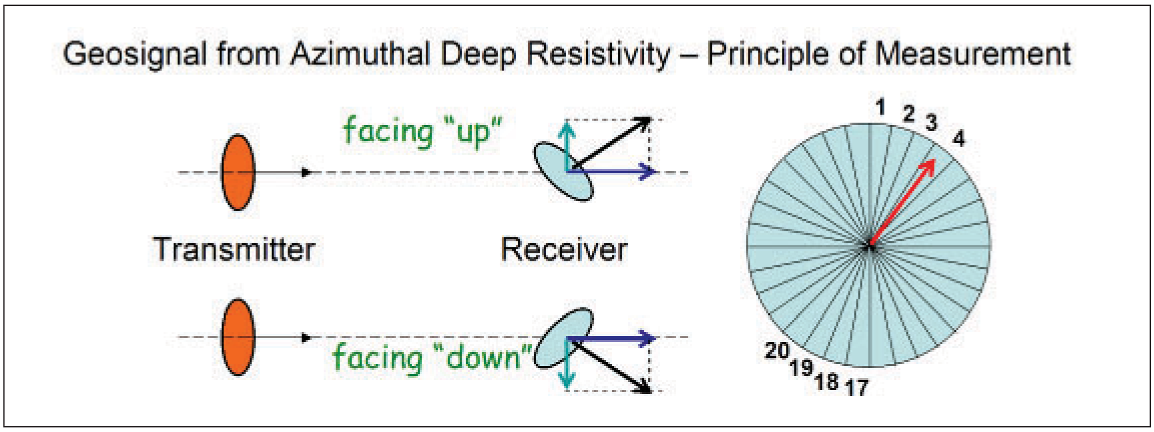


Fig. 6. The geosignal is obtained by combining phase readings and attenuation readings for two opposing azimuths. In practice, the geosignal is displayed as an image or as a single value corresponding to sector number 1, i.e., looking up.

advanced axi-symmetrical nonazimuthal wave sensors. The sensor array used in this application also includes an azimuthal sensitivity feature and long lateral reach feature;

The two central receiver antennas are tilted. This configuration creates a strong and predictable azimuthal sensitivity that makes the tool respond to the resistivity of the surrounding medium and to any non-axi-symmetrical resistivity in homogeneity. Of particular interest is the capability to detect an approaching geological event, including water zone, cap rock and shale lens.

One additional tilted, very long, spaced receiver antenna is located 64" from the center of the array. The far transmitter, in conjunction with this remote antenna, makes a large transmitter-receiver spacing of 112" that is capable of detecting an approaching boundary up to 18 ft away under favorable conditions.

For ease of interpretation and because of the large volume of information contained in the data, azimuthal resistivity logs are presented as images. Depending on spacing and frequency, these images originate from a few inches to several feet from the borehole wall. Only when the geology is known to be uniform is it sufficient to display a limited set of resistivity curves. In general, however, the deep images are continually monitored to help recognize any non-up-down event approaching the well path[2].

A series of additional azimuthal measurements are produced by the azimuthal deep resistivity sensor, optimized for geosteering. These measurements are called geosteering signals or geosignals. They are generated for all spacings and for each operating frequency. They are binned in 32 regularly spaced sectors around the circumference to provide azimuthal sensitivity. Geosignals are capable of detecting approaching boundaries from further away than the azimuthal resistivity logs and

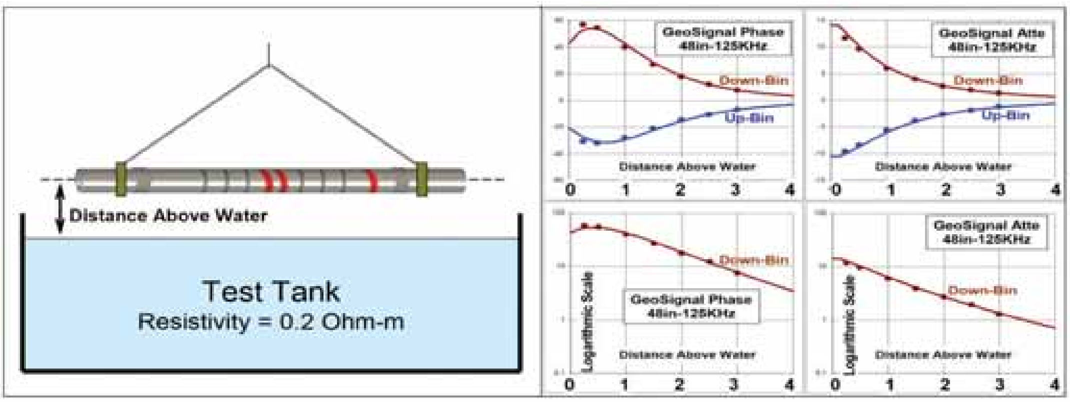


Fig. 7. The geosignal theory was verified in the laboratory. The tool was lowered progressively to a free water surface. The measured values, shown as dots, agree very well with the continuous curves predicted by the mathematical model. When plotted on a logarithmic scale, the geosignal values fall approximately on a straight line.

images. Figure 6 illustrates the method used to derive the geosignal. For the up-looking bin, a measurement of the field is taken when the receiver is facing up. Almost immediately afterward, a second measurement is taken with the tool facing down. The second measurement is subtracted from the first, and the result is plotted as the geosignal for the up-looking bin. In thick homogeneous formations where no boundaries are within range, or where the boundary effects are balanced in a thin bed (the electrical midpoint), the up/down measurements will cancel one another out, giving a geosignal of zero. If a boundary is within range of the tool, the difference in phase or attenuation of the signal between up and down will be either positive or negative, depending on the direction of the approaching boundary. This concept is readily expanded to each of the 32 azimuthal bins.

The theory of the geosignal was successfully tested in the laboratory by measuring and computing the distance of the sensor tool to the free surface of the water in a test tank, Fig. 7.

The threshold of detection of an approaching boundary is determined by assessing when the geosignal rises above the instrument noise floor. As a first approximation, the geosignal is an exponential function of the distance to the bed boundary and increases with the difference in conductivity between the formations on both sides of the boundary. The graph in Fig. 8a indicates that the depth of the first detection of an approaching boundary is approximately 18 ft to 19 ft when the resistivity contrast is 100 Ohm-m to 1 Ohm-m. In general, the more favorable condition is for the sensor to be in the higher resistivity formation seeking a lower resistivity formation. Examples simulated in Fig. 8a are based upon the model described in Fig. 8b, and illustrate the case of a well crossing from a resistive reservoir into a less resistive shale. The magnitude of the signal increases as the well gets near the roof. The ability to detect the approaching roof increases with the resistivity of the reservoir. The graph of Fig. 8a also shows the magnitude of the signal for reservoir resistivities varying from 10 Ohm-m to 1,000 Ohm-m. The distance of first detection of the roof, namely the distance to the boundary for which the geosignal rises above the detection threshold, is 20 ft in a 1,000 Ohm-m reservoir compared to only 11.5 ft in a 10 Ohm-m reservoir. If, however, the sensor is within the low resistivity formation, on the opposite side of the boundary, the depth of first detection is further reduced to 6 ft.

Although the geosignal senses a boundary from many feet away, it cannot identify precisely when the tool is near the boundary. The magnitude of the geosignal does not help in recognizing whether the well is straddling the boundary, running alongside the boundary from within the reservoir, or near the boundary but outside the reservoir. The "flat-topping" and slight reversal observed on the geosignal curve near the boundary suggests a +/- 2 ft uncertainty on the determination of the well's precise location, Fig. 8a. Borehole imaging helps to reduce this uncertainty. Gamma images, density images, or micro-resistivity images are used when the tool is near a boundary. For this case study, azimuthal density images were used to detect precisely any boundary cross-

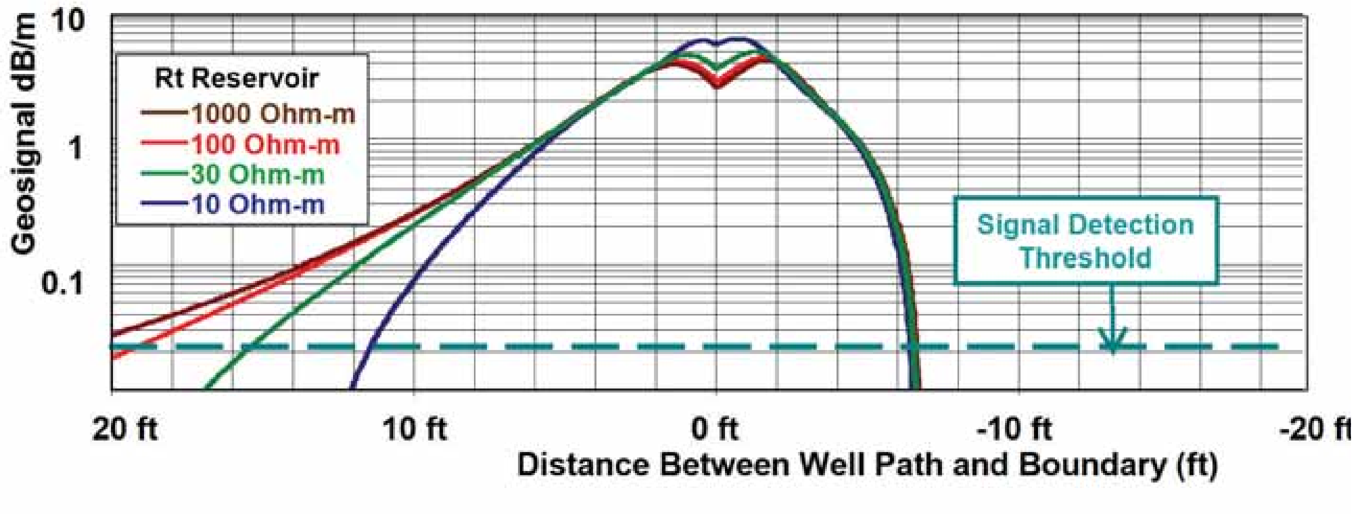


Fig. 8a. The geosignal points toward the less resistive interval. The magnitude of the geosignal is a strong function of the distance to the bed boundary. In this model, the geosignal increases as the well approaches the roof; maximum magnitude is attained near the boundary, then the signal drops off rapidly after the sensor has crossed into the low resistivity shale.

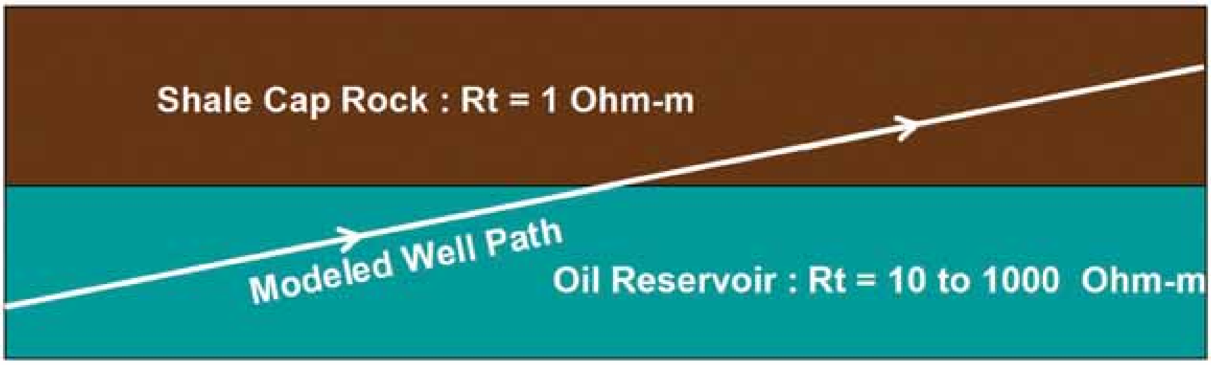


Fig. 8b. Model formation for Fig. 8a. The well is modeled going from the resistive formation below, approaching low resistivity cap rock, and crossing the transition between the two layers and into the low resistive cap rock.

ing and to compute the dip angle of the boundary with respect to the well axis.

CASE STUDY: GEOSTEERING WITHIN THE PRIMARY TARGET

Figure 9 shows the landing of the case study well in the primary reservoir target sand. The entry into the reservoir occurred at an approximately measured depth of X920. Upon entry into the reservoir, the wellbore angle was built up immediately to avoid exiting the bottom of the target productive layer. As expected, after entering the reservoir, the up-geosignal was positive, and the separation of the up-down resistivity indicated proximity to the roof. The deep resistivity image tracked the roof until the well came within distance to be sensitive to the floor. At an approximately measured depth of Y000, the geosignals crossed the zero value mark, and both up-resistivity and down-resistivity came together to indicate that the well was at the electrical midpoint of the reservoir7, which, for this example, is near the stratigraphic midpoint of the reservoir. The geosignals began pointing downward and the separation between the up-resistivity and the down-resistivity reversed.

The reversal is a forewarning of the well's approach to the bottom of the primary target. The deep resistivity image also showed very clearly the floor of the target directly below the well path. The well was still dropping slightly toward the lower boundary, but its relative rate of descent slowed. The well trajectory was turned

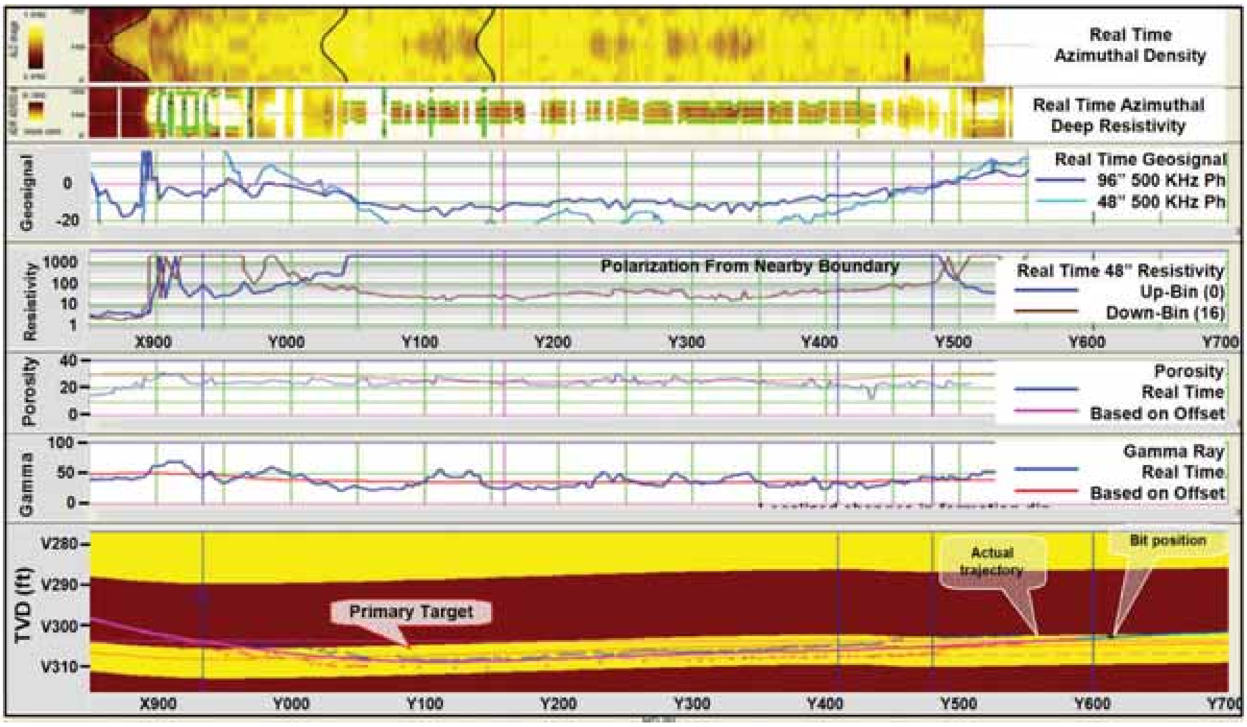


Fig. 9. The well lands in the primary target of Layer Y. The density image shows the entry into the reservoir at X920 ft and confirms that the well stays within the reservoir through the section shown above. Between reservoir entry and exit, the geosignals, deep electrical image, and up-resistivity down-resistivity forewarn of an impending exit through the bottom of the interval. Appropriate angle build maintains the well path within the reservoir for 600 ft.

up slightly, and the geosignals then reversed slightly between Y200 ft and Y400 ft measured depth. The well continued to be drilled at this angle and exited through the roof at a measured depth of Y550 ft, Fig. 9. Before exiting, a computation of the formation thickness based on an inversion of resistivity and geosteering indicated that the formation thickness had dropped to near 3 ft; and the decision was made to steer the well toward the secondary target.

CASE STUDY: LANDING AND GEOSTEERING WITHIN THE SECONDARY TARGET

Figure 10 shows the steering of the well into and within the secondary target reservoir. The transition from the primary target to the secondary target required approximately 450 ft, spanning the interval between Y550 and Z000 of measured depth. The initial target reservoir was crossed at approximately Y700. The logs show that the sand pinched out at this point and the decision to go for the secondary target was correct. The formation between the two targets is depicted in the model as shale. In reality, the criss-crossing between up-resistivity and down-resistivity suggests that the interval consists of thinly interbedded sands and shales. When landing in the secondary reservoir target at Z000 ft, azimuthal deep resistivity logs, deep resistivity images, and geosteering signals again exhibited the expected behavior when entering a reservoir from the roof: The deep resistivity image shows low resistivity above the sensor and the geosignals point "up," confirming a low resistivity formation above the well path. The gamma ray showed a drop in radioactivity, but the contrast of the density image was not strong enough to confirm the event.

Geosteering through the secondary target, the well was placed near the roof of the sand interval. The well was kept there for most of the remaining drilling interval. Proximity to the roof is indicated by the deep resistivity image, by the geosignal, and by the very large separation between up-resistivity and down-resistivity. During a short interval between Z350 and Z380, there was a brief exit through the top of the reservoir. This exit was not detected by the azimuthal deep resistivity sensor, but clearly observed on the density image: The sinusoidal pattern seen in Fig. 10 at Z350 indicates an entry into the shale immediately above the well. The next sinusoidal pattern observed at Z380 confirms a rapid exit from the shale.

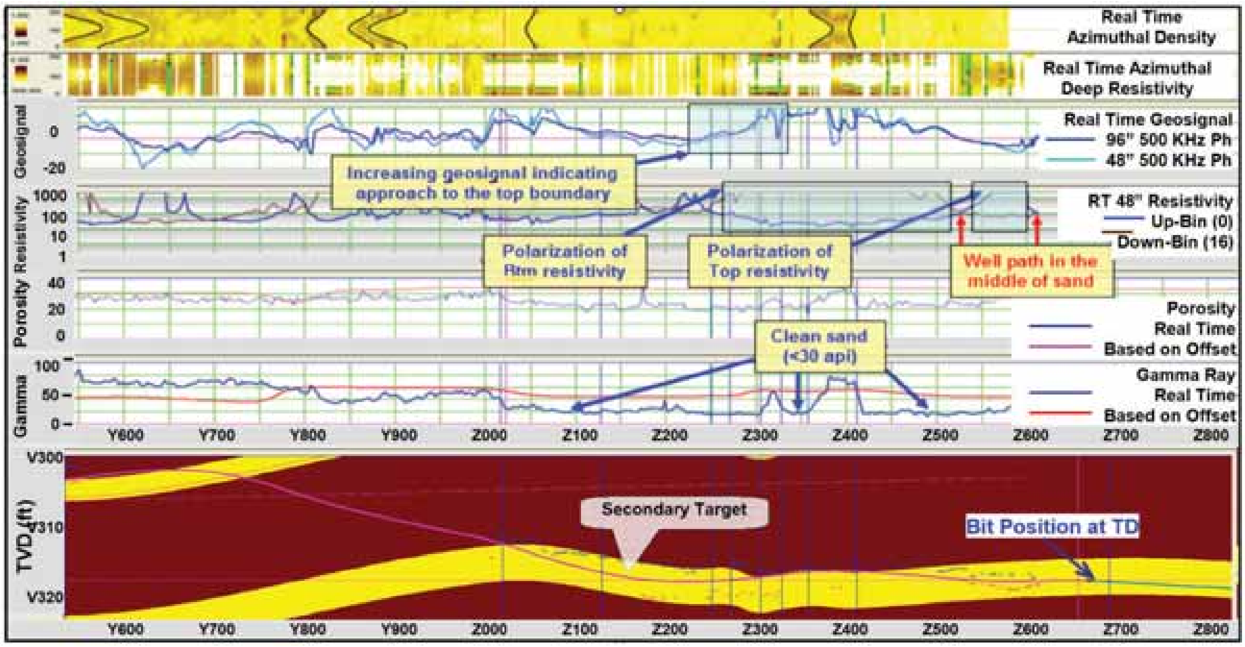


Fig. 10. The well exits the primary target at depth Y550 then enters the secondary target at depth Z000. In the secondary target, geosteering is maintained in the upper section of the reservoir. One brief reservoir exit is detected at Z360 by the density image, but not by the deep resistivity sensor.

CASE STUDY: RESULTS

Proactive geosteering using the azimuthal directional resistivity (ADR) and azimuthal density images resulted in the placement of the well first in the primary target reservoir and then in the secondary target reservoir. A total reservoir length of 1,760 ft was drilled, yielding an overall net/gross of 73%. Individual reservoir lengths were 630 ft for the primary target and 650 ft for the secondary target.

A petrophysical evaluation of the formation was conducted using the logging while drilling (LWD) logs. The results of the interpretation are displayed in Fig. 11. They confirm reservoir entries and exits observed while drilling and geosteering. Reservoir contact shown by the geosteering section agrees with that determined by petrophysical analysis.

CONCLUSION

The geosteering challenges presented in this study were met with the right complement of proactive geosteering with an azimuthal deep resistivity sensor and reactive geosteering with density images. Geosteering within the primary target was initially successful until the bed thinned out, leading to exiting for the secondary target. The resistivity contrast, however, combined with the high sensitivity of the geosignal, was sufficient to forewarn of impending reservoir exits. Timely corrections to the well angle based on azimuthal deep resistivity readings were successful at maintaining the well path within the reservoir throughout the primary target, and nearly throughout the entire secondary target. The short exit from the secondary target sand illustrated the need for additional technologies that are sensitive to the near wellbore environment. In this case study, the azimuthal density was used for this purpose. A result of the steering exercise was that the nonproductive interval was almost exclusively limited to the path from the primary target to the secondary target.

ACKNOWLEDGMENTS

The authors wish to thank Saudi Aramco management for their support and permission to present the information contained in this article. The authors would also like to acknowledge the contribution of several colleagues, including Mostafa Badawy, Ian Murugesu and Hussein Al-Filfil.

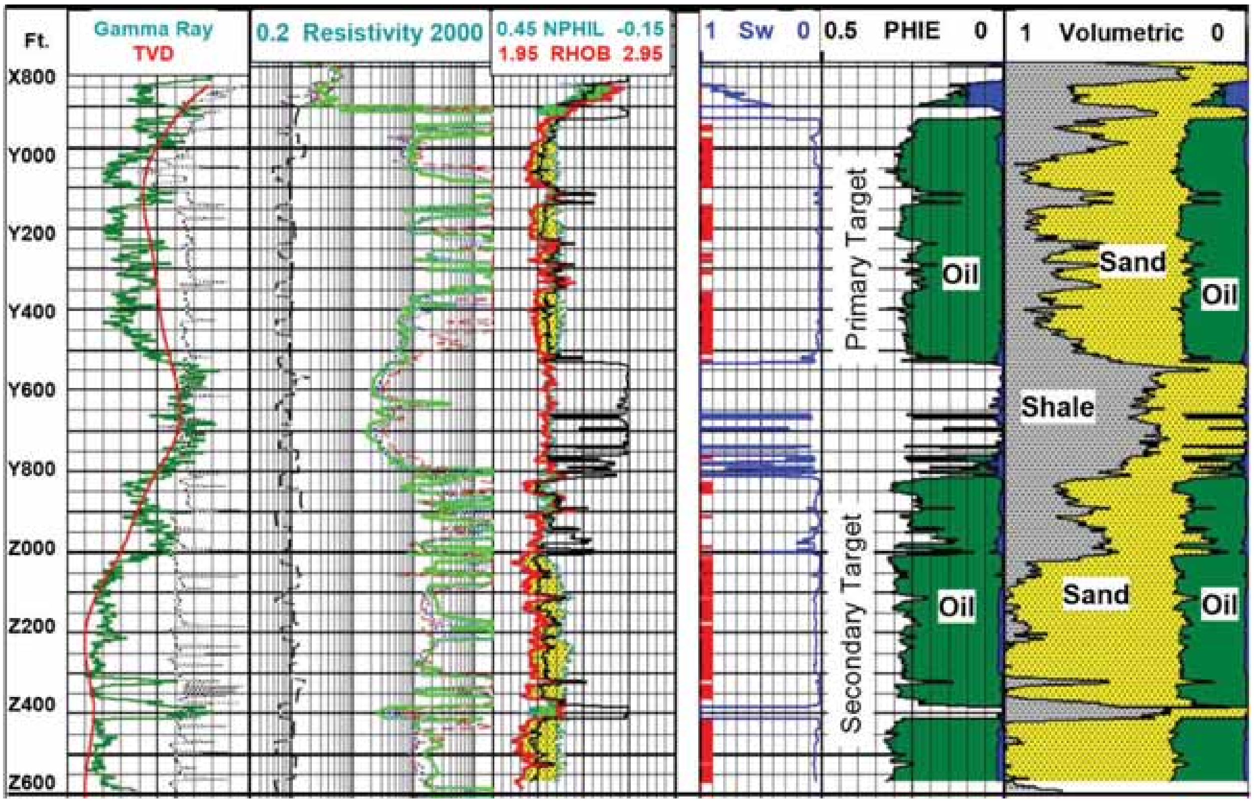


Fig. 11. The petrophysical evaluation of the formation surrounding the well is based on a resistivity, density, neutron, gamma combination. There is good agreement with the reservoir contact derived from geosteering.

This article was presented at the SPE Annual Technology Conference and Exhibition, New Orleans, Lousiana, October 4-7, 2009.

REFERENCES

1. Bell, C., Hampson, J., Eadsforth, P., et al.: "Navigating and Imaging in Complex Geology with Azimuthal Propagation Resistivity While Drilling," SPE paper 102637, presented at the SPE Annual Technical Conference, San Antonio, Texas, September 24-27, 2006.

2. 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.

3. 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.

4. 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 Conference, Bahrain, October 22-24, 2001.

5. Bittar, M.: "Electromagnetic Wave Resistivity Tool Having a Tilted Antenna for Determining Horizontal and Vertical Resistivities and Relative Dip Angle in Anisotropic Earth Formations," U.S. Patent 6,163,155, December 19, 2000.

6. Bittar, M., Hveding, F., Clegg, N., Johnston, J., Solberg, P. and Mangeroy, G.: "Maximizing Reservoir Contact in the Oseberg Field Using a New Azimuthal Deep-Reading Technology," SPE paper 116071, presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, September 21-24, 2008.

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

The Detecting Capability of TEM: the Case of Underground Cavities

By Xue Guoqiang, Institute of Geology and Geophysics, China; Michael S. Arvanitis, Geomorph Instruments, Greece; Ghunaim T. Al-Anezi, King Abdulaziz City for Science & Technology, Saudi Arabia; Bandar Duraya Al-Anazi, King Abdulaziz City for Science & Technology, Saudi Arabia.

It was with sadness that Saudi Arabia Oil and Gas learnt of the untimely death of Bandar Duraya Al-Anazi. He was an active Researcher at KACST and a regular contributor to Saudi Arabia Oil and Gas. He will be missed.

In order to fully assess the transient electromagnetic method, a very common tool in engineering exploration, we tested its ability in the detection of underground caves in buildings. We give the mathematical model for underground caves and the transient electromagnetic response formulation of underground caves in spherical coordinates and we analyze the response of underground caves, both resistive and conductive ones. We apply the method to find a cavity in a coal mine site and the results have been verified by drilling data. From the physical model analysis and calculation, TEM method proves an efficient method for the detection of underground cavities.

Introduction

With the rapid development of China, especially in the field of construction, there is the need for a useful geophysical method which will be applied in highway inspection, detection of underground caves and water resources. As underground caves always lie irregularly, drilling is not the right method to detect them especially in complex areas. In comparison, EM methods are cost effective, fast and efficient methods.

As the exploration of such geological bodies is crucial for construction, we will try to formalize the electromagnetic response features of cavities. Transient Electromagnetic Method (TEM) is a time domain method. TEM is based on the principle of using electromagnetic induction to generate measurable responses from sub-surface features, these responses are converted to apparent resistivity or conductivity values that vary with depth at each sounding site. Subsequently, to map changes in resistivity or its inverse, conductivity, with depth [1] one of the first applications of TEM was described by Ward (1938). TEM has many advantages such as not requiring direct contact with the ground as in the case of DC-electrical methods, small volume and topography effect, high resolution, the same basic techniques can be used to investigate the shallow and deep structure in the range of a few meters to 1000 meters and applicability on various surveying conditions. Although it finds a lot of applications in engineering exploration [2], there are some factors that can influence its ability and precision, so a more profound theoretical approach is needed.

The study of TEM response characteristics in layered media to solve deep geological structure problems has already been discussed [3, 4], as well as case studies with underground caves [5], theoretical analysis of conductive caves [6], studies on the numerical calculation of underground geological formations [7, 8, 9, 10]; but there are few studies on the underground cave response. In this paper, we give the equations of a spherical body and analyze the physical course and response character of cave. We calculate also the response of a high resistivity cave and apply the method on a coal mine.

1. Mathematical modification of the TEM response for underground caves

The fundamental law of electromagnetic field is given by the Maxwell equations:

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad (1)$$

$$\nabla \times \mathbf{H} = \mathbf{j} + \frac{\partial \mathbf{D}}{\partial t} \qquad (2)$$

$$\nabla \cdot \mathbf{B} = 0 \qquad (3)$$

$$\nabla \cdot \mathbf{D} = \rho \quad (4)$$

Where E is the electrical field intensity (*V/m*), B is the magnetic induction in Tesla, H is the intensity of the magnetic field (*Wb/m²*), D is the electric displacement vector (*C/m²*), j is the electric current density (*A/m²*) and ρ is the free-electric density or electric charge density (*C/m³*). Although the underground caves have various shapes, they can be considered as spherical bodies or as a combination of spherical bodies. Thus, we consider the sphere as a model (Fig.1). The conductivity of the spherical body is , its radius r0, the buried depth is h0 and the conductivity of the host rock is σ1.

The transmitted current is shown below:

$$I(t) = \begin{cases} 1, t > 0 \\ 0, t < 0 \end{cases} \quad (5)$$

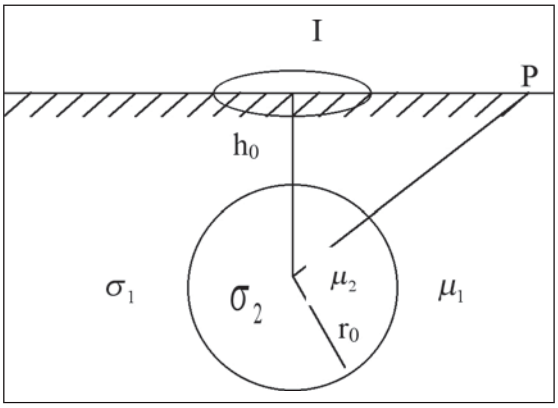


Fig. 1: The electric model of underground cavity

In TEM sounding, we must fully consider the conductivity of the media. There is both conduction and displacement current. As the spectrum of the frequency of the step current is F(ω)=1/iω+πδ(ω) (what is d, ω, ι etc), low-frequency is in abundance; in real problems, we care a lot about low-frequency as it has the deeper penetration depth, so the displacement current is neglected when we solve the TEM problem.

To make things easier, we introduce the scalar potential function DeBye [6] Let:

$$\mathbf{E} = -\mu \frac{\partial}{\partial t} \times (r\mathbf{Q}) \quad (6)$$

$$\mathbf{H} = \nabla \times \nabla \times (r\mathbf{Q}) \quad (7)$$

From the Maxwell equation we see that the function satisfies the following equation in the time-domain:

$$\nabla^2 \mathbf{Q} - \mu\sigma \frac{\partial \mathbf{Q}}{\partial t} = 0 \quad (8)$$

The function DeBye fulfils the following equation in the frequency domain:

$$\nabla^2 \mathbf{Q} - k^2 \mathbf{Q} = 0 \quad (9)$$

Where, $k = (-i\omega\sigma\ \mu_0)^{1/2}$,

Using the boundary conditions, the general solution can be written as:

$$\mathbf{Q} = \sum_{n=0}^{\infty} \sum_{m=0}^{n} \mathbf{A}_{m,n} \mathbf{b}_n (kr) \mathbf{L}_n^m (\cos\theta) \mathbf{h}(m\phi) \quad (10)$$

$A_{m,n}$ is a coefficient b_n (kr)is the spherical Bassel function L_n^m (cos θ) is the Legendre function and h(mϕ) is the Hanker function. We can obtain the solution in the time domain based on the transform and the boundary condition. We can also get the solution of the electromagnetic field with the help of the equations (6) and (7).

In spherical coordinates where circle loop lays on above the cave, the relationship between Q and electromagnetic component for the centre loop is:

$$E_r = E_\phi = B_\phi = 0 \quad (11)$$

$$E_\theta = -\frac{1}{\sin\theta} \frac{\partial^2 \mathbf{Q}}{\partial t \partial \varphi} \quad (12)$$

$$B_r = \frac{\partial^2 (r\mathbf{Q})}{\partial r^2} - \mu\sigma \frac{\partial (r\mathbf{Q})}{\partial t} \quad (13)$$

$$B_\theta = \frac{1}{r} \frac{\partial^2 (r\mathbf{Q})}{\partial r \partial \theta} \quad (14)$$

For the case of conductive cave embedded in insulating host rock:

let: $\sigma_2 = \infty$, $\sigma_1 = \sigma$, then

$$\mathbf{Q}(r,\theta,t) = \sum_{n=1}^{\infty} G\ \mathbf{P}_n(\cos\theta) \sum_{p=1}^{\infty} \mathbf{M}(\kappa_{np}) \mathbf{b}_n(\kappa_{np} t) \exp\left(-\frac{\kappa_{np}^2 t}{\mu\sigma}\right) \quad (15)$$

where: $$\mathbf{b}_n(\kappa_{np} r) = \begin{cases} \mathbf{j}_n(\kappa_{np} r)(r \geq r_0) \\ \mathbf{j}_n(\kappa_{np} r_0)\left(\frac{r_0}{r}\right)^{n+1} (r > r_0) \end{cases} \quad (16)$$

$$M(\kappa_{np}) = 2(2n+1)\left(\frac{r_0}{a}\right)^n [\kappa_{np}^2 r_0^2 j_n(\kappa_{np} r_0)]^{-1} \quad (17)$$

$$G = \frac{\mu m}{4\pi a^2},\ P_n(\cos\theta)$$

is the first type of the Legendre function.

For the case of insulating cave embedded in conductive host rock:

let: $\sigma_1 = 0$, $\sigma_2 = \sigma$, then

$$\mathbf{Q}(r,\theta,t) = \sum_{n=1}^{\infty} G\ \mathbf{P}_n(\cos\theta) \sum_{p=1}^{\infty} \mathbf{M}_{np} \mathbf{b}_n(k_{np} r) \exp\left(-\frac{k_{np}^2 t}{\mu\sigma}\right) \tag{18}$$

where:

$$\mathbf{b}_n(k_{np} r) = \begin{cases} \mathbf{j}_n(\kappa_{np} r)(r \le r_0) \\ \left(1 - \frac{\lambda^2 \kappa^2 r_0}{4n^2 - 1}\right) \mathbf{j}_n(\kappa_{np} r_0)\left(\frac{r_0}{r}\right)^{n+1} (r > r_0) \end{cases} \tag{19}$$

In the real measurements, we usually measure inductive electro-motive force of loop instead of components of the electromagnetic field. The parameter that we calculate is:

$$\varepsilon(t) = 2\pi a \sin\alpha \mathbf{E}_\varphi = 2\pi a \sin\alpha \frac{\partial^2 \mathbf{Q}}{\partial t \partial \theta} \tag{20}$$

For the conductive and nonmagnetic spherical body, the response is [11]:

$$h(t) = \left[T + \frac{1}{3} - 2\left(\frac{T}{\pi}\right)^{1/2} - 2\sum_{m=1}^{\infty}\left\{T^{1/2} erf\left(\frac{m}{T^{1/2}}\right) - 2m\,erfc\left(\frac{m}{T^{1/2}}\right)\right\}\right] u(t) \tag{21}$$

Where:

$$u(t) = \begin{cases} 1, t > 0 \\ 0, t < 0 \end{cases},\quad erfc(Z) = \frac{2}{\sqrt{\pi}} \int_Z^{\infty} e^{-x^2} dx,\quad erf(Z) = \frac{2}{\sqrt{\pi}} e^{-z^2}$$

h(t) is the response of magnetic field in time domain, T is the characteristic parameter.

Taking into account the loop, the TEM field's equation for spherical body is [11]:

$$V(t) = 3\pi^{-1}\mu_0 \frac{Ia^3 R^2 r^2}{(R^2 + h^2)^{2/3}(r^2 + h^2)^{3/2}} \sum \exp\left(-k^2\, t/\pi\right) \tag{22}$$

Where: R is the radius of transmitter loop, *r* is the radius of the receiver loop and *V(t)* is the secondary induced attenuation voltage. The equation (22) reflects that the electromagnetic response of the underground spherical body is related to the conductivity of the spherical body, to the depth, radius, the scale of receiver or transmitter loop, the host rock and to the transmitter current.

2. The physical characteristic analysis of electromagnetic response of underground cavity

When the primary field is cut off, the vortex current is excited by the geological body. If we suppose that there is a spherical body, the underground vortex flow's distribution in space differs with time. In Fig. 2 we show the course of the TEM response curve in the case of underground cavity. In the early stage, the vortex flow exists on the surface of the spherical body (Fig 2.a), its distribution state can maintain the initial uniform field, and the current's distribution has no relation with the conductivity of the spherical body. Because of the energy loss, caused by the underground cave, the energy diffuses into the cave at the second stage (Fig 2.b) and the vortex flow in the spherical body varies with time. During the last stage, the distribution of vortex flow in cave is stable (Fig. 2.c).

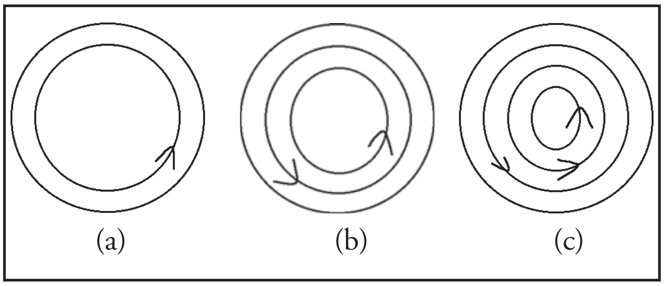


Figure 2. The course of TEM response of cave

The course can also be explained in Fig. 3, where we get the TEM response curve above the cavity; in this figure the horizontal direction shows time while the vertical represents response force.

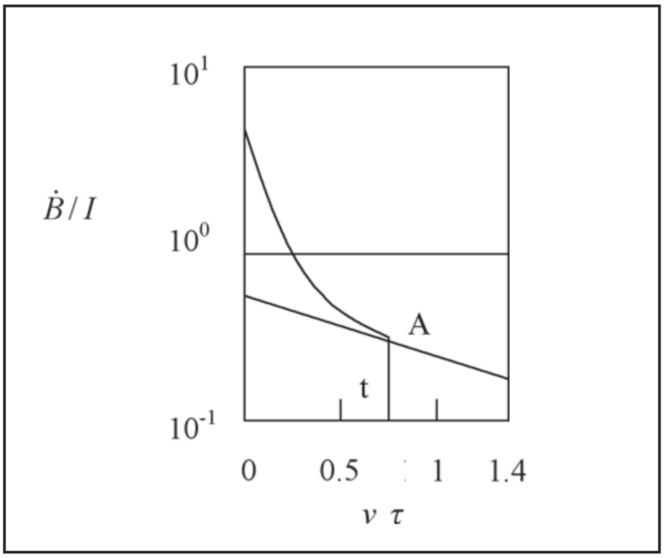


Fig 3 The TEM response curve above the cavity.

Where, B = V(t)/SN and S is the area of receiver loop; N is the turn of the receiver loop. From this Figure, it can be seen that in the very first stage, the curve attenuates approximately exponentially, and in the second stage, the curve attenuates as approximately linearly. The point where the curve changes is marked with A and the time with t. From the following equation, we can compute the initial time $\tau = 2t$, when the curve starts to reach the last stage. The relationship between conductivity parameter σ and radius α can be written as [12]:

$$\tau = \mu_0 \sigma a^2 / \pi^2 \quad (23)$$

Where τ is the characteristic parameter of time.

TEM can be used to detect underground conductive caves as well as to distinguish underground high resistivity bodies. We have calculated the response of a two-dimensional underground cave with the finite-difference method, under the condition of a centre–loop configuration. Fig. 4 shows the responses of a high resistivity cave and of host rock at 0.03ms time delay. Horizontal direction shows space while vertical the EMF of response. The buried depth is 45m, the radius of the spherical body 20m, the length of transition square 50m. The resisitivity of the cave is 5000Ω and of the host rock 1000Ω. Solid line represents the response of the host rock and the dashed line the response of the high resistivity cave. The maximum of induced voltage lies above the center of the spherical body.

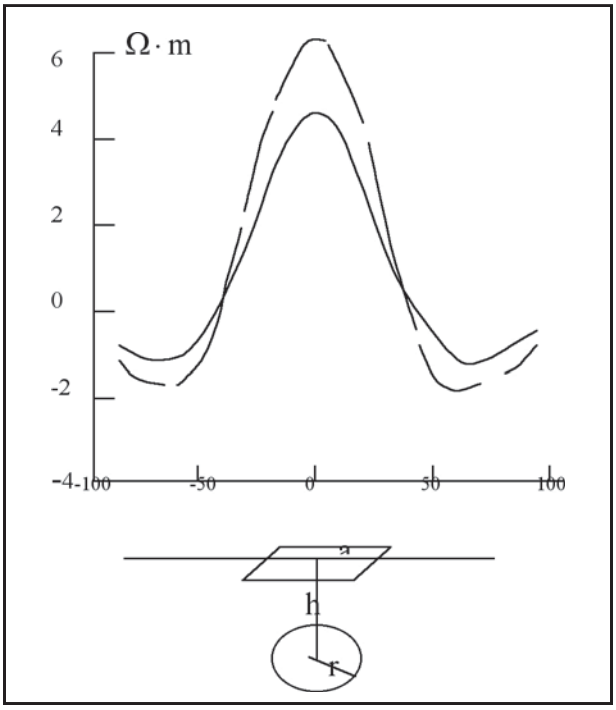


Figure 4: The response curves of high resistivity cavity and host rock

We can clearly see that EMF is high when host rock exists, while EMF is low when high resistivity vortex current exists. As there is difference between the host rock and the cave, we can get a theoretical basis to detect underground target in real case-studies.

3. Case study: an underground cavity detected using TEM

We used the TEM method In order to investigate the range of a cave in the coal mine of ShanXi province. We employed large-loop TEM soundings. Fig. 5 shows the contour drawing of the apparent resistivity of line 04. We can see three high resistivity anomalies at 30m, 50m and 75m respectively. These anomalies can be defined as the response of the air-filled coal tunnel. Considering the geology information we get from Fig. 6, the depth of the tunnel is 50m and its thickness about 20m. We verified these results with drilling data at the depth of 30m. From these we got that the depth of the top tunnel is 48m and its thickness is 22m.

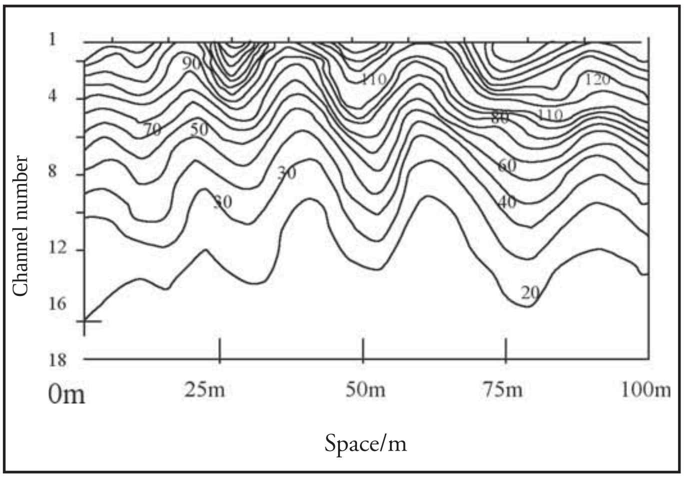


Fig. 5: The apparent resistivity contour map of the line 04

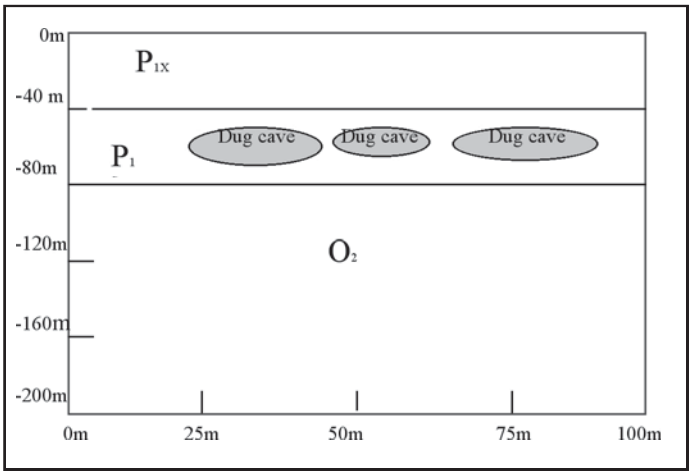


Fig.6: Interpretation of line 04

We gave the mathematical expression of TEM response's in the case of underground cavity and we also checked the ability of the method in cavities detection. We considered both high resistive and conductive caves. With the help of model analysis, we got a realistic theoretical model and this has found a successfull application on a coal mine.

TEM can be used to explore underground cavities effectively, where other methods can not be used easily; moreover, it has the deeper penetration ability and the least volumetric effect.

Although this is a simple theoretical model, the study must be intensified in more complex cases. We are currently working on more concrete and complex numerical analogues to the underground cavity using finite-differences.

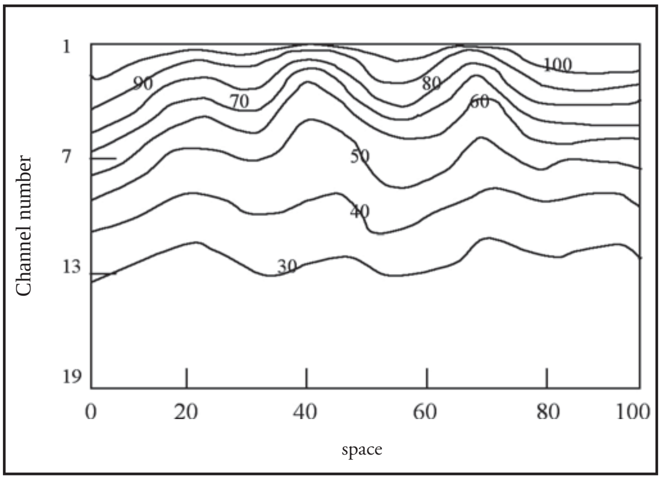


Fig.7: The contour drawing of apparent resistivity of line 41

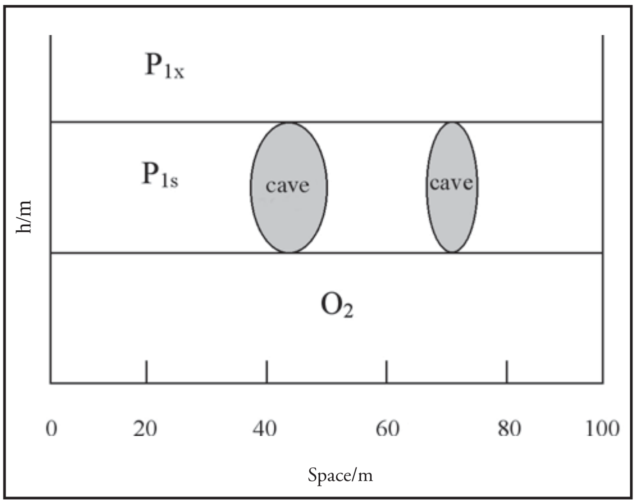


Fig.8: Interpretation of line 41

References

[1] Yanshu, Fu Jun Mei, Li Zheng The availability of transient electromagnetic method in prospect of underground cave coal geology and exploration [J]1999, Vol 27 No 2, 64-68

[2] Fang Wenzao, Li Yuguo, LiYiu, The Theory of TEM Soundings[M], North-West Industry University Press, XiAn 1993

[3] Xue Guoqiang, Li Xiu. Transform from transient electromagnetic (TEM) electric section into pseudo-seismic section [J] Journal of Oil Geophysical Prospecting, 2003, 38(4): 444-446

[4] Xue Guoqiang, Li Xiu, SongJianping, Guo Wenbo Theoretical analysis and numerical calculation of loop-source transient electromagnetic imaging [J] Chinese Journal of Geophysics 2003, 47, (2) 338-343

[5] Guoqiang,Xue, Jianping ,Song; Yanshu Detecting shallow caverns in China using TEM [J]. Leading Edge (Tulsa, OK), v 23, n 7, July, 2004, p 694-695

[6] Ding Shirong, Fang Wenzao. The transient response of a spherical geological body exited by a step magnetic dipole [J] journal of Liao Ning normal university 1997, 20, (3): 218-223

[7] Chen Mingsheng Yan Shu Shi Xianxin Xie Haijun. Time-domain behaviour of transient electromagnetic field for 2D model [J], earthquake and geology. Vol 23, No. 2 2001

[8] Nabighian. Quasi-static transient response of a conducting half-space: An approximate representation, Geophysics, 44 (10):1700–1705. 1979

[9]Oristaglio,Hohmamn W. Diffusion of electromagnetic field into a two-dimensional earth-finite difference approach. Geophysics, 49(7): 870–894.1984

[10] Ogilvy R D. A model study of the transient electromagnetic coincident loop technique[J]. Geoexploration, 1983; 21: 231–3644

[11] Niu Zhilian Time-domain electromagnetic theory [M] The Center-South University Press, Chang Sha, 1992

[12] Zhao Jingxiang. geophysical prospecting electromagnetic[M], Geological Press 1992

New Technology in the Bakken Play Increases the Number of Stages in Packer/Sleeve Completions

By Neil Buffington, Justin Kellner, James G. King, SPE, Baker Hughes, Betsy David, Andronikos Demarchos, Louis Shepard, SPE, Hess.

Abstract

The Bakken, one of the last giants to be discovered in North America, extends from Montana through North Dakota and into Saskatchewan and Manitoba provinces in Canada. The USGS, in its latest study published in April 2008 (USGS 2008), estimates that the undiscovered US portion of the Bakken Formation holds 3.65 billion barrels of oil, 1.85 trillion cubic ft of associated gas and 148 million barrels of natural gas liquids. Being classified as an oil play dependent on full well-cycle margin efficiencies to increase profitability, technology will be a main driver in the success of the development of the Bakken.

Two technologies that have been critical to the current success of the Bakken are: horizontal drilling and hydraulic fracturing. Operators typically drill on 640 or 1280 acre spacing. Typical 1280-spaced lateral lengths are over 9,000 ft, at a total vertical depth (TVD) of 9,000 ft (Miller et al., 2008). Once extended reach horizontal drilling was proven reliable, attention was turned to optimizing production from these laterals. This article will present an enhancement to an existing technology that enabled the operator to vastly increase the effective flow area created by staged hydraulic fracturing. In the process of bringing this technology to market, both the service company and the operator agreed that the true value-adding function was the process that enabled expediting the product from concept to implementation.

The development of new technology by service companies is critical for operators to expand their operations, drive operational efficiency, and work profitably in ever harsher environments that are lower on the resource triangle (Fig. 1) (Masters and Grey, 1979). Product development is sometimes performed by service companies with requirements gathered from several operators, while at other times service companies will develop products specifically to meet the needs of a single operator. This article will describe a synthesis of these processes, and the design and testing hurdles encountered, for a project that met the needs of both a single operator and the service company. The product is expected to provide continued benefit throughout the Bakken drilling and completion campaign for this operator, as well as provide a solution for the broader market for the service company. As a result of this collaborative effort, a new product was conceptualized, developed, lab tested, field tested, and taken to market in an accelerated time frame.

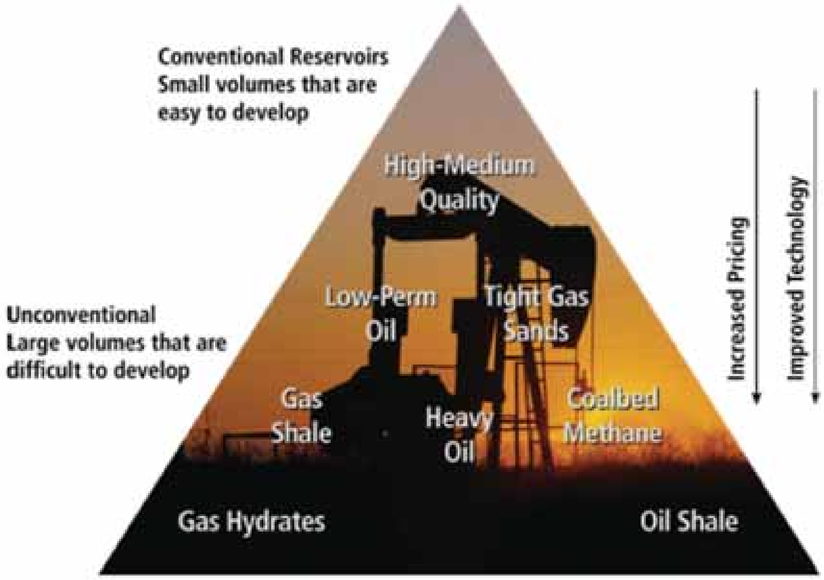


Fig 1. Resource Triangle.

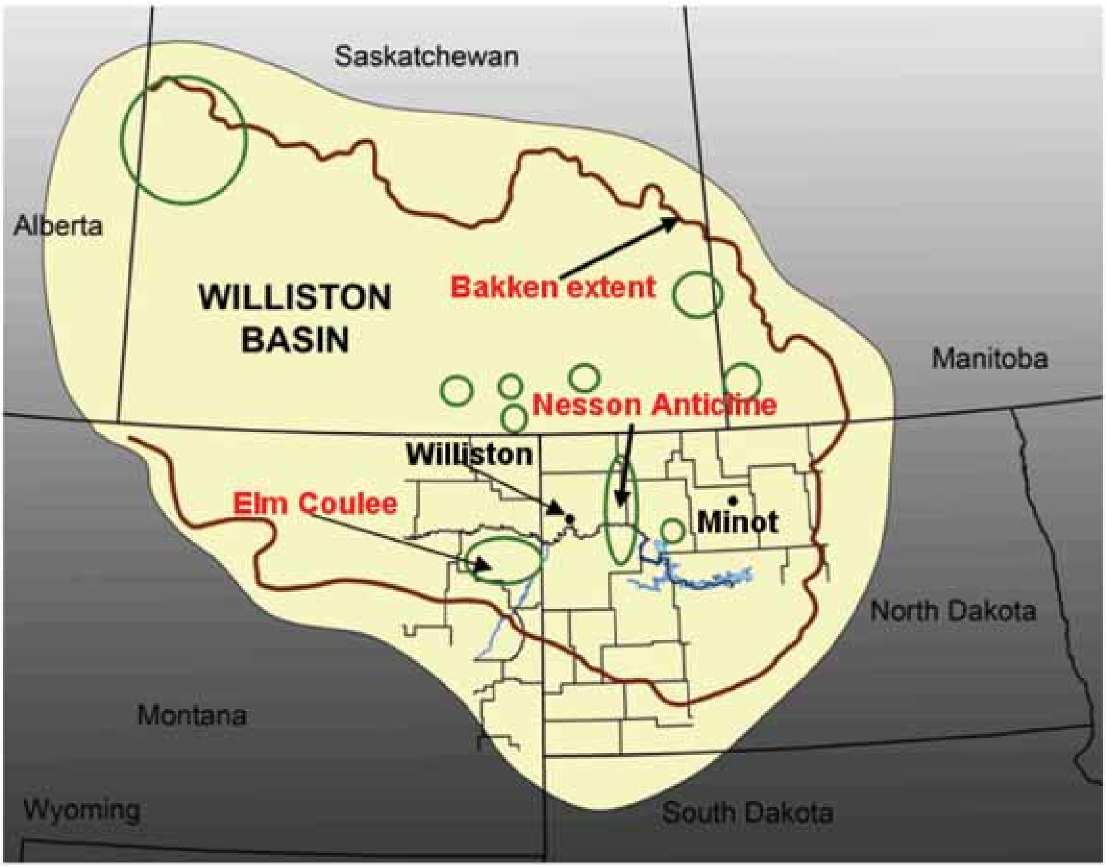


Fig. 2. Geographic location of Williston Basin and Bakken Formation.

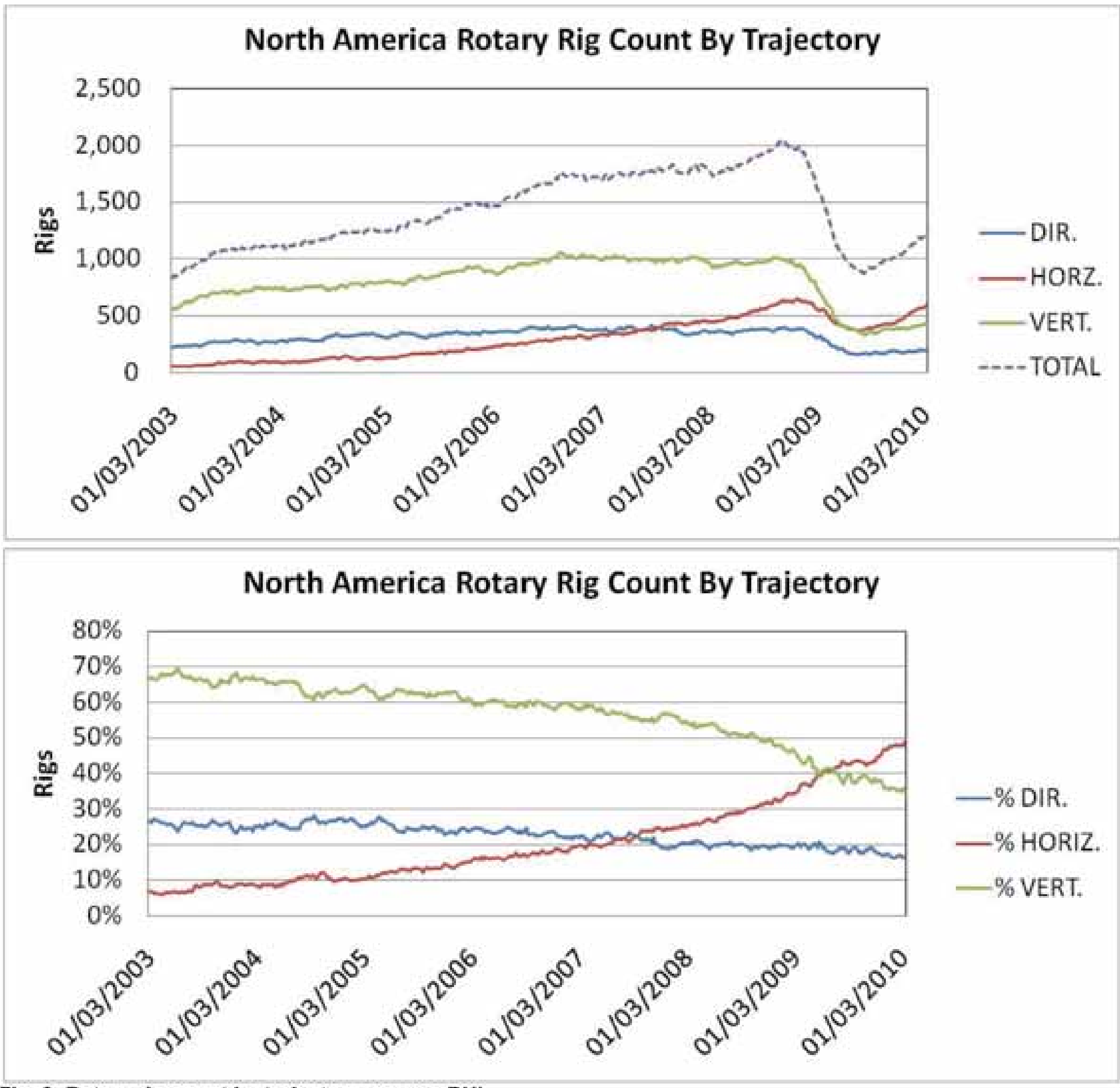


Fig. 3. Rotary rig count by trajectory, source BHI.

Introduction

Fig. 2 shows the location and extent of the Williston Basin including the Bakken formation. The Bakken formation stretches from central North Dakota through Northeastern Montana and north into the Manitoba and Saskatchewan provinces of Canada. The reservoir quality changes significantly throughout. It goes from high temperatures and over-pressured to low temperatures and normally pressured, from highly fractured to only slightly fractured, and from areas where wells have some pre-frac flow to areas that will not flow at all without stimulation. A reservoir that only flows with stimulation is called an “unconventional reservoir” (Holditch et al., 2007). Given the rapid decline of conventional reservoirs in North America, the majority of exploration and production activity is now concentrated in unconventional reservoirs, as seen by the concentrations of horizontal drilling rig activity in unconventional basins (Fig. 3). The experience and techniques from other plays, such as the Barnett Shale in Texas, have been brought to the Bakken, and adapted to the unique reservoir conditions to best extract the resource. Advancements in horizontal drilling and completion techniques in the last decade have greatly increased the oil and gas that are technically recoverable. Recent initial production (IP) announcements of 1,000 to 2,500 BOPD in North Dakota have made the Bakken play one of the fastest growing plays in the onshore US market.

Background

Oil was first discovered in the Bakken in 1951, in the Amerada Petroleum H. O. Bakken #1 in 12-157N-95W Williams County, North Dakota. Production was only economic in limited areas of Montana and North Da-

Fig. 4. OHP/S completion schematic.

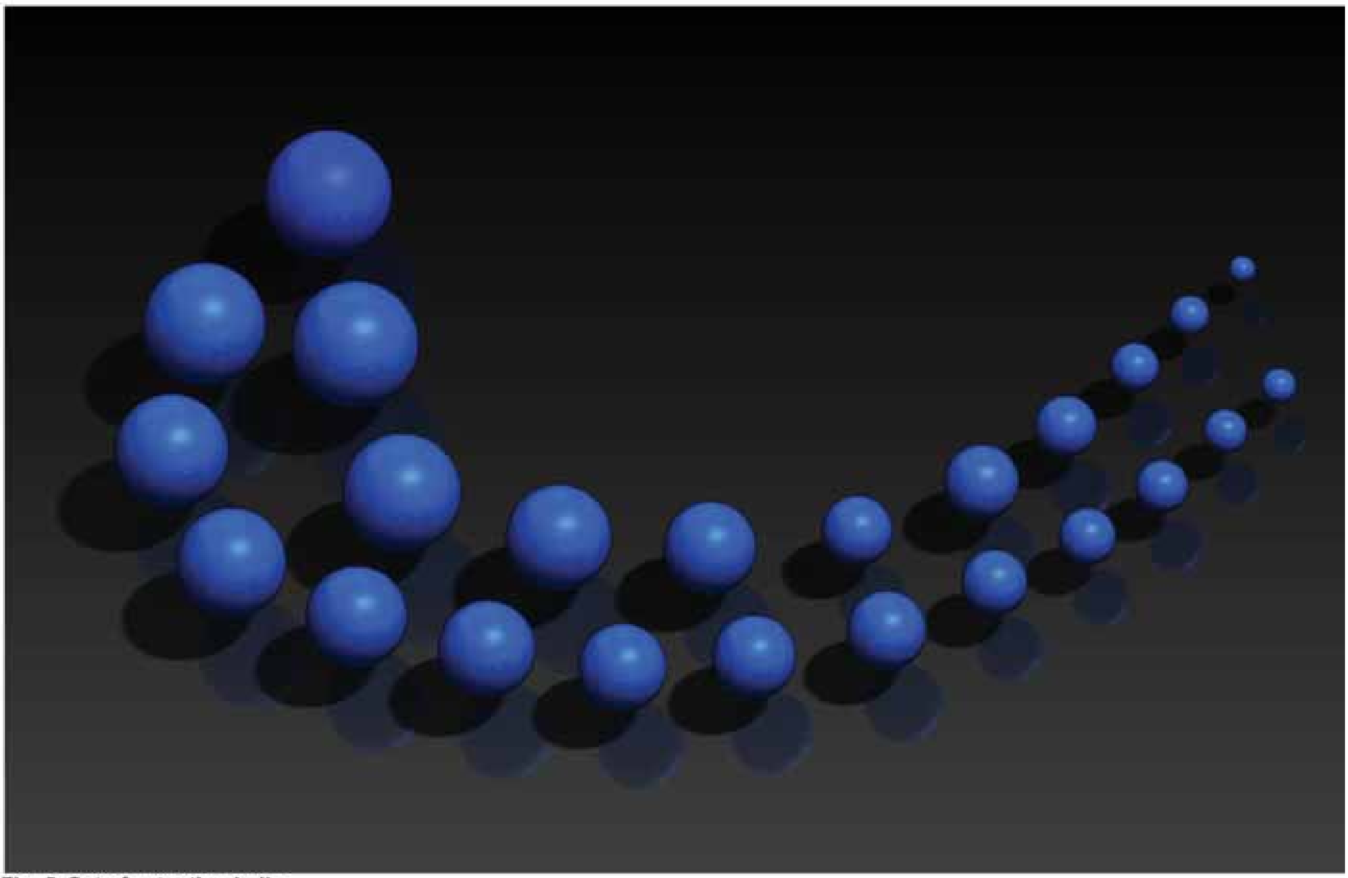


Fig. 5. Set of actuation balls.

kota in vertical wells. The operator drilled the discovery well in North Dakota in the 1950s and has maintained interest and investment in the area. They have gained significant knowledge and experience in the Bakken play.

The service company has also been actively involved in the Williston Basin since 1952, providing liner hanger and completion equipment. Through many years of cooperation and mutual benefit, the ground was laid for the development of advanced technologies to greatly expand the efficiency and effectiveness of openhole completions.

The operator's wells are drilled horizontally across two 640-acre sections (1,280-acre). Thus the common lateral length is over 9,000 ft. Operators have moved to multi-stage fracturing after determining that a single-stage fracture treatment did not effectively treat the entire lateral section. In light of the production results, multi-stage fracture treatments have become standard.

Multi-stage Fracture Treatment Methods

There are many technologies available to effect a multi-stage fracture treatment described in literature (Durst et al., 2008; Watson et al., 2008). These technologies have evolved rapidly over the past several years. The two predominant types are cased and cemented, and openhole completions.

The multi-stage openhole completion is typically performed with ball-activated sliding sleeves separated by openhole packers. In these completions, oil-swellable packers are utilized for annular isolation. In the Bakken, the openhole packer/sleeve system is preferred by many operators due to the cost effectiveness and high well efficiency of this method (Figs. 4 and 5).

A multi-stage openhole packer/sleeve completion (OHP/S) allows the operator to selectively place fluid during fracture treatments. This cost effective technique provides openhole isolation between stages. Additionally, if logging or other information from drilling so indicates, isolation can also be accomplished for fault lines, poor permeability sections, geologic hazards, or questionable water saturation sections, so the fracture fluid can be delivered to the specified section of the wells. Single-trip OHP/S offer the means to divert the fracture where desired to maximize the treatment.

Multi-stage Fracture Treatment Components

Completion systems of this type are modular and vary from application to application, but they are commonly made up of the following primary components: the liner top packer containing a tieback receptacle which is deployed with a hydraulic running tool and is set by applied hydraulic pressure, the openhole packers which are used to isolate zones, the frac sleeves which provide a communication pathway for both stimulation and production, and float equipment to control circulation while running in hole.

This type of isolation system uses specifically developed packer and sleeve technology to divert the fracture fluid to specific intervals. The assembly is run in the well in water based fluid. When the assembly is on bottom, diesel fluid is circulated around the openhole section to induce swelling of the oil-swell reactive element packers. This type of system requires an openhole element system capable of sealing in variable hole geometries (Miller et al., 2008). With the frac sleeves in the closed position and the float equipment in place, the well is secure and the drilling rig can then be moved to another location. The fracture treatment can be scheduled at a later date when the fracturing equipment becomes available (independent of rig schedule). After the fracturing surface equipment is rigged up, the first ball (the smallest ball) is pumped down to the first frac sleeve at the toe of the well. The frac sleeves are actuated by dropping a ball matched to their respective seat sizes and each stage is matched on a graduated scale from smallest (toe) to largest (heel). This action serves two major functions:

- Isolate the previously fractured zone.
- Open the corresponding frac sleeve.

The sleeves are pinned to shift open with applied differential tubing pressure across the ball. Successive increasing ball sizes are dropped to selectively actuate the corresponding sleeves and place fracture treatment in each interval across from the sleeve. Although re-closeable sleeves are available, sleeves that are designed to remain open permanently throughout the life of the completion are typically used in the Bakken. Additionally, the sleeves are rotationally locked to permit drillout of the seats, if desired.

The number of sleeves that can be run in an OHP/S system is limited by the number of ball seat increments available. The physics behind this limitation is threefold:

- The balls must have sufficient contact area on the seat, which is a function of the material shear strength of the ball.
- The balls must pass through the ID of the seats uphole from the seat that corresponds to that ball.
- The seats must have sufficient ID to permit the frac rates required for stages below without shifting open due to induced differential pressure.

At the time of the co-development project start, the industry maximum number of stages was around ten stages. Reservoir modeling and empirical data, both from the Bakken and other unconventional plays suggested that increasing the number of stages would substantially increase the productivity of the well. Therefore, the OHP/S systems must be improved to maximize the operational efficiency of the Bakken.

Design Process

Every product development company follows a specific design process to promote efficiency in an inherently difficult and iterative process. The service company uses what is called a "Stage-Gate" process. The process is comprised of Stages and Gates that describe the phases of a development project where information is gathered, decisions made, and progress measured. The system is commonly divided into customer-specific products and portfolio projects.

Customer-Specific Projects
Customer-specific projects are performed to develop products to meet a specific customer need. These projects typically fill a specific customer need but do not have a greater market requirement. Thus, customer funding and complete customer ownership of design requirements is required. Over a span of many years, this service company has completed many customer-specific projects, ranging from HP/HT to deepwater (Stuckey et al., 2002; Mason et al., 2002; Bussear and Barrilleaux, 2002). Though these projects often did find a wider market application after completion, the purpose, justification, design requirements, design process, testing, and qualification were specifically tailored to the project at hand, and were not guided by the larger market need.

Portfolio Projects
Portfolio projects are performed to develop products aimed at filling broad-based market requirements. These projects may result in individual products, product families or complete product platforms. Generally, wide surveys of market need are gathered and collated to generate the product requirements. Extensive cost, pricing, development, and strategic analysis are performed to quantify, qualify, and justify a portfolio development. Seldom is one customer's specific requirement allowed to guide a portfolio project, due to the concern of creating a product too narrow in scope for the wider market.

Amended Process
During the development of the new technology described in this article, an amended PDM process was used to accelerate time to market, and satisfy the operator's specific needs, while still focusing development effort on a product that would be acceptable to the perceived wider market.

Analysis

Benefits of Operator Collaboration in Design Process

Working with the operator throughout the design process greatly assisted in developing a product that met the needs of the operator and the general market. There were several key areas where the collaboration was specifically beneficial in expediting the delivery of the product to market.

Prior to prototype development, the statement of requirements was finalized with the operator. During the review of the initial detailed design and finalized statement of requirements, the operator raised concern over a particular component in the design, which was then redesigned. Without this collaboration, the service company design would have proceeded down a path that would have eventually proven flawed. With both the service company design team and operator's engineering group satisfied with the detailed design, the project moved forward to prototype development and validation testing.

Through collaboration with the operator, specific pass/

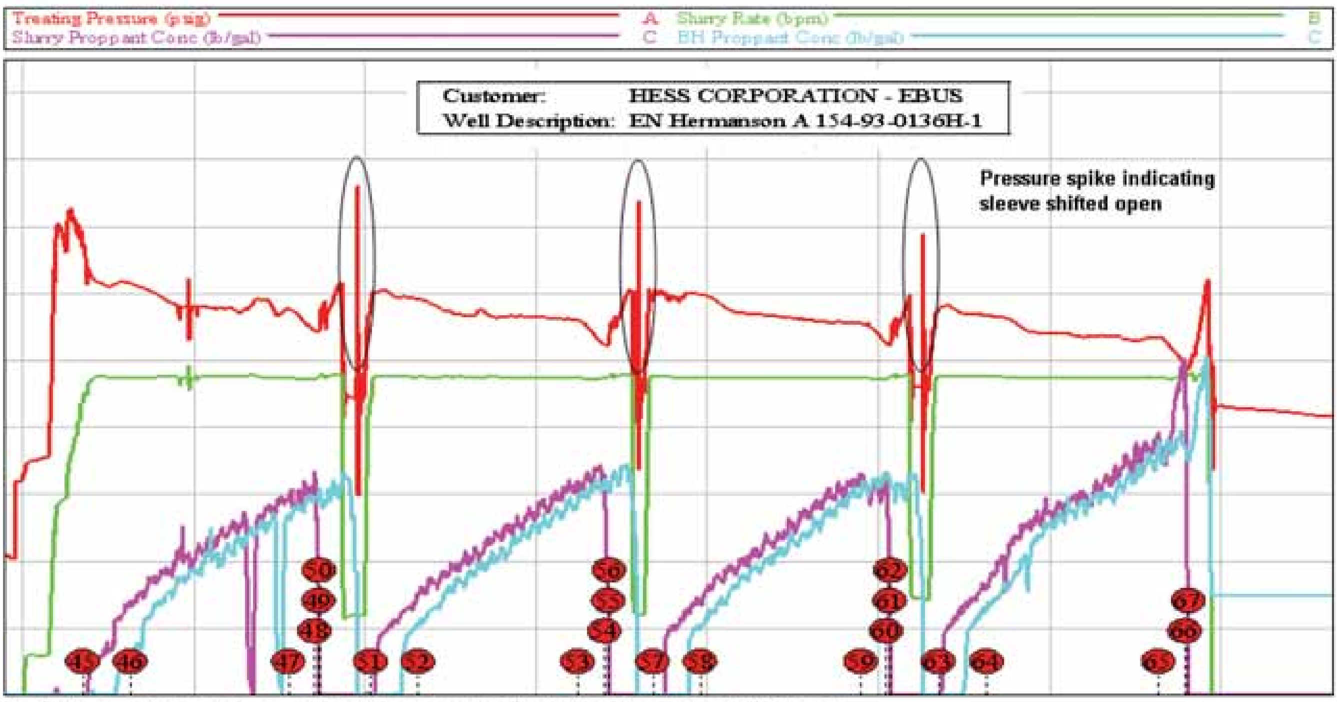


Fig. 6. Excerpt from pressure plot with pressure spike indicating sleeve shifted open.

fail criteria were developed, and testing was witnessed, to ensure the test plan did address concerns of both the design team and operator's engineering group. After the final design and test results were reviewed with the operator, an additional concern arose, resulting in a final validation test. Again, without the collaborative effort, the operator would have had less confidence in the new design. As a result of the thorough testing regime, and the clear and complete communication throughout the process, the operator had no reservations in running the first set of prototype tools in a production well. Thus, the product time to market was greatly reduced relative to a traditional project due to the easy access of a prototype run. With the first successful run, the operator was ready to include the design in their standard completion.

Design Challenge

To provide a solution in a timely manner, the design team used established and proven design elements and lessons learned from extensive testing during the development of the proven OHP/S system. The experience in the Bakken, and years of cooperation between the operator and the service company, steered the development. It became clear that the focus would be on the ball and ball seat combinations as this component of the system limits the number of stages to be fractured on a single completion.

Limits on Ball

Working with the operator, several limits were established regarding the ball alone. First, the maximum ball size for the system is driven by the operator's standard liner ID, pumping equipment/surface piping, and operational procedures. Each ball must flow through the surface piping and down the liner without hesitation, as timing to land the ball is calculated within 5 to 10 bbl of fluid pumped. This portion of the design requirements was critical since operator's company policy and operational limitations were considered.

Before each ball lands the flow rate is reduced so the operator can see a signature, or pressure spike (Fig. 6) generated on the pumping chart as the sleeve shifts. This is used as a positive indication that the sleeve has successfully shifted and the fracture treatment has been diverted into the desired interval or stage. If not timed properly, the ball will land on its corresponding seat, but the previous stage may be over- or under- flushed.

High pump/flow rates will also affect the minimum ball size run in the system. As the ball size decreases, the ID of the corresponding ball seat decreases. At the high pump/flow rates, the ID restriction creates a pressure drop across the smaller ball seats due to the reduction of the cross-sectional flow area. If a sleeve is not pinned properly, it might prematurely shift due to the pressure drop as a stage below is being treated. When isolation between stages is compromised by a premature shift, a desired interval is lost, and the operator has no way to tell which interval is being treated.

The final limitation on the ball is material density. With lateral sections of the completion over 9,000 ft, the ball must be light enough to flow through all liner restrictions (i.e. upper ball seat IDs) yet strong enough to withstand fracture pressures. Using both extensive material testing completed in the initial OHP/S system development, as well as field data, a material was chosen.

Initial Concept Generation

With a ball material chosen, the design team began looking into increasing the number of stages fractured in a single completion. Each ball essentially represents one stage to be treated. If the numbers of balls used in the system is increased, then the number of stages will increase. Driving design parameters, established through communications with the operator, included:

- Maintain treatment pressure capability.
- Double the number of stages.
- Maintain ability to flow all balls back out of the well.
- Maintain ability to mill out the ball seats.

Taking into account all ball limitations, the focus shifted to ball seat design.

Each ball in the existing OHP/S system lands on a ball seat with a fixed ID. Again tapping into the database of previous testing, it became clear that a certain contact area between the ball and seat is required for the ball to withstand the treatment differential. Given the ball properties and constraints, a ball seat with a fixed ID will not work. Simply doubling the number of stages using a ball seat with a fixed ID by cutting the ball size increment in half (i.e. ¼ in. increments to ⅛ in. increments) the contact area supporting each ball would be reduced by almost 50%. This nearly doubles the stresses on the ball. The contact area required for each ball to withstand treatment pressures is taken from the existing OHP/S system

Taking all design parameters and limitations into account, the team decided to pursue a collapsible ball seat system. The as run ID would allow all balls except for the corresponding ball to pass. After the corresponding ball lands, the ID of the ball seat is reduced or collapsed

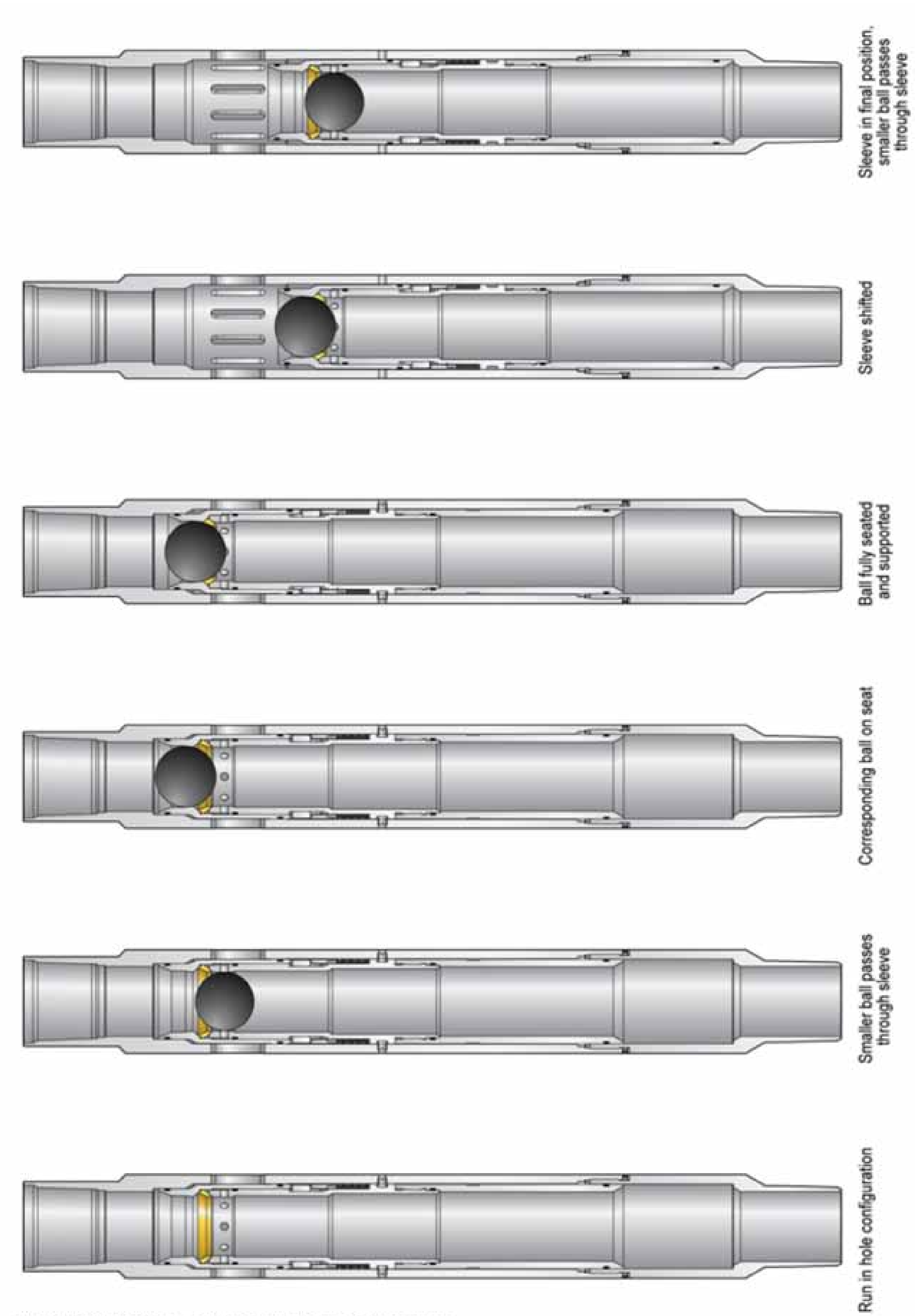


Fig. 7. Multi-position graphic of new design of frac sleeve.

to provide the contact area required to support treatment pressures. Fig. 7 shows the functional sequence of the sleeve with the collapsible seat from the run in hole position to production.

Intellectual Property Protection
After the need to develop a collapsible ball seat was clear, brainstorming began and several different ideas to satisfy the need were documented and submitted with the U.S. patent office for protection. The most feasible of the concepts generated were pursued and conceptual development continued.

Design Solution
Taking the most feasible concepts, each component of the ball seat was detailed and a plastic rapid prototype model of each was built. The models were then presented to several groups of specialists within the service company to review the design from the perspective of their respective expertise. Contributions from the multi-disciplined team from the beginning ensured the design team was in pursuit of the most efficient design.

Every feature of the existing OHP/S system was to be maintained while doubling the number of stages to be fractured. As the ball seat design moved from a simple seat to a collapsible seat containing moving parts, milling through the ball seat arose as the first major concern. If required, the operator must have the ability to mill through the seats to gain full bore access throughout the wellbore.

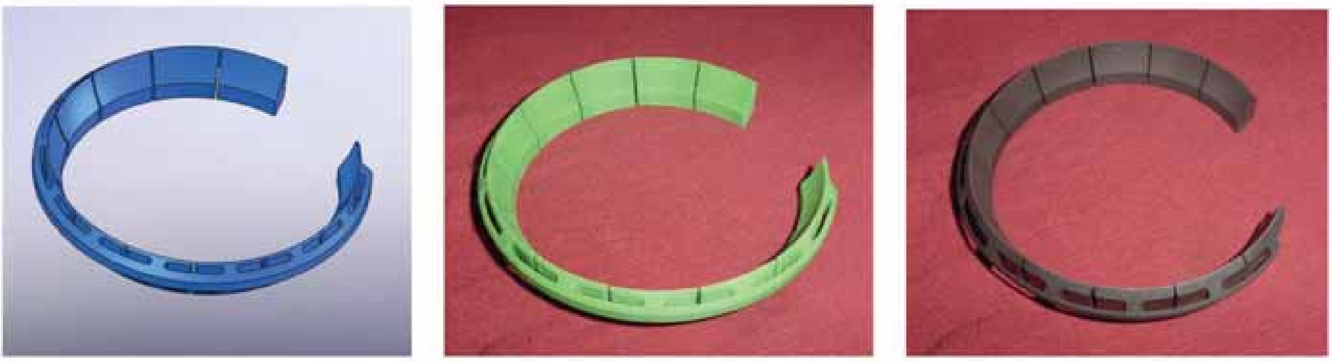
Operations and engineering personnel from the fishing group analyzed each concept in great detail, focusing on the ability of each to be milled through. After reviewing the rapid prototype model of each, the fishing group helped steer the design team toward the most feasible concept. Based on its ability to be milled, one primary concept was chosen for further development.

Product Manufacturability
Manufacturing and supply chain personnel were contacted to address the electrical discharge machining (EDM) process required to manufacture the main component of the collapsible ball seat. Due to production quantities expected, input from the manufacturing group was essential to validate the feasibility of producing the final design in sufficient quantities to meet demand. The reliability of the existing OHP/S system has been field-proven through thousands of runs. So, collaboration with the designers of the existing OHP/S system ensured all the advantages of the existing design were captured in the new design.

Collaboration of Service Company and Operator
Building on initial communication with the operator, the initial designs were presented to their engineering team as well as the personnel in the field that would be running the new system. Internally, the service company was concerned with the ability of each ball seat to be milled due to the collapsible components. During collaboration with the operator, concerns arose regarding the moving components of the ball seat becoming locked by proppant intrusion during fracture operations. After a detailed review with the operator, a development plan was finalized that would allow moving forward with a design that mitigated that risk. The plan included mill out testing and proppant extrusion testing.

Detailed Component Development and Validation
Pressure Integrity
Beginning with the pressure integrity of the chosen ball material seated on a collapsible ball seat, each concern documented during conceptual development and collaboration with the operator was addressed through component validation. Based on information gathered from previous testing, the amount of contact area generated by the collapsible ring for each different size ball is known. All previous testing was performed only on metallic ball seats. As such, a metallic collapsible ring was developed to provide the needed contact area, yet flex without yielding, allowing the ring to expand back to the as run position after the corresponding fracture operation is completed. Three-dimensional computer modeling and finite-element analysis (FEA) on concepts for different collapsible ring configurations were performed to optimize the design. Taking the design from the digital world to the actual world required EDM due to the intricate geometry. Fig. 8 shows the progression from the digital design to a functional prototype. Working closely with the prototype machine shop all test components that were needed to validate the pressure integrity and function of the collapsible components of the assembly were built.

Testing with the chosen ball material on the collapsible ball seat proved it could withstand pressures exceeding the rating of the service company's existing high performance OHP/S system. In the first round of testing the collapsible ring held the required differential, but did not fully expand back to the as run position after pressure differential was removed. This function is essential because, if the ring does not fully expand, it will act as an obstruction for all balls used to treat zones below as they return to surface during production. FEA was revisited and the design was modified and successfully retested



(a) (b) (c)

Fig. 8. Progression from (a) digital design to (b) rapid prototype to (c) actual prototype.

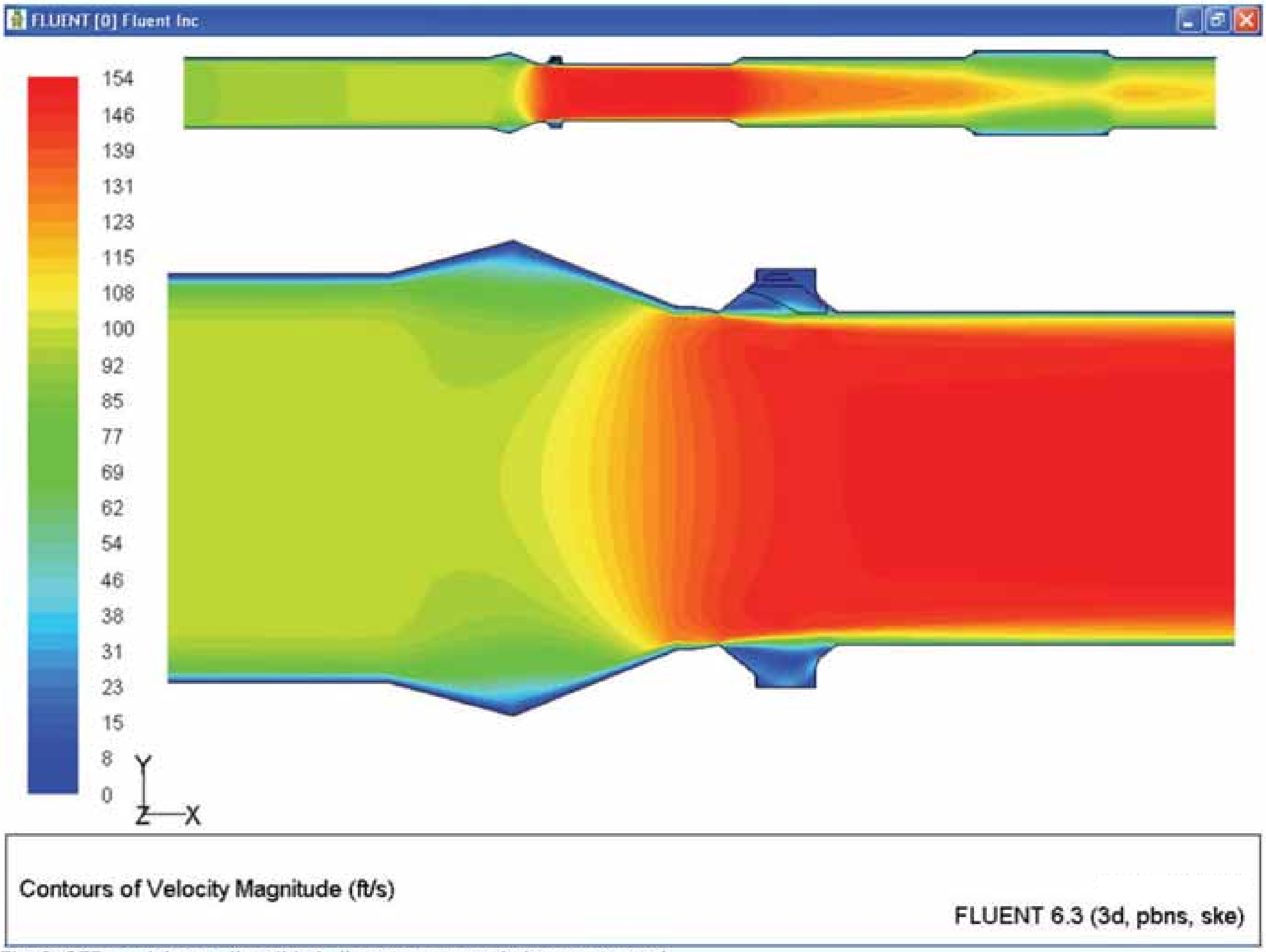


Fig. 9. CFD model on collapsible ball seat as stages below are treated.

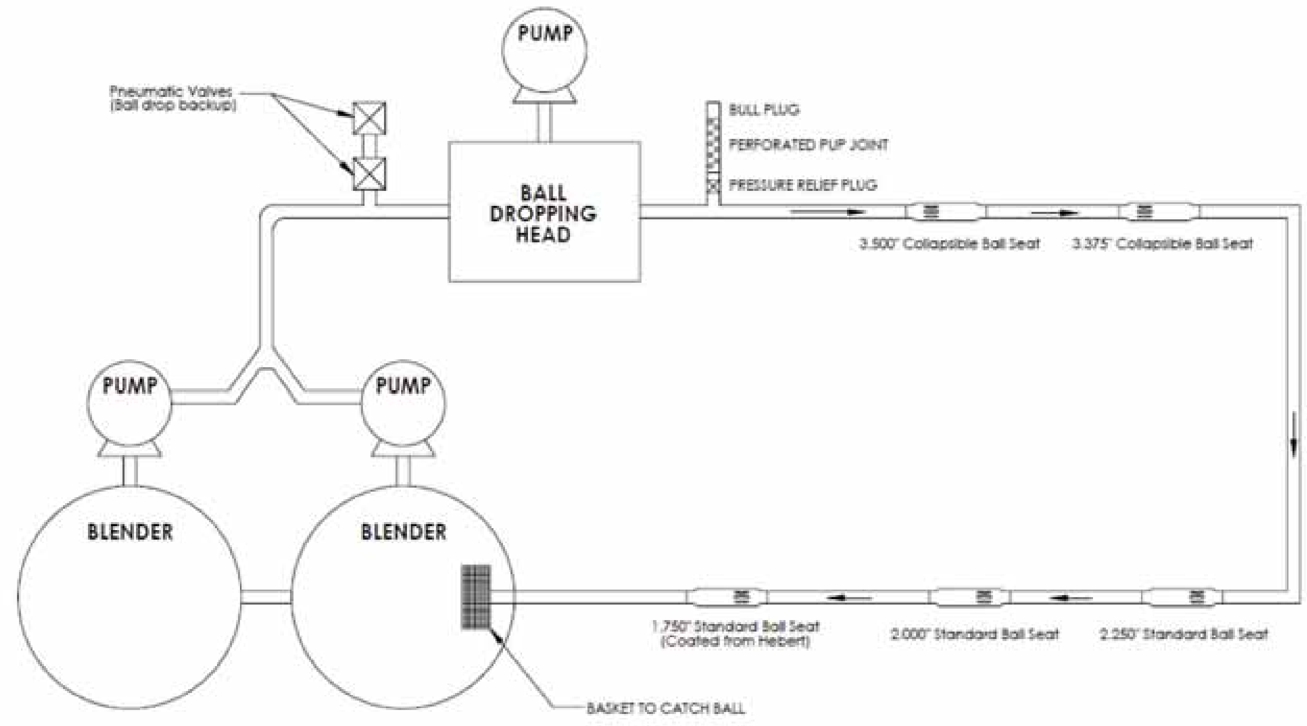


Fig. 10. Flow loop diagram

with the ring completely expanding back to the as run position.

Collapsible Ring Wash Out
Introducing the collapsible ring into the OHP/S system also introduces a relatively "free" component because the ring is not locked in place. The ring relies solely on its outward bias to keep it in place. Consequently, if the flow were to get behind the ring, there is concern that the ring could be washed out of the recess in which it sits and as stages below are treated. A computational fluid dynamics (CFD) analysis was run to ensure the ring would stay in place until the corresponding ball lands on seat. Fig. 9 shows that the high flow rates associated with hydraulic fracturing would almost completely bypass the ring.

Proppant Concerns
During the service company design process, two main concerns arose with proppant affecting the function of the collapsible ball seat. First, proppant intrusion between shifting components might cause the components to lock and not properly function when the corresponding ball lands on the seat. Two solutions were presented: Either block all proppant from critical areas with seals or create ports for the proppant that may intrude to flow out of the critical area during the collapse of the ball seat. The design team chose to add ports, but had to prove the concept valid.

A flow loop was set up to pump 500,000 lb of proppant at 20 bbl/min through one of the collapsible ball seat sleeves. Fig. 10 is a basic diagram of the flow loop layout where a ball will pass through one collapsible seat to land in its corresponding sleeve, actually shifting the sleeve open. After functioning properly and shifting open, the sleeve was disassembled to analyze proppant intrusion. Sand was found to have entered the critical area. But, upon shifting, it exited via the added ports, allowing the collapsible seat to function properly. Fig. 11 clearly shows the sand exclusion.

A second concern was expressed by the operator. The sleeve could become stuck during the fracture treatment due to sand packing off. As proppant is diverted by the ball landed on the collapsible sleeve to the formation at flow rates exceeding 60 bbl/min, it may fall out of the frac slurry and lock the seat in the collapsed position, thus preventing balls in previous stages from being able to flow back once the well is placed on production. In addition to the flow test, a second test was run with proppant, in the test lab. Proppant was packed on top of a shifted ball seat and then pressured up to simulate the treatment operation. The ball seat was found to have fully expanded back into the as run position, indicating that the design was sound.

Milling
After the pressure integrity was addressed and proppant

. 11. Sand exclusion and debris flow ports.

was proven not to affect the function of the tool, mill tests were arranged to prove the ball seat could be milled through if desired. Although the anti-rotation feature of the sleeve was carried over from the existing field-proven design, one component in the collapsible ball seat design is not rotationally locked. In the first milling test, the collapsible ring broke into segments rather than being completely milled through. The resulting segments were too large and could possibly stick a string of coiled tubing used during the mill operation in the hole.

The results of the mill tests were analyzed and the design of the collapsible ring was revisited. Upon further review, the geometry allowing the collapsible component to be flexible enough to provide the support required yet maintain high pressures presented issues during mill out validation. Rotationally locking the collapsible ring will not help to mill through the collapsible ball seat, as it would still break up into large segments.

Collaboration with the operator at this point of the development was extremely beneficial in finding a solution in a timely manner. As mentioned above, the performance and rating of the collapsible ball seat with a metallic ring exceeded that of the proven OHP/S system. So, when the milling issues arose, collaboration with the operator led to a design specifically satisfying their particular completion and fracture treatment requirements. If not for the open communication with the operator, the design team would have essentially had to start the design process over from the beginning to find a solution that would meet these original requirements. By adjusting the target requirement of pressure differential in the middle of the project, the costs of further development, and time to market were saved.

Optimized Solution

With both parties agreeing to a new pressure rating, nonmetallic options for the Flex Ring were visited. A new, easily milled nonmetallic material was function- and pressure- tested. The new material provided a solution that optimizes the sleeve's performance in the operator's well, not only holding the required differential across the ball seat during the fracture treatment, but allowing upward passage of the smaller balls from previous stages, and providing easy and reliable mill out when required.

Application

To confirm the performance of the equipment before converting the standard Bakken completion over to the new collapsible seat design, two prototype runs were performed on the EN-Hermanson A-154-93-0136H-1 and EN-Hanson-156-94-3031H-1 wells. These jobs were run in July and August of 2009. Both jobs were single laterals and were run without incident. Approximately one month after each installation, each well was fractured and the tools performed as designed (Fig. 6). Immediately after the successful fracture treatment of the second well, the standard completion method was converted over to the new sleeve design, starting with the EN-State B-155-93-1609H-1 in September, 2009. This well was deployed with the full complement of 18 stages (Fig. 12).

Job Procedure

The procedure used for both prototype runs as well as the full operational runs mirrors the procedures used in previous OHP/S jobs; the only difference is the greater number of sleeves and openhole packers deployed (Appendix 1).

Conclusions

The collaboration that existed between the operator and the service company was utilized successfully to create this new system for Bakken completions. This process is still being utilized to develop other tools and is expected to continue to benefit both parties.

Lessons learned include:

• Service/operator company collaboration can accelerate

Fig. 12. As Run drawing.

time to market for new high performance products.

• Cross-functional teams shortcut the iterative design-test-redesign-retest process in new product development by incorporating knowledge and input from people of diverse backgrounds and experience.

• Flexibility to revisit original requirements when facing development hurdles hastens time to market.

• Testing to requirements/requests of the operator smoothes the transition from product development to field implementation.

The field deployment of the collapsible ball seat design in the frac sleeves in the Bakken has been a complete success. Thus far, the equipment has performed flawlessly during run in and frac treatments. None have required the contingency mill out discussed above. The operator is pleased with the production improvement resulting from additional fracture stages, and the system has become part of the base design of the operator's Bakken completions.

Nomenclature

BHA – Bottomhole Assembly
BOPs – Blowout Preventers
HP/HT – High Pressure High Temperature
ID – Internal Diameter
OHP/S – Openhole Packer and Sleeve System
PU – Pick Up
SO – Slack Off
TIH – Trip In Hole
TVD – Total Vertical Depth
USGS – United States Geological Service

Aknowledgements

The authors would like to thank Hess Corporation and Baker Hughes for permission to publish this paper and for their assistance in preparing the paper.

References

Bussear, T. and Barrilleaux, M. 2004. Design and Qualification of a Remotely-Operated, Downhole Flow Control System for High Rate Water Injection in Deepwater. Paper SPE 88563 presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 18-20 October. doi: 10.2118/88563-MS.

Durst, D.G., Harris, T., Contreras, J.D., and Watson, D.R. 2008. Improved Single-Trip Multistage Completion Systems for Unconventional Gas Formations. Paper SPE 115260-MS-P presented at SPE Tight Gas Completions Conference; San Antonio, Texas, 9-11 June. doi: 10.2118/115260-MS.

Holditch, S.A., Perry, K., and Lee, J. 2007. National Petroleum Council Topic Paper #29, Unconventional Gas; 21 February.

Mason, J.N.E., Moran, P., King, J., and Cameron, P.D. 2001. Interventionless Hydrostatic Packer Experience in West of Shetland Completions. Paper OTC 13288, presented at the Offshore Technology Conference, Houston, Texas, 30 April – 3 May. doi: 10.4043/13288-MS.

Miller, B. Paneitz, J., Yakely, S., and Evans, K. 2008. Unlocking Tight Oil: Selective Multistage Fracturing in the Bakken Shale; Paper SPE 116105-MS; presented at SPE Annual Technical Conference and Exhibition, Denver, Colorado, 21-24 September. doi: 10.2118/116105-MS.

Pollastro, R.M., Cook, T.A., Roberts, L.N.R., Schenk, C.J., Lewan, M.D., Anna, L.O., Gaswirth, S.B., Lillis, P.G., Klett, T.R., and Charpentier, R.R. 2008. Assessment of undiscovered oil resources in the Devonian-Mississippian Bakken Formation, Williston Basin Province, Montana and North Dakota, 2008: U.S. Geological Survey Fact Sheet 2008–3021, 2 p. J.A. Masters; Deep Basin Gas Trap, Western Canada; AAPG Bulletin (1979) 63, No. 2: 152.

Stuckey, J., Urban, L., King, J., and Melancon, A. 2002. Mudline Tubing Hanger Experience in Auger-Gulf of Mexico Wells; Paper SPE 77629; presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, 29 September-2 October. doi: 10.2118/77629-MS.

Watson, D.R., Durst, D.G., Harris, T., Contreras, J.D. 2008. One Trip Multi-Stage Completion Technology for Unconventional Gas Formations; Paper SPE 114973-MS-P, presented at the CIPC/SPE Gas Technology Symposium, Calgary, Alberta, Canada, 16-19 June. doi: 10.2118/114973-MS.

Appendix 1. Running Procedure

Notes: Limit circulation pressure and rate to not exceed 700 psi or bbl/min.

1. Obtain tally from company hand. (drill pipe, liner, etc.)
2. Verify drill pipe thread.
3. Verify drill pipe tube ID. Ensure that IDs used in calculations are tube ID and not tool joint ID. Notes: Visually inspect ID of drill pipe to verify the internal upset.
4. Verify minimum IDs for setting ball
5. Check all tools and crossovers to verify presence on location.
6. Hold a safety meeting to discuss the job.
7. Use liquid locking compound on the float shoe and float collar. (Torque to spec)
8. Pick up and run the liner, swell packers, and frac sleeves in order as per recommendation. Make the tools up and run in the hole at a speed recommended by the service tool hand on location. Fill the liner and break circulation as needed.
9. Figure capacities and verify procedures while picking up liner.
10. After liner BHA is run in hole, switch over to the drillpipe elevators and pick up liner running tools. Make up tools. Rig down the casing crew.
11. Fill liner after first joint run in hole.
12. Get liner weight. Notes: Do not run any floats, inside BOPs, or any other check system in the drillpipe string. We must be able to drop and pump a setting ball to seat.
13. TIH slowly. (1½ min to 2 min per stand) Notes: Dope the pins only on the drillpipe. Do not lock the rotary table. The tool safeties to the left. Do not allow backlash. Fill pipe every row. Break circulation as needed.
14. Once on depth, get the PU/SO weights. Rig up pump company.
15. Break circulation. Notes: Displace any desired fluids (ie. diesel, etc.) at this time. After the hanger with pack-off is set, you will no longer be able to circulate! Drop 1-7/16 in. Kirksite setting ball. Allow to fall at a rate of 5 min. per 1,000 ft. Pump to seat at an idle. (2–3 bbl/min.) Seat ball and pressure up to 2,500 psi to set the hanger packer. Bleed off the pressure and push/ pull minimum of 50K to verify the packer is set.
16. Bleed off the pressure. Close in the annulus and pressure test the packer.
17. Bleed off the pressure. Hook back up to the drillpipe. Find neutral point with the bumper sub and slack off 50K of drillpipe weight. Kick in the pump and pressure up to 4,500 psi to open the bar ball sub and hydraulically disconnect the running tools. Bleed off pressure and pull up to verify you are released. If you cannot hydraulically disconnect, then bleed off all pressure and come to 10K of drill pipe weight slacked off. Rotate the drillpipe one turn to the left to safety out of the running tool.
18. Roll the hole to displace the hole as per recommendations.
19. POOH and lay down tools.

Meet Your New DGS Executive Committee

The Dhahran Geoscience Society's 2010-2011 Executive Committee officially took office on June 1. Members of the new Committee are listed below, followed by their biographies, photos, and post-election statements.

Thanks to all DGS members who voted in the election in May, and to Saudi Arabia Oil and Gas for printing the new DGS Committee.

President	Mohammad Al-Otaibi
President-Elect	Saleh Al-Dossary
Vice-President	George Haichao Yu
Secretary	Sarah Gilliland
Treasurer	Ahmed Daghistani
Monthly Meetings Chairperson	Saeed Hilal Al-Ghamdi
Publications Chairperson	Garth Jahraus
Field Trips Chairperson	Djafar Aitsaadi
Professional Development Chairperson	Yasmina Kechida
Membership Chairperson	Mansour Alyahyaey
Academic Development Chairperson	M. Asgharuddin Ahmed
Public Relations Chairperson	Assa'ad Ghazwani

President: Mohammed Al-Otaibi

Mohammed Al-Otaibi is a geophysicist working in Saudi Aramco's Geophysical Technical Services Division (GPTSD). His career with the company started as he was enrolled in the College Preparatory Program in 1985. After getting his Bachelor of Science Degree in Geophysics from KFUPM in 1990, he worked as a seismic processor. He attained his Masters Degree from Rice University in 1994, and later worked as a seismic interpreter in Saudi Aramco's Reservoir Characterization Department. Mohammed continued interpreting 3D seismic data after completing his Ph.D. in Geophysics at the University of Houston in 2002. His interpretation work has spanned clastic and carbonate oil and gas reservoirs. Since 2007, Mohammed has been working with GPTSD, providing technical support in the fields of seismic modeling, AVO, and inversion. He is a member of the SEG and EAGE, and has presented several papers at SEG, EAGE, and GEO conferences.

Mohammed is a member of Toastmasters International, and was the president of the Dhahran Toastmasters Club in 2003. In this regard, he enjoys training new employees how to present professionally and effectively. He also loves reading and writing articles related to self-development topics.

"I would like to thank all DGS members for the trust they put in this new Committee, and I promise to carry the DGS torch to even higher altitudes! Exciting and innovatively designed dinner meetings, rich educational sessions with quality distinguished lecturers, more prominent roles for students and young talents, as well as memorable field trips are all awaiting you! We promise to carry those and more in a creative way! Thanks again for your trust!"

President-Elect: Saleh Al-Dossary

Saleh Al-Dossary received his Bachelor of Science Degree in Computer Science, with a minor in Geophysics, from the New Mexico Institute of Mining and Technology in 1991. He received his Masters of Science Degree in Geophysics in 1997 from Stanford University, and in 2004, he received his Ph.D. in Geophysics from the University of Houston.

Saleh's career with Saudi Aramco has included development of edge-preserving and smoothing techniques in the company's Geophysical Research Group, and development of new seismic attributes, pre-stack depth migration algorithms, and other seismic techniques in the Exploration Application Services Department.

Saleh has two patents in seismic edge-preserving and detection technology. He is the author and co-author of several articles published by the Society of Exploration Geophysicists (SEG). Saleh received the Distinguished Employee Award in Saudi Aramco's Exploration Application Services Department in 1999, and the Outstanding Student Award from the University of Houston in 2003. He is currently a member of the SEG, the European Association of Geoscientists and Engineers (EAGE), and the Dhahran Geoscience Society (DGS). In 2000, he served as the Professional Development Chairman for the DGS.

"Thank you for electing me as the President-Elect for the DGS for 2010-2011. I am committed to continue the success of this great organization. I reiterate my commitment to continue the great work of my predecessors. Together with the newly elected DGS Executive Committee, I will focus on activities that enhance the knowledge, intellectual growth, and collaboration of our membership. My personal goal is to increase membership participation and to ensure that activities such as technical presentations, field trips, social activities, and dinner meetings meet the needs of the membership. I am passionate and committed to making the DGS both fun and valuable to our members."

Vice President: George Yu

George Haichao Yu holds a Ph.D. in Geological Sciences from Indiana University (USA) and a Professional Geologist registration in the USA, specializing in groundwater exploration, water resource management, groundwater modeling, remediation, and aqueous geochemistry. Prior to joining Saudi Aramco in 2006, George's experience included 14 years of environmental consulting in the USA and seven years with the Ministry of Geology and Mineral Resources of China. George is currently working in the Groundwater Division of Saudi Aramco's Reservoir Characterization Department. He is a member of the Geological Society of America (GSA), the America Geophysical Union (AGU), and the American Association of Petroleum Geologists (AAPG). George served as Secretary of the DGS during the 2007-2008 term, and he is currently the Society's Vice-President.

If re-elected, George will work closely with the DGS President and the Executive Committee to better serve DGS members and to focus on promoting geosciences. His vision for the Society is that of a regional organization affiliated with selected international organizations, with strong membership and clear focus on promoting geosciences among professionals in the Middle East.

"I thank all members for the trust being placed in me to serve as the Vice-President of the DGS. This is my second term serving the Society, and I shall use my experience to assist the President and the Executive Committee to make the DGS a fascinating organization for all its members – by offering well-planned field trips, technical and social programs, and networking opportunities. Looking forward, I feel the DGS is well poised to continue to be the most influential geoscience organization in the region."

Secretary: Sarah Gilliland

Sarah Gilliland joined Saudi Aramco as a secretary in 2002. She has a Bachelor of Arts Degree in Hotel and Catering Management and a Post-Graduate Diploma in Administration and Law.

Since 1991, Sarah has volunteered on, and led, working holidays with the British Trust of Conservation Volunteers, on habitat management and biodiversity projects -- from tree planting and dry stone walling in Northern Ireland, to chalk grassland management in France, to mangrove study with turtle monitoring in Thailand.

"I hope to continue to help the DGS operate effectively – including being proactive in the process to document all responsibilities and processes for each role on the Executive Committee. This will serve as a way to efficiently transfer knowledge to future Committee members."

Treasurer: Ahmed Daghistani

Ahmed Daghistani received his Bachelor of Science Degree in Geophysics from King Abdulaziz University in 2003. After graduation, he joined Saudi Aramco as a contractor, working on a core description digitization project in Saudi Aramco's Geological Technical Services Division (GLTSD). In 2005, he received a Contribution Award from the division. The same year, Ahmed was hired by Saudi Aramco, where he has since been working as a geophysicist in GLTSD's Modeling and Inversion group. In April 2009, he graduated from the company's Professional Development Program.

Ahmed's vision for the DGS is for the Society to be one of the biggest in the world – organized, professional, and efficient.

"I would like to thank those who have elected me to this position. I promise that I am going to do my best to improve the quality of work as much as I can. What I have in my mind currently is to have all things related to payment to be online rather than physically paying to the DGS. I would like to see the future of the DGS to be to the best, through hard work from all the members."

Monthly Meetings Chairperson: Saeed Hilal Al-Ghamdi

Saeed Hilal Al-Ghamdi joined Saudi Aramco in 1979, and worked as an electrician in the company's Mechanical Services Shops Department until 1988. During that time, Saeed completed all Aramco school requirements. He then went to King Abdulaziz University, where he received his Diploma in geophysics. Saeed subsequently returned to Saudi Aramco, in the company's Geophysical Data Processing Division.

In 1991, he went to Salem State College to get his Bachelor of Science Degree in Geological Science. After graduation, Saeed joined Saudi Aramco's Geophysical Data Processing Division, where he worked in the division's Near-Surface Modeling Team until 2002. Since then, he has been working on a 2D/3D seismic processing team in the same division..

"I will do my best to serve the committee and to make another successful year by organizing the monthly meetings in a professional manner."

Publications Chairperson: Garth Jahraus

Garth Jahraus graduated from the University of Alberta in 1973 with a Bachelor of Science Degree with Specialization in Geophysics. After graduation, he worked for Mobil Oil Corporation – in Calgary, Dallas, and Dhahran (seconded to Saudi Aramco). After leaving Mobil in 1981, Garth worked for Mitchell Energy in The Woodlands (Texas), Enserch in Abu Dhabi and Dallas, Veba Oil Operations in Tripoli, Libya, and Western Atlas/Baker Hughes in Houston. Work assignments with these companies included prospect generation, and reviews and recommendations of numerous farmout offers worldwide.

Garth has been with Saudi Aramco since December 2000, in the company's Area Exploration Department. His duties include reviewing and editing well proposals, reviewing and editing technical documents for publication or presentation outside Saudi Aramco, and a number of other responsibilities.

It is my goal to continually improve our Society's newsletter, 'The Oil Drop'. The more members that contribute to our newsletter – in form of articles, suggestions, and feedback – the more it can be improved. I look forward to hearing from you.

Field Trips Chairperson: Djafar Aitsaadi

Djafar Aitsaadi graduated from the Algerian Petroleum Institute in 1985, with a Bachelor of Science Degree in Geophysics. After graduation, Djafar worked as a petrophysicist with Sonatrach Algeria, and served in the military. In 1989, he received his Masters of Science Degree in Geophysics from University Pierre et Marie Curie Paris IV (France). Djafar was then hired by CGG Paris, where he processed 2D and 3D seismic data. His career with CGG also took him to Libya and the United Kingdom, where he continued in seismic processing.

In 2001, Djafar joined Saudi Aramco as a processing geophysicist in the company's Geophysical Data Processing Division.

During his spare time, he enjoys running and windsurfing.

Thank you all for voting for me.
I will do my best to organize geological trips in and outside of the Kingdom, and will make your dreams come true with a Mada'in Saleh trip.

Professional Development Chairperson: Yasmina Kechida

Yasmina Kechida received her Bachelor of Science Degree in Geology (with an option in Geochemistry) from the University of Paris XI in 2000. In 2001, she received her Masters Degree in Geology (with an option in Sedimentology) from the same university. In 2003, Yasmina received a Masters Degree in Petroleum Geosciences from IPF (French Petroleum Institute). Before joining Saudi Aramco in April 2009, Yasmina's career involved assignments with Total and GDF in Paris, Schlumberger in Congo and Gabon, Paradigm in France and London, and Techsia in France. During her career, her work has involved sedimentology, geochemistry, petrophysical modeling, sequence stratigraphy, and log analysis. Yasmina currently works in Saudi Aramco's Reservoir Characterization Department, where she is involved in special studies in the department's Geological Modeling Division.

Yasmina's interests include swimming, history, geopolitics and first aid. She is a member of the European Association of Geoscientists and Engineers (EAGE), the Society of Petroleum Engineers (SPE), and the Dhahran Geoscience Society.

My main objectives while on the new DGS Executive Committee include bringing to Dhahran valuable people to share the latest news about geosciences, having a look at the different subjects of interest to the world, and understanding better the events that affect the world today. I hope that you will enjoy the dinner meetings, as I will enjoy sharing with you the best of the geosciences. I would like to thank all the DGS members who voted for me, Mohammed Otaibi, our new DGS President, and all the newly elected members of the Committee. We wish you the best for this new year with the DGS.

Membership Chairperson: Mansour Alyahyaey

Mansour Alyahyaey joined Saudi Aramco in 2004. He received his Bachelor of Science Degree in Exploration Geophysics from the University of Oklahoma in 2009. Mansour currently works on the Near-Surface Modeling Team in Saudi Aramco's Geophysical Data Processing Division. Throughout his college years, he attended several Society of Exploration Geophysicists (SEG) conventions.

Mansour's main interests include seismic processing and modeling, in particular multiple attenuation and near-surface problems. In his free time, he enjoys traveling and experiencing different cultures, as well as watching and playing football and basketball.

Mansour's vision for the DGS includes more short courses on various geoscience-related topics, as well as initiating online access to publications such as GeoArabia.

*"I would like to thank the DGS members who trusted me and gave me their vote.
As the new Membership Chairperson, I pledge to increase the number of members (especially college students) and to continue to provide social gatherings for our members such as field trips and technical meetings."*

Academic Development Chairperson: M. Asgharuddin Ahmed

Mohammed Asgharuddin Ahmed graduated from Osmania University in 1988 with a Bachelor of Science Degree specializing in Mathematics and Physics. In 1990, he attained his Diploma in Computer Studies in the U. K.

Mohammed began his career designing and implementing communications networks in Riyadh. From 1998 to 2002, he worked for Riyadh Bank, implementing and certifying computer networks.

Currently, Mohammed is working at Prince Mohammad University as a communications infrastructure designer. In November 2009, he attained the professional qualification of RCDD (Registered Communications Distribution Designer), awarded by BICSI (Building Industry Consulting Services International).

Mohammed joined the Dhahran Geoscience Society in 2009.

Dear Members: Thank you for electing me to the DGS Executive Committee. I consider it a great honor to be a part of this Committee. I want to let all the DGS members know how gratifying it is to receive your support and encouragement. I am fully aware of the hard work and achievements of the previous members of the society and shall strive to build upon their successes. I am excited to have been elected to this position of Academic Development Chairperson. I have long had an interest in the cause and activities of the society. I am eager to serve DGS in concord with all the executive committee members for the benefit of all. Once again, please accept my sincere thanks and I look forward to your suggestions and support

Public Relations Chairperson: Assa'ad Ghazwani

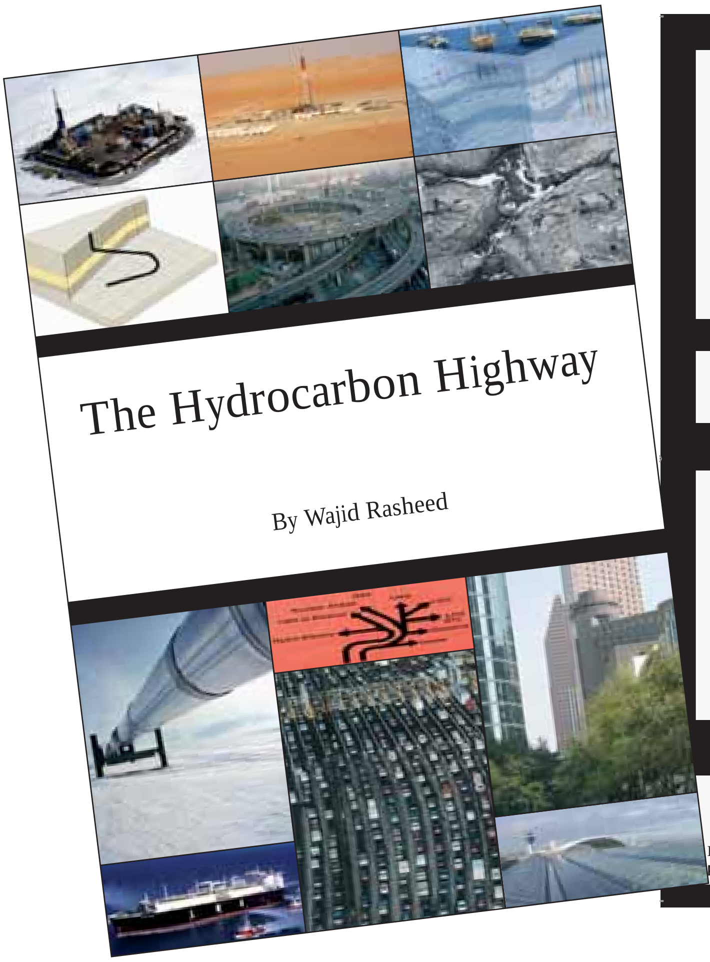
Assa'ad Ghazwani graduated with a Bachelor of Science Degree in Geology from King Abdul Aziz University in Jeddah.

He joined Saudi Aramco in 2004, and is now a geochemist with the company's Regional Resource Assessment Division.

Assa'ad is currently studying for his Masters of Science Degree in Petroleum Geology at King Fahd University of Petroleum and Minerals.

My mission is to amplify the previous effort of sharing knowledge and contributions between the DGS and other GCC geoscience societies, as well as obtaining DGS funding from sponsors in order to support DGS activities.Finally, I would like to express my appreciation to those who voted for me for this term.

Pregnant Ladies and Fish Bones




"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

Striking oil relies on Exploration and Production processes. This chapter presents standard well planning and construction methods. It concludes with geo-steering, expandable tubulars and digitalisation case histories.

Designer, horizontal and multi-lateral are common well types which are drilled to enable access to hydrocarbon reserves, lower field development costs and improve production. 'Pregnant ladies and fish bones' describe complex twisting well-paths that have become necessary to access and drain numerous reservoirs into a single wellbore[1].

Before the process of well engineering can begin, however, oil companies must complete a series of other activities. In sequential order, these range from geophysical surveys to well planning to drilling and completions. Later, we will present case studies of geo-steering, expandables and digitalisation.

Seismic

X-rays enable doctors to 'see' inside the body and locate injuries without using a scalpel. Similarly, seismic

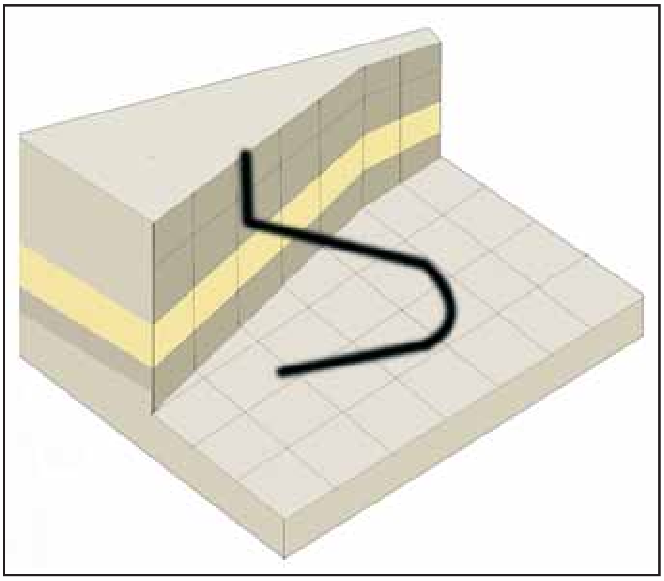


Figure 1 - Pregnant Lady Well Profile

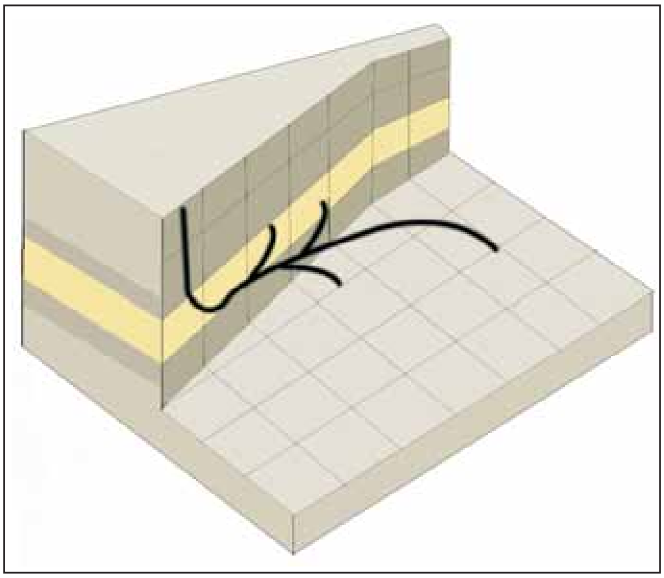


Figure 2 - Fishbone Well Profile

enables scientists to 'see' inside the earth and locate potential hydrocarbon-bearing structures without using a drill bit[2].

An acoustic means of investigating the earth, seismic is used by oil companies to locate potential hydrocarbon-bearing structures within their acreage. Shooting seismic is the first step in reducing the risk accompanying oil and gas exploration. It enables the Geophysical and Geological team (G&G) to 'look' deep into the oil company's acreage and interpret the type and geometry of rocks contained therein.

In this way, hundreds of square kilometres with vertical depths reaching two miles (six km) or more can be imaged without incurring the time, financial and

Figure 3 - Seismic Provides An X-Ray Image Of The Earth

environmental costs of drilling several dry holes. With diligence, geoscientists will find 'bright spots' – the industry term for a potential hydrocarbon reservoir. Bright spots will often form the basis of top drilling prospects. In this way, seismic allows the rapid and effective imaging of vast surface areas and the pinpointing of reservoir locations and properties. Drilling on bright spots is not a 'slam-dunk' as several International Oil Companies (IOCs) discovered in the early 1970s in offshore Florida. The bright spots were clearly there, but only a drop of oil was found.

Sound Waves

Shooting seismic essentially relies on a 'source' that emits sound waves ranging from 1 to 100 hz, and a 'geophone' that records the reflected waves as they 'bounce' back from different rock formations. This data is mapped by powerful computers using thousands of processors to yield 'processed' seismic information. This information forms 'seismic' sections which usually represent 10 km depths of the earth at a time[3].

The G&G team pores over these sections gaining knowledge of formation thicknesses, locations, beds, dipping planes and the all-important potential oil and gas reservoir. Coupled with advanced visualisation software, it is possible to 'walk through the earth' – a reference to viewing the distribution of rock layers or stratigraphy according to its depth and properties.

Pay-Per-View

As we have seen (*Chapter 6: Properties, Players and Processes*), oil and gas leases may be state or privately-owned tracts either onshore or offshore. In either case, seismic cannot be shot without a permit. There is a rising scale of regulatory demands associated with seismic activity which follows the general rule that offshore seismic (shooting water bottoms) permits are more stringent than those onshore. Locations within nature reserves will have even more demanding permitting criteria.

In all cases, an Environmental Impact Assessment (EIA) will be undertaken by the oil company and submitted to the appropriate environmental regulatory authority for approval. To conduct seismic, a fee is usually paid to the landowner. Prices are determined by adjacent finds, the degree of exclusivity, regulatory burden, general market forces and whether the acreage is private or state-owned.

Needle in a Haystack

Licensed acreage refers to areas where an oil company or group of oil companies has obtained exclusive rights to explore, develop and produce hydrocarbons. Clearly, finding oil and gas is a complex process with greater complexity added by offshore or remote locations and large unexplored blocks.

Waves, whales and winds are just some of the challenges facing a seismic program. Others include sea-currents, sea-traffic, minimising environmental impact and the technical challenges associated with the seismic process itself. These technical challenges are related to receiving clear signals and reducing background noise which can distort seismic data. Accurate seismic saves oil companies millions of dollars that would otherwise be spent in drilling dry holes and reduces the environmental impact of drilling[4].

Environmental Regulations

Regulations governing seismic are comparable in most oil and gas provinces and are based on wider environmental protection laws. The application for consent to conduct or permit seismic is only issued after the EIA considers various factors including disturbance to animal life. In the case of shooting water bottoms, the animals most sensitive to disturbance are cetaceans (marine mammals) such as whales and dolphins (see Figure 4).

Marine Mammal Observers (MMOs) are employed solely to minimise disturbance to cetaceans during seismic activity. For sensitive marine areas, the MMO must also be an experienced cetacean biologist or similar. Often, surveys are required to be conducted during summer months and during daylight; if there is poor visibility such as fog or storm weather, the survey may be stopped.

Regulations state that at least 30 minutes before a seismic source is activated, operators should carefully observe from a high observation platform whether there are any cetaceans within a 1600 ft (487 m) zone of the vessel.

Hydrophones and other specialised equipment may provide further indications of submerged animals, and such equipment is to be used in particularly sensitive areas. If cetaceans are present, seismic sources cannot be activated until the animals have moved away, normally after at least a 20 minute waiting period[5].

Except for sensitive areas, all seismic surveys using a source size of more than 180 cubic inches must follow a slow ramp-up procedure. In other words, irrespective of whether marine mammals have been sighted,

Figure 4 - EIA Minimises Disturbances to Animal Life

acoustic activity should be increased slowly. This can include starting with the smallest air gun and slowly building up. Space does not permit examination of other restrictions and procedures, but seismic activity is controlled and an extensive written report must be sent to the authorities after the survey is completed.

Surface Tow

The most common source of 'shooting water bottoms' is an air gun which releases compressed air into the water generating an acoustic shock wave that travels to the seabed and beyond. Seismic sources are towed behind the seismic vessel slightly beneath the surface of the water.

A streamer is towed behind the vessel on the surface of the sea picking up reflected sound waves. Usually, a streamer contains hundreds of pressure-sensitive hydrophones in a near-buoyant cable that can be 2 miles (3.2 km) or more in length.

A geophone is a type of seismic receiver placed on land or on the seabed that records seismic waves by registering the minute movements of particles. In offshore operations, geophones are configured to record both compression waves (P-waves) and shear waves (S-waves). This is because sound travels through liquids (the sea) as compression waves, while it travels as both compression and shear waves through solids (the earth below the seabed).

Brown and Green Fields

Seismic has evolved greatly over the years and has applications in mature fields as well as the exploratory phases of oilfield development. The industry uses the terms brown and green fields respectively to describe the age of the field. In fact, seismic provides tremendous value during the production of an oilfield and as mature fields start to decline (see *Chapter 9: Mature Fields* for detail).

Deeper reservoirs, or those located below salt, would have been overlooked previously as seismic was not capable of being imaged beneath shallow reservoirs or below formations containing thick layers of salt. Accompanying advances in seismic enable imaging of deep targets, a drilling technology first that has overcome the directional control and drilling torque problems related to drilling 32,800 ft (10,000 m) or more. The current world record depth well is 40,320 ft (12,293 m).

For deeper or sub-salt seismic, two seismic vessels are run together with both shooting and using long streamers. Global Positioning Systems (GPS) are used to keep the two vessels at a known distance and this maintains the required distance between the source and streamer to accurately measure seismic reflections from deep and sub-salt formations. A new technique called 'coil shooting'[6], whereby a single source/acquisition vessel sails in overlapping circles while acquiring

> Although there may be some basic information on formation markers, porosity and permeability, temperatures, and the expected hydrocarbon gas or oil, much more information needs to be predicted such as the reservoir pressure, formation markers, the TVD to the tops of formations, and a range of other pressures.

data, provides rich-azimuth seismic imaging of deep and sub-salt formations at less than half the cost of traditional means.

'Shooting seismic' is crucial to reducing oil and gas exploration risk because it enables the G & G team to visualise deep inside the earth and locate promising structures without the cost and impact of drilling[7].

4D Seismic

Time lapse or 4D seismic accompanies the lifecycle of an oil and gas asset providing valuable seismic information on the asset as it matures (see *Chapter 9: Mature Fields* for more detail). 4D seismic (the 4th dimension is time) is a technique involving comparison of successive 3D seismic surveys taken over the same area. Geoscientists can detect the effect of fluid migration over time and thus deduce the reservoir's preferential drainage patterns. This information is invaluable in situating additional in-fill wells or altering the pattern of injector wells versus producer wells. In one example, comprising the largest 4D survey ever acquired, the operator (Petrobras) was able to relocate 11 already-planned deepwater well trajectories and plan an additional nine wells for a total of 20 wells affected. The changes saved the company about US $900 million, which would have been the cost of drilling the 11 wells in the wrong place, and it expects to gain considerable profits from the 20 wells drilled in the right place.

Well Planning

Well planning is the process of creating a blueprint for constructing oil and gas wells. Here is a behind the scenes look at the key components of well planning and their interaction[8].

The well plan, a book-like bundle of engineering and legal documents, covers all aspects of designing, drilling and completing a given oil and gas well. Large operators may refer to this as the 'pre-drill package' (purists may argue about the exact usage of terms but they both refer to the same thing). Smaller oil companies will simply refer to the documents as the well plan.

This should be distinguished from the well profile, which only describes the proposed architecture and sizes of the well.

We have already seen how raw seismic information is processed into geological data. After poring over this data, bright spots and prospects are identified; however, a prospect must be converted into a well plan. Prospects are potential oil and gas reserves, destinations so to speak, and well plans are a means of reaching them[9].

Faster, Better, Cheaper

Picture this: six months before spudding a deepwater wildcat, the drilling team members are scratching their heads. Which rig will they contract? Will they keep the fragile balance between Pore Pressure Fracture Gradient (PPFG) and mud weight? Which drilling fluid will they use in high-pressure zones? Will they deliver a well that flows on time and within budget?

One way of managing budgets (as well as risk and uncertainty) is the Drilling Well Optimization Process (DWOP), also known as 'Drill the Well on Paper'. This refers to the process of analysing each step of the well construction process to generate ideas for improving performance and reducing cost. We will look at this concept in greater detail in due course. For now, it is important to define the technical limit for each activity or the minimum time required to complete each task in a perfect world. This will serve as a theoretical value only and can never be achieved as an actual target. Next, a realistic target based on the best past performance is established, which becomes the performance benchmark for the well[10].

Blueprint

Getting to the blueprint stage requires various scenarios to be enacted (DWOP) and huge volumes of information to be analysed and formatted. Well planning is a very broad concept that encompasses:

• The management of phased well construction service and supply processes to meet a desired timeline and objective
• Commercial aspects of contracts and pricing for well services and equipment
• Financial cover in terms of insurance and liabilities
• Legal conditions such as compliance with regulatory framework and outlining limits of responsibilities
• Design and operational aspects that cover detailed engineering drawings of well construction
• Health and safety considerations
• Environmental protection, and
• Political/cultural/linguistic aspects of the operations.

There can be as many as 100 different regulatory conditions and as many service and supply companies on a single well project. Subsequent issues will look in depth at regulatory issues such as permit to drill, supply and services procurement such as rig type, services contracts and well types. For now, we shall look at the main features of well planning and accompanying risk as well as the engineering aspect of a vertical exploratory well[11].

Essential Information

A well plan has essential information such as well number, location, block, partners, and level of confidentiality (confidential wells are called 'tight-holes'). It will include items such as the:

• Well objectives
• Surface location
• Longitude and latitude
• Eastings and Northings
• Water depths (in the case of offshore wells)
• Measured Depth (MD)
• True Vertical Depth (TVD)
• Azimuth
• Spud dates
• Critical dates such as first oil (which would really only be entered by a true optimist), and
• Seasonal or environmental factors that may affect operations.

The well plan also includes such things as:

• Rig details, rig preparations, transportation of the rig and setting it up
• Well control and contingencies
• Pressures (PPFG) and temperature (gradient)
• Directional targets and sidetracks
• Bottom Hole Assembly (BHAs) and hydraulics
• Casing depths and cementing details
• Contact list of key personnel, and
• Completions—how the final section of the well will be finished or completed.

Targets

Targets usually refer to geological targets, which are the depths of formations that likely contain oil and gas. They can also refer to pre-determined casing points. Depths are expressed as vertical and measured depths. TVD, for our purposes, refers to a depth taken from a ninety degree straight line from the surface down to the depth of interest. The measured depth is the actual distance drilled. Other formations or markers along with their age and lithology, i.e. sand/shale, will be noted. The TVD is measured from the top of the target to the bottom height of the reservoir. When you read that a reservoir had 78 feet (25 m) of 'pay' or oil-bearing sands that refers to the vertical thickness of the oil and gas reservoir. 'First oil' refers to the first time at which production of a certain reservoir occurs[12].

In the Dark

Reservoir information on exploratory drilling or wildcats will be limited if not unavailable. Although there may be some basic information on formation markers, porosity and permeability, temperatures, and the expected hydrocarbon gas or oil, much more information needs to be predicted such as the reservoir pressure, formation markers, the TVD to the tops of formations, and a range of other pressures. Only upon drilling will the true values be confirmed.

Regulatory Compliance

All regulations including health and safety considerations and environmental protection will be cited and acted upon.

Potential Hazards

Hazards are identified as geological/formation—related and environmental/operational. Exemplifying the former are shallow gas, shallow water flows, charged zones, depleted zones, overpressure, abnormal temperatures, the presence of H_2S or CO_2 and pressure faults. These will be covered in part by the well control plan which will have considered all aspects of well control and associated equipment. This includes:

- All wellhead components
- BOP stack and valves
- Accumulator
- Choke and kill lines
- Choke manifold
- Gas buster (or poor boy de-gasser)
- Drill string safety valves
- Standpipe manifold
- High pressure mud lines and systems (including cementing system)
- Drill strings
- Drill stem testing surface and subsurface equipment,
- Subsea well control equipment (if drilling from a floating vessel).

Operational hazards range from wellbore positioning (such as avoiding collision with existing wells or pipelines), avoiding shipping channels and avoiding cetaceans or other protected marine life. Operational risks include maintaining casing integrity, avoiding casing wear, maintaining wellbore stability and managing any pressure ramp near the Total Depth (TD).

Formation Evalution Plan

The Formation Evaluation Plan includes provisions for Logging-While-Drilling (LWD) or the electrical wireline logging program. This will outline the requirements for cutting samples, mud logging and formation evaluation logging. This allows the oil company to describe formations and understand actual drilling conditions which will vary from the seismic. Formation Pressure-While-Drilling (PWD) tools also exist. These can replace wireline or pipe-conveyed logging services and are made up as part of the BHA. This allows operators to measure formation pressure as it is encountered which improves well control, safety and drilling efficiency[13].

Potential hazards such as shallow gas flows or severe pressure changes can be noted earlier and preventative action taken which lowers risk and operational costs. Usually, these systems make use of binary coding using mud pulse telemetry where the surface operator and subsurface tools communicate by means of pressure pulses that are sent through the column of drilling mud. Mud pulse telemetry cannot be used while making a connection; this is one of its drawbacks.

Mud-Logging System

During drilling operations, a multitude of measurements are taken and monitored. Temperature, pressure, depth, torque and loading are just a few. Several systems exist on rigs to fulfill this function with mud-logging being a primary one.

The use of mud-logging systems was first introduced in the industry in the 1960s. Since then, advances in instrumentation and in the number of measured parameters have resulted in sophisticated mud-logging systems[14]. The advent of deepwater drilling also contributed to the progress of mud-logging techniques. Deep and ultra-deep water environments require very accurately controlled drilling operations. Any failure or negligence may cause human injury and economic losses. To control processes accurately, enhanced mud-logging is required.

Mud-logging systems encompass three different types of data. First, they collect and analyse drill cuttings (shale-shaker samples). Secondly, they measure and monitor the condition and content of the drilling fluid

Figure 5 - View of Cuttings Analysis

returns. Finally, they monitor and record mechanical parameters related to the drilling operation. All provide invaluable data as to whether the formations encountered bear oil and gas or how drilling is going[15].

Examining Cuttings

Drilling chips or returns, also known as 'cuttings', provide the operator with information as to whether hydrocarbons have been found by carefully examining cuttings brought up by the circulating mud. The mud logger or geologist samples cuttings from the flow equipment using a microscope or ultraviolet light to determine the presence of oil in the cuttings. Where gas reserves are concerned, they may use a gas-detection instrument. Often paleontologists examine drill cuttings under a microscope to detect and identify fossils that indicate the age of the formation and perhaps clues to its deposition[16].

During drilling, a mud logger will observe mud-logging parameters for any abnormalities. If an observed parameter presents unusual behavior, the mud logger immediately communicates this to the driller who will carry out certain procedures to solve the problem. Actually, the system allows the programming of alarms that will sound in the mud-logging cabin, alerting the mud-logger that the value of the observed parameter is outside the programmed range.

The number of observed parameters may vary according to a particular characteristic of the drilling operation, but the most commonly measured parameters are:

- Well depth (depth)
- TVD
- Bit depth
- Rate of Penetration (ROP)
- Hook height
- Weight on Hook (WOH)

- Weight on Bit (WOB)
- Vertical rig displacement (heave)
- Torque
- Drill string rotation per minute (rpm)
- Mud pit volume
- Pump pressure
- Choke line pressure
- Pump strokes per minute (spm)
- Mud flow
- Total gas
- Gas concentration distribution
- H2S concentration
- Mud weight in and out
- Drilling fluid resistivity
- Drilling fluid temperature
- Flow line
- Lag time, and
- Standard length[17].

Only some of the listed parameters are measured using sensor devices; some of them are estimated from measured parameters. The WOB, for instance, is an estimated parameter that is calculated using hook weight (a measured parameter) and the weight of the drill string elements (which allows for buoyancy in drilling mud and wellbore inclination).

Well Logging

Using a portable laboratory truck-mounted for land rigs, well loggers lower devices called logging tools into the well on electrical wire-line. The tools are lowered all the way to the bottom and then reeled slowly back up. As the tools come back up the hole, they are able to measure the properties of the formations they pass[18].

Electric logs measure and record natural (spontaneous potential) and induced (resistivity) electricity in formations. Some logs ping formations with acoustic energy and measure and record sound reactions. Radioactivity logs measure and record the effects of natural and induced radiation in the formations. These are only a few of the many types of logs available. Since all the logging tools make a record, which resembles a graph or an electrocardiogram, the records or logs can be studied and interpreted by an experienced geologist or engineer to indicate not only the existence of oil or gas, but also how much may be there. Computers have made the interpretation of logs much easier and logging tools using real-time transmission systems are now capable of imaging the wellbore as it is drilled[19].

Although, logging and measurement while drilling (LWD and MWD) tools have been available for many years, it is only recently that advances in data transmission and interpretation have progressed to generate accurate images of the wellbore. These images are based on real-time data and offer insight into what is really happening downhole.

Typically, a high-quality image is drawn from detailed, 3D resistivity data. This data is supplied by a resistivity tool similar to a logging formation micro-imager, which is run on wireline. This resistivity tool is capable of identifying wellbore features and characterising faults, cementation changes and threaded or spiraling caused by bit whirl. Software transforms the resistivity data into images of 3D wellbores that are viewable at all angles with simple mouse movements. The resistivity measurements are transformed into 360-degree azimuthal plots around the circumference of the wellbore to provide extremely detailed images[20].

The combination of resistivity and density services based on real-time logging images and geo-steering techniques enables operators to reduce risk and overcome geological uncertainties commonly associated with complex wells. Ultra high telemetry rates (12 bits per second) have been successfully used to optimise horizontal well placement as well as warn of wellbore stability issues before they become serious enough to jeopardise operations or impact drilling costs.

Wellbore stability problems are detected with ultrasonic callipers from density or sonic LWD tools. Hole enlargement or washouts can be identified while drilling or during subsequent trips. This is beneficial as it helps monitor wellbore stability and allows adjustments to be made to mud weights or effective circulating density as required. Wellbore stability problems are confirmed using vision technology incorporating Azimuthal Density/Neutron viewer software, which provides density image and calliper data while drilling. The software also generates 3D images and calliper logs. Together, these offer easier methods of understanding wellbore conditions during drilling operations. Additionally, the 3D density images and ultrasonic calliper allow wellbore instability mechanisms to be better characterised, and when necessary, resolved. This is particularly important in completions where gravel packs or expandable screens are required. The ultrasonic and density calliper information gathered during drilling can indicate whether hole quality is good enough to permit specialised completions to proceed. Up-logs obtained on a subsequent wiper trip allows visualisation of the hole enlargement and stress failures after drilling[21].

> Formation core samples may be taken and these are the most important way of examining formations and any oil-bearing strata.

Specialised software uses a recorded mode to gather real-time dip information, provided by the LWD resistivity imaging tools. This information is harnessed to view geological structures and reduce the uncertainties in pre-existent geological models.

The software also allows structural dip picking from images, which can be used in combination with the real-time data for structural interpretation. Bed dips and layer thickness are also characterised, permitting the evaluation of structural cross-sections. The reduction in risk and geological uncertainty has made wellbore imaging hard to resist for production companies.

Pressure While Drilling

PWD tools are used to make accurate downhole measurements of:

- Equivalent Circulating Density (ECD)
- Kick detection, including shallow water flows
- Swab/surge pressure monitoring while tripping and reaming
- Hole cleaning
- Hydrostatic pressure and effective mud weight, and
- Accurate Leak-Off Test (LOT) and Formation Integrity Test (FIT) data.

Coring

Formation core samples may be taken and these are the most important way of examining formations and any oil-bearing strata. Cores are extracted by a 'core barrel' which usually takes 10 to 13 ft (3 to 4 m) lengths of the formation. As the core barrel is rotated, it cuts a cylindrical core a few inches in diameter that is received in a tube above the core-cutting bit. A complete round trip is required for each core taken. Much smaller and less representative cores may be extracted using a sidewall sampler in which a small explosive charge is fired to ram a small hollow cylindrical bullet into the formation. The bullets are tethered to strong retaining wires. When the tool is pulled out of the hole, the bullets containing the small core samples come out with the tool. Up to 72 of the small samples can be taken per trip at any desired depth. This provides positive real evidence of cross-flow, permeability and porosity. Laboratory tests are complex and can include fluorescence gas chromatography (TSF)[22].

Sampling and Screening of Cores

On board the ship, cores are physically described, logged and sampled. Three sections from the bottom half of each core are sampled for geochemical analysis. Deeper core sections are used in order to avoid contamination from modern petroleum pollution sources near the surface. Analysis of three sections per core increases the likelihood of encountering petroleum seepage, which is typically not distributed homogeneously throughout the sediments. All core material is frozen and stored until it is returned to the lab[23].

The objective of these analyses is to characterise the composition and origin of solvent-soluble hydrocarbons. The cores are stored in specially created conditions to preserve their characteristics.

Drilling to Total Depth

The final section of the well is what the operating company hopes will be a production hole. The formation of interest (the pay zone, the oil sand, or the formation- bearing hydrocarbons) will determine the answer to the make or break question: 'Is the well commercial, i.e. does it contain enough oil or gas to make it worthwhile to run the final production string of casing and complete the well?'

After the operating company has studied all the data from the various formation tests, a decision is made on whether to set production casing and complete the well or to plug and abandon it. If the hole is considered to be dry, that is not capable of producing oil or gas in commercial quantities, it will be plugged and abandoned. Sometimes, a dry hole may be sidetracked in an attempt to make contact with productive formations. This is usually the case if formation faulting is detected because a well drilled just a few feet on the wrong side of a fault can miss the pay zone altogether. It's a relatively simple task to drill a sidetrack, and certainly less costly than starting over.

At times, not enough oil or gas may be present to justify the expense of completing the well; therefore, several cement plugs will be set in the well to seal it off. As oil prices are cyclical, it is often the case that wells that were plugged and abandoned in the past may be re-opened to production if the price of oil or gas has become higher. The cost of plugging and abandoning a well is far lower than the cost of a production string of casing; therefore, the operator's decision is invariably oil or gas price driven[24].

Setting Production Casing

If the operating company decides to set casing, it will be brought to the well and for one final time, the casing and cementing crew will run and cement a string of casing. This casing is 'floated' into the hole to take advantage of its buoyancy and relieve the rig from holding the immense weight of several thousand feet of large diameter steel pipe. A 'float shoe' seals off the bottom of the casing and keeps drilling mud from flooding the casing as it is runs into the hole. Usually, the production casing is set and cemented through the pay zone; that is, the hole is drilled to a depth beyond the producing formation and the casing is set to a point near the bottom of the hole. As a result, the casing and cementing actually seal off the producing zone but only temporarily. After the production string is cemented, the drilling contractor's job is almost finished except for a few final touches.

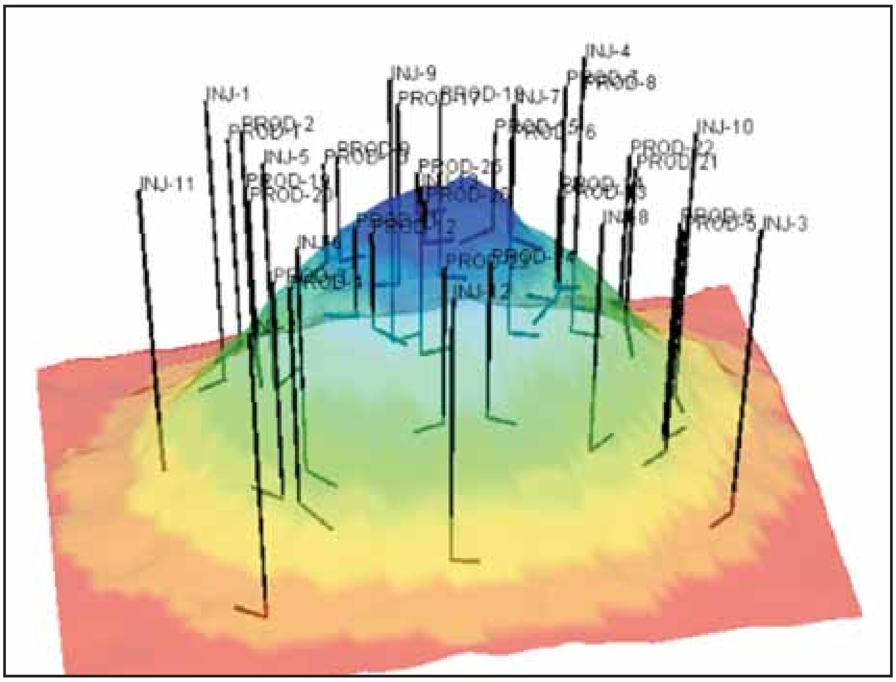


Figure 6 - Well Placement In Field Development

Cementing

After the casing string is run, the next task is cementing the casing in place. An oilwell specialist cementing service company is usually called in for this job. Cementing is fundamental to the integrity of the well and considers factors such as annular volumes, formation-cement-wellbore interaction, slurry and set properties as well as cement sheath strength. Cement behaviour differs according to depth, pressure, temperature and loading conditions; however, this behaviour needs to be considered to ensure a good cement job.

Cementing applications include sealing the annulus after a casing string has been run, sealing a lost circulation zone, setting a plug in order to 'kick-off' a wellbore deviation or to plug and abandon a well.

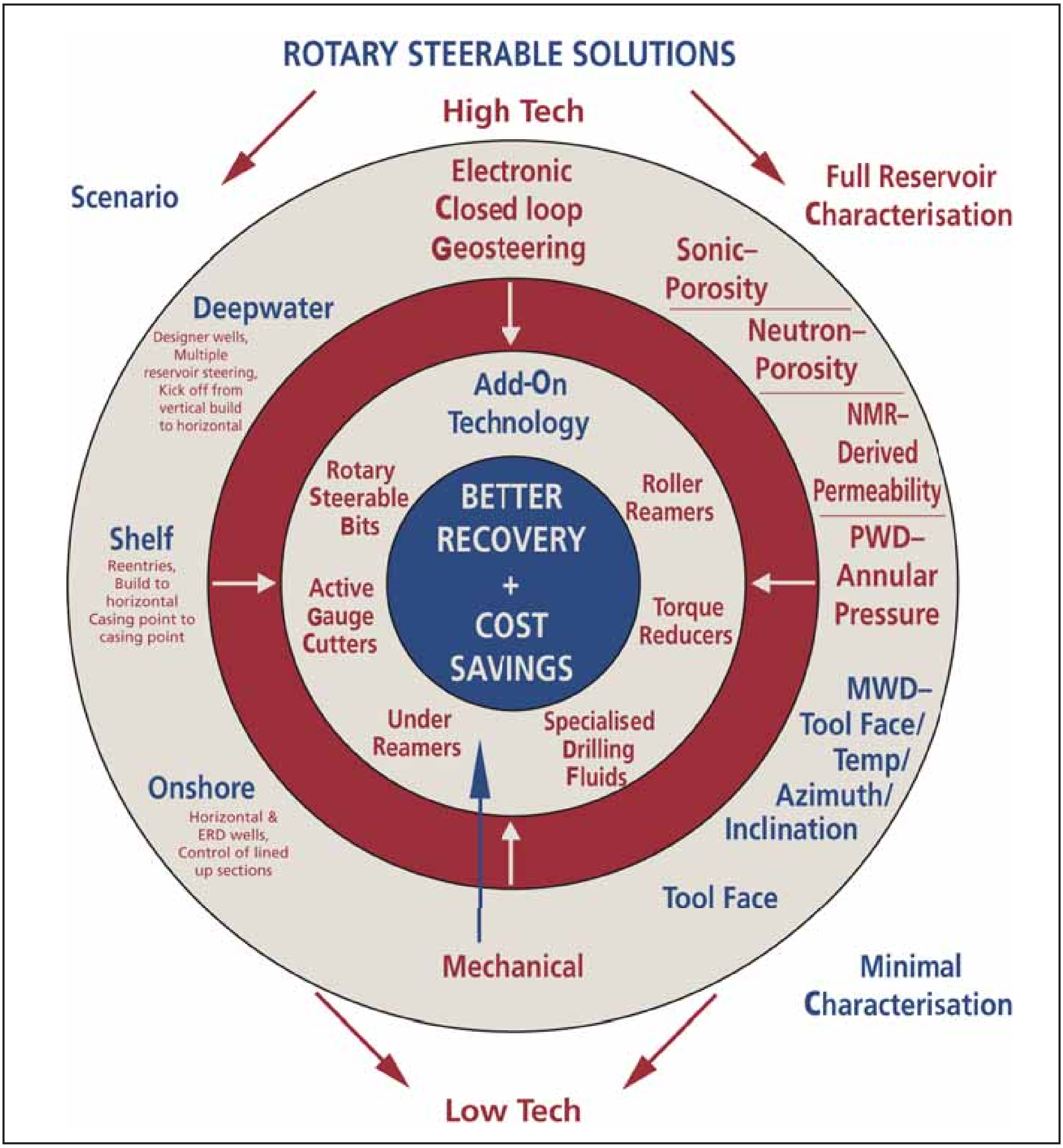


Figure 7 - Geo-Steering Technologies From High to Low Tech (EPRasheed)

Cementing involves pumping a cement slurry down the inside of the casing. When the slurry reaches the bottom, pump pressure is raised and this pops open a valve in the float shoe to allow the cement to be pumped out of the bottom of the casing, out the bottom end and back up the annulus. When the proper amount of cement volume has been pumped to seal off the casing and support it in the borehole, a plug is pumped to the bottom that wipes the wet cement off the inside of the casing and forces it all to the bottom, leaving the casing clean and ready for the next step in the completion process.

Perforating

Since the pay zone is sealed off by the production string and cementing process, perforations must be made in order for the oil or gas to flow into the wellbore. Perforations are simply holes that are made through the casing and cement and extend some distance into the formation. The most common method of perforating incorporates shaped-charge explosives, a principle that was developed during the war to penetrate tanks and other armoured vehicles. The shaped–charge, when fired, creates a high-velocity, ultra-high pressure plasma jet that penetrates the steel casing, the cement sheath and several feet out into the formation rock. Several perforating charges are arrayed in a radial pattern along the carrier gun. They are usually fired simultaneously, but may be fired sequentially for special applications using select-fire equipment.

Acidising

Carbonate reservoirs (See *Chapter 1: Origin of Oil*) often hold oil, but the oil may be unable to flow readily into the well because the carbonate formation has very low permeability. Rocks that dissolve upon contact with an acid, such as limestone or dolomite, are often 'acidised' to optimise production. Acidising is mostly performed by an acidising service company and can be done with or without a rig. It consists of pumping appropriately sized volumes of acid down the well where it travels down the tubing, enters the perforations, and contacts the formation. When the acid enters the formation, it etches channels that provide flow paths for the formation's oil or gas to enter the well through the perforations[25].

Fracturing

When rocks contain oil or gas in commercial quantities but the permeability is too low to permit good recovery, a process called fracturing may be used to increase permeability to a practical level. Basically, to fracture a formation, a fracturing service company pumps a specially blended fluid down the well and into the formation under great pressure. Pumping continues until formation integrity is overcome and literally cracks open. The fracturing fluid contains solid particles called 'proppant' (which can be plain sand or more-sophisticated material such as high-strength ceramic beads) suspended in a slurry, usually consisting of a polymer gel. When the formation fractures, the gel and proppant penetrate the fissure and travel out to the extreme end of the fracture. When pressure is relieved, the formation fracture tries to close, but is propped open by the proppant material. After the pressure is released, a de-viscosifier chemical called a 'breaker' is released into the gel to lower its viscosity and allow it to flow freely back into the well without disturbing the proppant or washing it back out of the fracture[26].

Case Study: Geo-Steering

In order to maximise drilling in the 'filet mignon' of the reservoir, geologists often require tight TVD corridors to be maintained or for several reservoirs to be drilled at a optimal inclination and azimuth. To achieve this, TVD and directional corrections can be made in either rotary or oriented mode. The limiting factors associated with oriented drilling led drilling engineers to seek rotary options[27]. Since the first use of the technology in the early nineties, rotary steerable systems have been proven as 'fit for purpose' and particularly well-suited to horizontal and multi-lateral drilling. Today, they are essential to geosteering as they almost universally deliver higher penetration rates, better hole quality and improved steerability[28].

Refining BHAs Through Offset Data

Thorough analysis of offset data enables BHAs to be refined and optimised. An extensive database allows previous BHA performance to be pinpointed and considered, thereby increasing the success of future BHAs. Once the major factors are characterised – bit walk tendencies, lithology, bedding and dip angles, BHA type, components, spacing and configuration – they can be collated to calculate the likely changes in wellbore curvature that the system can create. By extending the use of rotary steerable systems to field development programs or horizontal drilling campaigns, these benefits make very substantial cost savings[29].

Rotary Steerable Technology

Advances in rotary steering technology are bringing intelligent systems even closer. Although geosteering systems capable of finding and accessing reservoirs without human input are still some years away, several rotary steerables exist today. While high-tech electronic solutions

> Once the major factors are characterised – bit walk tendencies, lithology, bedding and dip angles, BHA type, components, spacing and configuration – they can be collated to calculate the likely changes in wellbore curvature that the system can create.

are sophisticated by nature, these systems are especially suited to costly complex designer wells. A different approach is being adopted by a number of smaller service providers who are developing more cost-effective systems for the intermediate market. While most still rely on electronics, there are also simple systems reliant on mechanical devices. Simple or sophisticated, all systems can generate cost savings and improve recovery[30].

Less clear is whether criteria exist to make one system better than another. Perhaps a more objective approach is to determine the best fit by broadly matching rotary steerables with the varying dictates and expectations of deepwater, shelf or onshore drilling and completions.

Drawing these variables together, Figure 7 depicts deepwater, shelf and onshore sectors and its appropriately matched technology. Certainly, a rotary steerable system must help reach the reservoir and optimise the footage drilled within it, but beyond this there are many reservoir and well-dependent variables. The dogleg severity (the change in direction, measured in degrees per hundred feet, required to reach optimal reservoirs) performance of a rotary steerable system, for example, should be matched with the complexity and number of targets involved. In complex designer wells, sophisticated systems shine; in less complex horizontal wells, simple systems suffice. Similarly, costs also drive system choice. It is well known that the tight economics of onshore or shelf assets cannot withstand high rig rates, let alone expensive downhole equipment. Here, a match depends as much on reservoir placement needs* as it does cost. Consider deepwater versus onshore trip costs. In the former, an average round trip may cost US $500,000; the same trip onshore is hardly a tenth of this figure. In the first instance, it makes commercial sense to minimise trips; however, onshore it might make better commercial sense (depths and profile permitting) to induce trips by using conventional steering technology to line up sections and run in with rotary steerables where they have best effect[31].

Deepwater exploration frontiers are characterised by the highest rig rates in the industry and extreme exploration risk. This means contingency planning is a key component of deepwater operations. Relatively straightforward activities, such as logistics, can be rendered complex due to the remote and specialised nature of operations. Consequently, sophisticated rotary steerable systems that maximise efficiency and minimise risk are not only desirable, but necessary.

In these deepwater instances, a full range of reservoir characterisation tools is also required. Sophisticated systems, coupled with full logging capability, reflect and meet deepwater frontier needs as offset data is often scarce and further asset development is dependent on data acquisition and interpretation. The general rule is the more data acquisition and characterisation the better. Data gathered while drilling supplements the pre-drill seismic package by increasing the footage drilled in optimal reservoir zones. A good rule-of-thumb is to consider the time-relevance of information; if the information is required to make critical decisions while drilling, real-time systems should be used[32].

Conversely, because mature assets usually are well-characterised and offset data is plentiful, the same degree of data acquisition may be unnecessary. This makes mature or onshore fields ideal candidates for simpler rotary steerable tools. As one moves down the characterisation list, there is a diminished need for complete characterisation. Intermediate or mature shelf assets may not require nuclear magnetic resonance or sonic logging, and in a marginal onshore context it is highly likely that a full LWD suite becomes redundant. Little more than toolface, azimuth, inclination, temperature and formation identification is required in this context. In exceptional onshore cases, the uncertainty associated with complex targets may require further logging, but often MWD plus a gamma system provides ample data. In this way, technology can be pared down to bare essentials and costs can be lowered. What may have once been considered a marginal or mature field can be revisited with new economic parameters and perhaps be revitalised.

Often, however, a serendipitous use of real-time data pays dividends. Recently, an operator drilling in the shallow shelf waters of offshore Texas, encountered two extremely abrasive formations. On an offset well, each consumed ten drill bits to get through the zones. The logging requirements were not particularly sophisticated, but the service company pointed out that if the sections were drilled using its rotary steerable system with ultra high-speed telemetry, it could measure and monitor drill bit vibration thought to be the cause of the rapid bit-wear. The operator accepted the recommendation and with real-time vibration monitoring, was able to detect and analyse the circumstances causing bit wear. By adjusting weight-on-bit, rpm and mud weight, the operator was able to minimise destructive vibration and drill both problem sections with a single bit each, saving more than US $2 million from US $12 million Approval For Expenditure (AFE). The sophisticated solution costs more, but rig time was saved by eliminating eight bit change trips, and the added cost was more than compensated by the rig-time savings.

Add-On Technology

Representing opportunities for reducing casing wear, torque reducers can help overcome the concerns of the effects of increased rotation on tubulars. Also, roller reamers aid BHA stabilisation and reduce downhole vibrations. Under-reamers enable the diameter of production holes to be increased (especially important in deepwater scenarios where narrow pore pressure fracture gradients can jeopardise reservoir hole size) by allowing casing to be telescoped without sacrificing production. Specialised drilling fluids exist to reduce torque and improve rotary drilling efficiency[33].

Case Study: Expandable Tubulars

Although the reality of a downhole monobore (a single diameter casing string from well-head to reservoir-toe) is not in existence yet, half of the essential technology has been proven.

In the late 1990s, a relatively small group of engineers within Shell E & P, Halliburton and Baker Hughes laid out the plans for a technology that would have made Erle P Halliburton smile[34].

By forming technology ventures with Enventure (Halliburton) and E²Tech (the precursor to today's independent expandable technologies from Baker Hughes), Shell gave the nascent expandable market the support it needed. Shell would later go on to sign deals with Weatherford allowing it to enter the expandable market.

In parallel to these deals, some service companies had already developed the expertise to expand slotted tubulars and were realising commercial downhole applications. Similar commercial applications for solid tubulars, however, have only become available in the past two or three years. Now, a broad range of operators have expanded solid tubulars to overcome well construction challenges such as preserving wellbore diameter, isolating lost circulation zones below the casing shoe and sealing-off swelling or poorly consolidated formations.

Today, there are three main open-hole applications for expanding solid tubular: slimming down well designs, contingency casing and repairs, handling lost circulation and bypassing trouble zones.

Slimming Down

In the deepwater arena, technology offers a real alternative to the seven or eight string casing configurations where 'telescoped casing' or 'borehole tapering' can severely restrict the production hole diameter in the geological objective. Another feature of the technology is that through 'localised' applications, repairs can be made to damaged or worn casing while patches or old casing strings can be replaced without the need for costly cutting and pulling casing. From an engineering perspective, wellbore stability and burst/collapse ratings of casing can be maintained in this way[35].

Contingency

Contingency systems can provide operators with an extra string of casing, which can be the decisive factor in terms of successfully drilling deepwater prospects. Increasing the section length of the casing without compromising casing diameter is especially useful in operations where large diameter top hole casing sections are otherwise technically or cost prohibitive. Consequently, it can be said that the technology gives the operator two casing strings for the price of one. The system enables operators to extend a conventional casing program for an exploratory well to reach promising zones that are deeper than anticipated.

Lost Circulation and Trouble Zones

For unexpected lost circulation or shallow-water flow zones in deepwater and sub-salt environments, the system provides affordable contingency solutions. In sub-salt environments, the system offers the most cost-effective solution for original casing that is stuck high or for reaching TD with larger production casing. Unexpected trouble zones are a common challenge in sub-salt or deepwater low-fracture-gra-dient environments. The open hole technology allows the operator to simply drill another hole section to bypass these zones. In older fields requiring redevelopment, the system can help reach deeper reserves and isolate water or gas zones that have penetrated horizontal re-entry wells. The well is drilled to the target reservoir, casing is run, cemented and expanded.

This technology holds much promise for deepwater fields where deep targets below the mudline may not be accessed economically with conventional technology.

Before the economies of scale regarding standardised casing design and supply materials, however, there are still further operational and design challenges that must be overcome. These challenges are the delivery of so called 'gun barrel' under-reamed gauge holes, increasing the expansion ratios of under-reamers to above 25% of pass through or body size, callipering, cementing type and method, maintaining a consistent internal diameter of casing which has been expanded at connections, and reducing the risk of swab/surge dependent on the expansion method. Here rotary expansion may have some advantages as the application of torque and weight is used to expand the casing as opposed to weight/force applied axially. At any rate, top down expansion is always preferable because if the expansion mechanism fails then any subsequent fishing can be achieved more easily. In the opposite, it is harder to fish a larger diameter component into or within a smaller diameter as would be the case of bottom up expansion.

Case Study: Digitalisation

Imagine producing a commodity but not knowing how much you have to begin with or have left. This kind of blind production is likely to be a relic as digitalisation promises to offer oil companies the ability to see production in the form of subterranean migration of hydrocarbons as they are produced over the lifecycle of the asset. As well as radically changing production, it promises to do the same with drilling completions through remote-controlled centres[36].

Combined with 3D seismic, e-drilling will provide the technology to realise real time modelling, supervision, optimisation, diagnostics, visualisation, and control of the drilling process from a remote drilling expert centre. This system will enable decision makers to have better insight into the status of the well, and formation surrounding the well, and thus make better and quicker decisions. This is of particular importance when problems or unusual situations arise and experts are called in to make decisions. They will quickly be able to grasp the situation and make the correct decision.

As compared to classical integrated reservoir engineering studies, an event solution study typically includes seismic and geology characterisation, reservoir simulation, history matching, field development, facilities and economics. Performed in two to three months, the event solution is characterised by a myriad of multiple parallel workflows and processes to assemble a rapid and integrated reservoir understanding towards the study objective, which includes uncertainty analysis and risk assessment to focus on what really matters. A team of 20 to 30 experts collectively work during the project's duration, providing synergy of mind and direction to reach the study objective and maintain consistency in each study discipline.

By combining real-time drilling analysis with 3D visualisation, the system allows all involved personnel a common working tool. It also provides the user with access to historical data (playback scenarios) for experience exchange and training. The overall result is a more cost-effective and safer drilling and well construction operation.

Seismic multi-component 3D and 4D technologies, along with better seismic imaging, help drill more productive wells because they provide greater precision of the location and migration of hydrocarbons. Multi-component involves larger volumes of data and enables the direct detection of hydrocarbons as well as reservoir geometries.

Vertical Seismic Profiling (VSP) aids exploratory and development drilling by reducing risk and uncertainty. In this way, seismic has evolved from being an exploratory risk mitigating tool to a reservoir management tool with applications in mature fields.

Recently, companies have successfully implemented seabed permanent seismic arrays which take a lifecycle approach and include taking repeat shots, overlaps and using permanent cables that use fibre optics.

By creating visualisation rooms in different operational sites and in other locations where engineers can 'see' reservoirs, oil companies can image 'harder to see' reservoirs such as thin layers which can be missed by conventional seismic. Visualisation serves as the 'common language' that enables geophysicists, geologists, engineers and asset managers to work effectively toward a common goal. With 4D time-based seismic, it is also possible to view migration as two time-lagged surveys, say a year apart, which will show how hydrocarbons have moved. This has tremendous value in understanding reservoir fluid paths and behaviour which ultimately means more oil.

Using satellites and fibre optic cables to communicate with multiple pay zones, the industry has set its sights on truly intelligent completions and has commercialised the downhole tools required to harmonise production.

In the old days, the equation was pretty simple: one reservoir meant one completion which meant one well. This changed, however, with the advent of dual completions, which allowed a single wellbore to receive production from two reservoirs. Although dual completions could reduce well numbers by half, reserves were not exploited effectively and well numbers remained unnecessarily high. Combining completions to co-mingle production from multiple pay zones reduced well numbers and costs, but two drawbacks emerged. First, well intervention was required more often than not. Second, heterogeneous reservoirs were treated as if they were identical.

“By creating visualisation rooms in different operational sites and in other locations where engineers can 'see' reservoirs, oil companies can image 'harder to see' reservoirs such as thin layers which can be missed by conventional seismic.”

The ideal approach is to treat pay zones individually as this makes for a much deeper understanding of reservoir characteristics. Consequently, this leads to better reservoir management, which in turn means higher levels of production over a longer life span. This was the overwhelming logic behind single and dual completions. Large numbers of wells, however, do not make the best use of resources.

Although reservoirs are complicated, intelligent completions are simple. Essentially, they take a big-picture view and aim to cost-effectively manage heterogeneous pay zones. Production from interrelated or layered reservoirs must be continually regulated and co-mingled and real-time data must be provided to make the best management decisions regarding the use of a network of downhole chokes, gauges and fibre optics to regulate production.

It is widely recognised that depleting one reservoir affects another nearby. By regulating the flow and pressure of several reservoirs, a balance can be achieved to ensure reservoirs behave according to what is best in light of the big picture. Zonal isolation is a good example of how intelligent completions can help predict, isolate and balance water and gas influxes in different locations according to long-term needs. Another benefit is that gas and water can be injected into multilateral or multilayer reservoir zones with a better understanding of how this will affect production from interconnected reservoirs.

By manipulating a downhole network of chokes and gauges, a production engineer seated hundreds of miles away can manage the production of several reservoirs, wells and fields. In this way safety is improved, costs are cut, and more reserves are accessed.

Broadly speaking, high-cost developments such as subsea installations with high intervention costs are particularly well-suited to intelligent completion. Their greater depths and complex well trajectories also make them ideal candidates. Two other areas suited to intelligent completion are selective production of multiple reservoirs and the optimisation of artificial lift operations.

With intelligent completion still in its infancy, financial costs are high and investment can be justified only on high-return projects. Technical restrictions also exist. Usage is limited to wellbore diameters of seven inches or larger, with high flow rates typically 6,000 bbl or greater. Downhole temperatures cannot exceed 120°C (247°F).

Despite these limitations and relatively few worldwide installations, major oil companies are devoting more resources to completing wells intelligently.

Truly intelligent completion systems are, however, not in the immediate future. Perhaps a more accurate description of today's technology would be remote control completions, as completions are not yet closed-loop. In other words, they are not autonomous, self-controlling systems and human input is still required. With technology moving at an inexorable pace, closed-loop completions will still be a goal for the long term.

Representing unquestionably better production, automation is an irreversible process. Each downhole sensor that sends real-time data makes us more conscious of its value. As more equipment is integrated within the intelligent completion, it becomes more difficult to view reservoirs separately. Automation offers an unprecedented flexibility in terms of asset and production management strategy. As commodity prices fluctuate, production from a given field can be halted or accelerated to mirror market conditions.

We have seen how complex the well construction process is and how imaginative well profiles such as Pregnant Ladies and Fishbones help strike oil and maximise its production. We have seen that the ultimate decision to complete or plug and abandon a well is dependent on the oil price. As oil reserves become scarcer, *Chapter 8: Extreme E & P* considers the most daring of wells that are drilled in the deepest waters, Arctic conditions and deepest reservoirs. What was once thought unthinkable has now become part of our oil and gas reality.

References

1. My first encounter with the 'Pregnant Lady' well profile was with Shell to avoid drilling a highly unstable zone while numerous 'Fishbones' were found in Saudi Aramco. Fishbones are also known as multi-laterals.

2. Seismic Inversion by Mrinal K. Sen, ISBN: 978-1-55563-110-9 Society of Petroleum Engineers.

3. Principles of Petroleum Development Geology by Robert Laudon, ISBN: 0-13-649468-4, Prentice Hall.

4. Seismic reduces but does not eliminate the risk of dry-hole. Dr Drill always has final say.

5. Actual requirements will vary from country to

country depending on the environmental or marine authority.

6. The cost increases due to time involved but much higher quality data is acquired.

7. Again seismic will reduce risk but may miss features. Drilling is required to be certain.

8. Originally from 'Well Planned' by Wajid Rasheed Brazil Oil and Gas Issue 4 2005.

9. Theoretical means of course, the well needs to be constructed.

10. This is set by all members of the team.

11. Vertical wells may require a means of directional control due to formation trends or other drilling problems.

12. First oil is notoriously difficult to predict.

13. Abnormal Pressures While Drilling—Origins, Prediction, Detection, Evaluation. Jean-Paul Mouchet and Alan Mitchell, ISBN: 9782710809074 Editions TECHNIP

14. Mud Logging J C Placido et al Brazil Oil and Gas Issue 4.

15. Idem.

16. Pollen and spores are also examined especially as fossils will have been broken up by the drilling process.

17. Many other parameters exist and are dependent on operational need.

18. Certain wireline logging applications have been superseded by LWD.

19. Harts E & P Dec 2003 Drilling Column. This article was written jointly with the late Chris Lenamond 'Downhole Vision'.

20. Idem.

21. Idem.

22. Obviously the problem lies in the time delay between cores being acquired and analyzed.

23. Theoretically cores should be frozen. Although desirable, this is not always possible, especially in desert areas.

24. As with all things in the industry which are oil price driven.

25. Applied Drilling Engineering, Textbook Vol. 2 A.T. Bourgoyne Jr., K.K. Millheim, M.E. Chenever, ISBN: 978-1-55563-001-0.

26. Idem.

27. Society of Petroleum Engineers/Canadian Institute of Mining. Wajid Rasheed Paper 65504 Controlling Inclination in Tight TVD Corridors. Presented at the International Conference on Horizontal Technology, Calgary, Canada, Nov 2001.

28. 'Drilling', American Association of Drilling Engineers, Official publication. Sep 02 'Power steering'. Discusses the Rotary Steerable market.

29. Idem.

30. Well documented across the industry.

31. 'Drilling', American Association of Drilling Engineers, Official publication. Sep 02 'Power steering'. Discusses the Rotary Steerable market.

32. Harts E & P Dec 2002 Drilling Column 'Deepwater faces its own challenges'.

33. Applied Drilling Engineering, Textbook Vol. 2 A.T. Bourgoyne Jr., K.K. Millheim, M.E. Chenever, ISBN: 978-1-55563-001-0.

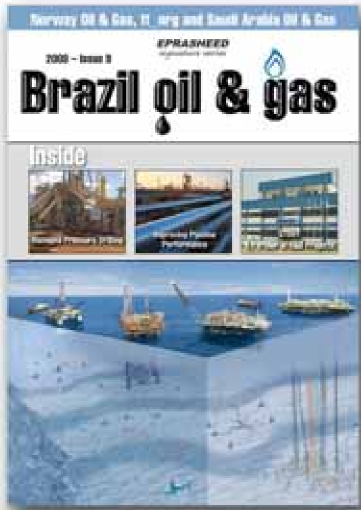
34. Harts E & P Oct 2004 Drilling Column. Expand your mind.

35. Keynote Address, Society of Petroleum Engineers Annual Technical Conference, Houston, USA. 2004 by Wajid Rasheed 'Reaching the potential of the Monobore: Intelligent tubulars, drill-pipe and underreamers.

36. Harts E & P 2002 Wajid Rasheed 'Intelligent wells linked by satellite'.


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


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


Brazil Oil & Gas, Norway Oil & Gas and Saudi Arabia Oil & Gas
EPRASHEED
tt_nrg


Norway oil & gas
EPRASHEED
Inside


OGEP 2010
The 2nd Saudi Meeting on
Oil and Natural Gas Exploration
and Production Technologies
KFUPM Campus, Dhahran, Saudi Arabia
December 18 - 20, 2010
Call for Abstracts
Academia - Petroleum Industry
Synergy for a Better Tomorrow
Organizers
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.

Call for Abstracts

The Technical Committee solicits participation from international and local professionals, experts, scientists, and educators through submittal of extended abstracts (up to 4 pages) for technical presentations and posters.

Submittal Instructions:

1. Extended abstracts must be a minimum of 1000 words and up to 4 pages). Please refer to OGEP 2010 website for deadline dates.

2. Submissions should be in English and should briefly state the objectives, methodology; application conclusions of the work and future follow up if any.

3. Extended abstracts should be submitted using the attached Abstract Submission Form online through the OGEP 2010 Web Site: http://www.kfupm.edu.sa/ogep2010/ or www.OGEP2010.org and an auto-reply confirmation email will be sent to each submitter.

4. Accepted extended abstracts will be given the opportunity to submit full manuscript for publication, or published as submitted, in meeting proceedings and any

other meeting's information media, including the website.

5. Selective papers might be peer reviewed by KFUPM for potential publication in the Arabian Journal for Science and Engineering (AJSE) published by King Fahd University of Petroleum & Minerals in Dhahran, Saudi Arabia after meeting the journal's publication guidelines.

6. Authors are responsible for obtaining necessary clearance from their management, partners, and government agencies (as applicable).

7. Papers may be submitted for oral or poster presentations, and the type of presentation must be stated with the abstract submission.

8. An abstract submission form is included opposite and can also be downloaded from the meeting web site.

9. In case of several contributors, the principal author for correspondence should be designated.

Deadlines

Abstract submittal: Refer to OGEP 2010 website for deadline dates.
Acceptance Notification: Refer to OGEP 2010 website for deadline dates.

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.

OGEP 2010

السعودي الملتقى
الثاني
تقنيات

Extended Abstract Form:

In order to ensure publication on the CD-ROM, authors should submit their abstract online:

Title:____

Extended Abstract (minimum 1000 word & up to 4 pages): (please state objectives, methodology, application and conclusions)

Please specify the most appropriate technical category related to your abstract from the attached Technical Categories List:

Primary Technical Category: ______________________________

Secondary Technical Category:______________________________

Please indicate whether your extended abstract is for oral or poster presentation (please tick one):

☐ Oral: I am willing to do a poster presentation in case an oral presentation is not possible. Yes ☐ No ☐

☐ Poster

☐ I would you like to submit: ☐ a paper or ☐ an extended abstract for the meeting proceeding.

Please list names in the order they should appear in publication:

Corresponding Author Information:

Name:______________________________

Company/institute: ______________________________

Address: ______________________________

City/Postal code: ________________ Country: ________________

Tel.No.: ________________ Fax. No. : ________________

E-mail: ______________________________

Has material been presented previously? Yes ☐ No ☐

If yes, indicate place and date: ______________________________

Short Biography of Presenter: ______________________________

An auto-reply e-mail will be sent out upon successful submission

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.

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

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

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.
- 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.

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

Saudi Arabia oil & gas

www.saudiarabiaoilandgas.com

Contribute to Saudi Arabia Oil & Gas during 2010

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 2010 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

Frac-Point Openhole Fracture Completion System

The one-trip, multistage system for tight gas success

Get to TD quickly and reliably. Accurately fracture multiple intervals in a single trip. Eliminate the need for cementing and perforating operations. Turn marginal unconventional-reservoir prospects into moneymakers.

Choose the Frac-Point™ system if you want a versatile, integrated system that can be optimized for your specific needs, with proven high-performance technology from the world's largest completion toolbox.

And when you choose the Frac-Point system, you get the knowledge and global resources of Baker Hughes, a leader in completion technology.

Meet the challenge of unconventional reservoirs with the Frac-Point system.

www.bakerhughes.com/fracpoint