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2015 – Issue 43

Saudi Arabia oil & gas

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Official Publication ATS&E 2015

SPE ANNUAL TECHNICAL
SYMPOSIUM & EXHIBITION

April 20 – 23, 2015 | DHAHRAN EXPO, SAUDI ARABIA



HARNESSING TODAY'S KNOWLEDGE
AND FUTURE TECHNOLOGY TO MEET
GLOBAL ENERGY DEMAND



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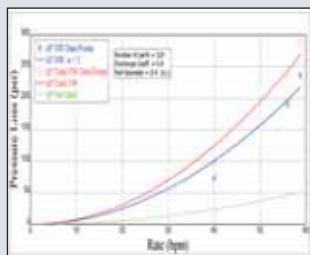
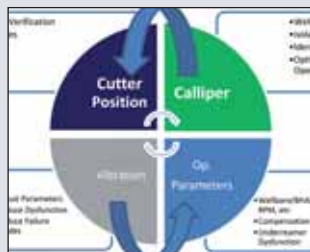
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By Saad Al-Mutairi, PhD.

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Message from the Chairman

Dear Colleagues,

On behalf of the Society of Petroleum Engineers – Saudi Arabia Section (SPE-SAS), we are pleased to welcome you to the 2015 SPE Annual Technical Symposium and Exhibition (ATS&E). This event will be held on 20–23 April 2015 in Dhahran Expo, Saudi Arabia. The symposium's theme, 'Harnessing Today's Knowledge and Future Technology to Meet Global Energy Demand', highlights the remarkable efforts exerted by the Upstream industry, to make use of current knowledge to introduce future technologies in order to meet the global energy demand.

The ATS&E represents the cornerstone of SPE-SAS activities, and is exponentially growing in members, representation and importance, both nationally and globally. The ATS&E is recognized as an international platform for oil and gas industry leaders, experts, researchers and young professionals to exchange technical knowledge, discoveries, innovative ideas, case histories, research & development projects and new technologies while networking with each other. The event provides an exceptional opportunity for GE Oil & Gas to promote its market position and showcase its recent technologies, products and services.

The technical symposium features a rich program, encompassing pre-event courses and workshops, various technical sessions, and a vibrant panel discussion. The event is also coupled with an exhibition to showcase services, products, new technologies, and best practices, which all address the Upstream industry challenges. The

opening ceremony will involve presentations delivered by recognized leaders in the oil and gas industry.

I would like to extend my gratitude to our generous sponsors and partners. Their contributions have been instrumental in making this event a reality.

I would like also to express my appreciation to the volunteer committees who have selflessly dedicated a great deal of their personal time to ensure the success of this event. I would also like to thank our official publication, Saudi Arabia Oil & Gas magazine.

Finally, I wish you an informative, rewarding, and successful symposium.

Best regards,

Saad Al-Mutairi, PhD, ATS&E 2015 Chairman



HARNESSING TODAY'S KNOWLEDGE AND FUTURE TECHNOLOGY TO MEET GLOBAL ENERGY DEMAND

Opening Ceremony



SPE ANNUAL TECHNICAL
SYMPOSIUM & EXHIBITION
April 20 - 23, 2015 | Dhahran Expo, Saudi Arabia



HARNESSING TODAY'S KNOWLEDGE AND FUTURE TECHNOLOGY TO MEET GLOBAL ENERGY DEMAND

You are cordially invited to the
opening ceremony on Monday, April 20, 2015 at 6:30 p.m.
in Dhahran Expo (Emerald Hall).



Mr. Ahmad Al-Sa'adi
Service Line Head Technical Services
Saudi Aramco



Dr. Jean-Lou Chameau
President
King Abdullah University of
Science and Technology



Dr. Helge Hove Haldorse
President
Society of Petroleum Engineers

You can register online at <http://spesas.org/atse/>.

Dr. Saad Mutairi
Chairman, 2015 SPE -SAS Annual
Technical Symposium & Exhibition

ATS&E

Panel Discussion



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2015

SPE ANNUAL TECHNICAL
SYMPOSIUM & EXHIBITION
April 20 - 23, 2015 | Dhahran Expo, Saudi Arabia



SPE
Saudi Arabia Section



HARNESSING TODAY'S KNOWLEDGE AND FUTURE TECHNOLOGY TO MEET GLOBAL ENERGY DEMAND

You are cordially invited to the
Panel Discussion on Wednesday, April 22, 2015, from 1 – 3 p.m.
"Under the Spotlight, Knowledge & Technology,
Showcasing the Energy Industry"



Dr. Nabeel Al-Afaleg
Chief Petroleum Engineer
Saudi Aramco



Mr. Sherif Foda
Production Group President
Schlumberger



Dr. Chan-Sul Jung
Executive Vice-President and Head
of Engineering Division
Samsung Engineering



Mr. Richard Lewis
Vice-President of Technology Integration
Weatherford



Dr. Mario Ruscev
Vice-President and Chief Technology Officer
Baker Hughes



Dr. Jamal Al-Khonaifer
Division Head
Saudi Aramco
SESSION MODERATOR

Dr. Saad Mutairi
Chairman, 2015 SPE-SAS Annual
Technical Symposium & Exhibition

Pre-Event Courses & Workshops



2014/2015 SPE-SAS
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Multiphase Flow Metering, Challenges & Trends

Mohamed Nabil Noui-Mehidi
Petroleum Engineering Consultant



April 19, 2015 | Le Meridien Hotel | Al-Khobar

Abstract:

Multiphase Flow Metering has seen substantial advances in the last decade. The development of multiphase flow meters is still, however, considered an important field in the oil and gas industry. The course will be an opportunity for oil and gas engineers, researchers and field operators to understand the challenges encountered in this field. Moreover, participants will be able to identify gaps that need to be addressed to improve measurement techniques, hardware and data handling. The focus will be on presenting existing multiphase metering technological development and highlighting challenges faced in operations with present technologies. A brief introduction to multiphase metering challenges at the surface and downhole will be covered, dynamical & physical effects will be discussed and research needs will be presented.

Speaker Bio:

Mohamed is currently a Petroleum Engineer Consultant in Production Technology at the EXPEC Advanced Research Centre, in Saudi Aramco, Saudi Arabia. He has over 25 years of experience in multiphase flow research and industrial applications. Mohamed Mehidi holds a PhD in Energy & Resources from Kobe University, Japan and Magister in Thermo-Fluids from the University of Science & Technology of Algiers, Algeria. He has overall more than 70 published technical papers in fluid dynamics, chemical engineering and upstream petroleum.



2014/2015 SPE-SAS
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Intelligent Field Infrastructure Architecture, Components, and System Data Flow Overview

April 19, 2015 | Le Meridien | Al-Khobar

Abstract:

This course provides detailed technical overview of the different I-Field Infrastructure components including Electrical Submersible Pump (ESP), Multiphase Flow Meters (MPFM), Permanent Down Hole Monitoring Systems (PDHM), Smart Well Completion, surface instrumentations, communication, system interfaces, and the supervisory control data acquisition and application systems. This session will also include an overview for data flow journey for from the sensor to the engineer's desktop. Case study scenarios will be used to demonstrate best practices as well as optimal deployment strategies.

Speakers' Bio:

Tofig A. AlDhubaib

Tofig A. AlDhubaib was a senior petroleum engineering systems consultant at Saudi Aramco. He has over 25 years work experience in upstream computer applications development and systems support. He is one of the key participants in the development and support of Saudi Aramco's intelligent fields.

Dr. Soloman Almadi

Soliman is currently a professional Engineering Consultant in communication, process control systems infrastructure, system integration, and Intelligent Field in Saudi Aramco, Saudi Arabia. He has over 20 years of experience at different capacities in the engineering, planning, and deployment of automation, integration, network and system solutions.

Tofig A. AlDhubaib

Senior Petroleum Engineering Consultant



Dr. Soloman Almadi

Professional Engineering Consultant

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2014/2015 SPE-SAS
ANNUAL TECHNICAL
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SPE "Recommended Post-Frac Flowback Procedures for Unconventional Wells Cleanup" Workshop

April 19, 2015 | Le Meridien | Al-Khobar

In this workshop, industry experts will share their experience and best practices in recommended post-frac flowback procedures for the clean-up of unconventional gas wells. Adhering to recommended flowback procedures is essential to recover frac-fluids contained in the fractures at controlled flow rate. This will delay possible pre-mature gas breakthroughs and maximize effective frac length.

The workshop will include presentations from Operators as well as Service Companies. During this period of intense activity, in which Saudi Aramco is unlocking the Kingdom's unconventional resources, subject matter experts will share their valuable experiences and lessons learned in this subject. Several regional and North American field cases will be presented and discussed throughout the workshop.

Who Should Attend?

Drilling Engineers
Petroleum Engineers
Drilling Data Specialist
Drilling Software Specialist
Technology Fellow

Chairpersons

Ali Shawaf
Mohammed Issaka
Rick Middaugh
Bill Lindsay

ATS&E



2014/2015 SPE-SAS ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION



SPE "Step-Change in Reservoir Technologies; Breakthrough Approaches & Innovative Techniques" Workshop

April 19-20, 2015 | Le Meridien | Al-Khobar

This workshop covers a wide range of new approaches and innovative technologies that are employed to optimize oil recovery. The workshop discusses advanced recovery techniques such as Smart Waterflooding and steamflooding. Such methods are being applied more frequently on a field scale. The use of digital rock and advanced well testing as examples of breakthrough approaches is also presented. The concept of digital rock has become a significant research area recently due to its many advantages such as modelling pore scale physics and enhanced reservoir characterization. Advanced well testing techniques are introduced for better understanding of fracture connectivity. Innovative technologies will include a discussion on how to enhance our production and reservoir monitoring approaches compared to current practice.

This workshop is designed as a platform to share and exchange ideas and experiences covering several reservoir engineering topics. Through the breakout sessions, concepts and guidelines are crystalized for this step-change in reservoir technologies.

Who Should Attend?

Reservoir Engineers
Production Engineers
Chemical Engineers
Petrophysicists
Geologists

Committee Members

Amar Alshehri
Humam AlGhamdi
Ali AlKhateeb
Husam Maghrabi
Eduardo Pacheco
Ivo Nuic
Hamood Ashraf
Ahmad Garwan
Wael Abdullah

HARNESSING TODAY'S KNOWLEDGE AND FUTURE TECHNOLOGY TO MEET GLOBAL ENERGY DEMAND



2014/2015 SPE-SAS
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Log Evaluation of Organic Shale Reservoirs: Focus on Liquid Producers

Dr. Richard Lewis
Petrophysics Technical Manager
URG Schlumberger



April 20, 2015 | Le Meridien Hotel | Al-Khobar

Abstract:

This class will expose participants to log evaluation basics for organic shale reservoirs utilizing petrophysical tools including triple combo, geochemical, NMR and sonic logs. It will guide participants to experience unconventional reservoirs petrophysical details such as mineralogy, TOC quantification, effective and total porosity, water saturation, volumetric calculation, and formation stresses.

The course will commence with basic geologic pore system model definition to provide an interpretation base for participants. Correlation workflows between core analysis and logs will be explored as a necessary step in determining pay and potentially producible hydrocarbon volumes for liquids producers. The final part will include relevant equations to estimate TOC, effective porosity, hydrocarbon in place and permeability to gas.

Speaker Bio:

Rick is the developer of the gas shale evaluation workflow that was initially fielded ten years ago and has been applied to more than 3000 wells in North America. Rick is also the interface to the Schlumberger research and engineering groups for the development of evaluation technologies for unconventional reservoirs. In his current position, he manages a group responsible for the continual improvement for this workflow, for its introduction and application to the international market, and for the development of workflows for the evaluation of liquids-producing shales. Rick has also worked for Shell Oil and the U.S. Geological Survey. Rick received a BS degree from UCLA and MS and PhD degrees from Cal Tech, all in geology.



2014/2015 SPE-SAS
ANNUAL TECHNICAL
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SPE "Drilling Ahead of Bit" Workshop The Way Forward

April 20, 2015 | Le Meridien | Al-Khobar

In this workshop, industry experts will share their experience of 'Drilling Ahead of Bit' techniques and best practices in drilling data acquisition, quality control and analytics. The workshop will include presentations from Operators, Service Companies, Upstream Technology Centers and Research Institutes.

Experts will discuss several 'Drilling Ahead of Bit' challenges and techniques including accurate well placement, dynamic prediction of drilling troubles, and several methods for optimizing drilling operations.

This Workshop will focus on some of the on-going projects utilizing optimized drilling technologies and will also highlight future potential developments.

Who Should Attend?

Drilling Engineers
Petroleum Engineers
Drilling Data Specialist
Drilling Software Specialist

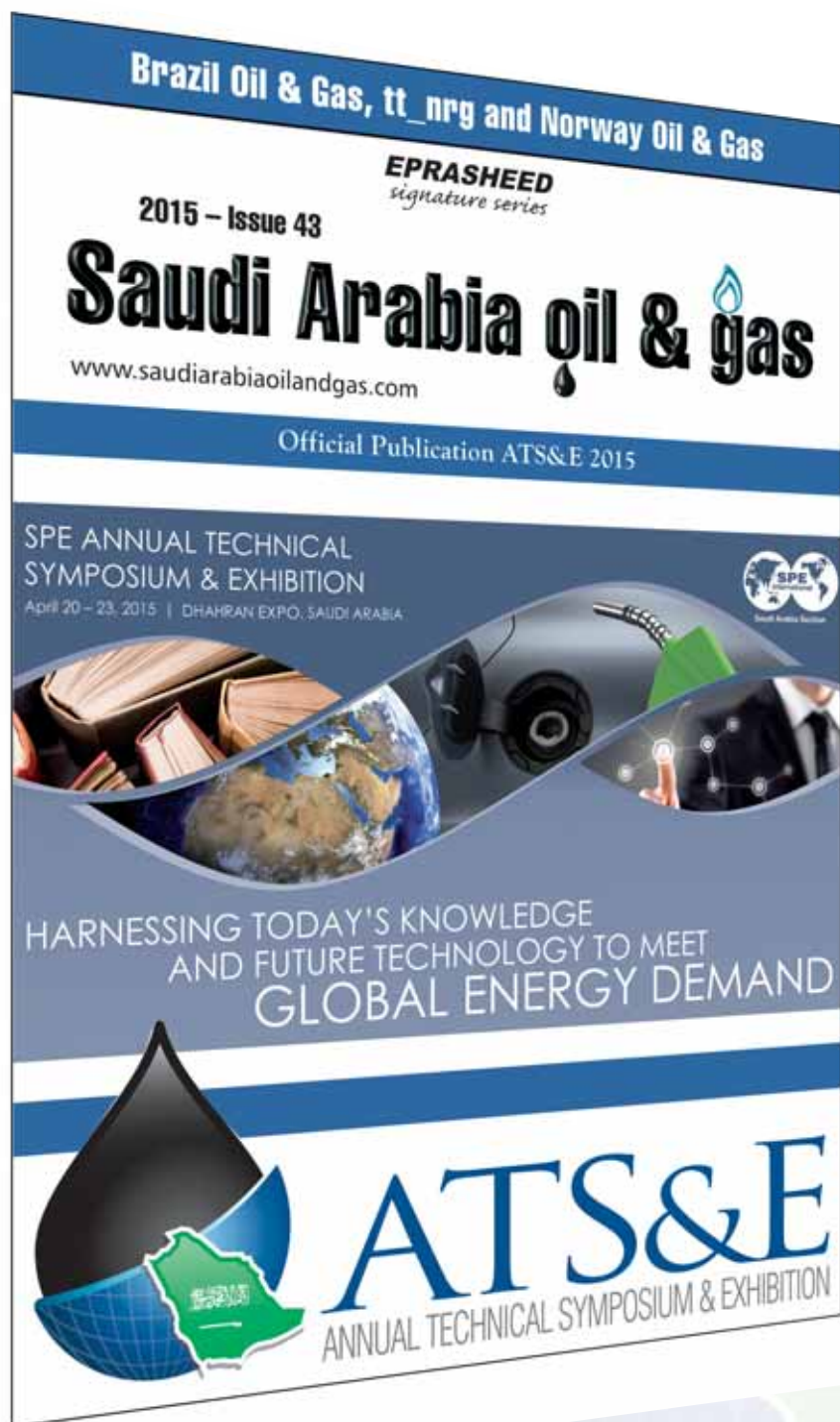
Chairpersons

Musab Al Khudiri
Hermann Spoerker
Jon Curtis
Nezar A. Talhah

Committee Members

Faisal Al Sanie
Ramzi Miyajan
Mohammed Hazzazi

SPE Saudi Arabia Section 2015



The Annual Technical Symposium and Exhibition (ATS&E) is considered a prime event that highlights the aim of the Society of Petroleum Engineers – Saudi Arabia Section (SPE-SAS), which is to provide the means for trading technical information concerning the oil and gas industry. Over the past two decades the event has grown in size, representation and significance, and, with its technical sessions, publications, training courses and workshops, is renowned as a key resource. The symposium also shares new technologies in the oil and gas industry, attracting people from different corporates around the region. It has reinforced relations with other SPE sections, not just in the Middle Eastern region but worldwide.

Recognized over the years by local and international oil and gas scientific communities, it is now also acknowledged by SPE International, which has led to

2015

Saudi Arabia oil & gas Official Techni

Annual Technical Symposium and Exhibition

the inclusion in the SPE online e-library of papers accepted in the ATS&E.

The 2015 ATS&E theme, 'Harnessing Today's Knowledge and Future Technologies to Meet Global Energy Demand', calls for knowledge sharing and best practices, as well as addressing technology challenges from around the globe.

The symposium this year features a rich program encompassing two pre-event courses, two pre-event workshops, 20 technical sessions and a vibrant panel discussion. The program will be complemented by recognized keynote and distinguished speakers.

In 2015, for the 8th successive year, Saudi Arabia Oil & Gas is proud to be the Official Technical Publication of SPE SA ATS&E, providing both coverage of the event and a comprehensive review.



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2014

Brazil Oil & Gas, tt_nrg and Norway Oil & Gas

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2014 – Issue 37

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Official Publication ATS&E 2014

SPE ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION

April 21 – 24, 2014
Seef, Al-Khobar, SAUDI ARABIA

UNATTAINABLE
UN SUSTAINABLE
UNCONVENTIONAL
MADE POSSIBLE



ATS&E

ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION

2013

SPE ANNUAL TECHNICAL SYMPOSIUM & EXHIBITION
MAY 19 – 22, 2013 | AL-KHOBAR, SAUDI ARABIA | SEEF CENTER

The Society of Petroleum Engineers (SPE) - Saudi Arabia Section is pleased to invite you to submit a paper proposal for the 2013 SPE Annual Technical Symposium & Exhibition, taking place May 19-22, 2013, at Seef Center in Al-Khobar.

The technical program committee accepts abstracts under Exploration and Production (E&P), highlighting:

- New Technologies
- Case Histories
- Fundamental Research
- Field Applications
- New Field Development

The Upstream Innovation Space,
Lighting Our Way
to a Better Tomorrow

The ATS&E Areas of Interest Include:

- Performance drilling and well construction
- Unconventional reservoirs exploration and development
- Improved oil recovery and enhanced oil recovery (EOR)
- Reservoir modeling and simulation
- Stimulation and completion optimization
- Reservoir characterization
- Formation evaluation
- Production operations and technologies
- Reservoir engineering and management
- Production facilities technologies
- Geophysics and reservoir characterization

The ATS&E is a platform for regional and international professionals, academics, and researchers to exchange views, expertise and knowledge, and to promote the latest industry research and technology. I look forward to your participation in this event.

The submission deadline for abstracts is December 2, 2012, and authors will be notified of proposal acceptance by January 9, 2013.

Al-Raddadi, Chairman
2013 SPE Annual Technical Symposium & Exhibition
Email: al.raddadi@spe.org

SUBMIT ABSTRACTS NOW

2010

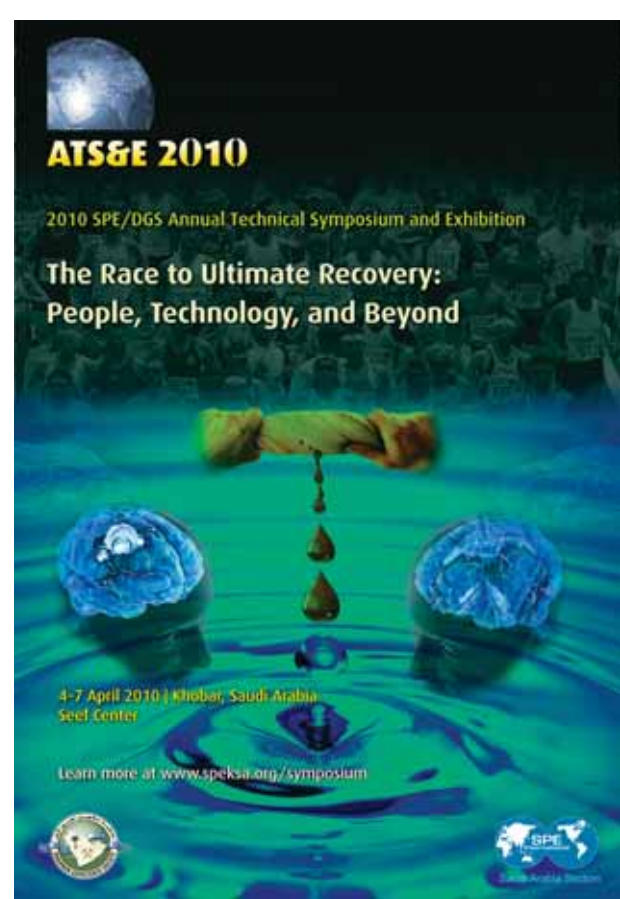
ATS&E 2010

2010 SPE/DGS Annual Technical Symposium and Exhibition

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

4-7 April 2010 | Khobar, Saudi Arabia
Seef Center

Learn more at www.speksa.org/symposium



2009

SPE
Saudi Arabia Section

2009 SPE Saudi Arabia Section Technical Symposium

9-11 May 2009, Saudi Arabia

“Pushing the Technology Envelope for Higher Recovery”

The Society of Petroleum Engineers (SPE) Saudi Arabia Section is pleased to invite you to attend and participate in the 2009 SPE Technical Symposium and Exhibition to be held from 9 to 11 May 2009 at the Le Méridien Hotel, AlKhobar, Saudi Arabia.

Over the past 25 years, the SPE Annual Technical Symposium of Saudi Arabia Section has been an important E&P gathering for regional and international industry professionals to discuss and exchange expertise and to promote the latest innovations and technologies.

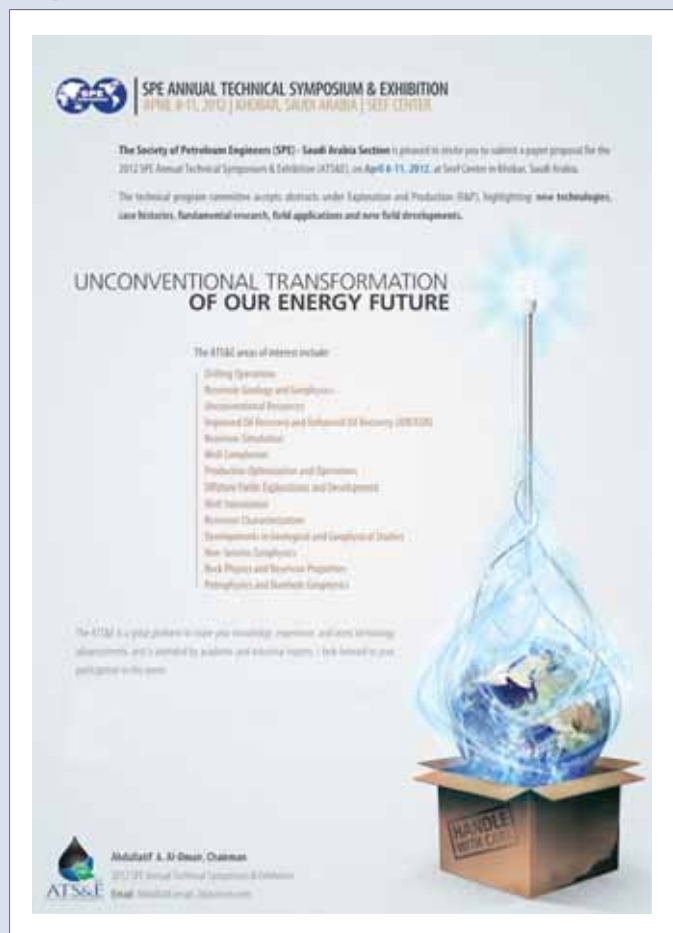
The technical program covers the following topics:

- Drilling and Completions
- Production Enhancement and Operations
- Petrophysics and Formation Evaluation
- Reservoir Management and Simulation
- Reservoir Geology and Geophysics
- Special Topics and Emerging Technologies

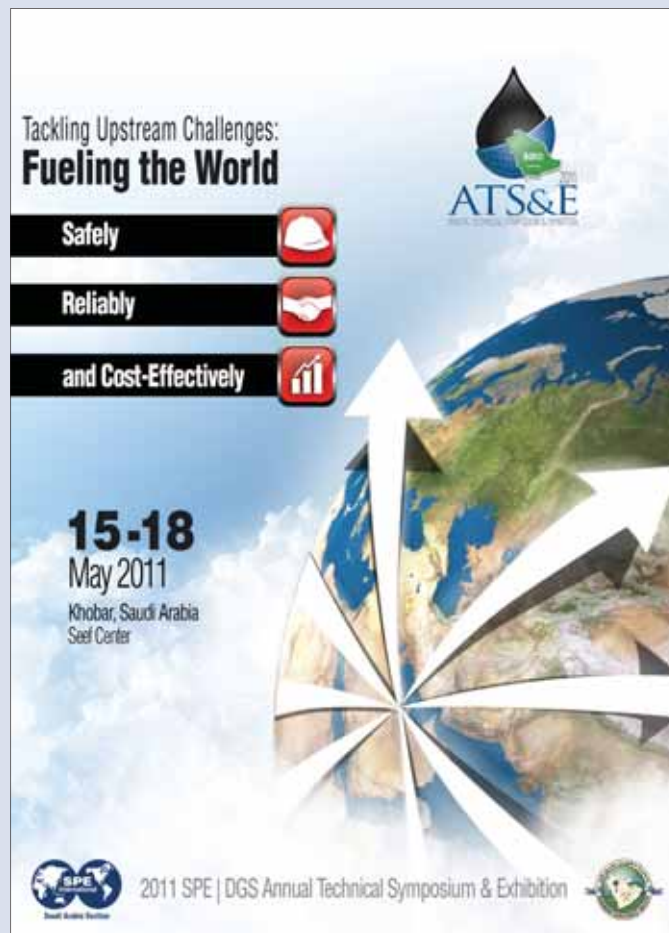


Technical Publication of SPE SA ATS&E for the 8th Year

2012



2011



2008

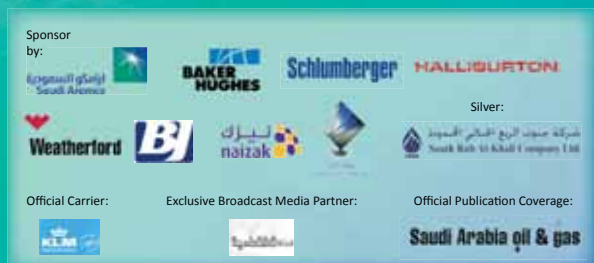
Engineers Saudi Arabia Section Technical Symposium and Exhibition



Local and international companies are encouraged to avail this event and show their state-of-the-art technologies at the recognized region of the largest oil and gas reserves and production. Make your plan to attend and actively participate in this event.

Dr. Ashraf M. Al-Tahini, Chairman
2009 SPE Annual Saudi Arabia Technical Symposium

For more information, please visit:
<http://www.speksa.org/symposium.htm>



Want to be a Sponsor? Please Join us.



The Society of Petroleum Engineers (SPE) Saudi Arabia Section is pleased to invite you to attend in the 2008 SPE Technical Symposium that will be held at the Le Meridien Gulf Hotel, Al-Khobar, on May 10-12, 2008. The symposium will have keynote speeches, technical sessions, poster sessions, and a panel discussion with local and international participation.

The keynote speakers at the opening ceremony are:

- **HRH Prince Abdulaziz Bin Salman Bin AbdulAziz Al-Saud**
Assistant Minister for Petroleum Affairs, Ministry of Petroleum & Mineral Resources
- **Mr. Dave Lesar**
Chairman of the Board, President & Chief Executive Officer, Halliburton
- **Mr. Amin H. Nasser**
Business Line Head, Exploration & Producing

The technical program covers the following topics:

- Reservoir Management
- Formation Evaluation
- Production Enhancement
- Drilling and Workover Technology
- Reservoir Characterization and Simulation

You also will not want to miss hearing the panel discussion entitled *"Smart Well Completion Unlocks Volatility"*

We hope you will attend and actively participate in this event.

Dr. Hamoud A. Al-Anazi, Chairman
2008 Technical Symposium
SPE Saudi Arabia Section

For more information, please visit
<http://www.speksa.org/symposium.htm>

Official Magazine:

Saudi Arabia oil & gas

Program

Session 1

Tuesday, April 21

Hall-A

Formation Evaluation (1)

08:00-09:30

Session Chairpersons: Gabur Hursan, Saudi Aramco
Ivo Nuic, Baker Hughes

8:00 – 8:10	Keynote Speaker	Nedhal M Al Musharfi (General Supervisor – Reservoir Description Division, Saudi Aramco)
8:10 – 8:30	SPE-SAS-105	Processing Formation Test Data to Reduce the Risk Inherent in Capturing Representative Samples in Zones with Highly Varying Permeabilities. <i>James Deering, Mustafa Abdul Mohsin, Aramco; Mark Proett, Aramco Services Company; Sami Eyuboglu and Waleed Fakhry, Halliburton</i>
8:30 – 8:50	SPE-SAS-108	Combining Managed Pressure Drilling and Advanced Surface Gas Detection Systems Enables Early Formation Evaluation and Enhances the Drilling Efficiency in a Deep Gas Exploratory Well in Saudi Arabia <i>Ayoub Hadj-Moussa, Raul A. Garrido Cruz, Muhammad A. Mugeem, Ahmed M. Alghuryafi, Roberto C. Duran, Saudi Aramco, Ayoub Hadj-Moussa, Cherif M. Mazouz, Steve Austin D'Souza, Rami Aloudat, Weatherford</i>
8:50 – 9:10	SPE-SAS-111	Formation Sampling While Drilling during Critical Time of Invasion in Order to Improve Cleanup <i>Falah Osaimi, Ilite Mustafa, Saudi Aramco</i>
9:10 – 9:30	SPE-SAS-114	Overcoming Formation Evaluation Challenges in Short Radius Re-Entry Wells in Aging Reservoirs <i>Amir Hamed, Weatherford; Ibrahim Ageel, Chingiz Baikelov, Pablo Sanchez, Saudi Aramco; Maged Yassin, Karim Ammar, Sunil Gupta, Osamah Al-Momen, Weatherford</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-330	A New Innovation by Saudi Aramco: Well Engineering Schematics for Design & Analysis Using Digital Well Files <i>Musab AlKhudiri, Faisal S. Sanie, Saudi Aramco</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-321	Slim LWD Spectral Gamma Ray for Both Well Placement and Petrophysical Evaluation of Clastics Reservoir in Saudi Arabia <i>Mohamed L. Zeghlache, Richard Palmer, Saudi Aramco; Hesham M. Elmasry, Alibassiouny Abdelkader, Ahmed F. Mohamed, Weatherford</i>

Session 2

Tuesday, April 21

Hall-B

Production Operations and Technologies (1) 08:00-09:30

Session Chairpersons: Mike Haas, Saudi Aramco
Abdullah Al Mulhim, Weatherford

8:00 – 8:10	Keynote Speaker	Faisal Al Beheiri (General Supervisor – Southern Area Gas Production Engineering, Saudi Aramco)
8:10 – 8:30	SPE-SAS-201	Design and Qualification Testing of Large Bore Subsurface Safety Valve for High Rate Gas Wells <i>Ali Al Muslim, Karam Yateem, SA, Ali, Mohammad A. (Athar), Saudi Aramco</i>
8:30 – 8:50	SPE-SAS-204	An Integrated Approach for Downhole Leak Detection <i>Ali M. Albussain, M. Enamul Hossain, AbdAzziz AbdRahim, Rahul Gajbhiye, KFUPM</i>
8:50 – 9:10	SPE-SAS-207	First Autonomous ICD Installation in Saudi Arabia, Modeling a Field Case <i>Mohammad Al Kadem, Nasir Alsuwayigh, Saudi Aramco, Abdulrazzaq Almuhaish, Saudi Aramco</i>
9:10 – 9:30	SPE-SAS-336	Model of Hydraulic Fracture Initiation from the Notched Openhole <i>Gallyam Aidagulov, O. Alekseenko, Schlumberger Novosibirsk Technology Center, Russia; F. Chang, K. Bartko, Saudi Aramco, Dhahran, Saudi Arabia; S. Cherny, D. Esipov, D. Kuranakov, V. Lapin, Institute of Computational Technologies SBRAS, Novosibirsk, Russia.</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-153	The Impact of Dissolved Ions on the Reservoir Fluids and Rock Interactions in Carbonates <i>Mohammed Alotaibi, Ali Yousif, Saudi Aramco</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-354	Integration of Petrophysical and Geomechanical Properties for Enhanced Fracture Design <i>Hamad Kharraa, Ahmed Al-Ameer, Faris Al-Qahtani, Ali Al-Sultan, Mustafa Al-Abbad, Osama Al-Obaid, Saudi Aramco</i>

Session 3**Tuesday, April 21****Hall-A**

Drilling and Workover Operations (1)

10:30-12:00

Session Chairpersons: Mohammed Al Badran, Saudi Aramco
Wael ElSherbeny, Baker Hughes

10:30 – 10:40	Keynote Speaker	Faisal Al Nughaimish (Manager – Offshore and Gas Drilling Engineering Department, Saudi Aramco)
10:40 – 11:00	SPE-SAS-129	Completion Approach in Saudi Aramco for Unconventional Gas Wells Using Full Monobore 4 ½” Cemented Casing Completion <i>Salahaldeen Almasmoom, Juan I. Gonzalez, Domingo A. Ramos, Omar A. Faraj, Saudi Aramco</i>
11:00 – 11:20	SPE-SAS-132	Can Proppants Do More Than Hold the Fracture Open? <i>Pedro Saldungaray, Terry Palisch, Josh Leasure, Schlumberger</i>
11:20 – 11:40	SPE-SAS-135	Enhancing Drilling Operations in SHYB Oil Field by Relating Drilling Azimuth to Formation Geo-Mechanics; A Field Wide Case Study <i>Majed Alrabeih, Ivan Ramirez, Saudi Aramco</i>
11:40 – 12:00	SPE-SAS-138	Innovative Coiled Tubing Deployed Zonal Isolation of a Highly Permeable, Acid Fractured Carbonate Reservoir in Saudi Arabia <i>Syed Danish, Keshan Deonaraine, Halliburton; Angel Arenas, Halliburton</i>

Session 4

Tuesday, April 21

Hall-B

Reservoir Engineering and Management (1) 10:30-12:00

Session Chairpersons: Mabkhout Al Harthi, Saudi Aramco
Yildiray Cinar, Saudi Aramco

10:30 – 10:40	Keynote Speaker	Khalid O. Subai (Manager – Southern Area Reservoir Management Department, Saudi Aramco)
10:40 – 11:00	SPE-SAS-261	First Successful Application of Distance to Bed Boundary Technology to Achieve Maximum Reservoir Contact in Horizontal Wells in Saudi Aramco Gas Reservoir <i>Mahbub Ahmed, Ali Habbtar, Rajeev Brent Samaroo, Nasser Qahtani, Saudi Aramco</i>
11:00 – 11:20	SPE-SAS-264	A Comprehensive Approach for Assessing Remaining Oil Saturation and Sweep Efficiency in a Large Carbonate Reservoir <i>Amer Al-Anazi, Dimitrios Krinis, Abdullatif Al-Omair, Tareq Al-Zahrani, Saudi Aramco</i>
11:20 – 11:40	SPE-SAS-267	Reservoir Geomechanics: An Important Component to Better Understand Reservoir Behavior <i>Alfonso Varela-Pineda, Khaqan Khan, Saad Al-Mutairi, Saudi Aramco</i>
11:40 – 12:00	SPE-SAS-270	A Complex Naturally Fractured Reservoir Case Study: Fracture System Understanding is Key to Development Drilling Success <i>Stig Lyngre, Danang R. Widjaja, Saudi Aramco, Faleh M. Al-Shammari, Saudi Aramco, Uthman F. Al-Otaibi, Saudi Aramco, Murad F. Barghouty, Saudi Aramco</i>

Session 5

Tuesday, April 21

Hall-A

Improved Oil Recovery & Enhanced Oil Recovery (IOR/EOR) (1)

1:00-2:30

Session Chairpersons: Majed Al-Suwailem, Saudi Arabia Chevron
AbdulKarim AlSofi, Saudi Aramco

1:00 – 1:10	Keynote Speaker	Dr. Sunil Kokal (Senior Petroleum Engineering Consultant – Expec Advanced Research Center, Saudi Aramco)
1:10 – 1:30	SPE-SAS-156	Evaluation of Thermochemical Stimulation Technology For Heavy Oil Reservoirs in the Portioned Zone between Saudi Arabia and Kuwait <i>Saleh Almutairi, Gamal O. Remila, Saudi Arabian Chevron</i>
1:30 – 1:50	SPE-SAS-159	Chemical Enhanced Oil Recovery Pilot Design for Heglig Main Oil Field-Sudan <i>Husham Ali, Tagwa Ahmed Musa, Abe Dourodi</i>
1:520 – 2:10	SPE-SAS-162	Defining the Optimum Properties of Chelating Agents to be Used as EOR Fluid for Sandstone Reservoirs <i>Mohammed Attia, Mohamed Ahmed Mahmoud, Sudan University of Science and Technology, Computer Modeling Group (CMG)</i>
2:10 – 2:30	SPE-SAS-351	A New Practice of Streamline Simulation for Compositional and Miscible Floods <i>Mohamed Nagib, Alan Burns, Leeds University, Derek Ingham, Leeds University, Ahmed El Banbi, Cairo University</i>

Session 6

Tuesday, April 21

Hall-B

Reservoir Characterization and Geophysics (1)

1:00-2:30

Session Chairpersons: Denis Schmitt, Saudi Aramco
Mohammed Mahmoud, KFUPM

1:00 – 1:10	Keynote Speaker	Aus Al Tawil (Manager – Reservoir Characterization Department, Saudi Aramco)
1:10 – 1:30	SPE-SAS-225	Evaluation of the Impact of Scale-dependent Geological Parameters on the Well Test Behaviour of Fissured Reservoirs (Single-phase) <i>Abdulmajeed Almutairi, Saudi Aramco, Alain Gringarten, Imperial College London</i>
1:30 – 1:50	SPE-SAS-228	Compositional Analysis and Treatment of Oil-field Scales <i>Hicham El Hajj, Omprakash Pal, Bilal Zoghbi, Halliburton</i>
1:520 – 2:10	SPE-SAS-231	Seismic-data Assisted History Matching Using Ensemble based Methods for the Norne Field in Norway – A Real Field Study <i>Klemens Katterbauer, Santiago Arango, Shuyu Sun, Ibrahim Hoteit, Saudi Aramco</i>
2:10 – 2:30	SPE-SAS-234	Improving Reservoir Characterization with Seismic Data Preconditioning – A Case Study of Saudi Arabian Channel Detection <i>Saleh Al-Dossary, Saudi Aramco</i>

Session 7

Tuesday, April 21

Hall-A

New Developments in Alternate Energy Resources

2:40-3:40

Session Chairpersons: David Kersey, Saudi Aramco
Amro ElShurafa, KAPSARC

2:40 – 3:00	SPE-SAS-309	Feasibility Study of Photovoltaic Microgrids and Their Application in Powering Remote Onshore Oil and Gas Surface Instrumentation <i>Angelo V. Faez, Salvador Ruvalcaba, Saudi Aramco</i>
3:00 – 3:20	SPE-SAS-312	Economics of Steam Generation for Thermal EOR <i>Marwan Chaar, Milton Venetos, Wyatt Enterprises; Justin Dargin, University of Oxford; Daniel Palmer, GlassPoint Solar</i>
3:20 – 3:40	SPE-SAS-315	A Review of Recent Developments and Challenges in IGIP Estimation of Coal Bed Methane Reservoirs <i>Rizwan A. Khan, Dr. Hasan Salman Al-Hashim, KFUPM, Shams Kalam, KFUPM, Mirza Talha Baig, KFUPM</i>



Session 8

Tuesday, April 21

Hall-B

Advances in Reservoir Simulation

2:40-3:40

Session Chairpersons: Beven Yuen, Saudi Aramco
Tariq AlZahrani, Saudi Aramco

2:40 – 3:00	SPE-SAS-249	Streamline Guided Assisted History Matching Methodology: A New Approach <i>Majdi Baddourah, Ali A. Alturki, M Ehtesham Hayder, Ahmed S Al-Zawawi, Saudi Aramco</i>
3:00 – 3:20	SPE-SAS-252	Utilization of Streamline Simulation Technology for Water Cut Management: A Case Study <i>Hassan Alzayer, Hong Wei Jin, Mohamed Nagib, Qusai Alabdrubalnabi, Saudi Aramco</i>
3:20 – 3:40	SPE-SAS-255	A Methodology for Identifying & Quantifying Uncertainties (Seismic to First Phase Field Development) in Reservoir Simulation. Case Study of Two Fields in Saudi Arabia <i>Babatunde Moriwawon, Ali Alturki, Saudi Aramco, Ali Al-Shawaf, Saudi Aramco</i>



Session 9

Wednesday, April 22

Hall-A

Evolution in Unconventional Resources (1) 08:00-09:30

Session Chairpersons: Carl Dismuke, Saudi Aramco
J. Wesley Martim, Schlumberger

8:00 – 8:10	Keynote Speaker	Ibrahim Arnaout (Head of Unconventional Production Operations, Saudi Aramco)
8:10 – 8:30	SPE-SAS-285	Modeling in Multi-Stage Hydraulic Fracturing Patterns to Optimize Shale Reservoir Production <i>Abdulraof Almulhim, Azra N. Tutuncu, Colorado School of Mines, Hossein Kazemi and Najeeb Alharthy, Saudi Aramco</i>
8:30 – 8:50	SPE-SAS-357	Fracturability Index is a Mineralogical Index <i>Ahmed AlZahabi, Texas Tech University; Ghazi D. AlQahtani, SPE/ Saudi Aramco; Mohamed Soliman, Texas Tech University; Ravi Vadapalli, Texas Tech University; Bateman Richard, Texas Tech University; George Asquith, Texas Tech University</i>
8:50 – 9:10	SPE-SAS-291	Fracturing a Tight Sand Formation with High Frac Gradient Onshore Saudi: Challenges and Solutions <i>Ali Almomen, Ali Al-Saihati, Saudi Aramco</i>
9:10 – 9:30	SPE-SAS-294	Impact of Imbibition Mechanism on Flowback Behavior: A Numerical Study <i>Abdulraof Almulhim, Saudi Aramco, N. Alharthy, A.N. Tutuncu, H. Kazemi, Colorado School of Mines</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-333	IPR Utilization in Optimizing Wells' Production Under Rigorous Flow Conditions <i>Nooreddeen Albokhari, Saudi Aramco</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-342	Feature Selection-Based ANN for Improved Characterization of Carbonate Reservoir <i>Kabiru Akande, Mr Taoreed Owolabi, Dr Sunday Olatunji, KFUPM</i>

Session 10

Wednesday, April 22

Hall-b

Production Facilities Technologies (1)

08:00-09:30

Session Chairpersons: Khalid Al Mohanna, Saudi Aramco
Dennis Cai, Saudi Aramco

8:00 – 8:10	Keynote Speaker	Mohammed Al Musharraf (General Supervisor – Upstream Technical Support Division, Saudi Aramco)
8:10 – 8:30	SPE-SAS-177	Successful Installation of Multistage Choke Valve Technology in Water Flow Lines to Reduce High Pressure Drop Across Choke Valves <i>Abdullah Al-Saeed, Salah Al-Mousa, Saudi Aramco, Mohammed Al-Ajmi, Saudi Aramco, Martin O'Donnell, Cameron</i>
8:30 – 8:50	SPE-SAS-180	A Market Survey of Offshore Underwater Robotic Inspection Technologies for the Oil and Gas Industry <i>Fernando D. Ledezma, Ayman Amer, Saudi Aramco, Fadi Abdellatif, Saudi Aramco, Ali Outa, Saudi Aramco, Hassane Trigui, Saudi Aramco, Sahejad Patel, Saudi Aramco, and Roba Binyahib, Saudi Aramco</i>
8:50 – 9:10	SPE-SAS-183	Electric Submersible Pump Installation and Commissioning – Challenges and Lesson Learned from Giant Field Development <i>Mohammed Al-Khalifa, Robert Cox; Hossam Saad, Saudi Aramco</i>
9:10 – 9:30	SPE-SAS-186	Improved Gas Flow Prediction through Chokes using Artificial Intelligence Techniques <i>Murtada Elhaj, A. Abdulraheem KFUPM</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-345	Utilizing J-function to Mitigate OOWC Uncertainty Using Petrel Platform <i>Saud AlOtaibi, Saudi Arabian Chevron</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-348	Productivity Increase Estimate in Multi Stage Fracturing in Horizontal Wells for Tight Reservoirs <i>Mirza T. Baig, Sami Alnuaim, Saudi Aramco</i>

Session 11

Wednesday, April 22

Hall-A

Improved Oil Recovery & Enhanced Oil Recovery (IOR/EOR) (2)

10:30-11:50

Session Chairpersons: Ahmed Al Eidan, Saudi Aramco
Sultan Al Enezi, Saudi Aramco

10:30 – 10:50	SPE-SAS-165	Synergistic Effects of Surfactants Mixture for Foam Stability Measurements for Enhanced Oil Recovery Applications <i>Mudassar Mumtaz, Isa M Tan, Muhammad Mushtaq, University Technology Petronas</i>
10:50 – 11:10	SPE-SAS-168	A Novel Technique Combining the Cyclic Steam Stimulation and Gas Push Using Top Injection and Bottom Production for Increasing Steam Efficiency <i>Suranto A.M., Wisup Bae, A.K. Permadi, Sejong University</i>
11:10 – 11:30	SPE-SAS-171	Laboratory Evaluation of Different Modes of Supercritical CO ₂ Miscible Flooding for Carbonate Rocks <i>Fawaz, AlOtaibi, Xianmin Zhou and Sunil Kokal, Saudi Aramco</i>
11:30 – 11:50	SPE-SAS-174	Measurements of Volumetric Phase Behaviour of Mixtures of n-decane and CO ₂ at High Pressures and High Temperatures <i>Saifur Rahman, M. E. Kandil, KFUPM, N. Al-Saifi, KFUPM, A. Sultan, KFUPM</i>

Session 12

Wednesday, April 22

Hall-B

Drilling and Workover Operations (2)

10:30-11:50

Session Chairpersons: Isa Al Umairin, Saudi Aramco
Bradley Zukiwsky, Weatherford

10:30 – 10:50	SPE-SAS-141	Formation Pressure Estimation & Miocene Clay Minerals Assemblages Identification, Drilling Challenges and Mitigation, Integrated Case Study, Gulf of Suez, Egypt <i>Wael El Sherbeny, Dr. Khalid Abde alla, Prof. M. Darwish, Prof. M. El Kammar, Baker Hughes</i>
10:50 – 11:10	SPE-SAS-144	Chelating Agent for Uniform Filter Cake Removal in Horizontal and Multilateral Wells: Laboratory Analysis and Formation Damage Diagnosis <i>Hussain Al-Ibrahim, Tariq Almubarak, Saudi Aramco, Mohammed Bataweel, Saudi Aramco, Peter Osode, Saudi Aramco, Abdullah Al-Yami, Saudi Aramco</i>
11:10 – 11:30	SPE-SAS-147	Drilling and Completion of Challenging Shallow, Extended-Reach Wells from Remote Drill Site in a Populated Area <i>Brett Fischbuch, Saad S. Al-Shammari, Emmanuel O. Nwosu, Suresh Jacob, Alberto Miliani Paez, Stig Lyngra, Saudi Aramco</i>
11:30 – 11:50	SPE-SAS-150	The Ideal Approach for Casing Leak Repairs in Saudi Arabia “Breathing Life into Dying Wells” <i>Ahmed Ismail, Baker Hughes</i>



Session 13

Thursday, April 23

Hall-A

Reservoir Engineering and Management (2)

8:00-9:30

Session Chairpersons: Talal Al Mousa, Saudi Aramco
Abdulbari Al Arefi, King Saud University

8:10 – 8:30	SPE-SAS-273	Characterisation of a Wet Gas Reservoir and its Impact on Reserves Estimate <i>Hamad Marri, Saudi Aramco</i>
8:30 – 8:50	SPE-SAS-276	Comprehensive Reservoir Vertical Interference Testing to Optimize Horizontal Well Placement Strategy in a Giant Carbonate Field <i>Mabkhout Al Harthi, Cesar Prado, Khalid Kilany, Majid Al Otaibi, Saudi Aramco, Murat Zeybek and Asif Amin, Schlumberger</i>
8:50 – 9:10	SPE-SAS-279	Step Change in Hydraulic Fracturing Strategy by Analyzing Detailed Anatomy of Pre-Khuff Clastic Gas Reservoir Field Experience to Achieve Production Enhancement <i>Ammar Ali, Mohammed Islam, Saudi Aramco</i>
9:10 – 9:30	SPE-SAS-282	Devising & Optimizing Development Strategies Using a History Matched Reservoir Model Indicates Potential Increases in Recoverable Oil from Heterogeneous Carbonate Reservoirs in the Partitioned Zone – South Fuwaris Field Case Study <i>Ahmad Al-Aruri, Saud Al-Otaibi, Saudi Arabian Chevron</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-318	An Artificial Intelligence Approach in Predicting Water Saturation <i>Wael Alharbi, Abdulazeez Abdulraheem, KFUPM; Fatai Anifowose, KFUPM</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-339	Integrated Petrophysical and Reservoir Characterization Workflow to Enhance Permeability and Water Saturation Prediction <i>Meshal Al-Amri, Saudi Aramco, M. A. Mahmoud, King Fahd University of Petroleum & Minerals, Tariq Al-Ghamdi, Hamad S. Kharraa, Saudi Aramco</i>

Session 14

Thursday, April 23

Hall-B

Reservoir Characterization and Geophysics (2) 8:00-9:30

Session Chairpersons: Thomas Dickson, Saudi Aramco
Anisur Rahman, Saudi Aramco

8:10 – 8:30	SPE-SAS-237	Uncertainty Analysis in History Matching and Prediction Sensitivity of a Highly Complex Saudi Arabia Clastic Reservoir: A Case Study <i>Sharizan Sudirman, Ahmed Al-Harbi, Khalid Al-Alwan, Abdullah Al-Najem, Saudi Aramco</i>
8:30 – 8:50	SPE-SAS-240	Use of Wellhead Data for Pressure Transient Analysis for Deep and Hot Gas Wells <i>Akim Kabir, Sebastian Lopez, Saudi Aramco</i>
8:50 – 9:10	SPE-SAS-243	Harnessing the Power of Type-2 Fuzzy System in the Prediction of Reservoir Properties. <i>Sunday O. Olatunji, Ali Selamat, Universiti teknologi Malaysia and the Dean of K-Economy Research Alliance , Abdur Raheem Abdul Azeez, Department of Petroleum Engineering, King Fahd University of Petroleum and Minerals, Saudi Arabia</i>
9:10 – 9:30	SPE-SAS-246	Comparative Analysis of Feature Selection-Based Machine Learning Techniques in Reservoir Characterization <i>Kabiru Akande, Taoreed Owolabi, Dr Sunday Olatunji, KFUPM</i>
E-poster Alternate 9:40 – 10:00	*SPE-SAS-324	Application Suite for 24/7 Real Time Operation Center <i>Musab Khudiri, Sajjad A Paracha, Waseem Awan, Saudi Aramco</i>
E-poster Alternate 10:10 – 10:20	*SPE-SAS-327	Optimizing Well Design in Saudi Arabia: Successful Application of Managed Pressure Drilling Enables Drilling Across Multiple Pressure Zones and Running Liner Using Constant Bottom-Hole Pressure Technique <i>Ayoub Hadi, N.O. Pinero Zambrano, I.M. Al-Ageel, M.A. Muqeem, A.S. Al-Mutawa, Saudi Aramco, C.M. Mazouz, A. Hadj-Moussa, A. Zeb, F. Al-Ghamdi, Weatherford</i>

Session 15

Thursday, April 23

Hall-A

Evolution in Unconventional Resources (2) 10:30-11:50

Session Chairpersons: Carl Lindahl, Saudi Aramco
Nacer Guergeb, Halliburton

10:30 – 10:50	SPE-SAS-297	First Fractured Horizontal Well with an Offset Horizontal Microseismic in KSA <i>Mohammed Kurdi, Kirk Bartko, Saudi Aramco</i>
10:50 – 11:10	SPE-SAS-300	Phase Trapping Damage in Tight Gas Reservoirs <i>Nick Bahrami, Arshad Ahmed, Halliburton Saudi Arabia, Tony Montgomery, Halliburton Saudi Arabia</i>
11:10 – 11:30	SPE-SAS-303	Chemically-Induced Pressure Pulse: A Novel Fracturing Technology for Unconventional Reservoirs <i>Ayman Al-Nakhli, Saudi Aramco</i>
11:30 – 11:50	SPE-SAS-306	Adaptation of Modern Techniques in Economic Exploitation of Unconventional Gas Reservoirs in the Emerging Regions <i>Puneet Sharma, Halliburton</i>



Session 16

Thursday, April 23

Hall-B

Formation Evaluation (2)

10:30-11:50

Session Chairpersons: James S. Deering, Saudi Aramco
Steve Crary, Schlumberger

10:30 – 10:50	SPE-SAS-117	NMR Logs Help Formation Testing and Evaluation <i>Gabor, Hursan, James S. Deering, Francis N. Kelly, Saudi Aramco</i>
10:50 – 11:10	SPE-SAS-120	Application of the New Dielectric Technology to the Formation Evaluation of Middle Eastern Carbonate and Sandstone Reservoirs – A Case Study from Saudi Arabia <i>Said Mahiout, Edward A. Clerke, Saudi Aramco, Ibrahim Mohd Azizi, Saudi Aramco, Ali Belowi, Saudi Aramco, Rayan Ghanim, Saudi Aramco</i>
11:10 – 11:30	SPE-SAS-123	Integrated Approach implemented to Identify Viscous Hydrocarbons Utilizing Multiple Logging Technologies, Case Histories, Kuwait <i>Wael El Sherbeny, Baker Hughes, Khalid Ahmed, Kuwait Oil Company, Tharwat Hussain, Ayman Darwish</i>
11:30 – 11:50	SPE-SAS-126	Unlock the True Potential of Tight Hydrocarbon Zones in a Lower Cretaceous Reservoir in a Giant Field in Saudi Arabia <i>Haytham Osman, Ramy Abd Elkader, Saudi Aramco, Ramy Ahmed, Schlumberger, Kuntal Majumdar, Schlumberger, Abdullah Ebrahim, Schlumberger</i>

Session 17

Thursday, April 23

Hall-A

Production Facilities Technologies (2) 1:10-2:30

Session Chairpersons: Sami Logan, Saudi Aramco
Nashi Al Otaibi, Saudi Aramco

1:10 – 1:30	SPE-SAS-189	Data Analytics and Statistical Hypothesis Testing: Making the Difference Between Passing or Failing a Wet Gas Multiphase Flow Meter Field Trial Test (Case Study) <i>Ruvalcaba Velarde, Ruben Villegas Rodriguez, Saudi Aramco, Angelo Vidal Faez, Saudi Aramco, Mohammed A. Asiri, Saudi Aramco</i>
1:30 – 1:50	SPE-SAS-192	Estimating Energy Loss Through Wellhead Chokes <i>Xiao, Jinjiang, Saudi Aramco</i>
1:50 – 2:10	SPE-SAS-195	Magnetic Flux Leakage (MFL) Technology Provides the Industry's Most Precise Pipe Integrity and Corrosion Evaluation, Accurately Characterizing Casing and Tubing Strength. Technology Overview and Case History <i>Wael El Sherbeny, Abba Abdesslam, SPE, Ayman Darwish, Ivo Nuic, Baker Hughes</i>
2:10 – 2:30	SPE-SAS-198	Innovative Hydrate Management Assessment in Early Conceptual Design Phase: A Success of Life Cycle Cost Approach in Offshore Gas Field Development <i>Ardian Nengkoda, Bader Harbi, Megat Rithauddeen, Shadi Adel, Mutaz Daas, Saudi Aramco</i>



Session 18

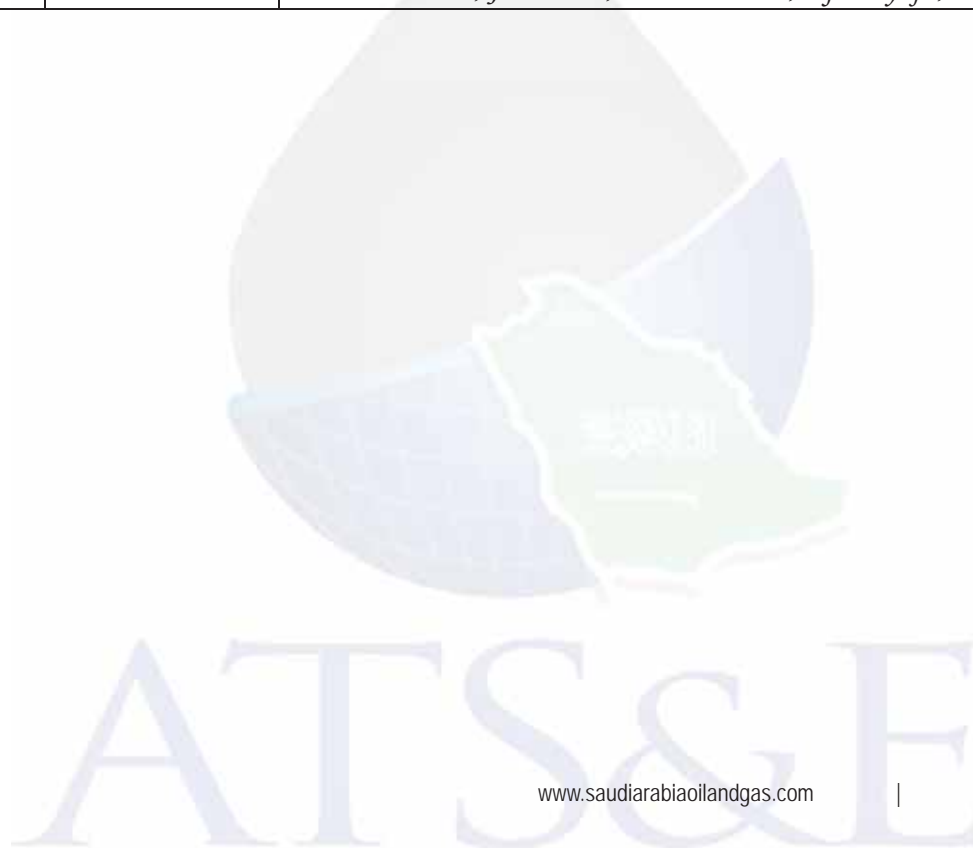
Thursday, April 23

Hall-B

Production Operations and Technologies (2) 1:10-2:30

Session Chairpersons: Meshal Al Amri, Saudi Aramco
Hicham ElHajj, Halliburton

1:10 – 1:30	SPE-SAS-213	Innovational Technique in Utilizing Real-Time Downhole Pressure and Distributed Temperature Surveying for Skin Quantification during Matrix Stimulation in Complex Multilateral Well in Saudi <i>Nooreddeen Albokhari, Talal Ghamdi, Saudi Aramco; Ramy Ahmed, Schlumberger, Abdulrahman Al-Dosary, Schlumberger</i>
1:30 – 1:50	SPE-SAS-216	Autonomous Detection of Hydrocarbon Releases using the IntelliRed Optical Gas Imaging System <i>Jonathan Morris, Hazem Abdelmoati, ExxonMobil Research Qatar</i>
1:50 – 2:10	SPE-SAS-219	Assessment of Water Injection-Related Scale Risks for an Onshore Carbonate Oilfield Incremental Development Project <i>Peter Osode, Mohammed Bataweel, Saudi Aramco, Najeeb, P., Saudi Aramco, Mohammed Khaldi, Saudi Aramco</i>
2:10 – 2:30	SPE-SAS-222	Analysis of High Temperature Sour Gas Wells to Mitigate Corrosion and Scale Formation <i>Sunder Ramachandran, Ghaithan Al-Muntasheri, Aramco Research Centre Houston, Jario Leal, Saudi Aramco, Irfan Syafil, Saudi Aramco</i>



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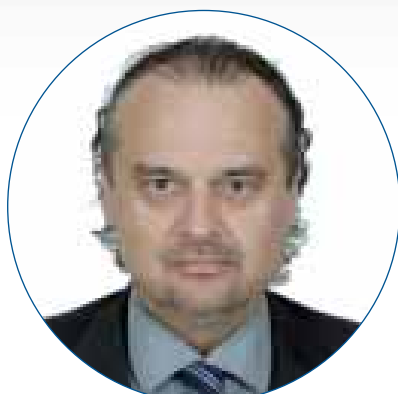
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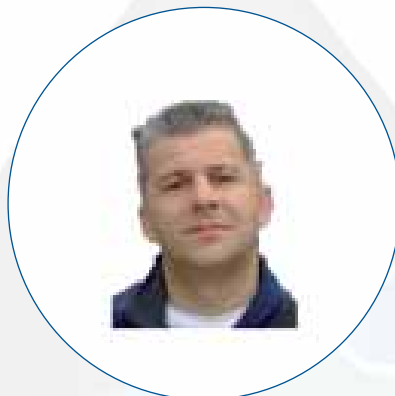
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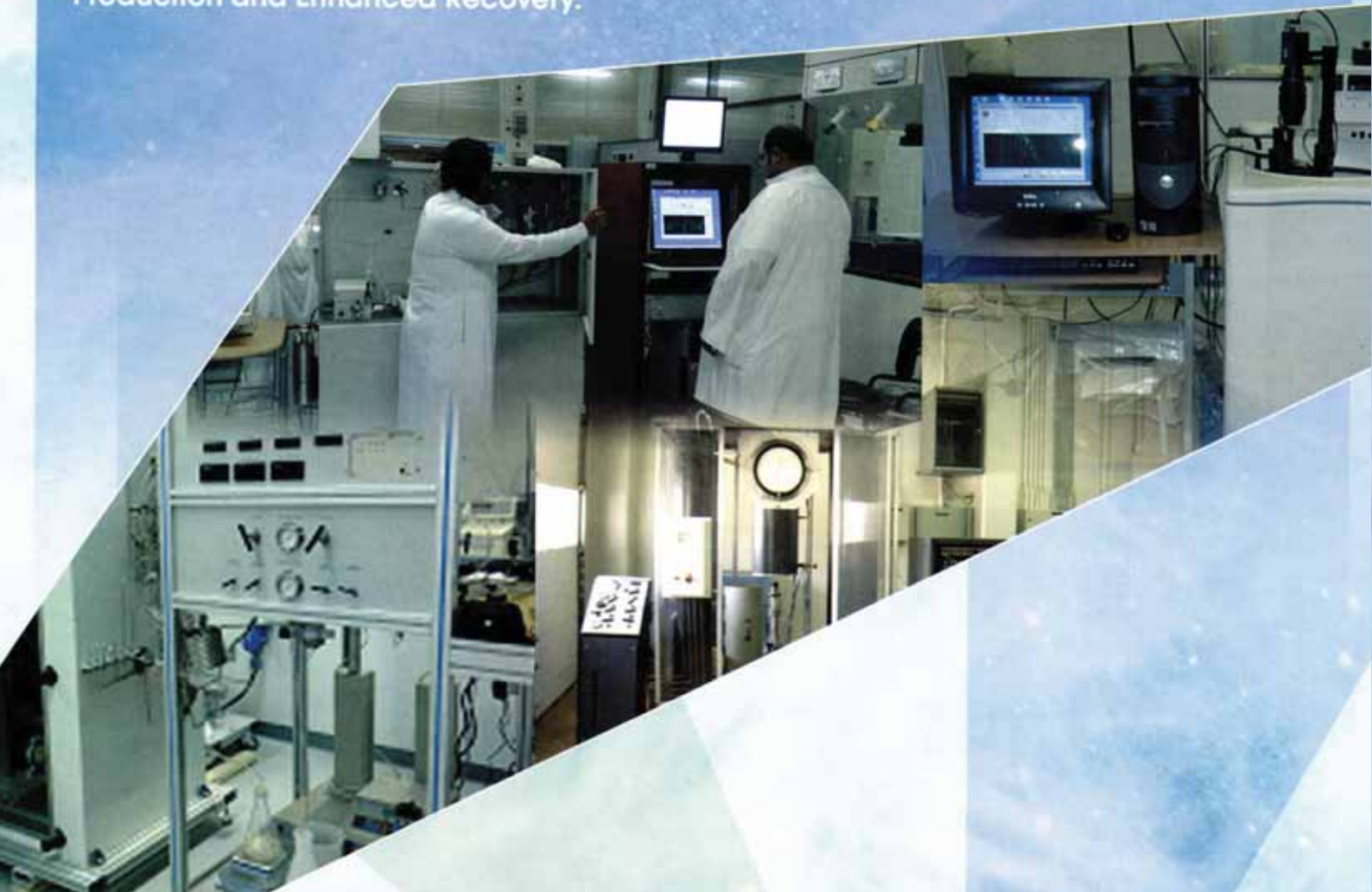
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Oil and Gas Research Institute

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

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



Services Provided

Service	Techniques
CONVENTIONAL CORE ANALYSIS	<ul style="list-style-type: none"> ▶ Helium Porosity (Ambient Conditions) ▶ Gas Permeability & Porosity (Low and Reservoir Overburden Stress) ▶ Klinkenberg Correction ▶ Liquid Permeability (Reservoir Conditions)
SPECIAL CORE ANALYSIS (SCAL)	<p>CAPILLARY PRESSURE TESTS</p> <ul style="list-style-type: none"> ▶ Centrifuge Techniques (Reservoir Conditions) ▶ Low and High Pressure Mercury Injection and Withdrawal Technique ▶ Pore Size Distribution (PSD) <p>RELATIVE PERMEABILITY MEASUREMENTS</p> <ul style="list-style-type: none"> ▶ Unsteady State Flooding Technique (Reservoir Conditions) ▶ Centrifuge Technique (Reservoir Conditions) <p>WETTABILITY TESTS</p> <ul style="list-style-type: none"> ▶ Centrifuge USBM Method ▶ Contact angle Measurement (Ambient and Reservoir Conditions) ▶ Interfacial Tension Measurements <p>PETROGRAPHIC SERVICES</p> <ul style="list-style-type: none"> ▶ Sieve Analysis ▶ Particle Size Analysis ▶ Thin section
RESERVOIR FLUID ANALYSIS	<ul style="list-style-type: none"> ▶ Interfacial & Surface tension ▶ Gas and Gas Condensate Viscosity ▶ Refractive index and pH ▶ Contact angle
ADVANCED RESERVOIR ENGINEERING	<ul style="list-style-type: none"> ▶ Water-Oil /Water-Gas Displacement ▶ Gas Flooding and WAG ▶ Chemical Flooding
PETROLEUM RELATED ROCK MECHANICS	<ul style="list-style-type: none"> ▶ Uniaxial, Triaxial, and Hydrostatic Compressive strength ▶ Stress-Strain Behavior ▶ Failure Envelope ▶ Elastic moduli ▶ Bulk and Pore Compressibility ▶ Fracture Toughness

Saudi Aramco's IP Week Reception Highlights Opportunities



LONDON, 11 March 2015 – More than 500 of Saudi Aramco's partners and customers attended a company reception at International Petroleum (IP) Week held in London. This year's focus was on "strategies for the changing oil and gas landscape".

The Saudi Aramco reception, themed "Enabling Opportunity", underlined the commitment to remain on track to achieve long-term goals. The evening was an opportunity for Saudi Aramco to host stakeholders and give attendees a platform to discuss opportunities within the sector.

"In 2014 alone, we hired thousands of new employees and pledged to invest billions over the next decade across the value chain," said Salah Al-Hareky of Saudi Petroleum Overseas Ltd. (SPOL), Saudi Aramco's London-based crude marketing arm.

"The numbers emphasize our desire to continue pursuing the right investment opportunities, even in times of uncertainty when convention dictates consolidation rather than expansion."

The company highlighted its continuity over the past 12 months amid declining oil prices, which is evident in its increases in investment and human capital. Saudi

Aramco has committed to increase spending on research and development, as well as on the people working in it.

"We are going beyond reliability and responsibility, extending our focus in areas such as innovation," said Al-Hareky. "We believe innovation is the key to making our resources more accessible, useful, sustainable and competitive."

IP Week, a thought-leadership forum for the global oil and gas industry, is organized by the Energy Institute (EI), a technical partner of Saudi Aramco through its Europe-based arm, Aramco Overseas Company. The three-day event saw more than 2,000 delegates from across the oil and gas industry – including CEOs, policy makers and academics – discuss the challenges within the sector and how to approach them.

According to the EI, this year's event was unique given the ongoing political uncertainty around the world, placing greater emphasis on the role of oil and gas in sustaining society.

The company also gifted attendees at the reception with products made by Al-Faisaliya, a women's welfare society based in the Kingdom, which supports cultural and community awareness programs. ●

Saudi Aramco Endorses 2015 Global Risk Awards



LONDON, 18 March 2015 – For the second consecutive year, Saudi Aramco endorsed the 2015 Global Risk Awards. Hosted by the Institute of Risk Management (IRM) in central London, the awards champion excellence in the field of managing risk.

About 400 leaders from 20 countries attended the ceremony, which is considered to be the annual highlight within the risk industry.

Saudi Aramco sponsored the award for “Managing Risk across Boundaries”, which recognizes individuals or teams that have executed a strategic approach to the risks related to operating across geographic borders.

“Rewarding excellence in business areas related to our industry is vital for us as it shows that we not only continue to pursue best practices ourselves, but also recognize and praise it when it is demonstrated by others,” said Ahmad A. Al Sa’adi, vice president of Gas Operations, who presented the award.

The winner of the award was accounting giant

PricewaterhouseCoopers. Other notable winners on the night included the Emirates Nuclear Energy Corporation and Dubai’s Roads and Transport Authority, demonstrating the increase of risk awareness within the Middle East/North Africa region.

Reflecting on the night, IRM chairman José Morago said: “In uncertain times such as these, the best risk professionals help their organizations grasp the opportunities, as well as manage the threats, that risk offers. Tonight’s awards show the risk profession at its very best.”

Ian Livsey, IRM chief executive, added: “Everyone shortlisted tonight should be proud. They are at the cutting edge of managing the very real risks the world faces today. As the world’s interconnected risks evolve ever faster, they show how the role of risk practitioners grows ever more vital.”

The IRM, an independent nonprofit organization, is considered to be the leading professional body for risk management. ●

Novel Workflows and Underreaming Measurements Reduce Risk by Supporting Decision Making

By Wajid Rasheed, John Thorogood and Jaime Bernardini, Smart Wellbore Systems (Including Smart Reamer).

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Abstract

This paper presents novel well construction workflows and downhole measurements to improve the success rate with close tolerance casing and cementing operations. Drilling engineers routinely ‘flip the coin’ and mentally take the risk of inferred underreaming. Considering the downtime that occurs across the industry such decisions are not sound. So why are they still taken? Routine decision-making shows a preference for riskier options even if safer options are available.

This paper details workflows and operational measurements that lead to safer and more efficient outcomes. The psychology of controlling risk in decision making is extensively discussed. A recommendation is made for a controlled workflow incorporating ‘gates’ to break routines. This supports the drilling engineer to consciously focus on a key operational gate that is a cause of downtime or operational risk. Critically, this ensures riskier decisions based on inferred underreaming are challenged and gated before sequential well construction activities occur. A further level of support is provided by new downhole measurements. Wellbore diameter is measured using callipers and the downhole status of the underreamer is tracked using magnetic position sensors.

Preferential workflows incorporate these measurements and consequently operations such as the following can be managed more effectively:

- a) Running casing/cementing. Check final underreamed wellbore diameter. This reduces the risk of casing getting stuck or an out-of-spec cement job.
- b) Underreaming across a section or a trouble zone subject to radial shrinkage or hard stringers. Check wellbore diameter and verify underreamer status. This can trigger a repeated cycle of expansion and check effective deployment of the cutters and the status of the cutters. If cutters have extended yet calliper is below gauge this can indicate a radially-shrinking formation with time or cutters worn or missing.
- c) Activating a near bit-reamer. Check wellbore diameter and verify underreamer status across the section to ensure satisfactory underreaming of the section. This ensures the rat-hole is enlarged only when the section is at the pre-determined hole size or any remedial work has been completed. This reduces the risks associated with rat-hole enlargement.
- d) Activate a secondary redundant reamer. Check wellbore diameter and verify underreamer status. This

saves a trip to replace a worn underreamer and avoids premature or unnecessary activation.

e) If cutters are extended yet calliper data shows undergauge then the cutters are worn or missing. Operational parameters such as flow, torque, weight etc can also be monitored and correlated.

The paper concludes with a discussion and statistical analysis of risk factors that can be controlled using the workflows and operational measurements.

Introduction

Due to close tolerance casing profiles underreaming has become an integral part of drilling workflows. However, industry statistics show underreaming anomalies cause downtime, as detailed by Aburto et al (2009). Workflows can include dedicated reaming runs/remedial reaming to ensure wellbore diameter meets required tolerances, as detailed by Rasheed (2008). This is important because wellbore diameter tolerances directly affect the success of casing and cementing. Currently, there are limited measurements of the underreamed wellbore, which makes it difficult to analyse the root cause of anomalies.

Workflow Gaps

Often, the driller does not know and cannot easily determine what the underreamed wellbore diameter is. Additionally, the effective status of the underreamer cutters is difficult to determine. Most downhole measurements are based on disparate and singular components that may not actually be relevant to the underreamed hole, as detailed by Rasheed et al (2005). Consequently, there is a lack of suitable downhole equipment providing:

- Effective underreamed wellbore measurements
- Effective underreamer cutter position measurements in-situ
- Comparative measurements occurring substantially at the same time as underreaming (downhole parameters, fluid characteristics) or in the underreamed part of the BHA (flow, rpm, vibration, etc)

This has created a number of gaps in workflows which are related to the borehole (lack of visibility of underreamed wellbore diameter) and borehole equipment (lack of visibility of underreamer cutting diameter in-situ).

Underreamed Wellbore Gaps

- Direct measurements of the wellbore diameter (and/or underreamed hole)
- Wellbore Anomalies (Radial Closure)

- Lack of verified underreamer cutting performance/cutter positions
- Reliance on pilot-hole acquisition, i.e. LWD measurements are taken after underreaming
- Reliance on inferred indicators (torque, SPP, cuttings volumes)

Underreamer Equipment Gaps

- Lack of direct measurements of cutter positions in-situ/underreamer cutting performance
- Lack of data to perform Root Cause Analysis of Anomalies/Predict failure and determine accurate MTBF values
- Expandable stabilization above reamer, changes in parameters, wall side forces, bending stresses
- Reamer effects of vibration, high torque and general failure modes, hydraulics, flow or fluid changes
- Integrated underreaming models considering bit and directional drilling

Challenges

These are mainly related to stabilization above the reamer and ensuring measurements are taken in the underreamed hole in a timely manner. For example, a distinction should be drawn between pilot hole stabilization which is based on bit size, for example 12.25", and the underreamed hole stabilization, for example, based on 14.75".

An increase of approx. 20% of wellbore diameter creates stabilization issues (see Fig. 1), which shows that a 12.25" pilot BHA will be unstabilized in a 14.75" underreamed hole. Consequently, LWD/sonic sensors will be subject to 2.50" of unstabilized non cyclical movement and/or deflection.

Significant measurement uncertainty is generated by a lack of stabilization in both vertical and inclined wellbores, as detailed by Bonner et al (1992) and Orban et al (1998), as the LWD calliper falls to the lowside or is off-centred, making such measurements unfit-for-purpose.

Although the decision maker could accept the downtime associated with tripping back a LWD sensor into the reamed hole, the measurement is not satisfactory because it is inherently uncertain. If the measurement were taken on pulling out of hole the delay between underreaming and measurement becomes critical:

- Drill and underream 12.25" to 14.75" from a depth of 15,000 feet to 17,000 feet across swelling shale beds/radially closing salt. The drilling/underreaming rate

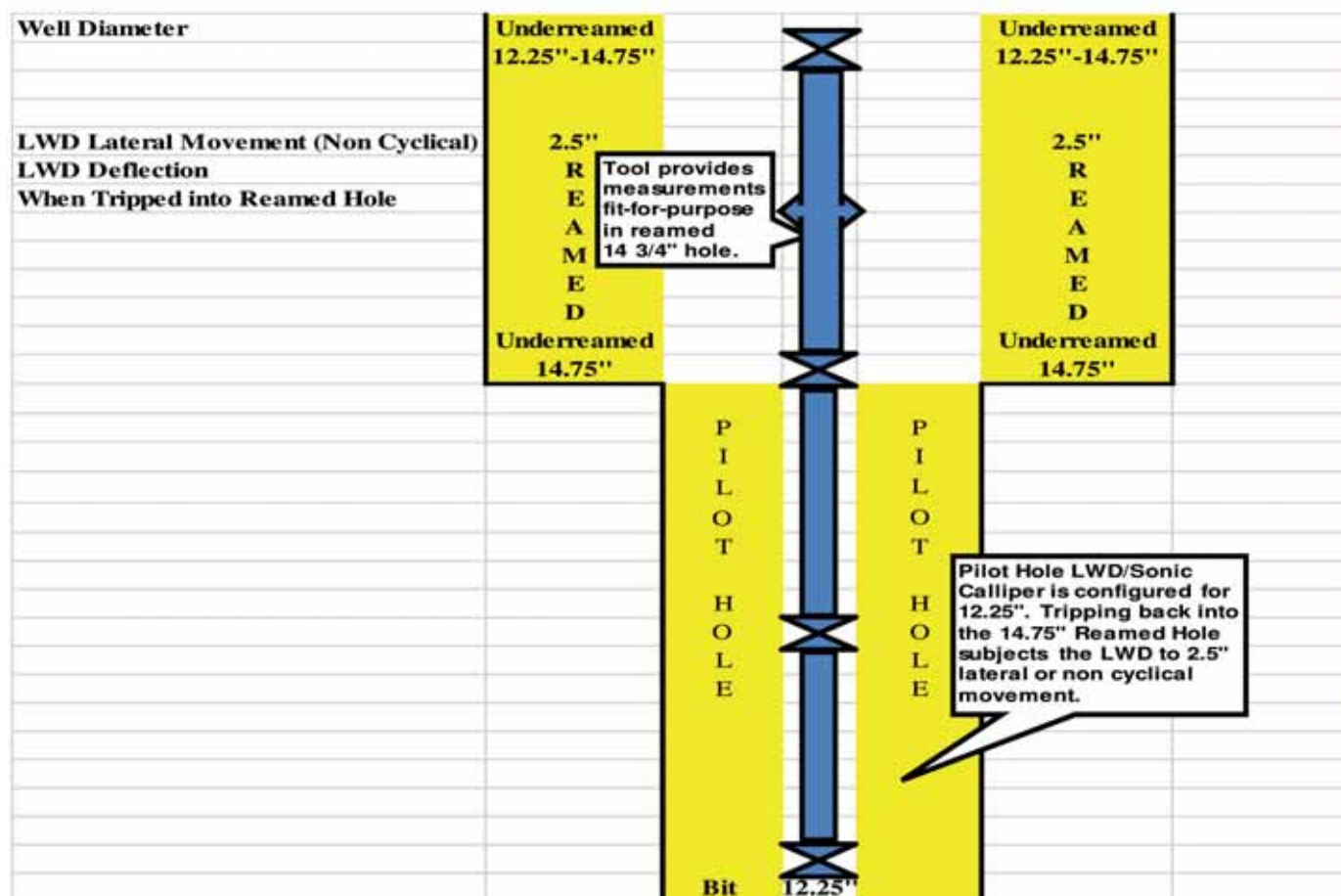


Fig. 1 Shows Lateral Movement and BHA Stabilization in Pilot and Underreamed Hole.

Component	Length (ft)	Gauge/OD (in)
5" HWDP (4 Joints)	503.98	5.00
Crossover	377.58	8.25
4 x 8-1/4" Collar (4 Joints)	374.58	8.25
Selectable Retrivable Tool	254.58	9.98
3 x 8-1/4" Collar (3 Joints)	248.48	8.25
10-1/2" IB Stabilizer	158.48	10.63
Smart Reamer Position in BHA	124.58	8.25
10 5/8" x 12" Under - Reamer	123.58	12.00
10-1/2" IB Stabilizer	109.58	10.50
8" Pony Collar	103.58	8.00
Crossover	93.58	8.00
10-1/2" IB Stabilizer	89.58	10.50
Acoustic	66.98	9.00
Neutron Density LWD/MWD	64.48	8.41
Res-GR-PWD	37.48	9.10
10-1/2" IB RSS Stab	18.48	10.50
10 5/8" Rotary Steerable	13.48	10.63
10 5/8 " PDC Bit	1.00	10.63

Fig. 2 shows a typical drilling assembly incorporating the tool (124 feet) solution directly above the underreamer (123 feet), the LWD pulser (64 feet), Rotary Steerable (13 feet) and bit (1 foot). As these distances are fixed in the BHA the 8.5% LWD sensors are unable to measure the 12% underreamed wellbore.

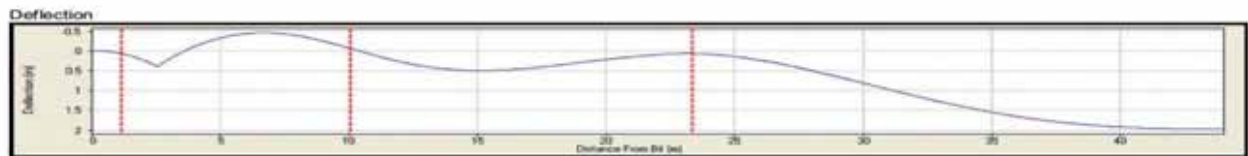


Fig. 3 BHA Deflection and Distance from Bit.

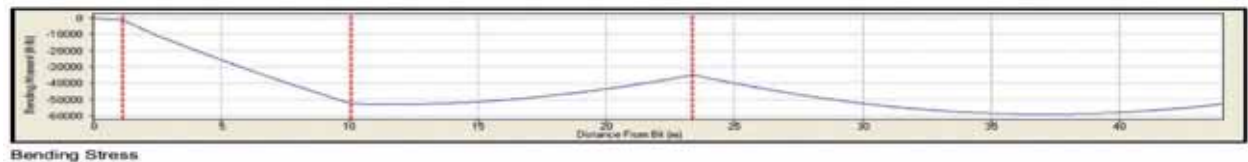


Fig. 4 BHA Bending Stress and Distance from Bit.

of penetration is 33.6 feet per hour, providing a total section drilling time of 60 hours. Distance from Reamer to Bit is 120 feet approx.

- Use LWD hole diameter sensor on the trip out of the wellbore to measure underreamed wellbore.

Measuring the wellbore interval 60 hours post drilling/reaming is unsatisfactory as it adds operational uncertainty. Establishing that there is radial closure of the wellbore and/or a need to re-ream certain sections due to undergauge hole post underreaming reduces the time window available for underreaming before the hole closes in but it also misses the opportunity to prevent downtime, as the section is only measured after a significant time delay. The significant time delay makes it impossible to know whether the root cause of the hole problem is the rate of radial closure or the underreamer. Consequently, it is not possible to improve decisions on a trip, well or field development basis.

Innovative Borehole Measurements

The technology provides fit-for-purpose time-based borehole measurements and images allowing the drilling team to:

- Pinpoint narrow wellbore sections caused by underreamer wear or changes in geological strata
- Eliminate downtime related to casing running in a narrow wellbore
- Avoid costly retrieval of equipment, loss of equipment and in the worst case a sidetrack
- Accurately predict cement volumes to ensure sealing of casing

The technology benefits from direct measurements above the underreamer and complements pilot hole data acquisition. The technology provides real-time underreaming verification, thereby reducing the risk of hole closure and stuck-fish (the drill-string or BHA

becomes stuck in the hole) and reducing uncertainty of not knowing the rate of radial closure/optimal casing points.

Challenges Overcome

The following challenges with existing LWD tools were overcome:

- Drilling friendly and flexible placement – permits low cost / low risk compared to LWD tools and prohibitive costs
- Availability in large underreamed hole i.e. 22", 17.75", 14.75" etc
- Above Reamer overcomes pilot hole configuration of LWD Neutron Density or Sonic being unstabilized/uncentralized in underreamed hole
- High accuracy in oil based mud; downhole calibration overcomes changes in density, temperature, pressure, salinity, creating erroneous readings
- Through-Bore permits drop-ball if required and overcomes fishing and flow restrictions based on restricted ID flow path of other LWD technology
- Optimized power management overcomes battery/turbine power constraints and allows for long life
- 4.50" radial depth measurements (12.5PPG mud) whereas typical LWD calliper depth is 1" or less radially

Deployment

Measurements and images resulting from deployment in multiple wells to date are described (see Figs 6 – 8). The technology has been proven in acquiring wellbore measurements with multiple BHA types. There have been no failures to date. The longest accumulated footage without any failure on a single tool is approx. 10,000 feet (3,000 m) drilled with 450 hours circulating and 250 hours on bottom drilling.

Well 5 – Above Flex Collar

A single run was made to the section's total depth of



Fig. 5 Programming and data download from the tool is simple and fast. 231,236 records downloaded in 35 minutes.

approximately 800m and measurements performed in slide and rotary mode with hole diameters, varying from 11", 12.25", 13" and 13.5". The formations were chalk, sand and clay, with inter-bedded shale and quartz, with typical soft to medium hardness on the scale and low uniaxial compressive strengths. Because the tool was placed directly above the Flex Collar, the tool was subject to the highest bending moments and stress in the BHA. The highest BHA deflection of 2 inches (see Fig. 3) and bending stress of 60,000 foot/pounds [ft/lbs] (see Fig. 4) were applied on the tool. Despite this, the tool survived the 59 hours on bottom directional drilling without any failure.

Well 7 – Dual Reamer

Two runs were planned and successfully made to TD using the same BHA with the same tool logging 900m. Data was downloaded in 35 minutes after each run. The runs provided excellent survey results and a proven BHA Solution to image the wellbore in slide and rotary drilling (up to 170 RPM). Drilling dynamics shock and vibration were maintained at $\leq 2G$. The tool was run between dual roller reamers.

Data can be used to determine vibration modes while underreaming (see Fig. 9). To minimise vibration an Expandable Stabiliser should be run above the underreamer. The Expandable Stabiliser also stabilizes the Calliper while underreaming. Where underreamer cutter positions are known these can be compared with calliper data. In either case, correcting for displacement/motion is not required and a simple visual inspection of data suffices.

Innovative Underreamer Equipment Measurements

The technology provides measurements of in-situ underreamer cutter positions which are used to isolate anomalies. Formation related issues, i.e. wellbore

shrinkage or collapse, can be distinguished from underreamer modes, i.e. activated or deactivated. This enables an exact root cause of anomalies to be identified. Also, once cutter positions are known, a MTBF of the system can be determined and its useful life predicted with higher certainty. This supports the decision to activate a contingency reamer.

Tracking Reamer Cutter Status

A trivial case is illustrated with reamer cutter positions (Cutter 1, Cutter 2 and Cutter 3) plotted against time or depth (see Fig. 10). From top to bottom the sloping curve shows cutters are activated. The cutters are deactivated mid-way shown by the 'stairway' plot and then reactivated. The block position sensor on the underreamer is a direct measurement of the effective radial cutter position at a given spatial and temporal position in the wellbore.

Complex Case

In this complex case cutter positions 1 and 3 correlate but cutter position 2 presents an anomaly (see Fig. 11). This could be due to vibration, bending moments or an inability to maintain the cutter itself active. The technology is able to detect and distinguish between these conditions. Anomalies within underreaming BHAs can be better understood by working with the operator and the underreamer manufacturer to record forces acting on the BHA/underreamer and operating parameters.

Comparative Measurements

The new measurements enable the drilling engineer to construct safer and more efficient workflows that ensure gauge. Comparative measurements determine conditions of the interior of the wellbore as well as the status of underreamer cutter positions. In this way, a detailed picture is built up which allows measurements to be used holistically rather than relying on single

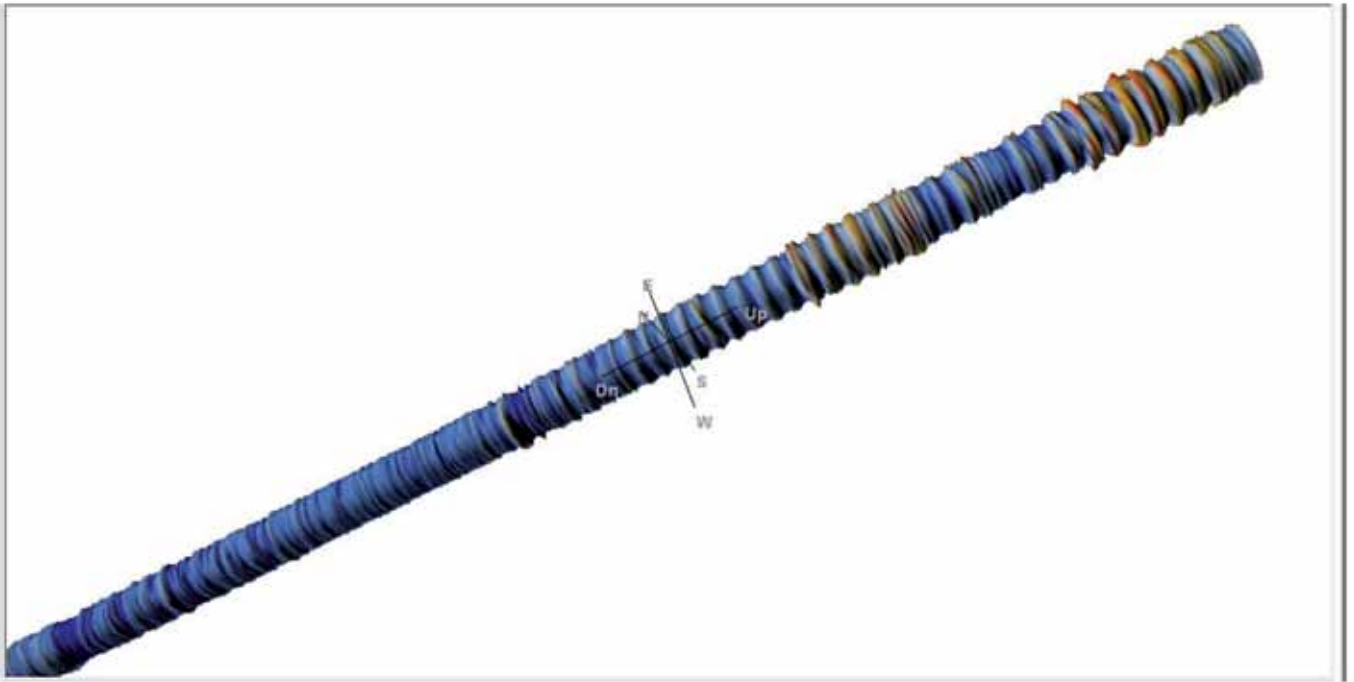


Fig. 6 shows wellbore image data with characteristic spiralling evident in this 200m section which was predominantly a consolidated formation with laminations.

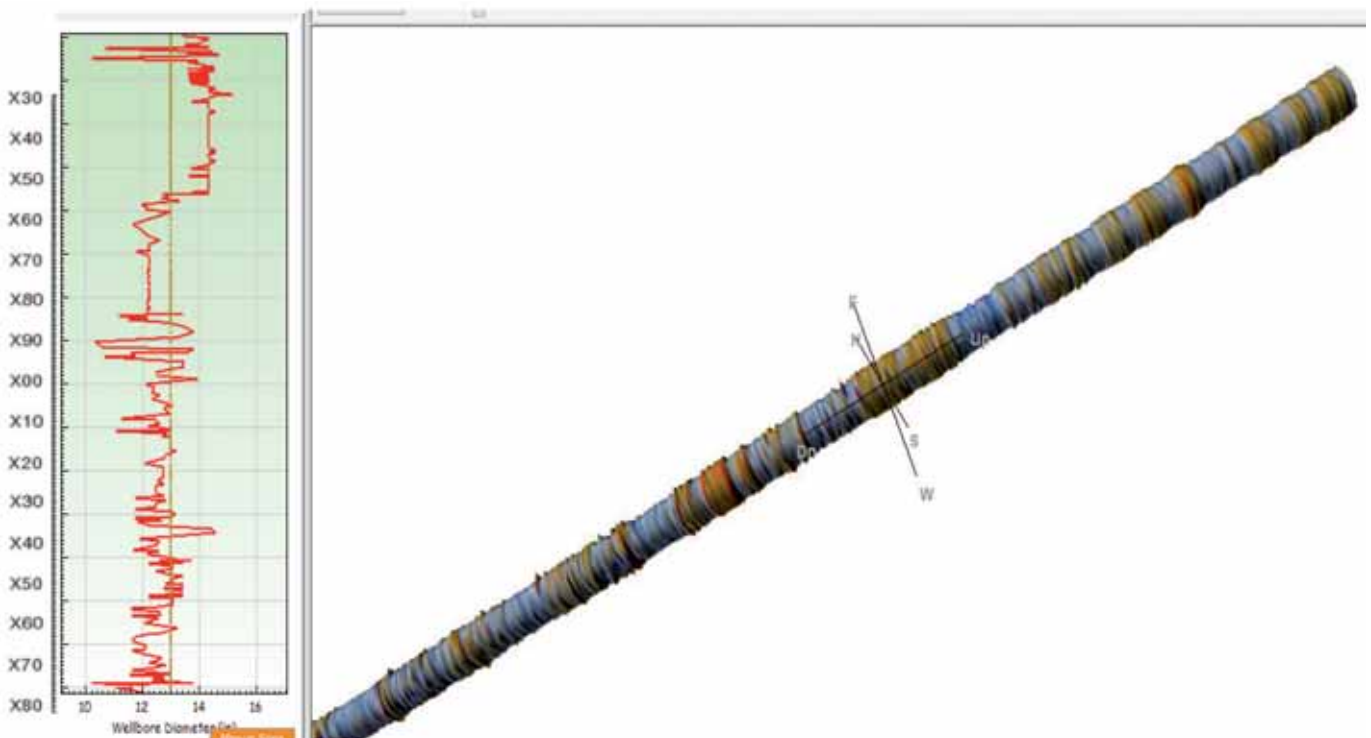


Fig. 7 shows wellbore diameter and a corresponding wellbore image across an interbedded formation with narrow and overgauge sections. Ballooning is seen in all quadrants and a breakout is visible in the N/S Direction. The corresponding wellbore diameter on the left can be seen as 14.75" X 30m to X 68m rapidly dropping to 12.25" bit size and then fluctuating around 13" approx. for 120m.

measurements (Rasheed, 2008). Drilling engineers can outline workflows with measurement feedback to support robust decisions. Fig. 12 illustrates relationships between calliper and cutter positions to optimise operating parameters and minimize harmful vibration. This can be performed while drilling or from offset well data for planning new wells.

The drilling engineer can achieve a more efficient workflow by comparing wellbore calliper data with cutter positions to confirm whether the cutter blocks are fully extended, partially retracted or missing completely (see Fig. 13). Put simply, if cutter positions and wellbore gauge readings do not match there is an anomaly. Wellbore diameter is not solely a function of the bit

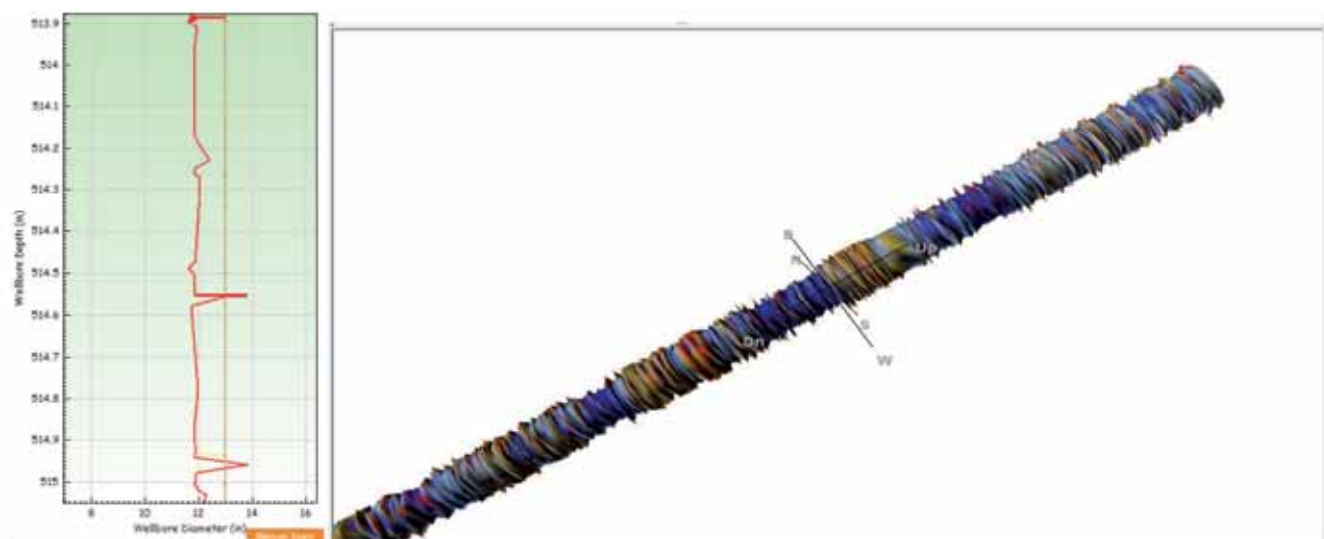


Fig. 8 shows spiralling across the section below. Blue is tighthole (approx. 12.25%) and yellow is enlarged (approx. 14%). The figure shows wellbore diameter depth interval magnified to 0.1 meter intervals. The image remains at a 100m scale to easily visualize wellbore conditions. Calliper data is especially useful when compared with underreamer cutter position data.



Fig. 9 plots Time and Vibration (Rotational, Lateral and Axial) and Time of Flight (TOF) measurements.

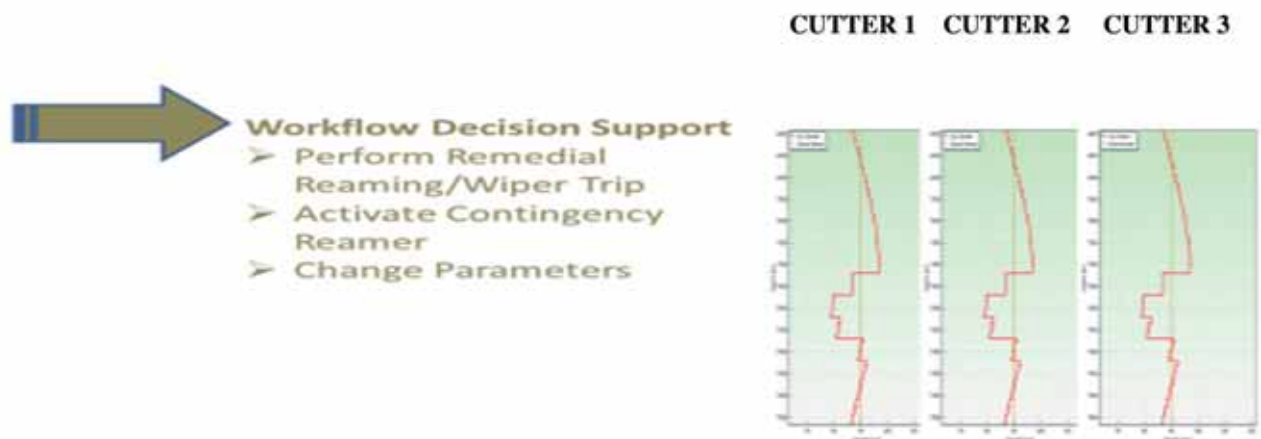


Fig. 10 Trivial Case of Tracking Reamer Cutter Block Positions.

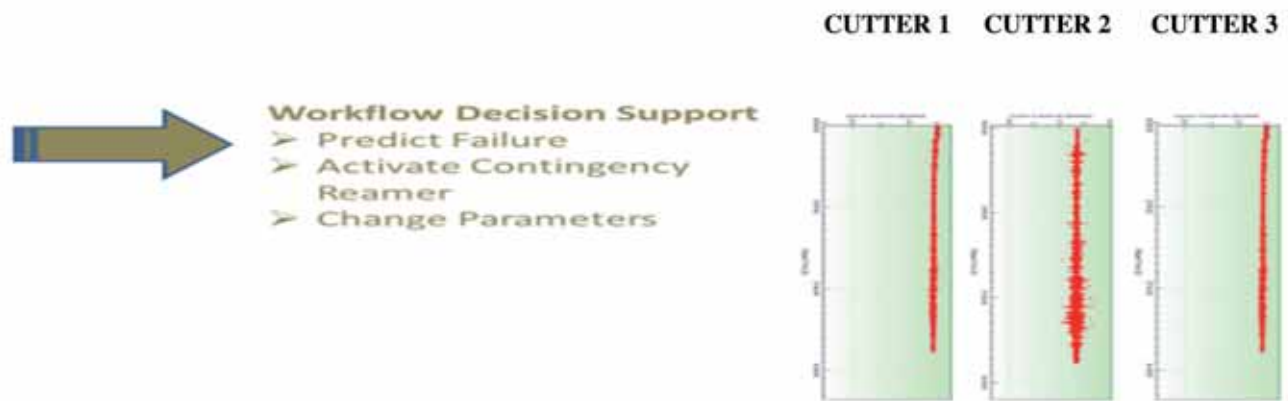


Fig. 11 Complex Case of Tracking Reamer Cutter Block Positions.

and underreamer, but a complex interplay of 3 point geometry as discussed by Eddison et al (2008), hydraulics detailed by Ledgerwood et al (2000), formation types, drill-string interaction detailed by Mitchell (2008), comparative measurements of calliper and cutter block position detailed by Rasheed (2008) allow decision makers to analyse a broad range of operational anomalies and control risk.

Performance in Deepwater and Subsalt

Comparative measurements are useful as they offer solutions to a broad set of operational problems which cannot be solved otherwise. Firstly, wellbore diameter measurements map radial creep, swelling, rubble zones or wash outs. Second, position sensors measure actual underreamer cutter extension. Consequently, comparison of calliper measurements and cutter positions offers a reliable decision making basis. The highest levels of drilling and operational performance occur with direct cutter position sensing and wellbore

calliper measurements (see Fig. 13), as discussed by Bernardini et al.

The Psychology of Controlling Risk

Psychological factors play a central role in the way risk is assessed and controlled. Typically, individuals prefer riskier options after experiencing a financial loss, while they generally prefer safer options when the choice takes place after experiencing a financial gain (Losecaat et al, 2014). Related factors such as knowledge, experience, skills, attitude, aptitude, training, etc., are well documented. The decision path itself can be habit forming (Dezfuli et al, 2010), with a tendency for decision-makers to fall into habits or known decision traps. Common decision traps are listed below:

- 'Do nothing' because the decision maker is more likely to be punished for having taken positive action.
- Financial, contractual, bureaucratic or procedural reasons often tend to preserve the status quo.

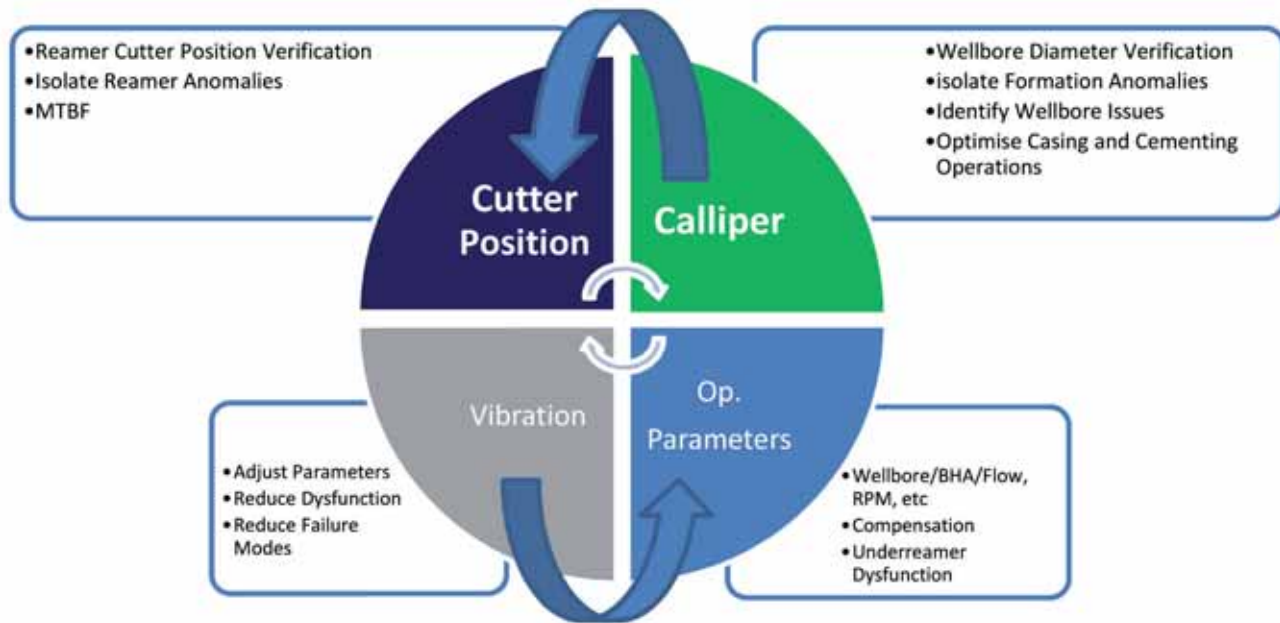


Fig. 12 Shows Comparative Measurements Ensure Gauge and Optimise Drilling Performance.

- Bias distorts analysis of perceived or real risks. People tend to be strongly influenced by dramatic experiences which are easier to recall, even if a neutral statistical analysis of experience would yield a different answer.
- Greater weight is given to evidence that confirms prior views and even to seek out such evidence preferentially.
- Knowledge is distributed differently within groups, individuals and organisations.

By incorporating comparative measurements in the workflow it is possible to avoid decision traps and improve performance. Accuracy and measurement uncertainty can be handled according to ASME (2001) and Guideline for Uncertainty in Measurement (GUM 1995).

Workflow Efficiency

The status quo continues to rely on all sorts of inferred measurements and programmed inefficiency. Risk and uncertainty are highest with remedial reaming/dedicated reaming planned into the workflow. Additional risks of stuck casing, cementing issues, etc., may also occur, rendering such a workflow inefficient (see Fig. 13).

An intermediate technology such as tracking the reamer or measuring the wellbore is not entirely satisfactory because inefficiency is still planned into the workflow based on whether the underreamer is working or the wellbore is radially closing inward.

The technology pathway that leads to the highest

performance includes calliper measurements of wellbore diameter with measurements of cutter block positions. This reduces uncertainty as anomalies are properly identified and preventative action taken. Consequently, the risks of dedicated reaming runs, remedial reaming, stuck casing, cementing issues, etc., are much reduced.

Isolating Anomalies

By isolating anomalies related to the borehole or to the underreaming BHA, workflows can incorporate comparative measurements that ensure casing and cementing activities have a higher success rate. In order to deliver a pre-determined wellbore diameter the reamer must be in its activated state, defined as 'up-time' (see Fig. 14). Whether 'downtime' is attributable to the reamer depends on whether recommended operating parameters have been maintained, i.e. pump rates, BHA stabilization. For example, if the BHA recommendation based on offset wells or modelling shows that an expandable stabilizer will overcome bending moments on the underreamer but the BHA did not incorporate expandable stabilization, this would not actually count as failure as the underreamer was used outwith specification.

Because cutter positions are directly measured, the reamer can be tracked as fully activated or subject to an 'unplanned deactivation'. Unplanned cutter deactivation can be properly analysed for root causes by correlating operating parameters such as pump pressure,

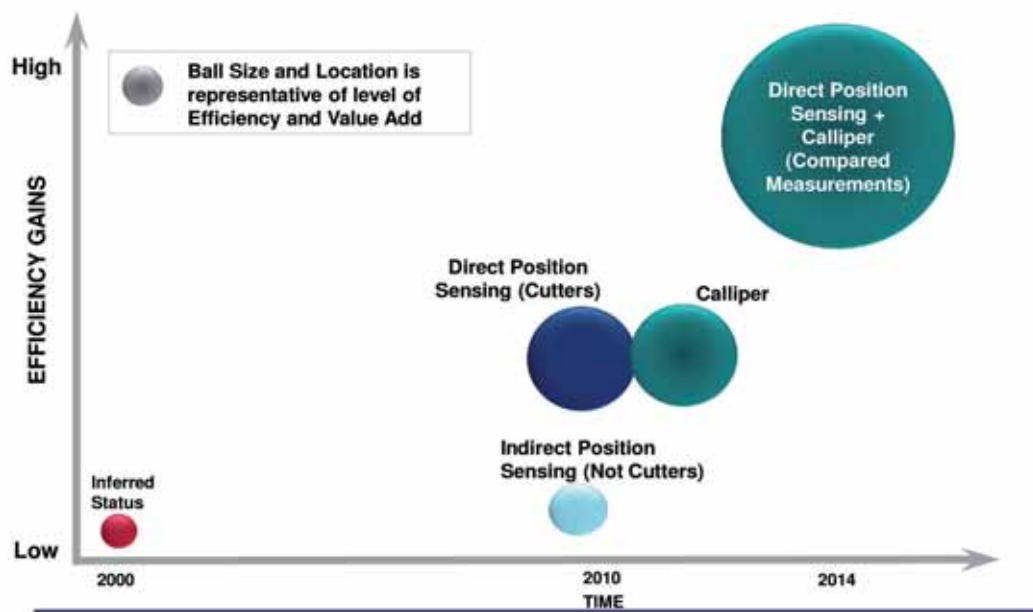


Fig. 13 Underreaming Efficiency/Performance Gains.

RPM, weight, flow, with cutter positions and wellbore diameter measurements. A further efficiency gain is enabled because MTBF analysis can be performed in conjunction with root cause failure analysis. Therefore, causal factors such as human error, changes in operating or environmental conditions can be determined, which cannot be done otherwise.

If operating parameters are maintained and unplanned deactivation occurs, a 'failure' is determinable. By monitoring the reamer status various decision gates can be introduced into the workflow (see Fig. 15, numbered boxes 1 to 7). This ensures operating parameters are kept within safe tolerance, thus reducing the risk of anomalies. The next step is to reconstruct decision paths using a logic chart. This forms a preferential workflow (see Fig. 15) using comparative measurements to provide insight into downhole conditions and can be user configured to meet workflow objectives. Software is programmed to first cross check the cutter block positional data from sensors placed on the cutter housing which can be retrofitted to existing reamers. This shows whether the block has actually been extended. If the block has extended yet the calliper data shows that the actual wellbore is below the planned wellbore size, the software alerts the user by means of mud pulse telemetry or wired pipe. In this way, the deepwater drilling engineer achieves much higher performance.

The preferential workflow can be combined with a RACI matrix (see Fig. 16). The workflow can be combined with

RACI (see Fig. 17) to provide a preferential workflow covering operational decision making. The combination of the underreaming workflow, RACI matrix (see Fig. 15, Fig. 16 and Fig. 17 respectively) allows the following decisions to be taken with confidence.

Decision 1: Running casing/cementing

Check final underreamed wellbore diameter.

Risk Reduction: Casing getting stuck or an out-of-spec cement job.

Underreaming across a section or a trouble zone subject to radial shrinkage or hard stringers. An exemplary workflow includes checking wellbore diameter and verifying underreaming status simultaneously. It is important that measurements are compared at substantially the same time. For example, if undergauge hole diameters are detected a decision can be made to trigger a repeated cycle of expansion and/or check effective deployment of the cutters/cutter status. If cutters have extended yet calliper is below gauge this can indicate a radially-shrinking formation with time or cutters worn or missing. In other instances uncertainty can be dispelled as to whether a change in operating parameters has led to deactivation.

Decision 2: Activate a near bit-reamer

In the case of rat-hole between the distance from the underreamer cutters and the bit (120' feet or more), check wellbore diameter and verify underreamer cutter block status across the section. This is very useful to ensure

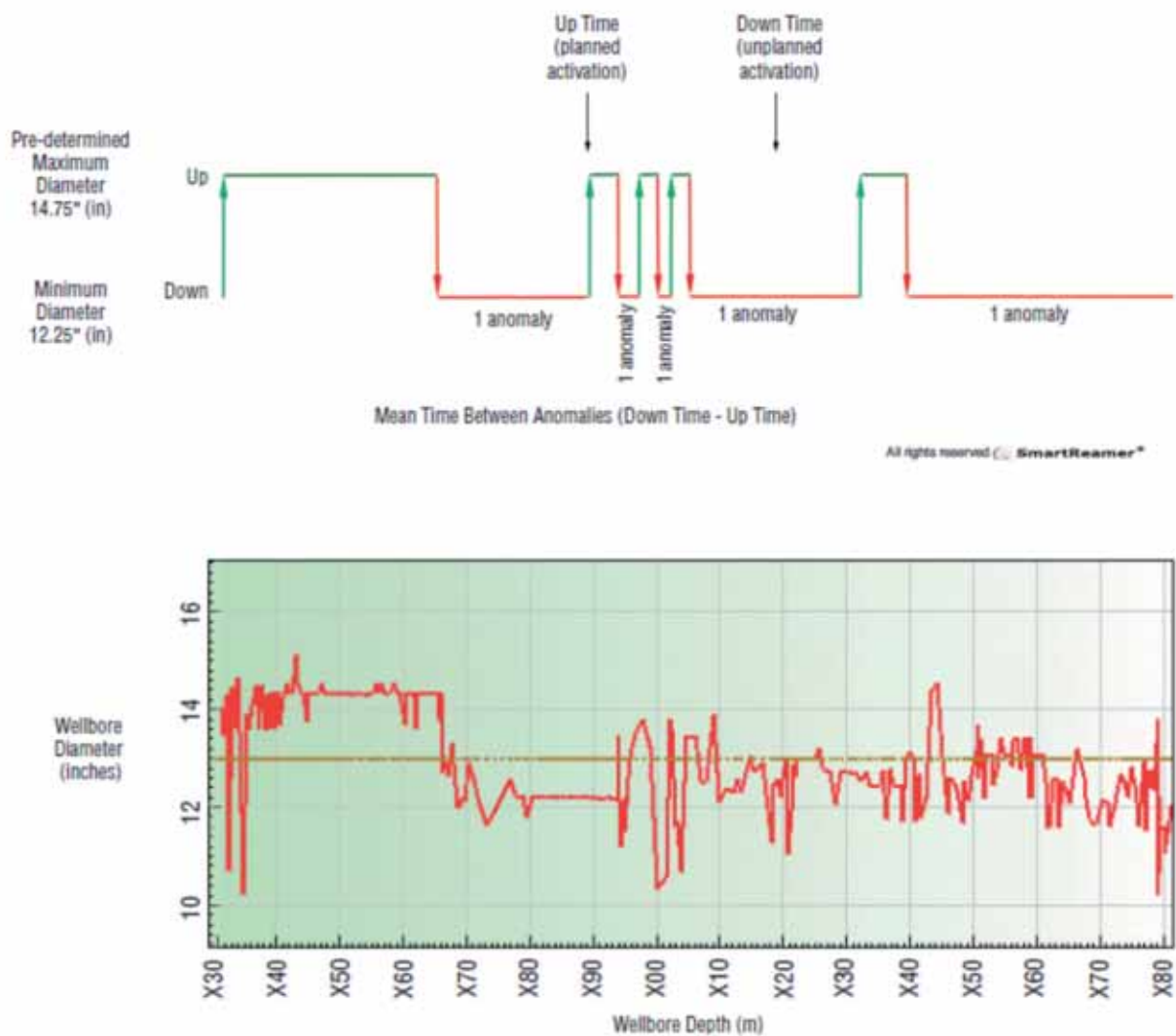


Fig. 14 Anomaly Analysis Based on Comparative Wellbore Diameter and Underreamer Cutter Positions.

that the section has been satisfactorily underreaming to the pre-determined diameter.

Risk Reduction: Risks associated with rat-hole enlargement, especially the loss of directional control or high vibration that is created when a near-bit reamer is used to underream a pilot hole without adequate stabilization. This ensures the rat-hole is enlarged only when the section is at the pre-determined hole size or any remedial work has been completed.

Decision 3: Activate a secondary redundant reamer
Check wellbore diameter and verify underreamer status. This saves a trip to replace a worn underreamer and avoids premature or unnecessary activation. If cutters are extended yet calliper data shows undergauge then the cutters are worn or missing.

Risk Reduction: In this way remedial underreaming actions are taken automatically to ensure operational

parameters are being observed. In the case of failure the tool can be replaced or the well construction activity repeated much earlier than previously. Operational parameters such as flow, torque, weight, vibration etc can also be monitored, correlated and adjusted.

Simultaneous well-bore enlargement, calliper measurements and underreamer cutter positions instantly detects undergauge hole and automatically conducts diagnostics in order to ensure the underreamer is functioning correctly. Once the corrective steps have been taken and calliper indicates that the planned hole diameter is still not being delivered a signal is sent to the rig-surface or to the location of the operating engineer so that a secondary redundant reamer can be activated. There is also a memory mode that stores sensor information that can be downloaded at surface.

Decision 4: Activate an Expandable Stabilizer
This can be based on measurements of wellbore,

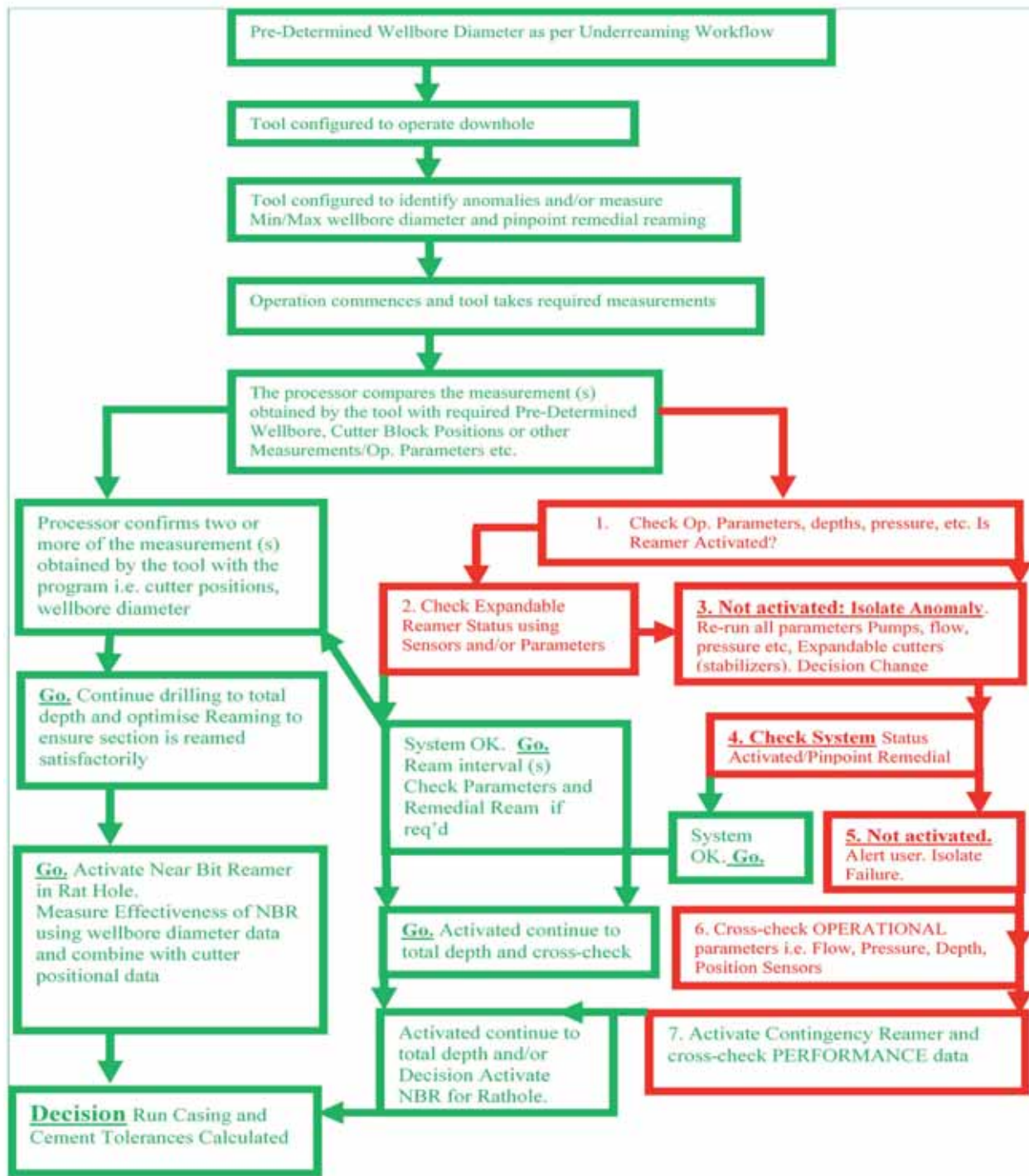


Fig. 15 Ensuring Gauge Preferential Underreaming Workflow.

	Drilling Manager	Rig Superintendent	Sr. Drilling Engineer	Sr. Company Man	Day/Night Company Man	Drilling Engineer On-Site	Tool Pusher	Day/Night Tool Pusher
Main Task	Manages the operation.	Manages rig operation.	Prepare drilling program & approve detailed rig procedure	Ensure execution of drilling program	Ensure execution of planned operations	Coordinate with Sr. Drilling Eng detailed procedures	Ensuring rig is ready to execute plan in safe manner	Supervise operations in efficient & safe manner
Responsibility level	Accountable for results	Responsible for rig results	Responsible for technical integrity	Responsible for onsite performance	Responsible for performance during shift	Responsible for enforcing plan	Responsible for rig operation	Responsible for safe operations during shift
Objective 1	Safe Operation	Safe Operation	Programs are approved on time	Efficiency	Efficiency	Programs are available on time	No accidents	No accidents
Objective 2	Finish well within AFE	Finish well on time	Right equipment and technology is available	Safety	Safety	Rig drilling teams understands plans	No rig downtime	No rig downtime
Personal Objective	No surprises or incidents to report	No accidents	No deviations from plan	Keep Authority	Follow Authority, learn	Learn and demonstrate competency	Enforce drilling contractor policies	Enforce drilling contractor policies; learn.
	Driller	Assistant Driller	MWD/LWD Engineer	Mud Logger	Directional Driller	Drilling Fluid Engineer	Underreamer Operator	
Main Task	Runs operations in efficient & safe manner	Assists Driller in running efficient & safe operation	Gather downhole drilling data	Gather drilling data & analyze mud carried material	Ensure well trajectory is as per program	Ensure drilling fluid properties are as per program	Ensure UR operation is as per plan	
Responsibility level	Responsible for safe operations during shift	Responsible for safe operations during shift	Responsible for obtaining good quality data	Responsible for obtaining good quality data	Responsible for efficiency & quality of directional well	Responsible for the quality of the fluid	Responsible for efficiency & quality of UR well	
Objective 1	No accidents	No accidents	Uninterrupted data gathering	Uninterrupted data gathering	Deviate the well as per plan	Keep mud properties as plan	Underream well as per plan	
Objective 2	No rig downtime	No rig downtime	No equipment failures	No equipment failures	No equipment failures	Borehole quality	No equipment failures	
Personal Objective	Enforce drilling contractor policies; learn.	Enforce drilling contractor policies; learn.	No disputes with others	No disputes with others	Maintain control	Keep low profile to avoid conflicts	No disputes with rig chain of command	

Fig. 16 shows a RACI matrix for Underreaming Operations.

vibration and cutter positions. Risk of loss of directional or underreaming control is reduced.

Decision 5: Ensure Cutting and Directional System Compatibility

In the case of multiple suppliers with multiple BHA components system compatibility must be ensured.

Helical Cutting method measures component performance from both a cutting and BHA perspective including a helical cutting action, flow optimization and vibration reduction as important aspects in achieving compatibility between different components in the system.

Risk Reduction: BHA dysfunction, poor drilling

dynamics and the effect of bending moments or formations leading to anomalies.

Compatibility of different components can be achieved by distributing cutter elements to engage the formation so that a first set of cutters is placed on the drill bit face extending to the outer ends of the drill-bit, and a second set of cutters is placed on the reamer block in a helical or diagonal pattern aligned with cutters extending from the bit. Both sets of cutters can be notionally wrapped along and around the wellbore before reaming. The cutter array for the reamer can be set in a substantially helical pattern with the principal axis of the helix substantially oriented in the direction of reaming across the length and breadth of the underreamer and aligned with the bit. The cutting performance and drilling dynamics

Fig. 17 Preferential Workflow for Underreaming Operations			Drilling Manager	Rig	Superintendent	Sr. Drilling Eng.	Sr. Company Man	D/N Collan	Drilling Eng Rig	Tool Pusher	D/N Tool Pusher	Driller	Assistant Driller	MWD/LWD Eng	Mud Logger	Directional Driller	Drilling Fluid Eng	Underreamer Eng
Pre-job	1	1	Define basis of well design - casing program, litho, etc															
	1	2	Identify technology needs															
	1	3	Select vendors: service companies + tools															
	1	4	Perform an interference analysis - cover gaps															
	1	5	Prepare drilling program															
Preparation	2	6	Approve drilling program															
	2	1	Define mobilization / utilization schedule															
	2	2	Define detailed equipment / tool specification															
	2	3	Request equipment / tool preparation															
	2	4	Tool assembly and testing															
	2	5	Tools mobilization															
	2	6	Tools reception at the rig site															
	2	7	Verify / test equipment prior rigging up															
Pre-run	2	8	Measure tool prior make up															
	3	1	Provide tool dimension diagram with fishing neck															
	3	2	Provide detail procedures for tool-BHA assembly															
	3	3	Provide detail procedures for tool surface test															
	3	4	Provide detail procedures for tool RIH															
	3	5	Provide detail procedures for tool drilling															
	3	6	Provide detail procedures for tool POOH and lay down															
	3	7	Provide contingencies for all of the above															
	3	8	Verify tool compatibility with other service providers															
	3	9	Verify deviations from original drilling program															
RIH	3	10	Review BHA design															
	3	11	Check availability of downhole and surface sensors															
	3	12	Agree on performance indicators															
	3	13	Construct and agree on a operational priority list															
	3	14	Define and agree a criteria to abort run and stop operation															
	3	15	Review and approve detailed-revised drilling program															
	4	1	Pull tool to the rig floor															
Drill	4	2	Make up tool to BHA, verify make up torque															
	4	3	Perform shallow hole test (functionality & pressure drop)															
	4	4	Verify RIH Cutting Position Sensors															
	4	5	Perform a downhole test															
	4	6	Get to the defined depth															
	4	7	Actuate the tools and drill ahead															
	5	1	Monitor Underreaming performance against plan															
POOH	5	1.1	Borehole calliper															
	5	1.2	Cutting block position															
	5	1.3	Vibration (Axial, lateral and torsional)															
	5	1.4	Shocks															
	5	1.5	WOB															
	5	1.6	Flow rate and pressure															
	5	1.7	Lithology															
	5	1.8	ROP															
	5	1.9	Cuttings volume															
	5	1.10	Cuttings geometry															
	5	1.11	Torque															
	5	1.12	WOB v WOUR Variance															
	5	2	Identify Anomalies															
	5	3	Apply defined contingencies to improve performance															
	5	4	Abort operation and POOH if needed															
	5	5	Circulate prior POOH															
Prior re-run	6	1	POOH															
	6	2	Verify tension while entering new casing															
	6	3	Tool visual inspection															
	6	4	Perform tool diagnostics															
	6	4.1	Verify tool actuation system															
	6	4.2	Measure tool cutting diameter with blocks in expanded position															
	6	4.3	Provide a preliminary report while POOH continues															
	6	5	Perform visual inspection of bit, rotary steerable, underreamer, etc.															
	6	6	Report anomalies if applicable															
	6	7	Decide next step															
Re-running	6	7.1	Reach casing point tool is in poor shape															
	6	7.2	Did not reach casing point tool is in poor shape															
	6	7.3	Reach casing point drill bit or DD tools are in poor shape															
	6	7.4	Did not reach casing point drill bit or DD tools are in poor shape															
	6	7.5	Order additional backup tools if required															
	7	1	Analyze anomalies (wellbore diameter/cutter positions)															
	7	2	Quantify the problem; where & how much															
	7	3	Identify the cause															
	7	3.1	Underreamer															
	7	3.2	Directional drilling															
	7	3.3	Drill bit															
	7	3.4	Tripping procedures or incidents															
	7	3.5	Drilling Procedures or incidents															
	7	3.6	Changes in lithology															
	7	3.7	Borehole stability - unplanned geomechanics															
	7	3.8	Borehole stability - mud/formation chemical interaction															
	7	4	Propose a solution															
	7	5	Propose new plan															
	7	6	Approve a revised drilling forward plan															
	8		Repeat sections 3, 4, 5, and 6															

Fig. 17 Preferential Workflow for Underreaming Operations.

of cutting structures – expandable reamer and drill bit – located 120 feet apart can be aligned for drilling different formation types; by synchronizing cutters on the reamer to the bit, cutting forces around the bottom hole assembly are equalized and thus harmful vibration minimized (Rasheed, 2008).

Decision 6: Ensure Directional Control

Rotary Steerable Considerations. Drill bit configuration can cause spiraling, as discussed by Marck et al, and the gauge area will affect the performance of the rotary steerable as it is this section that is primarily responsible for steering or tilting the bit, as discussed by Barton et al (2000). An active gauge area or shortened gauge has been considered as optimal, although this depends on the type of rotary steerable and formation. The pilot gauge area is also critical in providing a continuation from the outermost cutting area of the bit to the reamer cutting structures. An approach has been to model the cutters in continuation of the pilot bit and to engage the wellbore at certain points to distribute cutting and forces optimally so that both cutting is increased and side forces are equalized, detailed by Rasheed (2008).

Modeling the forces that will act on the bottom hole assembly by considering fixed diameter cutters extending from a central location to the outer ends of the bit to form a first diameter; and, an expandable reamer to provide a continuation from the first diameter and expand to a second pre-determined diameter by engaging the wellbore in at least 7 different circumferential points. Forces on the directional control system such as a rotary steerable and stabilizers for 3 point geometry can also be modeled. Lastly, cutter placement is optimised to reduce vibration around the bottom hole assembly.

Conclusion

Significant levels of uncertainty can be removed from underreaming workflows by comparing simultaneous measurements to isolate anomalies. Human psychology plays a central role in decision making. More robust decisions can be made by avoiding decision traps. Comparative measurements of borehole diameter and underreamer cutter positions generate a high degree of efficiency and complementarity. In turn, this supports preferential workflows that optimize rig time and reduce risk. Accuracy is verified according to ASME and GUM guidelines in handling measurement uncertainty. The downhole tools are easily fitted to all BHAs and have been proven robust with a single tool having drilled 10,000 feet and withstanding drilling conditions to provide the following types of measurements.

Borehole

- Wellbore diameters and images to help reduce formation issues (swelling, shrinkage, washouts)
- Help reduce casing running and cementing issues
- Ensure hole opening by real-time monitoring of underreaming operation
- Reduced risk of radial hole closure and stuck-fish

Borehole Equipment

Control over underreamer to maintain the required underreamer status.

- Tracking the Reamer reduces issues with cutter status and cutter wear
- Predict failure (catch underreamer when failing)
- Eliminate separate calliper log run
- Improve drilling and underreaming efficiency from casing point to casing point
- Enable use of contingency or near bit reamer and determine when activation required
- Optimised cementing

The Future – What is Needed

- Industry standards are required for drilling measurements and handling measurement uncertainty. The ASME guidelines are useful in this regard.
- Cross industry working group for continuous improvement of drilling measurements

Acknowledgements

Acknowledgement is made to Technology Strategy Board UK, Saudi Aramco and Petrobras.

Nomenclature

ASME – American Society of Mechanical Engineers
 BHA – Bottom Hole Assembly
 G – G force
 GUM – Guide to Measurement Uncertainty
 ISO – International Standards Organisation
 LWD – Logging While Drilling
 MTBF – Mean Time Between Failure
 NPT – Non-Productive Time
 PPFG – Pore Pressure Fracture Gradient
 RACI – Responsible Accountable Consulted Informed
 ROP – Rate of Penetration
 RPM – Revolutions/Rotations Per Minute
 SPP – Stand Pipe Pressure

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First Successful Proppant Fracture for Unconventional Carbonate Source Rock in Saudi Arabia

By Nayef I. Al Mulhim, Ali H. Al-Saihati, Ahmed M. Al-Hakami, Moataz M. Al-Harbi and Khalid S. Al-Asiri.

Abstract

Widely recognized as the world leader in crude oil production, Saudi Aramco has only recently begun to explore for unconventional gas resources. Saudi Aramco started evaluating its unconventional reservoirs to meet the anticipated future demands for natural gas. One of the subject plays that is currently being evaluated is a carbonate source rock with nanoDarcy permeability and very low porosity. The target formation has few, if any, analogs that can be used for comparison. Knowledge of the formation characteristics, geomechanics, stimulation response and production potential has been nonexistent until recently. Historically, all attempts to stimulate unconventional carbonate formations in Saudi Arabia with hydraulically fracturing have resulted in premature screen-outs. Recently, however, a successful two-stage treatment has proved that proppant fracturing techniques can be utilized to stimulate unconventional carbonate formations in Saudi Arabia after modifying the stimulation design, specifically the perforation strategy, fracturing fluids and proppant type. The Tuwaiq Mountain and Jubailah formations were treated with 104,000 lb and 114,956 lb of proppant, respectively. This article will discuss the hydraulic fracturing stimulation design, its execution and an evaluation of the successful treatment.

Introduction

Saudi Aramco's unconventional gas exploration efforts were spurred by the growing local gas demand and the economic success of shale exploration in the United States, Canada, Europe and Australia. Saudi Aramco started evaluating its unconventional reservoirs and their potential both to reduce oil consumption in the electricity sector and to fuel the anticipated future demands for natural gas.

According to World Energy Outlook (2002)¹, "The multistage fracturing technique has facilitated the development of shale gas and light tight oil production

in the United States and is believed to do so in the other countries with unconventional hydrocarbon resources."

Saudi Aramco therefore has embarked on an unconventional exploration and appraisal project to assess the potential of its unconventional resources in three geographic areas: Northwest, South Ghawar and East Ghawar. Hydraulic fracturing techniques will be utilized to enhance production by connecting natural fissures and creating high connectivity pathways for gas to flow into the well.

As stated, the initial focus is in the Northwest and in the area of Ghawar. Initial knowledge building from similar plays in North America is being supplemented with internal technical studies and research programs to help solve geological and engineering challenges unique to Saudi Arabia and to locate specific wells planned for 2014. The company is innovatively combining knowledge and research to maximize gas reserves and production from conventional and unconventional resources to meet growing domestic demand².

As of 2013, there was no commercial production of shale gas in Saudi Arabia, but horizontal wells currently being drilled may prove capable of flowing significant hydrocarbons.

Multidisciplinary Team

Extensive preparation, a multidisciplinary team approach, state-of-the-art operations, and the effective execution and performance of the stimulation design resulted in the first successful proppant fracturing treatment in an unconventional carbonate reservoir in Saudi Arabia. This success undoubtedly paved the way for the second phase of the exploration program and the drilling of the first horizontal well in the area. The multidisciplinary team approach was undertaken by a team of geologists, geophysicists, and drilling, reservoir

and stimulation engineers, who gathered to review the drilling and completion options, identify candidate reservoirs and decide on the appropriate stimulation design. The team worked to integrate various professions, technologies and available reservoir data to pursue one common goal.

As with any multidisciplinary team, each discipline had its own objectives. Focusing on common goals ensured they aspired to accomplish the same objective; success depended on four components: setting targets, sense of ownership, supportive culture and motivated people³. The team members had diversified backgrounds with various levels of experience, which were very important in the process of providing solutions.

Professionals in each discipline had a clear understanding of their roles and responsibilities and the impact of their work on the other team members. If one discipline didn't deliver, the others may not have been able to proceed³. The Saudi Aramco team coupled its effort with a service company throughout the process to ensure safety, quality and efficiency. The service company provided technical knowledge in drilling and formation evaluation, well construction and completion. There were risks associated with completing this well due to the high level of uncertainties and the lack of data available for this basin and the targeted formations.

Acid vs. Proppant Fracturing

Saudi Aramco has mainly utilized acid fracturing and acid matrix to increase production rates from carbonate formations in conventional gas fields, while proppant fracturing is utilized predominantly in sandstone formations. The fact that all previous attempts to hydraulically fracture carbonate formations in Saudi Arabia using proppant stimulation resulted in premature screen-outs after only 10% of the proppant had been placed in the formation clearly demonstrates the significance of the first successful proppant fracturing treatment in an unconventional carbonate source rock in Saudi Arabia. In large corporate environments, change is often difficult. This has especially been true in the area of well stimulation. Stimulation techniques employed in the past tend to become standard, and proposing change is perceived as risky by both the engineer and management. Unfortunately, the nature of the reservoirs being developed today present much less favorable conditions than in the past. Hydraulic fracturing stimulation designs that once worked well to establish short, damage-free fractures are not adequate today to economically produce the tighter unconventional reservoirs that are becoming the industry's mainstay.

The Jafurah Basic Source Rocks

During the Jurassic and much of the Cretaceous, deposition in the Jafurah basin, east of Ghawar field, was dominated by platform carbonates. The Jurassic sediments being targeted in the Jafurah basin as unconventional reservoirs are carbonate source rocks found within the Tuwaiq Mountain, Hanifa and locally basal Jubailah formations. The Tuwaiq Mountain formation shows high total organic content (TOC), low clay content, good matrix permeability, high gas saturation and effective porosity. Scanning electron microscope images reveal the dominant presence of organic porosity associated with kerogen. The Jubailah formation has average reservoir properties as compared with the Tuwaiq Mountain. The TOC is generally good with relatively higher clay content, more similar to the Eagle Ford shale play in the USA. The matrix permeability is in range with the majority of shale plays, and saturations still are moderate to high. Throughout the comparison of different reservoir properties in the Jafurah basin with the principal shale plays in North America, the Jurassic sequence in Saudi Arabia shows encouraging results for a potentially successful resource play. Geochemical data suggests that Jurassic organic-rich successions in the Jafurah basin are currently in the early gas condensate stage with respect to hydrocarbon generation. With advancements in the hydraulic fracturing technology, such prolific source rocks are expected to be an attractive unconventional exploration play. Well H-1, the first well drilled on a seismic anomaly in the basin, encountered a thick, organic-rich Jurassic source rock. The thick sequences of source rock in Well H-1, as well as other areas within the basin, further suggest the possibility of a commercially viable unconventional play. As a follow-up to the drilling of Well H-1, a geophysical forward modeling project was initiated to investigate the cause of the seismic amplitude anomaly in the Jafurah basin. The study revealed that the formation in Well H-1 has overall lower acoustic impedance, which appears to be the result of its high TOC.

Drilling and Coring

Well H-2, east of the giant Ghawar field, was drilled to evaluate several Jurassic source rock targets. The well was completed with 4½" tubing, a 7" liner with a 7" permanent packer and a 25 ft seal bore receptacle. The tubing and annulus were displaced with 65 pcf brine, Fig. 1. The well was designed to be reentered for horizontal sidetrack.

A total of five cores were cut for lab testing and analysis. Acid solubility tests were performed on the core plug samples to determine their solubility in hydrochloric

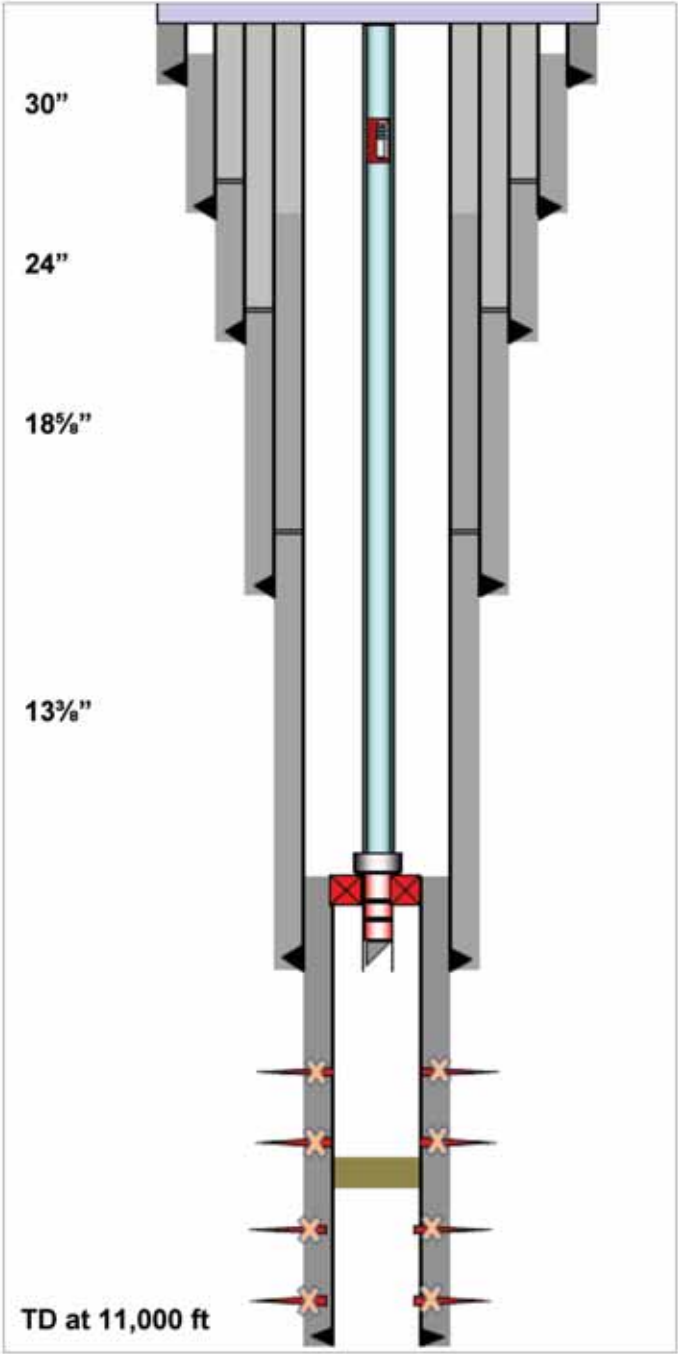


Fig. 1. Well H-2 cross section.

(HCl) acid. The core plug samples were tested in 15 wt% and 28 wt% HCl acid at a rock/acid ratio of 1 g/10 ml (5 g solid in 50 ml of acid), and the reaction time was 3 hours at room temperature. The weight of the solids was measured before and after the reaction with the acid, and the acid solubility was calculated from the change in the sample weight. The acid solubility test results were utilized while designing the stimulation treatment.

X-ray diffraction (XRD) analysis was performed on four core samples before and after the acid solubility tests. Each solid sample was homogenized and ground with an agate mortar for several minutes to achieve fine particle size and then mounted into the XRD sample holder

BH ISIP	11,133	PSI
Frac Gradient	1.05	psi/ft
BH Closure Pressure	10,390	psi/ft
Closure Gradient	0.98	psi/ft
Closure Time	448	min
Fluid Efficiency	0.91	
Net Pressure	592	psi

Table 1. Tuwaiq Mountain formation · DFIT pressure analysis

by back pressing. The sample fragments represented the actual reservoir while the ground samples exposed more surface area to the acid. The XRD analysis results showed that the four samples analyzed consisted mainly of calcite with smaller components of dolomite, quartz, anhydrite, pyrite and clays (kaolinite, chlorite, palygorskite and illite).

Perforation Design Strategy

When stimulating low permeability gas reservoirs, effective perforation design is critical for maximizing formation contact area and establishing communication with the target formation. Increased perforation penetration depth and higher shot density enhances injectivity, promotes effective stimulation treatments and improves well productivity in cased hole completions. Deep penetrating charges were employed in this well in conjunction with underbalance perforating to minimize perforation damage and ensure clean perforations. In addition, 3,000 gallons of 15% HCl acid were pumped as a preflush prior to pumping the pad in each stimulation treatment to further aid in debris removal from the perforation tunnels.

Prior to perforating each formation, the wellbore was displaced with treated brine, and a 3 3/8" high shot density gun system – with deep penetrating charges – was utilized to perforate a 28 ft interval in Tuwaiq Mountain and a 20 ft interval in Jubailah. The guns were configured for a shot density of 6 spf at 60° phasing with 0.4" entry holes. The deep penetrating charges provided the increased penetration depth required to establish good communication with the reservoir, resulting in improved injectivity during the stimulation treatments performed on both formations.

Stimulation Design Strategy

Due to the extremely low permeability matrix and the limited height of the target formations in this well, hybrid stimulation treatments were employed to

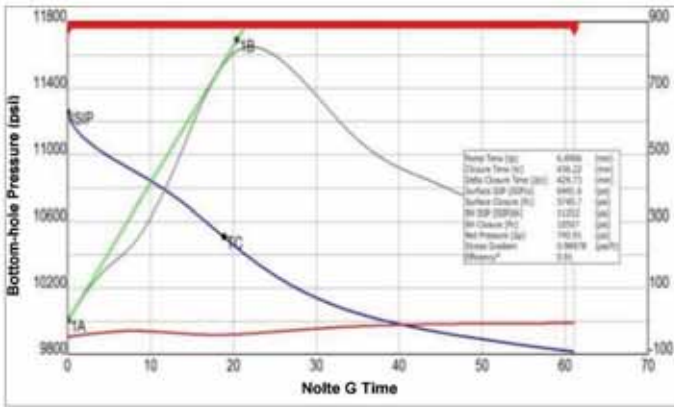


Fig. 2a. Tuwaiq Mountain formation · G-function plot analysis.

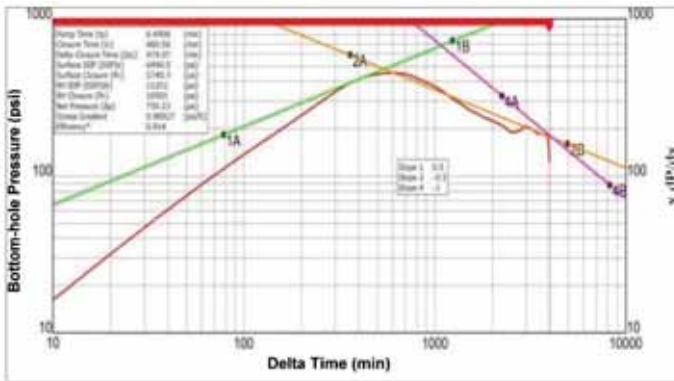


Fig. 2b. Tuwaiq Mountain formation · Log-log plot analysis.

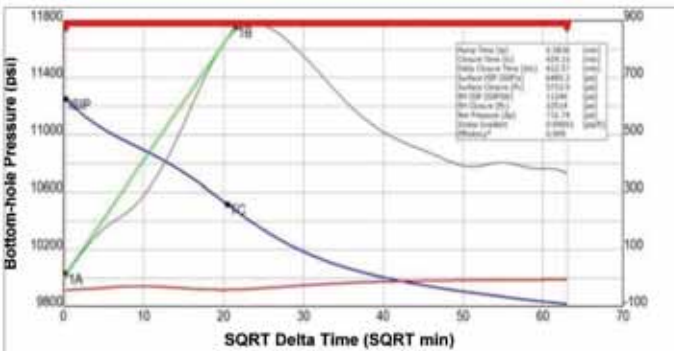


Fig. 2c. Tuwaiq Mountain formation · SQR plot analysis.

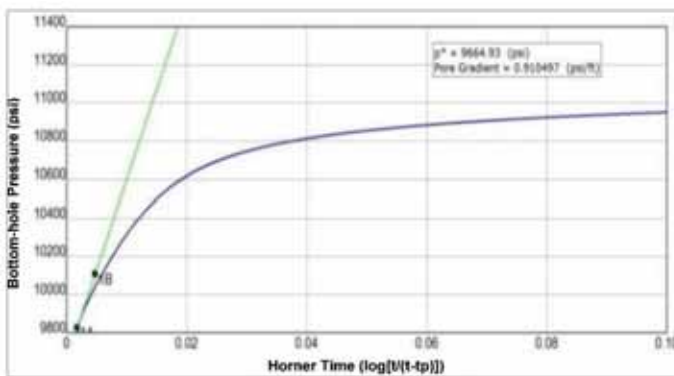


Fig. 2d. Tuwaiq Mountain formation · Horner plot analysis.

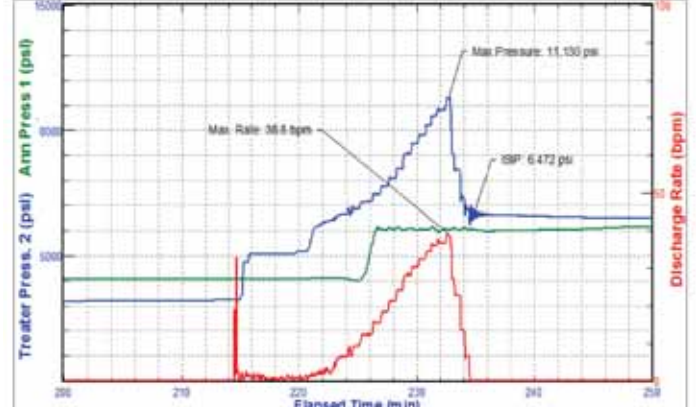


Fig. 3. Tuwaiq Mountain formation · SRT/SDT chart.

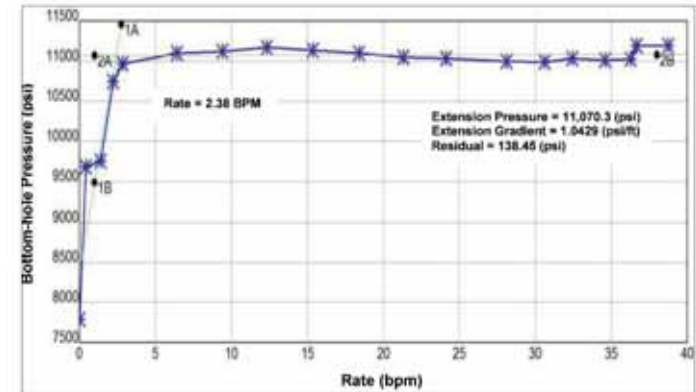


Fig. 4a. Tuwaiq Mountain formation · Step up diagnostics.

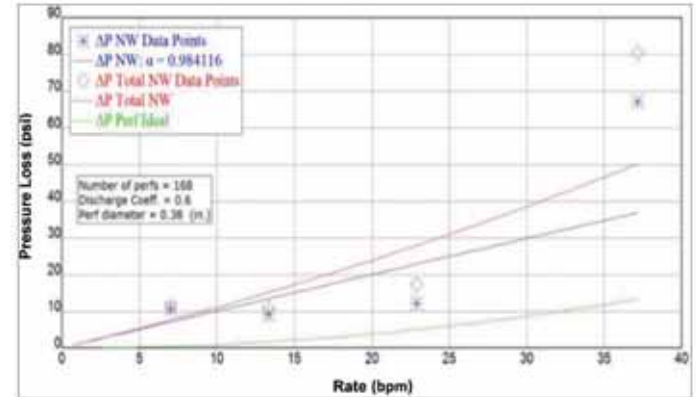


Fig. 4b. Tuwaiq Mountain formation · Step down diagnostic.

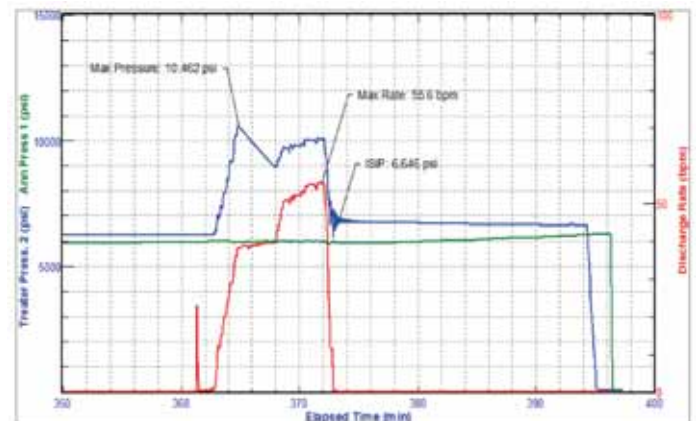


Fig. 5. Tuwaiq Mountain formation · Minifrac chart.

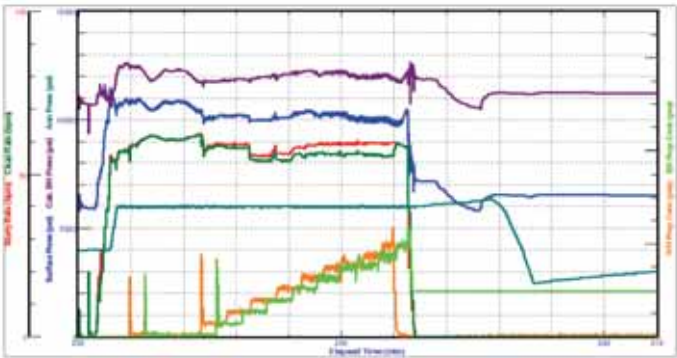


Fig. 6. Tuwaiq Mountain formation • Main stimulation chart.

BH ISIP	11,133	PSI
Frac Gradient	1.04	psi/ft
BH Closure Pressure	9,700	psi/ft
Closure Gradient	0.928	psi/ft
Closure Time	750	min
Fluid Efficiency	0.968	
Net Pressure	1,205	psi

Table 2. Jubailah formation • DFIT pressure analysis

establish fracture complexity and to provide sufficient proppant carrying capacity. Fracture complexity is required to establish commercial production from unconventional tight gas plays with nanoDarcy permeability, and hybrid stimulation designs combine the advantages of conventional and water stimulation treatments to achieve improved stimulation effectiveness by generating a large stimulated reservoir volume. The lack of available reservoir data for the target formations in this new unconventional play, coupled with the premature screen-outs experienced while attempting to pump proppant laden stimulation treatments in other carbonate reservoirs in Saudi Arabia, further supported the decision to take a more cautious approach to the stimulation design, specifically the ability to transport and place proppant.

Hybrid stimulation treatments utilize water, or gels with relatively low guar concentrations, to generate fracture geometry and employ cross-linked fluid systems to transport the proppant into the fractures once the fracture geometry has been created. A low viscosity pad promotes shear failures and aids in maximizing the stimulated reservoir volume, while higher viscosity gels and cross-linked fluid systems help to ensure sufficient proppant carrying capacity and placement. Utilizing a more viscous fluid system during the proppant transport stages allows for a more uniform proppant distribution

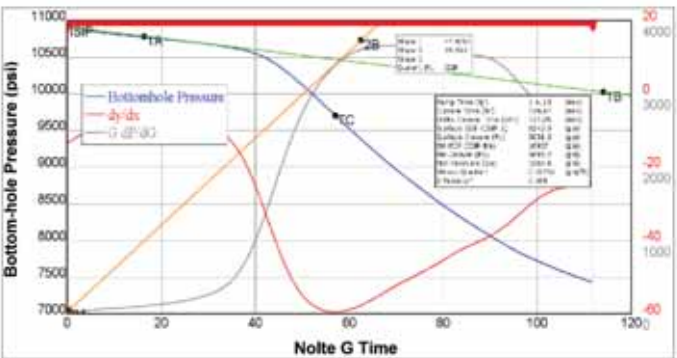


Fig. 7a. Jubailah formation • Nolte G-function analysis.

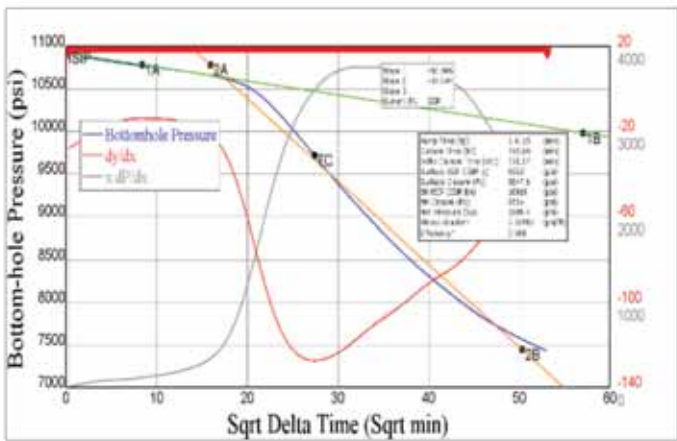


Fig. 7b. Jubailah formation • SQRT analysis.

prior to fracture closure due to the lower settling velocities associated with the linear gels and cross-linked fluids.

The specific hybrid stimulation treatments employed in this well were based on unconventional gas play analogs in North America. The hybrid treatment utilized a linear gel 10 lb/Mgal to generate fracture geometry, a linear gel 35 lb/Mgal to continue fracture propagation and to provide better proppant transport capability, and a borate cross-linked fluid system – designed for high temperature applications up to 300 °F – during the final stages to increase the apparent viscosity of the fluid to improve its proppant carrying capacity during the highest proppant concentrations. Base water analysis tests were performed to confirm fluid compatibility and to select the appropriate breaker schedule. An encapsulated breaker was pumped throughout the stimulation treatments to ensure an efficient polymer break, thereby minimizing formation damage and maximizing conductivity in the propped fracture.

A 40/70 intermediate strength ceramic proppant was pumped during the early stages of each treatment and a 30/50 high strength ceramic proppant was pumped during the final stages of each treatment to provide

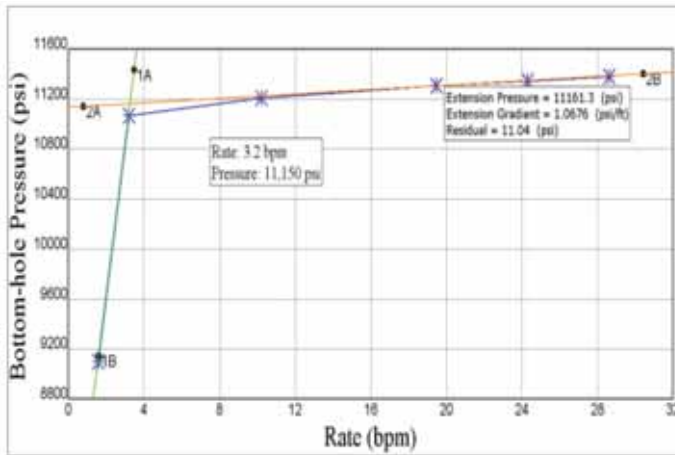


Fig. 8a. Jubailah formation - First step up diagnostics.

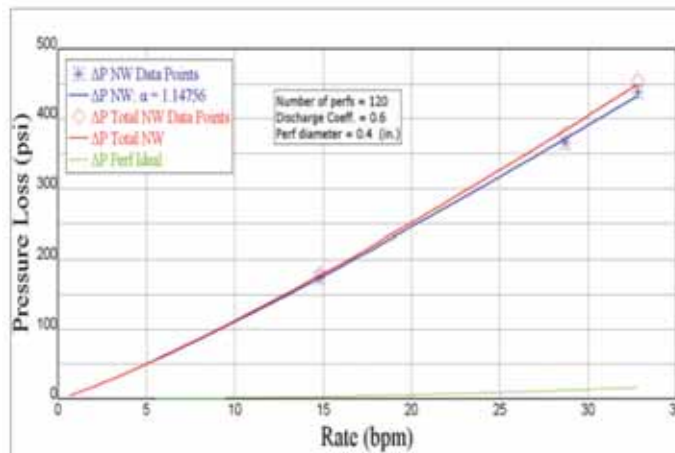


Fig. 8b. Jubailah formation - First step down diagnostic.

increased fracture flow capacity near the wellbore. The proppant was pumped in low concentrations throughout the job at a treatment design rate of 60 barrels per minute (BPM). Intermediate and high strength ceramic proppants were selected for use based on their improved performance characteristics in comparison with other proppants, specifically their superior strength, enhanced conductivity and increased productivity. The higher strength associated with intermediate and high strength ceramic proppants minimizes crush, enabling the proppant to retain its conductivity, and the uniform size and shape of ceramic proppants maximizes the porosity and permeability of the proppant pack. In addition, the thermal resistance provided by ceramic proppants minimizes proppant degradation in high temperature applications. A 30/50 intermediate strength nonradioactive traceable proppant was incorporated into the stimulation design for the Jubailah formation to assess the fracture geometry, specifically the propped fracture height. This nonradioactive traceable proppant was not utilized in the stimulation design for the Tuwaiq Mountain formation due to procurement issues.

Prior to pumping the main stimulation treatments in this well, diagnostic fracture injection tests (DFIT)

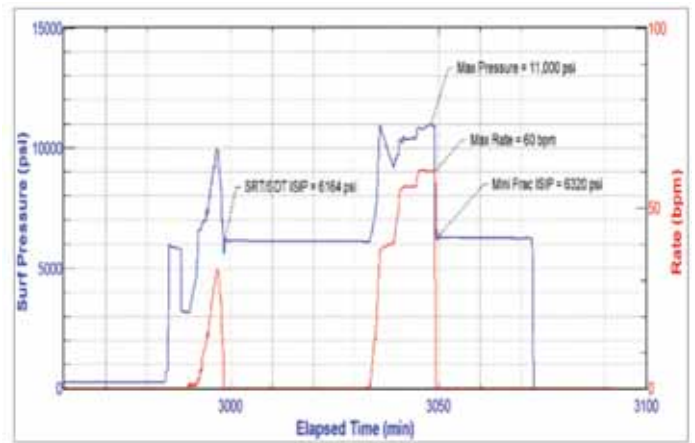


Fig. 9. Jubailah formation - First SRT/SDT and minifrac chart.

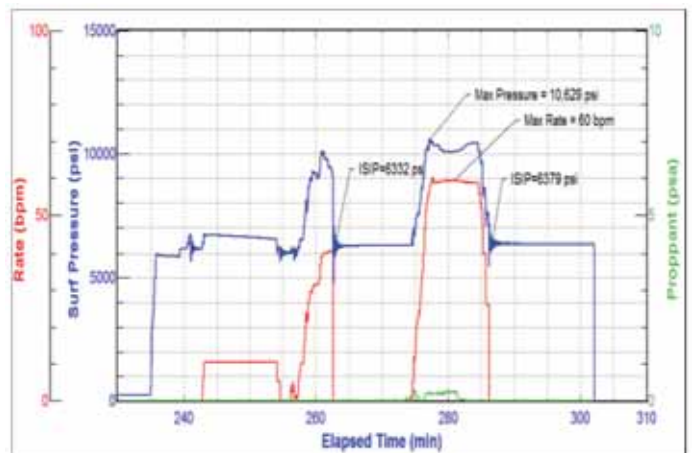


Fig. 10. Jubailah formation - Second SRT/SDT and minifrac chart.

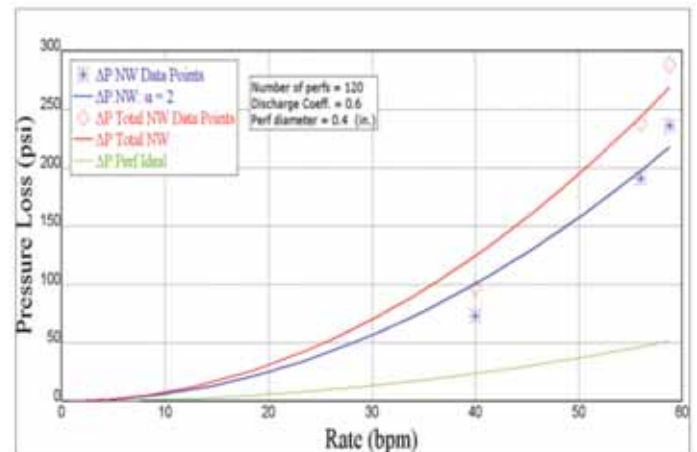


Fig. 11. Jubailah formation - Second step down diagnostics.

and calibration tests, specifically step rate tests and a minifrac, were performed to acquire information on the target formations. Temperature log and downhole memory gauges were run prior to performing the DFIT and calibration tests to acquire measurements to be used later as a baseline. The DFIT was performed to provide an estimate of the reservoir pressure, transmissibility and minimum stress within the target formation. A step up test was performed to obtain the fracture extension

pressure, and a step down test was performed to obtain the near wellbore friction, specifically to differentiate between the tortuosity dominated near wellbore friction and the perforation dominated near wellbore friction. The minifrac was performed to acquire information on fluid leakoff, fracture geometry and rock mechanics. This information was used to calibrate the stress contrast and the fluid leakoff. A second temperature log was run after completing the DFIT and calibration tests to examine fracture growth, and the bottom-hole gauges were retrieved prior to pumping the main stimulation treatments. The data recovered from the downhole gauges was used to correct the diagnostic data acquired during the DFIT and calibration tests, all of which was used to calibrate the geomechanical and 3D hydraulic fracturing stimulation models and to revise the final stimulation designs as necessary.

Tuwaiq Mountain Formation DFIT/Calibration Tests

Two DFITs were performed on the Tuwaiq Mountain formation. A total of 20 bbl of treated brine was pumped during the first DFIT at a maximum rate of 6.2 bpm and a maximum surface treating pressure of 6,500 psi. No clear formation break was observed and the pumping pressure continued to increase while pumping at a constant rate. The instantaneous shut-in pressure (ISIP) was approximately 100 psi below the treating pressure, and the drop in friction pressure was in line with the predicted friction values. No water hammer effect was observed, so the pressure was bled down through the wellhead isolation tool to the pit. The well flowed at nearly a constant pressure, indicating the presence of a compressible fluid in the wellbore.

A second DFIT was performed to ensure that a fracture was actually being initiated and that gas was not simply being compressed in the wellbore. A total of 38 bbl of treated brine was pumped during the second DFIT at a maximum rate of 5.0 BPM and a maximum surface treating pressure of 6,500 psi. Similar pressure behavior was observed during the second DFIT, confirming that the formation had already been fractured during the first DFIT. The average values, Table 1, of the diagnostic plots were corrected for a memory gauge set depth of xx,890 ft. A water hammer effect was observed, indicating good communication with the reservoir, and closure was observed after approximately 7.5 hours, Figs. 2a to 2d. Pressure monitoring continued for 66 hours before shutting the well in to perform the step rate tests. The initial DFIT pressure analysis was based on the calculated bottom-hole data, but was corrected based on the data recovered from the downhole memory gauges. Pseudo-radial flow was never achieved, so

reservoir transmissibility and pore pressure could not be determined. G-function analysis indicated fracture height recession, Fig. 2a.

Following the second DFIT, 248 bbl of treated brine were pumped to perform the step rate tests, Fig. 3. The maximum rate achieved during the step rate tests was 38.8 BPM with a maximum surface treating pressure of 11,130 psi, Figs. 4a and 4b. After monitoring the pressure decline for 2 hours, the well-bore was displaced with 165 bbl of liner gel 10. An additional 240 bbl of linear gel 10 lb/Mgal was pumped at a maximum rate of 55.6 BPM and a maximum surface treating pressure of 10,462 psi to complete the minifrac, Fig. 5. The pressure decline was monitored for 15 minutes.

Tuwaiq Mountain Formation Stimulation Treatment

The Tuwaiq Mountain formation hybrid stimulation treatment, Fig. 6, successfully placed 104,000 lb of 40/70 intermediate and 30/50 high strength ceramic proppant in the formation, pumping at a maximum treating rate of 62.6 BPM and a maximum surface treating pressure of 11,462 psi. The maximum proppant concentration during the treatment was 2.5 ppg. Forced closure was initiated within 5 minutes after shutdown, and treatment pressures were as predicted by the minifrac. Due to a chemical additive failure – specifically, a problem with the on-the-fly chemical control system – less than 20% of the chemical buffer was pumped, resulting in a cross-link failure throughout the majority of the cross-linked stages. The breaker and surfactant schedules were pumped as designed. Although the stimulation treatment was not pumped as designed, the actual fluids pumped during the treatment are less damaging and more conducive for fluid recovery than a cross-linked fluid system. In addition, these fluids are better suited for promoting shear failures within the rock and generating fracture complexity, which is more likely to meet the objectives of the unconventional gas stimulation program for this play. From a lesson learned standpoint, the impact of the chemical additive failure proved beneficial and clearly demonstrated that a linear gel fluid system was sufficient to transport proppant; the failure also provided valuable insight for the horizontal re-drill proposed for this wellbore. The Tuwaiq Mountain formation was isolated with a cement squeeze across the perforated interval and a bridge plug prior to initiating the DFIT and calibration tests on the Jubailah formation.

Jubailah Formation DFIT/Calibration Tests

A total of 9.9 bbl of treated brine was pumped during the DFIT performed on the Jubailah formation. The

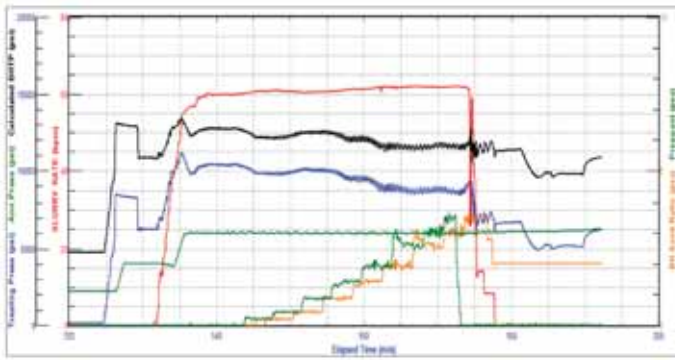


Fig. 12. Jubailah formation - Main stimulation treatment chart.

wellbore was displaced with 4.4 bbl of treated brine at 2.7 BPM, and an additional 5.5 bbl of treated brine was pumped at a maximum rate of 5.7 BPM after observing formation breakdown at 6,785 psi. A clear formation break and water hammer effect were observed, indicating good communication with the reservoir. The average after closure analysis values, Table 2, of the diagnostic plots were corrected for a memory gauge set depth of 10,517 ft. Closure was observed after 12.5 hours of pressure monitoring and after closure pressure monitoring was terminated after approximately 40 hours, Figs. 7a and 7b. As with the Tuwaiq Mountain formation, pseudo-radial flow was never achieved, so reservoir transmissibility and pore pressure could not be determined. G-function analysis indicated fracture height recession, Fig. 7a.

Following the DFIT, 115.5 bbl of treated brine was pumped to perform the step rate tests, Figs. 8a and 8b. The maximum rate achieved during the step rate tests was 33 BPM with a maximum surface treating pressure of 9,940 psi. After monitoring the pressure decline for 20 minutes, the wellbore was displaced with 158.3 bbl of liner gel 10 at a maximum rate of 35 BPM, Fig. 9. An additional 570.5 bbl of linear gel 10 lb/Mgal was pumped at a maximum rate of 60 BPM and a maximum surface treating pressure of 11,000 psi to complete the minifrac, Fig. 9.

Due to the higher than anticipated near wellbore friction losses observed during the initial calibration tests, Fig. 8b, the decision was made to perform a second series of step rate tests and minifrac, Fig. 10, including an acid preflush and a proppant slug to reduce near wellbore friction losses. The second minifrac was preceded with a 120 bbl of 15% HCl acid preflush pumped at 10 BPM and displaced with 181 bbl of linear gel 10 lb/Mgal. A total of 586 bbl of linear gel 10 lb/Mgal was pumped during the minifrac at a maximum rate of 60 BPM and a maximum surface treating pressure of 10,629 psi. A total of 3,145 lb of 40/70 ISP proppant was pumped during

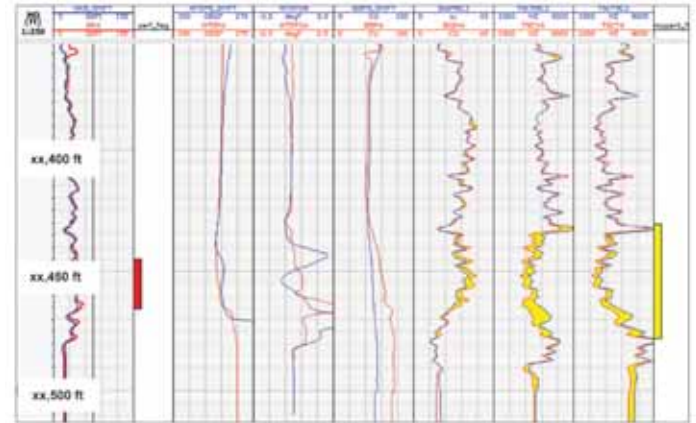


Fig. 13. Jubailah formation - NRT tracer log.

the minifrac at a 0.25 ppg proppant concentration. The minifrac was followed by a step down test pumped with 275 bbl of linear gel 10 lb/Mgal. The injection rate was stepped down from 60 BPM to 26 BPM prior to terminating injection. Analysis of the second step down test data, Fig. 11, was performed using the calculated bottom-hole pressure, which indicated a reduction in near wellbore friction losses of 350 psi at 30 BPM after pumping the acid preflush and second minifrac with a proppant slug.

A temperature log was run after the second step rate tests and minifrac to obtain more reliable data on the generated fracture height. Analysis of the temperature data suggested that the fracture height was confined to approximately 50 ft and did not propagate downward below xx,480 ft. Minor adjustments were made to the 3D hydraulic fracturing software to simulate the vertical fracture growth obtained from the temperature survey, and the proposed hybrid stimulation treatment schedule was rerun to acquire new fracture geometry data.

Jubailah Formation Stimulation Treatment

The Jubailah formation stimulation treatment, Fig. 12, successfully placed 114,956 lb of 40/70 intermediate and 30/50 high strength ceramic proppant in the formation, pumping at a maximum treating rate of 62 BPM and a maximum surface treating pressure of 11,223 psi. The maximum designed proppant concentration was 3.0 ppg, but was increased to 3.5 ppg during the final stage. All chemical additives were pumped as designed and forced closure was initiated within 5 minutes after shut down. Treatment pressures were as predicted by the minifrac.

Nonradioactive Traceable Proppant

To accurately assess the fracture geometry, specifically the propped fracture height, a nonradioactive traceable proppant was incorporated into the stimulation design

for the Jubailah formation. Nonradioactive traceable proppant is a near wellbore evaluation technique that accurately identifies proppant placement and the propped fracture height. Knowledge of the fracture geometry aids in stimulation performance evaluation and is integrated into the geomechanical and hydraulic fracturing simulation modeling software to optimize future stimulation designs. The nonradioactive proppant pumped during the stimulation treatment performed on the Jubailah formation contains a high thermal neutron capture compound that is dispersed throughout the proppant during the manufacturing process. This unique nonradioactive tracer eliminates the need for radioactive tracers and does not degrade over time, thereby allowing logging operations to be conducted throughout the life of the well.

A pulsed neutron logging tool was run in conjunction with a temperature survey before and after performing the main stimulation treatment on the Jubailah formation. The pre-stimulation pulsed neutron log established a baseline, which when compared to the post-stimulation pulsed neutron log, identified areas of depressed neutron response, signifying the presence of proppant.

The pulsed neutron logging tool run in this well was a 1.72" outer diameter slim-hole device with a pulsed neutron generator source and gamma ray detectors to measure neutron decay rates before and after the stimulation treatment. Prior to running each log, the wellbore was displaced with treated brine to ensure the logs were run in similar fluid environments.

The quality of the logs was good and the tracer signal was strong and clear. The final evaluation indicated a propped fracture height of 48 ft with the propped fracture height ranging from xx,430 ft to xx,478 ft, Fig. 13. After normalization, there was no clear increase in formation sigma (capture cross section) and little change in the gamma ray count below xx,478 ft, indicating that the fracture growth was confined and the fracture did not propagate downward. Due to the limited rat hole in this well, the pulsed neutron logging runs were initiated 25 ft below the perforated interval, rather than 200 ft below as recommended by the proppant manufacturer, thereby introducing a level of uncertainty with regard to the lower fracture boundary.

Conclusions

1. The multidisciplinary team approach assured safety, quality and efficiency.

2. The first propped fracture treatments for carbonate shale source rock stimulation by Saudi Aramco were a success. The job demonstrated a viable technique, which should be considered for more zones within the same play for better assessment.

3. A linear gel fluid system is sufficient to transport proppant and provided valuable insight for the horizontal re-drill proposed for this wellbore.

4. In the light of the success, the proppant fracturing design should be changed to achieve proppant placement and can be summarized as:

- Pumping small proppant sizes: 30/50 instead of 20/40 mesh.
- Shooting large internal diameter perforations.
- Maximizing the pumping rate by completing the future wells with 5½" to lower friction figures.

5. A production potential exists in these formations, and the results are encouraging. The Tuwaiq Mountain formation east of Ghawar appears to be a liquids-rich gas/condensate zone; therefore, hydraulic fracturing designs for wet gas/ condensate production should be considered.

6. Changes required include improved testing procedures and sample analysis.

7. Several meetings were conducted to capture the lessons learned and to make recommendations for improvements on the scheduled offset well. The scheduled offset well is 1 km from the H-2 well and will be drilled approximately 25 ft below the Tuwaiq Mountain formation. The well will horizontally appraise the reservoir flow capacity and resource potential of the Tuwaiq Mountain formation with 16 hydraulically fractured intervals across the lateral section.

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Biographies



Nayef I. Al Mulhim is a Gas Production Engineer in Saudi Aramco's Unconventional Production Engineering Division. Previously, he worked with Southern Area Production Engineering Department. Nayef has completed an intensive

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Ali H. Al-Saihati joined Saudi Aramco in 2007. He is currently a Petroleum Engineer working with the Unconventional Production Engineering Division. Previously, he worked with the Gas Production Engineering Division responsible for

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In 2007, Ali received his B.S. degree in Petroleum Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. He is a member of the Society of Petroleum Engineers (SPE), and he is an SPE Certified Petroleum Engineer.



Ahmed M. Al-Hakami joined Saudi Aramco in 1996 and has been involved in oil and gas exploration since. He is currently working as a Chief Explorationist on Saudi Aramco's Jufurah and Rub' al-Khali basins within the Unconventional Gas

Exploration and Development Department. Ahmed's areas of interest include basin modeling, organic geochemistry, and recently, unconventional gas exploration.

He is an active member of the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Engineers (SPE) and the European Association of Organic Geochemists (EAOG).

In 1996, Ahmed received his B.S. degree in Petroleum Geology from King Abdulaziz University, Jiddah, Saudi Arabia, and his M.S. degree in Geology with a sub-major in Organic Geochemistry from the University of Houston, Houston, TX, in 2004.



Moataz M. Al-Harbi is a Gas Production Engineer assigned to the Haradh Engineering Unit in the Gas Production Engineering Division in 'Udhailiyah. He has 17 years of diversified oil industry experience.

Prior to joining Saudi Aramco in 2004, Moataz worked at Schlumberger where he specialized in stimulation operations. Upon joining Saudi Aramco, he participated in the Production Engineering Specialist Program (PESP) as a Stimulation and Fracturing specialist candidate. Moataz has been actively involved in the successful implementation of a number of new technologies aimed at enhancing well productivity, and is a mentor to young Saudi engineers.

In 1996 he received his B.S. degree in Mechanical Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia.



Khalid S. Al-Asiri is a Gas Production Engineer in the Southern Area Production Engineering Department. He worked with the Ministry of Petroleum and Minerals before joining Saudi Aramco in 2002. Khalid has worked in several areas within the company, including Gas Production Engineering, Gas Well Completion and Services.

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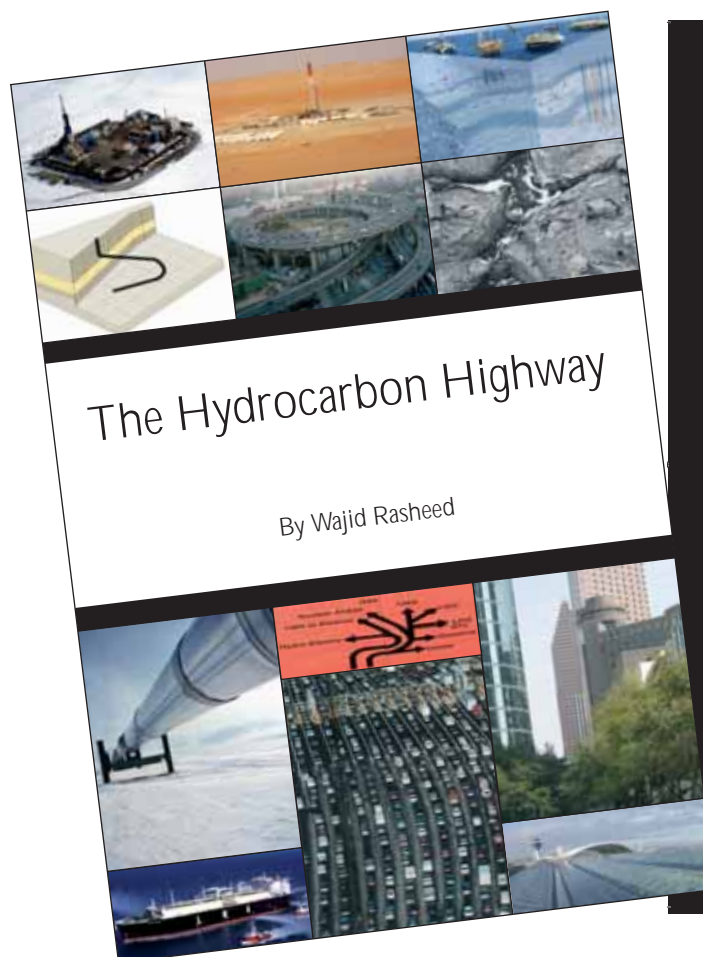
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The Fall of the Oil Curtain



"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 overview to the industry without bogging the reader down. I enjoyed the journey along the highway."

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"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

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What would a sketch of the global landscape of reserves and production look like? No doubt, its most salient features would be the growing appetite for oil and gas and the drive for reserves replacement from frontiers and mature fields. In the background, would lie the cycles of 'feast or famine' and the long lead times that govern investment and returns. Yet, tantalizingly hidden away is the essence of the industry — petroleum reserves.

The Oil Curtain neatly symbolises resource sovereignty and separates the hydrocarbon 'haves' from the 'have-nots'. It has led to the major part of proved global oil reserves being booked by National or State Oil Companies (NOCs). To illustrate the change of

ownership, in 1971 NOCs held 30% of total reserves while International Oil Companies (IOCs) held 70%. Today, NOCs have increased their share to 93% while IOCs hold 7%¹. What could have caused such a dramatic reversal in fortune?

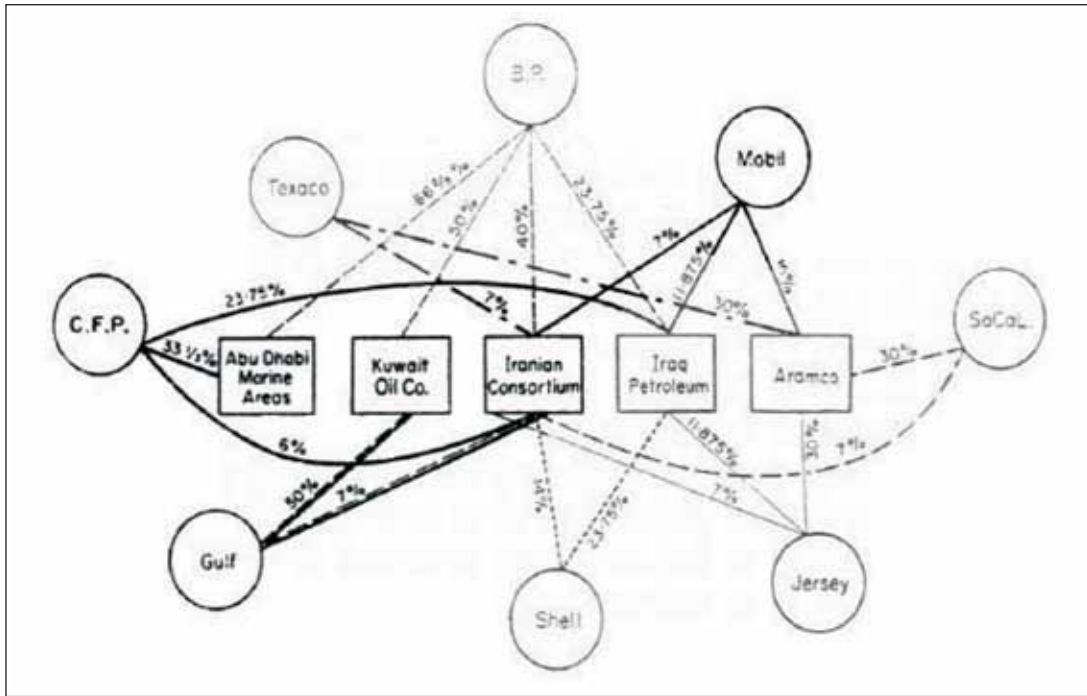


Figure 1 - Ownership Links Between Major IOCs (including Compagnie Française des Pétroles) and the Major Producing Companies in the Middle East after Edith Penrose, 1966

Since the early 1900s, the importance of oil in financial, political and strategic matters has been bubbling up to the surface. Eventually, this led to a pressing need for producing states to control oil. Mexico was first to 'shut' the Curtain by nationalising its oil assets and forming the wholly state-owned Pemex (Petróleos Mexicanos) in 1938². By 1960, resource sovereignty had fully matured into a global force and the Central Bank of Oil³ – OPEC (Organisation of Petroleum Exporting Countries) – was created.

The effects of the Oil Curtain have been a blunting of IOC access to oil and a partial blurring of the distinction between NOCs and IOCs. As the spheres of action of both types of companies increasingly overlap, the industry has become more geographically dispersed and institutionally fragmented. Not least, the Oil Curtain has driven certain IOCs to metamorphose into energy companies.

The Oil Is Ours

'The oil is ours' reads a sign as you leave Rio de Janeiro on the road to the oilfield city of Macaé. That sign is not a historic throwback or juvenile street graffiti, but a modern official billboard paid for by the Brazilian government. Its nationalistic message is that oil, and oil wealth, are too important to be left to foreigners and external market forces. This message is a recurrent one found worldwide. It is just the language and symbolism

that changes; Russia's Shtokman field, jobs for the boys; Niger Delta, moralists decrying the excesses of ex-pats; PdVSA and Bolivia; gringo go home.

Consider Shtokman and the decision of the Russian government to develop it alone – this is a clear message that the gas reserves could and would be developed without outside help which could otherwise be perceived as 'dependence' on foreign oil companies. Continuing unrest in the Niger Delta points to a different dynamic between regional and federal revenue sharing but nonetheless still nationalism. Bolivia's nationalisation of its Gas industry sends the same clear message. What is interesting is that both fully privatised and part-privatised companies were affected. StatoilHydro bid for Shtokman and was seen as the front runner and Petrobras invested heavily in Bolivia from Exploration and Production (E & P) to pipelines to marketing. In Venezuela and the Niger delta, the effects were felt by IOCs Exxon Mobil and Shell⁴.

Humble Oil

Oil has come a long way from its humble roots. Until the early 1900s, it was just a cheap fuel for lamps and heaters. How then could it be transformed into a strategic resource and military necessity within a decade? This rapid change was due to the convenience with which oil could be stored and transported, coupled with its high energy density. It was the most efficient

“By the end of the Second World War in 1945, the knowledge that oil was of great commercial and strategic importance was commonplace.”

fuel that mankind had discovered – the perfect fuel for the internal combustion engine and mechanised transportation. By 1911, it had replaced coal as the preferred fuel for the British Royal Navy. By 1918, other navies had quickly followed suit, creating a speed and logistics advantage that ultimately led to victory to those that used it. Accompanying the new-found status of diesel oil and gasoline as the fuels-of-choice for the war machine was the struggle to secure supply amidst the geopolitical upheaval of the times. In fact, it has been postulated that fuel shortages, not the Allies' military prowess, led to the ultimate demise of the Axis powers in World War II. The race had begun⁵.

Makeover

Principally driven by the British, French and American governments, numerous oil companies were set the task of securing oil supply for their countries' needs. It was through ownership of concessions in developing countries, and predominantly in the Middle East and Far East, that the IOCs grew.

Known as the 'Seven-Sisters*', – a term coined by the Italian oil tycoon Enrico Mattei referring to Exxon (Esso), Shell, British Petroleum (BP), Gulf, Texaco, Mobil and Socal (Chevron – plus an eighth, the Compagnie Francaise Des Pétroles (CFP-Total)⁶– these companies raced to find 'the prize'⁷.

During this growth period, the IOCs made huge strikes in oil and rapidly drilled the wells and built the pipelines and refineries that were needed to turn the flow of oil into revenue. This was undoubtedly the golden period of the IOCs but, despite expert negotiations and justifications, the geopolitical manoeuvring was being noticed by the producing countries.

Seeds of Discontent

In the period between the two world wars, more and more countries began realising their futures were contingent on controlling their own resources, oil especially. At the vanguard of this realization was President Cardenas of Mexico^{8,9}.

The seeds of nationalisation had been sown by Mexico in 1934 when it forcibly took over the shareholdings of foreign oil companies operating in Mexico resulting in the creation of Pemex which became the first 'nationalised oil company'. Venezuela and Iran soon joined Mexico by re-nationalising their hydrocarbons.

Winds of Change

By the end of the Second World War in 1945, the knowledge that oil was of great commercial and strategic importance was commonplace. Oil was associated with vast revenue flows as well as having kept

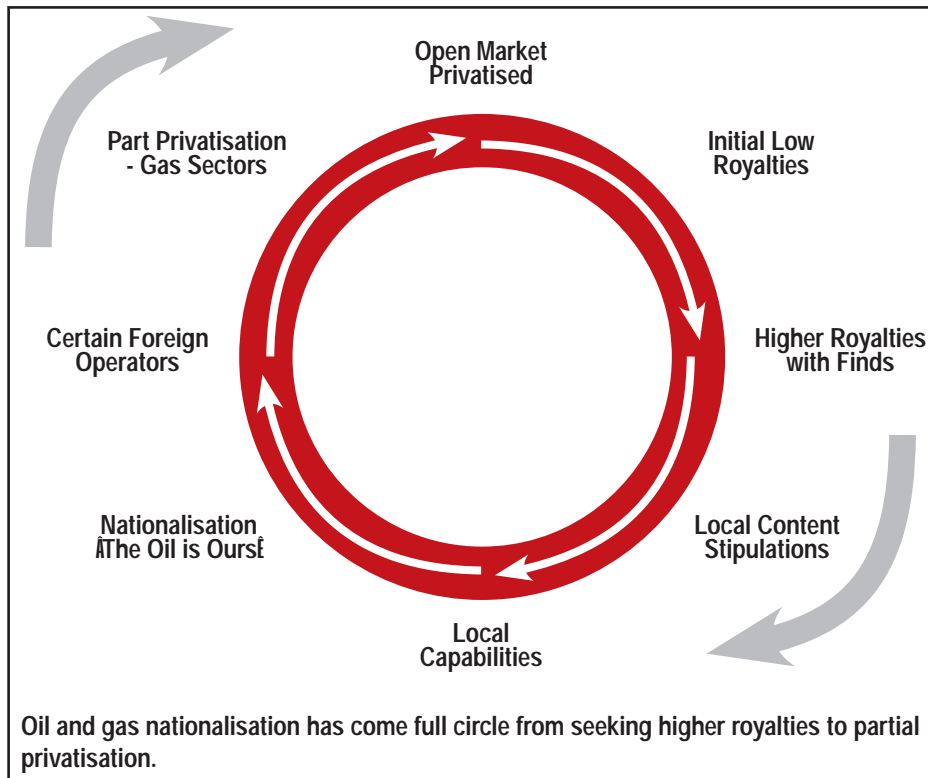


Figure 2 - Modern National Oil and Gas Policy

the 'war-machine' running. Consequently, colonial powers sought to control oil supplies.

In the post-war period, however, the winds of political change had swept aside the old colonial order whose political leaders acquiesced to foreign clients and replaced them with vocal nationalists who advocated sovereignty and independence. Exemplifying this were the strong voices of Gandhi in the Indian subcontinent, as well as Nasser and the Ba'ath party in the Arab states.

Viewed through the lens of political independence, control over natural resources had become an urgent necessity and, despite geographic and ethnic separations, a unified and growing chorus emerged with Mossadegh in Iran, Qasim in Iraq, Perez Alfonso in Venezuela and Tariki in Saudi Arabia all seeking to review oil contracts^{10,11,12}.

Initially, these individuals and countries acted alone, but as events unfolded affecting them all, they became increasingly united. The nationalist's central message was clear; oil was too important to leave in the hands of foreigners¹³. There was a need to regulate 'oil-rents' and end arbitrary payments from foreign oil companies.

Nationalist thinking was shaped threefold. Firstly, deals favoured foreign oil companies and foreign governments, not producing states. Foreign oil companies also controlled an outward flow of profits which were often the greater part of the producing countries' Gross Domestic Product (GDP). Generally, beneficiaries were foreign governments either directly through shareholder dividends or indirectly through taxes. Secondly, foreigners took vital political decisions affecting the sovereignty of producing countries. Oil production, foreign exchange earnings through oil sales, and ultimately, national debt were unilaterally dictated by foreign oil companies. Lastly, the military and naval campaigns of the Second World War, combined with the utility of oil in general transportation, left no doubt that oil was a primary strategic asset.

These factors created resentment among the political elites and the disenfranchised in producing countries leading to the conviction among producing states that oil profits should be shared equally between producing states that had territorial ownership of resources and IOCs who conducted E & P activities for oil¹⁴. Producing countries became united; the old deals had to be undone. New deals would treat territorial owners of resources and the IOCs as equals.

“Oil company profits, despite complex justifications to OPEC and despite falling prices, were still high compared to most other industries.”

Sovereignty Over Resources

Financial, political and strategic factors acted as a catalyst for resource nationalisation, most notably with Iran and Venezuela taking their first steps toward sovereignty during the fifties. In Iran, the government nationalised the oil assets of Anglo-Persian (the precursor to British Petroleum). In Venezuela, the government established the famous ‘50/50’ petroleum legislation that split oil revenues affecting US oil companies. Shortly after, Saudi Arabia, Algeria, Iraq and Libya followed suit¹⁵.

Nationalisation in Teheran and the reformulation of oil revenues in Caracas were pivotal events that directed the founders-to-be of OPEC – Juan Perez-Alfonzo, the Venezuelan Oil Minister, and Abdullah Tariki, the Saudi Arabian Oil Minister – to seek a mechanism that would stabilize prices. They found the solution in a global equivalent of the Texas Railroad Commission, which had successfully controlled US over-supply of oil to stabilize prices¹⁶.

The Compacto

During the Arab Oil Congress meeting in Cairo, Egypt in April 1959, Tariki and Perez-Alfonzo met to discuss what had been pressing so heavily on their minds. The two gentlemen had both reached the conclusion that the 50/50 principle should be replaced by a 60/40

split in favour of the producers. Within a year, the two men created the ‘Compacto Petrolero’ – an ‘Oil Commission’ that would permanently tip the balance of power in favour of producers. In some ways, this was the precursor to the Oil Curtain – the Compacto reshaped NOCs by aiming for a 60% share of profits. In due course by integrating their E & P, distribution, refining, transportation and retail operations, the NOCs would learn to compete with the IOCs¹⁷.

Birth of OPEC

Of course, the IOCs were avidly paying attention to the ‘Compacto’. Despite feigning disinterest in events, they turned to the spot markets and cut oil prices. Anglo-Persian (BP) had cut prices on the eve of the Arab congress meeting. Then, Standard Oil of NJ (Exxon) unilaterally cut the posted price of oil. Such a Machiavellian move would immediately affect the pockets and pride of producers, facts that were not lost on the decision makers who elected to keep the producers in the dark.

Rude words could have been a fitting response and perhaps, moves such as those that the oil companies had taken would have caused Alfonzo to use such words to describe oil politic¹⁸.

In any event, the cuts prompted a united response and

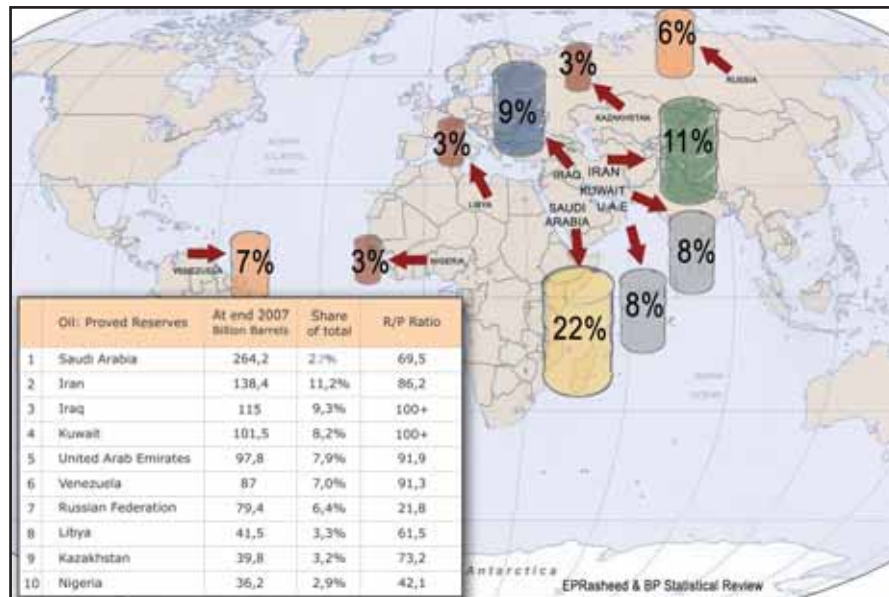


Figure 3 - Top Ten Global Oil Reserves 2007

a different kind of swearing. Iraq invited several major petroleum exporting countries namely Iran, Venezuela, Saudi Arabia and Kuwait to Baghdad for a historic meeting which led to the birth of OPEC on September 14, 1960.

OPEC's first resolution pointed to the oil companies as the culprits: 'That members can no longer remain indifferent to the attitude heretofore adopted by the oil companies in affecting price modifications; that members shall demand that oil companies maintain their prices steady and free from all unnecessary fluctuation; that members shall endeavour, by all means available to them, to restore present prices to the levels prevailing before the reductions'¹⁹.

The Princes Taught a Lesson

After the Second World War, the independence of former colonies sent out a shockwave – resource nationalisation. This in turn, created OPEC which signaled a decline in the hegemony of IOCs globally. By 1970, the oil companies were still enjoying a princely existence but only just. Between 1960 and 1966, their share of oil production outside North America and the Former Soviet Union (FSU) countries, had increased from 72% to 76%, leaving 24% for the NOCs²⁰.

Oil company profits, despite complex justifications

to OPEC and despite falling prices, were still high compared to most other industries. Rates of return for most IOCs were higher in 1966 than in 1960²¹, and IOCs were able to finance most E & P as well as refining, retail and petrochemicals out of crude oil profits made abroad. The IOCs argued with OPEC that the retailing network was needed to create markets for OPEC oil, which would otherwise go unsold; however, it was the scale of repatriated profits that were ultimately responsible for unraveling the IOCs' concessions²².

Sleeping Giant

The potency of OPEC remained dormant for a decade. In November 1962, OPEC was registered with the United Nations Secretariat²³. Yet, it was not until the mid-1970's that a growing group of countries nationalised (or in some cases re-nationalised) their hydrocarbon industries. In 1973, it was the combination of Libyan radicalism and an Arab oil embargo precipitated by US support for Israel in the Arab-Israeli war, that within a ten-month period in 1974, culminated in the price of a barrel of oil rising by 228 per cent²⁴.

The old order had given way to the new.

Between 1970 and 1976, nearly 20 countries asserted national sovereignty over their operations²⁵. In February 1971 after acrimonious disputes about prices, Algeria

“As modernity spreads, lifestyles that were once confined to wealthy classes in wealthy countries are now found up and down social classes and across the globe.”

nationalised all French interests within its territory²⁶. Shortly after, Libya announced the nationalisation of all BP's assets. This has continued to the present period where, most recently, Venezuela and Bolivia have nationalised IOC oil assets²⁷.

Driven by the need to develop gas reserves (to meet growing national and international demand for gas and to keep oil for exports), many countries had slowly relaxed national controls and through joint ventures, contracts with service companies and, exceptionally, ownership licences, larger oil companies were allowed to return to previously nationalised oil markets²⁸.

Modern national oil policy has come full circle (see Figure 1). It has evolved from seeking equal treatment to maximising royalties to stipulating local content to full re-nationalisation and now to partial privatisation for gas developments.

Yet in the latest period, nationalisation has resurged and this can be seen clearly in Russia's decision to develop the Shtokman field alone and remove certain IOCs from the Sakhalin development, while in Bolivia and Venezuela oil companies have had their licences revoked and lost production. Nationalisation has even surfaced in the North Sea with Norway's government-

controlled Statoil conducting a reverse takeover of NorskHydro. The Oil Curtain has spread.

As modernity spreads, lifestyles that were once confined to wealthy classes in wealthy countries are now found up and down social classes and across the globe. Think China and India. Together this relentless demand for oil and gas, which was already a strategic resource, has meant that oil and gas have become the world's most desired commodities.

In 2008, oil prices broke through the US \$125 per barrel level peaking at a ceiling of US \$147 before tumbling back to US \$35 all within a six month period. Nevertheless, it is easy to forget that oil is cyclical and therefore it is only a question of time before it goes up. The only question is whether the present down cycle has a prolonged hard landing from the peak²⁹.

New Seven Sisters

Nowadays, OPEC decisions get as much ink as those of major central banks³⁰. Yet beyond the paparazzi flashes and news-wire headlines, how important will OPEC and NOCs be for future oil supply? Realistically, the production of OPEC and certain NOCs will be vital for several generations to come. To understand that reality, simply look at (see Figure 3) the top ten reserve

“NOCs may not become global household brands, but they have set the trend that restricts IOC access to oil, and lately, the dividing line between the two is not so clear.”

holders worldwide: Saudi Arabia, Iran, Iraq, Kuwait, UAE, Venezuela, Russia, Libya, Kazakhstan and Nigeria. Seven of these countries – the first six and Libya – are all OPEC members. To see how important these new Seven Sisters are to future oil supplies, consider the reserves to production column (Figure 3) to see how many of today's top ten global reserve holders are likely to be producers in the US Energy Information Administration (EIA) Energy Reference Case year of 2030³¹.

At that time, I will be 60 years old and probably writing about the world's next 25 years of oil production. More to the point of today's top ten oil reserve holders, Russia will have dropped off the list while the new seven sisters and OPEC will still be producing away. What about the other current major producers? Canada has 22.9 years, the US has 11.7 years and Mexico has 9.6 years of oil reserves left at current production rates. Upshot: OPEC and the new Seven Sisters will grow both home and abroad. NOCs may not become global household brands, but they have set the trend that restricts IOC access to oil, and lately, the dividing line between the two is not so clear.

Fuzzy Logic

The fuzziness between private and state oil companies

stems from the NOCs that have 'gone global'. On the one hand, for certain companies the logic and returns of going global are compelling; add new production and export 'home-grown' technology. Yet, on the other hand, there is the risk of sudden nationalisation. Once wellheads, fields, pipelines and refineries are built, they cannot be dismantled and sent back 'home'. In the event of political change or a major dispute, the oil company's bargaining power is effectively reduced. Any share or interest it may have in production can only be sold off to the state which then becomes a question of expedient valuations rather than ownership.

What actually constitutes a NOC? Is it 100% state ownership or just a state majority? What if the company floats on the world's stock markets and has private shareholders yet retains a state majority?

The distinction depends on whoever holds 51% or more of voting shares and controls overall decision making power. If the majority shareholder is a government or state, the company must answer to them; therefore, such a company is defined a NOC. The opposite also applies. If the company's 51% voting majority is privately held or listed, it would be defined an IOC.

Shareholder distinctions shed light on the



Figure 4 - Downtown View of Houston (EPRasheed)

responsibilities of each company too. NOCs have a strong responsibility to steward oil wealth to meet the needs of a given nation and its population in a sustainable way. IOCs focus primarily on maximising returns; social responsibility is important, but not to the same degree as NOCs. Most people in the industry accept that profits must be balanced with social responsibility. Private shareholders generally accept this too. Corporate Social Responsibility (CSR) programmes within IOCs are abundant and this type of social spending does raise investors' eyebrows as long as returns are healthy. Part-privatised NOCs fall into this category also. Just how much social responsibility is deemed healthy depends on the shareholders.

We Speak Your Language

Notable NOCs such as Petrobras and CNPC operate well beyond their home territories. Both companies not

only retain majority government stakes, but also raise capital using a canny combination of state finance and international financial markets to develop domestic and foreign reserves. Where they really excel is by competing internationally for capital and upstream acreage and applying their unique technologies and know-how.

Accessing reserves or holding on to them is the producer's top challenge. Consumption is a given. Subsequently, finance, Human Resources (HR), technology and processes can be acquired.

Undoubtedly, production is one end of a transaction; consumers are needed too. Both depend on each other for the respective stability of demand and supply. Whatever affects the economies of oil consumers ripples through to producers and vice versa. The

“ The ultimate interests of oil producers and consumers... always converges in promoting stability of the worldwide economic framework and minimising economic shocks.”

ultimate interests of oil producers and consumers, therefore, always converges in promoting stability of the worldwide economic framework and minimising economic shocks.

The upshot is that reserve holders or producers, rather than retailers, determine rules. In this way, accessing reserves or holding on to them has become the producer's number one challenge – HR, technology, vertical integration and process efficiencies can all be subsequently acquired.

NOCs Go Global

Naturally then it is a ‘no-brainer’ for NOCs with global ambitions to compete for foreign reserves and production. Entering this competition makes sense for those NOCs such as Petrobras or the China National Petroleum Corporation (CNPC) that have limited reserves or high production costs at ‘home’ or where they can export ‘home-grown’ technologies abroad. It does not make sense for the new Seven Sisters who have abundant domestic reserves at relatively low production costs. In the latter, it makes more sense to stay ‘home’ and develop national reserves.

In the old days, it was fair to say that the IOCs conferred access to reserves. They had the technology, know-how and capital to create wealth from a natural resource.

Naturally, they bargained hard and got the lion's share. Those ‘old ways’ show that oil reserve holders used to recognise IOCs as equals, perhaps even as holding the upper hand as IOC participation was required for revenues to be realised³².

But Where Do the IOCs Fit Into All of This Today?

Much has been written on IOCs and our focus is on the growth of the NOCs which is far less documented; however, as the two are inextricably linked, it is worth briefly extracting pivotal events that are common denominators. It is widely accepted that the oil industry's fate was sealed by growing demand for transportation (military and consumer) and the steady supply of oil from refineries, pipelines and fields worldwide.

Numerous discoveries were made by geologists and drillers made production possible by always finding a way. In fact, the vertical integration and camaraderie of an inter-disciplinary approach positioned IOCs so well that it was almost as if each had its own principality of petroleum production³³.

Original Seven Sisters

A decade ago the price of a barrel of oil languished at US \$10. This triggered ‘mergeritis’ and reformed the original Seven Sisters. During the 1990s, the new

“As the Oil Curtain fell, the IOCs became accustomed to a gradually shrinking pool of accessible oil reserves that were ever more difficult and costly to produce.”

‘prize’ for these companies was finding synergies and economies of scale. Management consultants were set the task of merging these great disparate entities and analysts evaluated the mergers in terms of restructuring and costs.

In the corporate cost-cutting that ensued, locations and operations were rationalised. Many IOC’s consolidated their international operations in Houston. Research and Development (R & D), technology activities and technical disciplines were seen as unnecessary fixed costs that could be more profitably outsourced. At that time, only a handful of voices questioned rationalisation especially that related to technology R & D; it made sense financially and operationally. Ironically, technical outsourcing would strengthen the Oil Curtain and return to haunt IOCs.

Metamorphosis Begins

As the Oil Curtain fell, the IOCs became accustomed to a gradually shrinking pool of accessible oil reserves that were ever more difficult and costly to produce. This initiated the metamorphosis of the IOC with progressive companies such as BP and Shell repositioning themselves for the future, not just because they had seen ‘beyond petroleum’ but because they had felt ‘the Oil Curtain’ fall. This, however, does not

imply the fall of the IOCs; there are still plenty of global E & P opportunities around, albeit tempered by lower margins due to higher cost and technical challenges.

Oil companies’ future profits (and share prices) depend on production and reserves. As older fields decline, companies must find new production and decommission older structures. Our earlier look at the global reserves base shows the true significance of NOCs. Where reserves are institutionally accessible by IOCs, they are accessible only at considerably higher costs typified by technically challenging projects in ultra-deepwaters or the Arctic. In this way IOC ‘replacement’ costs tend to rise faster than NOC replacement costs. However, this is not always true as certain NOCs that have deepwater or heavy oil reserves may have comparable costs to those of IOCs.

The metamorphosis of more progressive IOCs into energy companies are clear trends for the future of the industry. Natural gas emerges as a bridge to alternates with certain IOCs quietly stacking up an impressive array of gas technologies and know-how. Here, BP has distinguished itself in LNG and solar know-how, while Shell has done the same in Gas-to-Liquids (GTL) and hydrogen (see *Chapter 13: Renewable Energy*).



Figure 5 - Rabigh Refinery (Courtesy of Saudi Aramco)

Houston, We Have a Capital

As the industry consolidated, Houston emerged as its capital city and its downtown skyline became synonymous with the global oil business. Today, Houston represents the oil consumption capital of the world. The oil production capital lies elsewhere. Characterised by a modest skyline and towering reserves, Dhahran takes that title. Moscow becomes the natural gas production capital and Doha that of Liquefied Natural Gas (LNG). Almaty, Baku, Bushehr, Lagos, Macae, Maracaibo are other emerging oil cities as the industry realigns. The combination of oil technology as a commodity, ascendant oil prices and the realignment of cities has strengthened the Oil Curtain. Ironically, as oil production technology becomes freely available on the market, access to oil reserves becomes more restricted.

Consolidation

Whenever the price of crude oil falls below a certain cut-off point, operators cut budgets and work orders, and oil service and supply companies enter into a period where revenues drop sharply. For many oil-related companies, this means a fall in their share yields

and ultimately a drop in stock prices. This increases the likelihood of takeover in two ways. First, asset rich companies with poor liquidity or cash flow difficulties find themselves financially exposed and become prime targets for takeovers and asset stripping. Second, product or concept rich companies who have often borne high R & D costs are swallowed up by larger organisations seeking to add value to their operations and increase market shares³⁵.

In this way, during the 90's low oil price environment (US \$10/bbl)³⁶, many upstream companies looked to the stock markets to increase oil and gas revenues effectively, by acquiring listed companies whose share price belied their reserve values. For this reason, cost reduction was an imperative³⁷ and 'performance optimisation' and 'well-cost reduction' became strategic. Nowhere was this strategy more relevant than in high-cost environments such as the North Western Euro-pean Continental Shelf. Ever since the late 1980s, this area has been characterised by the need to cut costs and to advance technology. In the 1990s, the scale of cost-cutting was widespread and was exemplified by the shedding of labour, outsourcing, contractual

“Technological advancement and innovation is typical of high-cost industries where saving time and money is vital to the commercial success of companies and the industry itself.”

terminations and ‘mergeritis’. The industry even institutionalised cost reduction through the creation of initiatives such as Cost Reduction in the New Era (CRINE) in the UK sector and NORSOK in the Norwegian sector³⁸.

Mergeritis

This gave rise to ‘mergeritis’ which re-formed* the world’s largest oil companies – Exxon and Mobil, Chevron and Texaco, BP, Amoco and Arco. Management consultants were set the task of merging these great entities by generating synergies and economies of scale. Analysts evaluated the mergers in terms of restructuring and cost-cutting to justify the acquisition costs and remain competitive against the low oil price³⁹.

In the corporate cost-cutting that ensued, locations and operations were rationalised. This led to Houston’s growth and importance within the oilfield. Many IOCs consolidated their international operations in Houston and it was the prevalent wisdom that R & D technology activities could be cast-off as unnecessary fixed costs that could be more profitably outsourced. At that time, the oil company rationalisation made sense financially and operationally.

Outsourcing Technology

Technological advancement and innovation is typical of high-cost industries where saving time and money is vital to the commercial success of companies and the industry itself. These factors have played a crucial part in the advancements made in well trajectories—such as seismic, multilateral, Extended Reach Drilling (ERD), horizontal and designer wells—and the enabling technologies to optimise production, and in so doing, increase profitability.

As operators became leaner, well profiles followed suit and the requirements for competitive tenders, data simulation and risk analysis increased. The bottom line was that service companies were being asked to contribute more value than ever before, in order to reduce well cost and optimise performance. In this way, the IOCs outsourced more and more, not just technology niches, but certain technical disciplines such as drilling or production engineering as well⁴⁰.

Service Sector Grows

Service companies grew in the interim. Simultaneously, they kept a watchful eye on US and international projects being planned out of Houston and carefully

noted cast-off R & D projects with a view to commercialisation. In this way, Houston evolved as the E & P capital of the oil industry and its downtown skyline characterised worldwide operations.

Ironically, it has been the convergence of technology outsourcing and ascendant oil prices that have strengthened the Oil Curtain. This is the self-fulfilling prophecy; as production technology becomes easier to get on the open market, oil access becomes more restricted.

Corporate Social Responsibility (CSR)

There was always a constant suspicion amongst producing countries that the IOCs were extensions of foreign governments, acting out colonial policy as required. This suspicion may have contributed to oil companies engaging in social programmes. It is unclear which IOC started wider social engagement such as education, hospitals and the development of local skills. What is quite clear is that such engagement gave rise to a wide ranging set of IOC initiatives such as sustainable development or CSR which were designed to ameliorate a series of sore issues that were rooted in inequalities between the producers and the IOCs. These ranged from the setting of volumes of oil exports, the repatriation of profits, the heavy dependence on imported goods and services to the princely lifestyle of foreigners posted to poor countries.

Sustainable development has grown to encompass the building of local capacity that may export technology and know-how, and the savings and investments of oil profits into non-oil related industries. Essentially, it means enfranchising locals in most aspects of the oil company's business either locally owned or managed⁴¹.

It can be argued that the geopolitical tension that lies at the heart of certain disputes results from the uneven distribution of oil-wealth. If that were not enough, the fact that oil is a finite wealth generator makes things worse. This ultimately highlights the undoing of any CSR initiative or investment. As long as disparities in the distribution of oil-wealth exist, CSR programmes are constantly in peril of being perceived at best as arbitrary acts of philanthropy or at worst empty exercises in public relations⁴².

The politics of revenue distribution can be a potential minefield for oil companies. They must satisfy the powers that be – state governments – and reconcile the valid needs of local groups, whether these are communities that have right-of-way over pipelines or

those that live in the state that produces oil or gas. If there are competing ethnic groups or self-perpetuating elites co-existing with poverty stricken masses, the oil company is sitting on a time-bomb. Paradoxically, sometimes it is the case that even if oil companies keep locals happy and build local industries, the government may still nationalise.

NOC/IOC – Corporate Transparency

Transparency or the lack of it was also a major influencer in the changing behaviour of IOCs. The IOCs saw that they were being targeted by savvy lobbyists and environmental activists that could impact their image (and share price) in their home countries. This coupled with anti-corporate demonstrations even led some IOCs (BP) to publish sensitive figures regarding tax payments abroad made to foreign governments in regard of operating agreements. Further, some oil companies aligned themselves to protecting human rights by joining the UN World Compact (Petrobras). Legislation that prevents corruption and emphasises due diligence has tightened up and defined the limits of ethical behaviour for companies acting abroad, and this influence has permeated the industry as a whole which has high levels of corporate governance⁴³.

We have seen that the real challenge facing the IOCs is that they face increasingly difficult operating conditions in E & P activities, not just regarding the physical landscape but rather a much more wide-ranging panorama of challenges. These include decommissioning, booking new reserves in a narrowing opportunity base, a socio economic and occasionally politically hostile landscape, a lack of E & P technology as a differentiator and environmental lobbyists. Perhaps, most of all, nationalisation has made operations more difficult. Here we trace the transformation of the NOC from quiet man to international giant⁴⁴.

NOC/IOC Distinctions

The distinction between NOCs and IOCs hinges on whether the NOC majority shareholder is the state, and therefore must ultimately answer to the state as opposed to a privately held IOC which answers to majority private shareholders only. This distinction explains why NOCs have a responsibility to meet the needs of the nation and the population that owns them, while maximising profit.

Nowadays, the industry recognises that profits must be balanced with social responsibility and private shareholders generally accept this. Most major IOCs have CSR programmes and this type of spending is not

“Considered by many to be the world’s largest oil company and the world’s largest NOC, Saudi Aramco controls one-quarter of all world hydrocarbon reserves and plays a vital role in fuelling Saudi Arabia’s socio-economic growth.”

generally questioned by investors, as long as returns are healthy. Part-privatised NOCs fall into this category also. In the case studies below, we look at NOC concepts of sustainability and social responsibility from two major oil exporters – Saudi Aramco. Two further case studies look at the part-privatised StatoilHydro and Petrobras as they compete internationally in the US Gulf of Mexico (GOM) and apply the technical respective differentiators of deepwater E & P technology⁴⁵.

Saudi Aramco

Considered by many to be the world’s largest oil company and the world’s largest NOC, Saudi Aramco controls one-quarter of all world hydrocarbon reserves and plays a vital role in fuelling Saudi Arabia’s socio-economic growth. In this context, Saudi Aramco routinely evaluates its development decisions on a combination of corporate and national contributions; for example, a petrochemical project with a Japanese chemical company contributes at both these levels by seeking to transform the Rabigh Refinery in Saudi Arabia into an integrated refining and petrochemical complex.

The evaluation showed that although Rabigh would be profitable, it was not the most profitable investment opportunity that Saudi Aramco was considering. What

Rabigh provided, however, was ‘the most combined value to the company and the nation’. The national component means that Saudi Arabian society will benefit from the foreign investment, the new jobs created and additional revenues⁴⁶. The corporate component means that Saudi Aramco will extend its petroleum value chain, upgrade oil processing and make its portfolio more profitable⁴⁷.

StatoilHydro

StatoilHydro is the Norwegian oil company and views its introduction to the stock exchange in Norway and in the US as a favourable move. According to StatoilHydro, it has the same requirements and terms for operation as any IOC while having the Norwegian government as its main owner gives it unique advantages, as it is not up for sale⁴⁸.

When many IOCs were cutting their R & D functions to reduce costs, StatoilHydro invested more in its R & D facilities and pioneered aspects of subsea and deepwater production. This has helped the company develop certain technology inventions. Part of this is due to the close relations all operators on the Norwegian Continental Shelf have with government authorities, who challenge operators to overcome new obstacles. The company’s goals are for the US GOM to become a core area for StatoilHydro by 2012 with

production of 100,000 bbl/d. It cites a favourable fiscal regime, stable government and yet – to find resources as key elements to meeting growth targets in the US GOM.

StatoilHydro's development strategy for the US involves a combination of farm-ins and acquisitions. This started with the Chevron farm-in within the Perdido Fold Belt, which resulted in the Tiger discovery. This was followed by the acquisition of Encana assets. At the same time, StatoilHydro farmed-in about 70 leases in the Walker Ridge area with ExxonMobil. This strategy continues with participation in the lease sales in the deepwater GOM area.

It also has a growing business feeding LNG from the Snøhvit field in Norway and from its Algerian assets to the Cove Point LNG terminal in Maryland.

The company has imported a lot of Norwegian offshore technologies that may be applicable for use in deepwater GOM; however, further tests are needed to prove that usage in Norwegian offshore water depths of 300-500 m are suitable for much deeper US GOM waters of 2000-2500 m. Increased recovery may be possible by using a subsea processing, subsea boosting and injection system and FPSOs with risers that have the ability to disconnect. This may be a good solution to secure equipment during extreme weather conditions like hurricanes. Ultimately, StatoilHydro has a wide variety of technologies at its disposal and those are likely to provide its international operations with a competitive edge.

China National Petroleum Corporation (CNPC)

CNPC, China's flagship oil company, plays an important role in China's oil and gas production and supply. Its oil and gas production accounts respectively for 57.7% and 78.3% of China's total output. CNPC is also a global player with E & P projects in Azerbaijan, Canada, Indonesia, Myanmar, Oman, Peru, Sudan, Thailand, Turkmenistan and Venezuela.

CNPC has bet heavily on R & D to increase E & P production and reduce risk in complex basins. It has developed solutions to improve recovery factors as well as reduce development costs. It has a strong sense of innovation and has technologies in reservoir characterisation, polymer and chemical-flooding. Other technologies include high-definition seismic, under-balanced drilling, ultra-deep well drilling rigs and high-tensile steel pipes.

Metamorphosis of IOCs

In the old days, IOCs conferred access and monetised oil reserves. IOCs alone had the technology, capital and know-how to tap the wealth of an unknown hidden natural resource. Naturally, they bargained hard and got the lion's share. Those 'old ways' show that oil reserve holders used to recognise IOC as equals, perhaps, even as holding the upper hand as the IOC was required for revenues to be realised⁴⁹.

Even before the Oil Curtain, some IOCs noted that the pool of accessible oil reserves would one day shrink. Progressive IOCs repositioned themselves for the future; some seeing 'beyond petroleum' and others shut out by the 'Oil Curtain'. This, however, does not imply the fall of IOCs. Some are perfectly adapted to evolve and there is still a healthy global E & P environment for them to adapt to.

The drawback is that this environment of extreme E & P has high replacement costs as margins are squeezed by technical challenges. Extreme E & P opportunities exist in ultra-deepwaters, Arctic, unconventional and in a dazzling array of gas-related technologies. These include: LNG which mobilises and commercialises stranded reserves; biogas which is renewable through biologically produced methane; Compressed Natural Gas (CNG) and LPG, that provide fuel for the transport and power-generation sectors; and, GTL which offers high quality gasoline fuel.

Of the original seven sisters, most have already adapted to an extreme E & P environment. Going further, BP has distinguished itself in LNG and solar power, while Shell has distinguished itself in Gas to Liquids (GTLs) and hydrogen.

Undoubtedly, IOCs face increasingly challenging operations – extreme E & P. Additionally, there are a wide-ranging set of challenges such as decommissioning, booking new reserves in a narrowing opportunity base, a lack of E & P technology as a differentiator and environmental lobbyists. Perhaps, most of all, nationalisation and resource sovereignty, has made business more difficult.

Despite this, IOCs retain refineries, retailing networks, brands, and direct access to international consumers. Certain IOCs, for example BP and Shell, have continued to be early adopters of new technology. That is praiseworthy, because by supporting innovative new ideas and signposting applications⁵⁰, these IOCs have significantly contributed to many E & P innovations,

“According to StatoilHydro, it has the same requirements and terms for operation as any IOC while having the Norwegian government as its main owner gives it unique advantages, as it is not up for sale”

i.e. rotary steerables and expandables across the industry. Those IOCs took risks to prove tools downhole and the benefits have been reaped by all types of oil companies.

Black Blessing

We have seen within a century how oil and gas have become the world's preferred energy source. Consequently, certain countries with the oil and gas wealth or the black blessing have benefitted. So which countries have made oil wealth a true blessing⁵¹?

Dubai and Stavanger are synonymous with oil wealth, but these cities also subtly show that the black blessing has been managed responsibly with a vision for the future. For these and other thriving cities, there are countless other stories of squandered oil-wealth and cities that have ended up as ghost towns. Yet, no single country's approach to the management of oil and gas has been perfect; it has been learned.

What works in one country is not necessarily the solution in another, but parallels and lessons exist. We shall see how the forces and needs acting on the North Sea were very different to those of the Arabian

Peninsula. Each country's profile is unique but what emerges is a common lesson: oil revenues 'rollercoaster' and are subject to depletion.

Dutch Disease

Due to the highly specialised requirements of the petroleum industry, personnel and equipment are often imported. If you have a pressing deadline, it is easy to think 'don't reinvent the wheel, import'. This, however, is dangerous. Firstly, capital flows become wholly dependent on cyclical oil and gas revenues. Secondly, the creation of local jobs and local infrastructure is limited as workers and equipment are 'outsourced'. The few jobs that are created are fringe industries and are very much dependent on the migrant workers and can easily vanish. Thirdly, excessive imports and the petroleum industry itself can inflate costs so that locals are excluded from housing, social and other activities. This is a double-edged sword as the higher-paying-oil related activities push out other less lucrative activities. Without diversification, these negative factors expose a country's dependence on oil wealth. When oil prices fall, the consequences can be disastrous, i.e. Norway and UK in the 1986 crash.

Before Oil

When considering the North Sea – Stavanger, Norway, Aberdeen, UK and the Arabian Peninsula – Dhahran, Saudi Arabia and Dubai or Abu Dhabi UAE it is revealing to see how these countries existed before oil. All of these countries had very different socio-economic profiles; healthcare, disposable income, education levels, transport links and indeed internal infrastructures were severely limited.

Yet, in each the black blessing has improved lives within the space of a single generation and has led to the creation of new industries (see Figures 5 and 6).

Pilgrims

In the Saudi Arabian peninsula, oil was discovered in the 1930s. At that time, exploration contracts for oil were scorned; in scorching desert temperatures, exploration was for a more valued resource, water.

Saudi Arabia had already been guaranteed an annual source of revenue due to the Hajj – the pilgrimage Muslims make to the city of Mecca; however, the country's infrastructure was underdeveloped which led to a weaker bargaining position. When the first contracts were signed, the Saudis received less than the equivalent of 5% royalties. With the discovery of oil and its growing geo-political importance, the Saudis' bargaining power increased.

Royalties grew to 50%. Other stipulations such as the improvement of transportation and telecommunication links followed. By the 1970s, the Saudis had started to buy-back the privatised oil company leading to the full ownership of Aramco and the country's reserves of 264 billion barrels of oil.

In reality, national oil policy has come full circle. It has evolved from seeking maximum royalties to stipulating local capacity to full re-nationalisation and now to partial privatisation for gas developments. To illustrate Saudi Aramco's local content, as of 2007 it had a total of 52,093 employees of which 45,464 were Saudis and 6,629 were expats. It has also signed gas exploration contracts with foreign oil companies such as Shell.

Gold and Pearls

In the UAE, a union of seven Emirates, the situation was different. Dubai had long been a regional trading hub and had far fewer reserves than Abu Dhabi which meant it quickly realised its economic future lay beyond its scarce oil reserves. Dubai's souks were known worldwide for all manner of commodities,

especially gold and Arabian pearls. Dubai continued to profit from trading until the cultivation of artificial pearls and world recession caught up in the 1930s.

The quality, size and quantity of artificial pearls could be controlled in such a way that demand for them grew quickly. Commerce dropped in Dubai and it was no wonder that, when news reached the ruling family in the UAE and Dubai that oil exploration licences were being sold in Saudi, negotiations quickly followed.

With the fullness of time, this led to the discovery of reserves of approximately 98 billion barrels of oil in the UAE. Presently, Dubai has developed a policy of cluster economies which have resulted in flourishing financial services, tourism and IT sectors.

A Tale of Two Cities

Before oil, Aberdeen and Stavanger were economically stable albeit sleepy fishing and maritime towns. During the early 1960s when gas was first discovered (oil came afterwards) in the Grönigen field in the Dutch Sector of the North Sea, Norway had high employment, a current account surplus and low inflation. From a socio-economic perspective, there was no pressing need to explore for and develop oil and gas.

With the 1973 oil crisis and accompanying embargo, geologists started scrambling for North Sea seismic. This instability in global geopolitics set the scene for the upper hand in negotiations with the IOCs. When the Norwegians and Scots asked for rewards beyond taxes and royalties, the oilmen obliged.

Differences Between the North Sea and Arabian Peninsula

The need to develop local knowledge was linked to the nightmarish operating conditions in Norway. In contrast, the Arabian Peninsula is an oilman's dream – punch a hole near a dome and chances are that oil will be struck. From the very start, these very different environments formed very different mindsets. This led to a historic laissez-faire approach to technology development in the Arabian Peninsula.

In contrast, Norwegian and British fields were located in the harsh North Sea, a dangerous environment where locating reservoirs was a costly, timely business. Here the application of technology made a vital difference. With good seismic, directional and real-time data, well construction costs could be halved. This was a compelling reason for the development of North Sea technology. In parallel, the gradual introduction



Figure 6 - Abu Dhabi View from Emirates Palace



Figure 7 - Oil and Gas Wealth Is Not Necessarily A Trade-Off Against The Environment. There Are Wider Considerations (EPRasheed)

of terms such as the famous ‘50% local content’ stipulation in exploration contracts helped develop local content.

Game-Changing or Incremental Benefits?

Technology of every type was necessary in offshore Norway and UK. The need for reducing risks and cutting costs was acute and technology could change the nature of the game, magically making uneconomic reserves profitable. In the Arabian Peninsula, the benefits of offshore technology did not apply. While other onshore technologies could be applied their technical and financial gains were insufficient. An incremental gain in production or cost-reduction was not compelling enough for such technology to be used in the Arabian Peninsula.

North Sea offshore operations, for example, routinely cost in excess of US \$200,000 per day including rig rental and crew costs. By contrast, onshore operations in the Arabian Peninsula do not often exceed US \$100,000. Additionally, the profile of Arabian reservoirs, i.e. their production rates and overall production size, are order of magnitude greater than North Sea finds which leads to lower overall finding, development and lifting costs in the Arabian peninsula.

By the 1980s, greater emphasis was placed on local content and local capacity building within the Arabian peninsula. This trend had its roots in the North Sea.

Build Locally

It is worth highlighting that prior to the early 60s, there was no oil and gas industry whatsoever in the North Sea. Yet, today the industry is a prime mover in the Scottish and UK economy.

How did this transformation occur within a generation?

Building local capabilities was always a ‘must-have’ for the North Sea. Eventually, this led to the creation of the service sector hub which exports oil and gas technology globally. At first, technologies were invented, tested and proven in the North Sea before being exported worldwide.

We have seen that until the mid 1960s, neither Norway nor the UK had an oil industry, but within years the chorus to create one was loud enough to be heard. In the early 70s, this led to the preferential use of local goods and services at times reaching 90% as required by law. In the early 70s, the Norwegians

“Undoubtedly, this shows that the black blessing has improved lives within the space of a single generation and has led to the creation of new industries.”

created Statoil, the operational oil company and as policy maker the Norwegian Petroleum Directorate (NPD). Accompanying this was a preferred policy for Norwegian goods and services coupled with a clause of transfer of know-how and research cooperation.

The UK and Norway's success in achieving high local content is largely due to these policies which have encouraged partnerships between foreign and domestic companies and made research programmes mandatory. Research has helped create smaller companies which have exported technology worldwide and grown. The University of Aberdeen Oil Centre lists 175 small companies working in the oil and gas sector. These range from small independents to technology companies.

In terms of production, Norway and the UK are very different. Norwegian oil and gas production has increased over the past decade to 3.1 MMbbl/d. The UK's oil production has fallen by 30% over the same period to current levels of 2 MMbbl/d. Yet, through demand for UK oilfield goods and services, the oil sector continues to generate substantial economic activity.

Smaller independents have entered the UK sector but the oil and gas industry has developed far more due to the formation of mechanical and petroleum engineering, academic and vocational training and associated consultancy services.

Seeds of Knowledge

Licensing terms for oil contracts stipulated the transfer of skills and competence to Norwegian companies. Personnel from Norsk Hydro, Saga and Statoil (these companies have merged into StatoilHydro) received training in the IOC training programmes and overseas postings.

The situation was slightly different for the UK as BP had already had international oil and gas exposure. In fact, this helped it discover and develop Forties (the largest North Sea UK field).

These seeds grew into the commercial success of numerous oil technology companies that export goods and services worldwide.

Technology Greenhouses

Today, there is a strong culture of oil and gas R & D; several well test sites and research companies exist. Illustrating this is the Bridge of Don Test site in Aberdeen, Rogaland Research and its test well in Stavanger and SINTEF (a company specializing in R & D).

As major oil companies shed R & D internally to cut costs, more R & D has been taken up by the service companies. This is not to say that major oil companies do not use or test new technologies; they do so in low-risk developments such as mature onshore operations. For the most part, however, the development and



Figure 8 - Drilling Rig in the Middle East (EPRasheed)

ownership of proprietary oilfield technology no longer lies with oil companies. There are some exceptions; the development of rotary-steerable systems to access complex well trajectories and expandable-casing for well construction was initiated by oil companies. NOCs are somewhat different as can be seen by Petrobras' R & D centre which has grown to support Petrobras' deepwater needs and has become a world leader in deepwater technologies. Norway and the UK have helped develop subsea technology and especially intelligent wells and real-time operations management. It should be noted, however, that the service side has played a crucial role in technology development in all cases.

Cluster Economies

It is recognised that the Arabian Peninsula's economies have been highly dependent on oil; it accounts for more than 75% of government revenues in the region. This made it crucial that the Peninsula diversify from oil dependence and open its markets to attract foreign capital. A good example of this is seen in Dubai which briefly had revenues in oil production but realised quickly that it could become a trading hub due to its location between Europe and the Far East and links within the Peninsula between Saudi Arabia, India and Iran.

Various initiatives were undertaken in Dubai; for convenience they can be classed as cluster economies.



Figures 9 and 10 - Old Stavanger Was Built On Fishing (EPRasheed)

Dubai began experimenting with cluster economies through the development of Dubai Internet City in 2000. This has grown to house over 5,500 knowledge workers today, while Dubai's Media City houses most of the leading global media companies. Dubai's financial markets have also grown.

The opening up of Dubai's real estate sector has also helped diversification. This is serving to support Dubai's tourism industry as it aims to increase the numbers of foreign tourists.

Dubai first sought to consolidate the economy's major components of trade, transport, tourism and real estate sectors. It then moved on to promote aspects of a 'new economy': IT and multi-media activities and e-commerce and capital intensive, high-tech manufacturing and services (see Figure 13).

Rainy Day Fund

After an economic rollercoaster that saw Norway with the highest debt ratio ever attained by any developed country, the Norwegian Parliament established the Petroleum Fund in 1990. It receives net cash flow from the oil industry as well as profits from investments. The fund is designed to protect the economy should oil prices or activity in the mainland economy decline, and to help finance the needs of an increasingly elderly population and to cope with declining oil and gas revenues. The idea is to use 4% of the fund in the annual budget, but in reality larger transfers are made.

Too Much Local Content?

Government departments provided incentives enabling operators and the private oil sector to identify technology needs and fill them. This led to a trial and error system where technologies were not always applicable; however, it is not so important to focus on any single research program that did not work because with time a local knowledge base and competence was created.

The preferential policy may have gone too far in some cases, leading to an introverted mindset. For example, in Norway in 1990 at least 80% new prospect content was domestic. The advantages were jobs and profits in Norway, but there was far too much dependence on the petroleum industry for Norwegian manufacturing while exports to markets in other oil producing countries were limited.

Undoubtedly, this shows that the black blessing has improved lives within the space of a single generation and has led to the creation of new industries. There are many ways to make the blessing last. We have seen how global power has shifted from IOCs to NOCs and how many NOCs want to compete in international markets.

We have also seen the metamorphosis of certain IOCs into Energy companies. What drives this shift is a growing awareness that, above all else, holders of the reserves determine the rules. The next question then



Figure 11 - Modern day Stavanger, home of Norwegian Oilfield Technology and the Norwegian FPSO (EPRasheed)



Figure 12 - Semi-Sub Platform (EPRasheed)

becomes clear – who actually holds the petroleum reserves? Are they globally dispersed or centralised in a few major locations?

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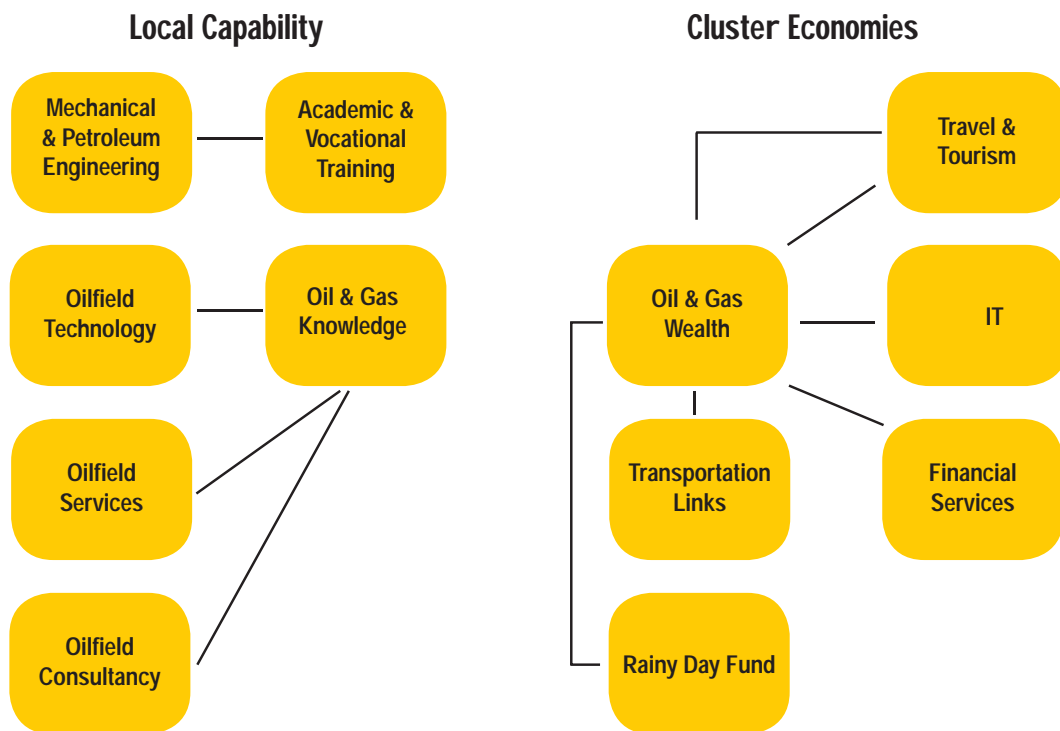


Figure 13 - Relationship of Oil and Gas in Economic Sustainability (EPRasheed)

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