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2007 - Issue 2

Saudi Arabia oil & gas

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Saudi Arabia Oil and Gas

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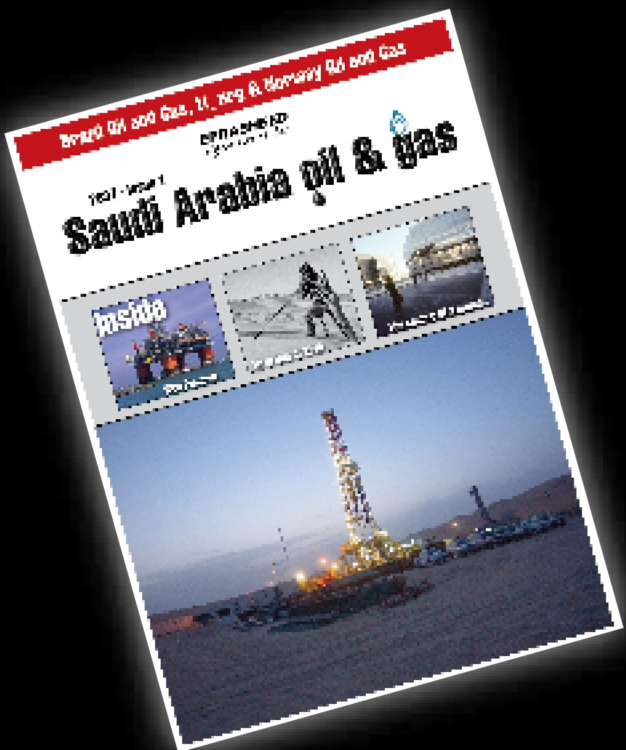

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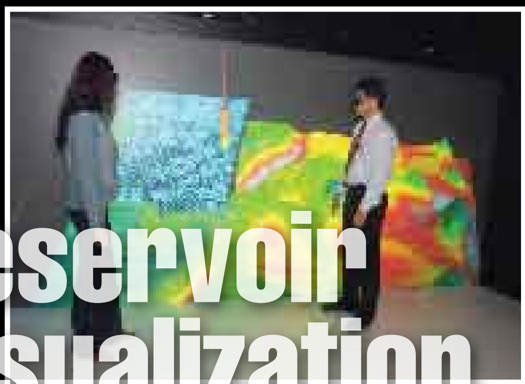

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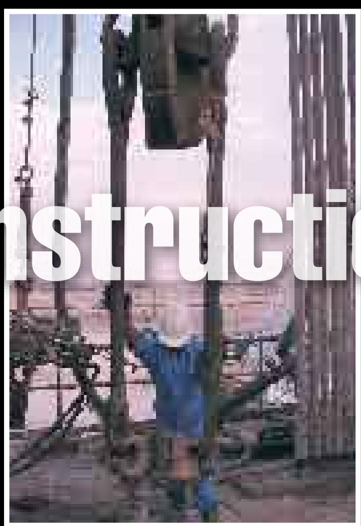

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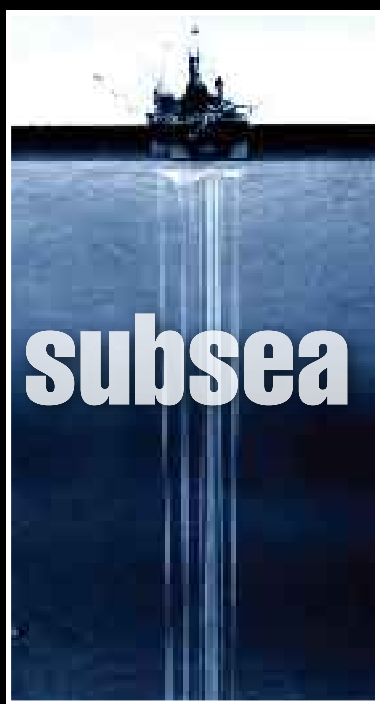

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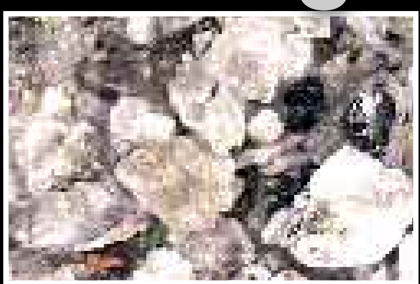


Focus on Oil Company R&D Centres

Saudi Aramco

Saudi Aramco's Research and Development Center (R&DC) recently held the first Downstream Workshop with Brazilian oil company Petrobras. The aims of the workshop were to strengthen the relationship between the two companies, learn about one another's R&D downstream activities, discuss best practices in R&D project management and develop collaborative projects.

Omar S. Abdulhamid

"With the memorandum of understanding signed by both companies, Petrobras and Saudi Aramco continue to work together closely," said Omar S. Abdulhamid, R&DC manager. "This workshop will help Petrobras and Saudi Aramco work together to tackle common technological challenges. We especially recognize the potential to gain from the strengths of each other and capitalize on the complementary skills and competencies both organizations have in research and development."

Under the umbrella of the National Oil Company (NOC) Forum, both organizations are promoting collaboration and addressing challenges facing all NOCs. Saudi Aramco is committed to making the forum a success and acknowledges the leadership role

Representatives of Saudi Aramco's Research and Development Cente strengthen their relationship.

"I'm very impressed by the arrangement of this workshop and happy with its outcome," said Alipio Pinto Jr., Petrobras R&D Center downstream general manager.

"I'm looking forward to seeing both companies working on at least one collaborative project," he said.

Petrobras demonstrated while heading the NOC Forum's Technology Working Group. Both organizations bring considerable know-how to the technology arena.

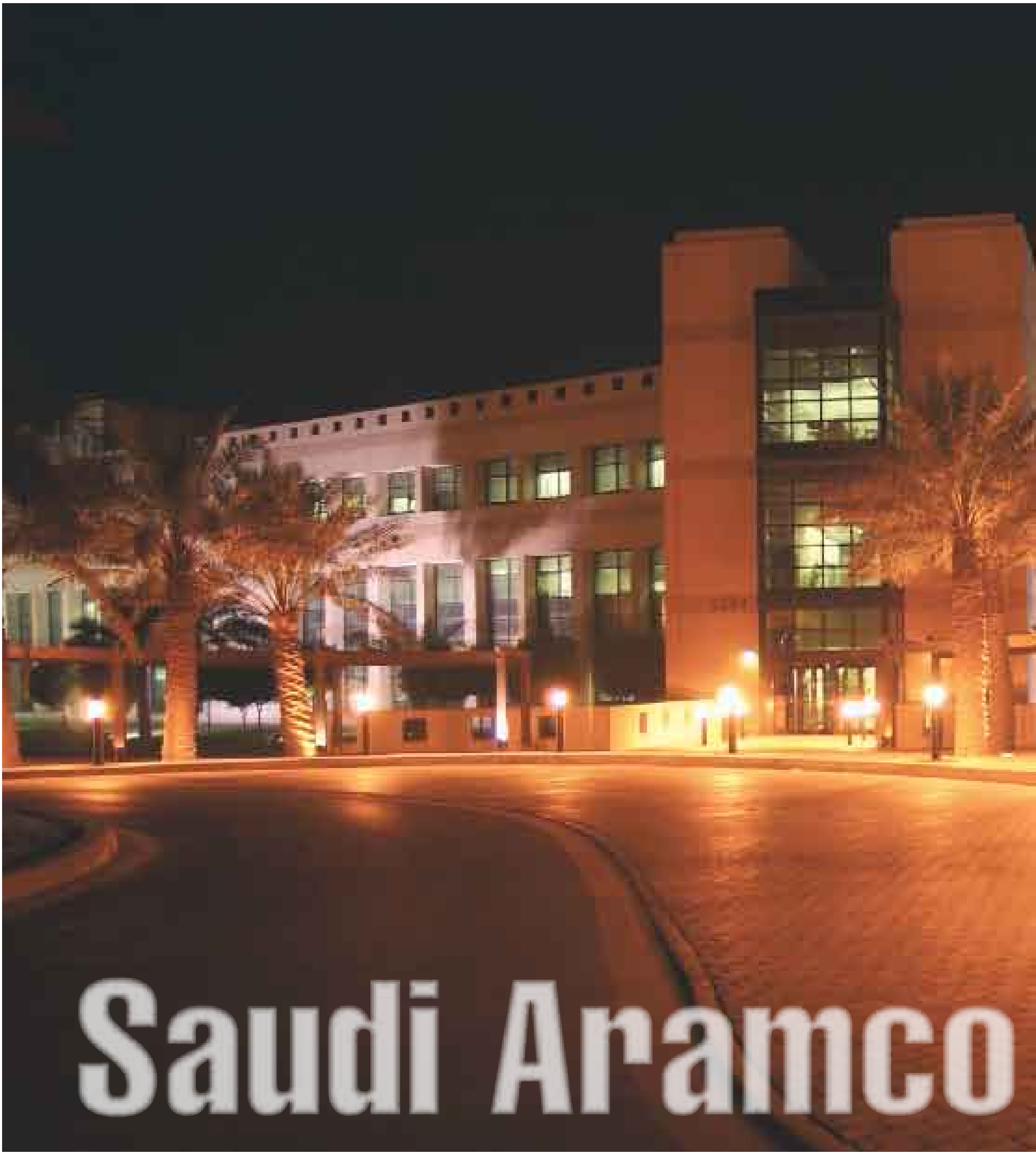
The workshop featured presentations and detailed discussions on crude and heavy oil desulfurization, oil-to-chemicals, hydrogen production and clean fuels.

r and the Brazilian company Petrobras came together to explore ways to

It also included discussions on human-resources management, along with visits to Saudi Aramco facilities.

Potential areas of collaboration include catalyst and process development related to hydrogen production from liquid fuels, nitrogen removal from heavy oil and olefin production. These areas will be further evaluated by both organizations with the intention to launch one collaborative project.

Alipio Pinto Jr.



"Research and development work is not new to u
is that it provides a better work environment for t
innovation and creativity" President and CEO Abdall

A yellow glow illuminates the south end, built in Phase I, of Saudi Aramco's recently expanded Research and Development Center in Dhahran.

s at Saudi Aramco, What's new about this project the scientists of our company to help unleash their ah S. Jum'ah said.

By Lori Olson White and Rick Snedeker

Abdallah S. Jumah said: “The nature and size of our oil fields and the huge magnitude of our operations as the largest integrated petroleum company in the world, and the operational challenges that we face during the execution of our activities, pose unique challenges and require solutions that cannot be brought in from somewhere else in the world.”

Muhsen F. Al-Ajmi, the Research and Development Center Department representative for the project, said, “Now we have a world-class facility which can accommodate the growing technical needs of our scientists in support of the strategic objectives and goals of the company. All those needs will be met in this facility for many years to come.”

Seamlessly blending with the existing structure along a graceful curving wall of glass, the expansion includes extensive laboratory and high-bay facilities, an administration building, a high-pressure materials study building for autoclave operations, a chemical quality assurance/quality control (QA/QC) building and an expansion of the existing Chiller Plant. In addition, the Phase II project includes parking and landscaping.

The expanded center’s 34,500 square meters of space contain pilot plants, workshops, offices, meeting rooms and 210 laboratory modules, which can be combined or separated. This configuration accommodates 330 employees, 75 percent of whom are Saudis. Saudi Aramco’s Engineering and Operations Services business line oversees the center.

The expansion project included new construction on seven buildings.

Buildings #2 and #3 each feature general laboratories with high bay areas accommodating the Research and Technology Division, Downstream Research and Development Division, Analytical Support Division, Material Science Research and Development Division and Services Support Division.

The three labs (including the one completed in Phase I), which feature special air handling units custom designed to meet scientist-defined requirements, house the heart and soul of Saudi Aramco’s quest for laboratory based innovation and invention. It is here that company scientists and technicians research solutions to the challenges unique to Saudi Arabia´s vast oil and gas fields as well as broad industry challenges.

A majority of the R&DC’s employees go to work in these laboratory facilities.

It is here that company scientists and technicians research solutions to the challenges unique to Saudi Arabia´s vast oil and gas fields as well as broad industry challenges.

Building #4 is the Administration Building and houses Research and Development Center management staff members and other key personnel within the department. Meeting space is also an important component of the building. Saudi Aramco has long recognized the need for teamwork in research, and R&DC scientists routinely collaborate with outside partners as well as home-grown experts in various disciplines within Saudi Aramco. It is here that many of those meetings take place.

Building #5, the High Pressure Materials Study Building, is a showcase facility for Saudi Aramco's commitment to ensuring the reliability and peak performance of company assets in a safe work-place environment. It is here that Saudi Aramco scientists conduct corrosion-related studies using so-called "sour gases" in a dynamic system. Every aspect of these critical studies was taken into consideration in the building's design and construction, from the need for control methods and condition monitoring to materials performance issues.

"This building was constructed with the highest standards of safety precautions," noted Al-Ajmi.

In addition to blast-proof chambers and facility-wide sensors that alert staff members should potentially hazardous conditions exist, the building's 24 autoclave chambers also allow scientists and technicians to make changes to the exacting testing conditions inside the autoclaves remotely.

Building #6 is the Chemical Quality Assurance Lab Building (CQAC). This was the first building completed in Phase II construction and works hand-in-hand with the gas testing lab built in Phase I, housing equipment and personnel to perform quality assurance studies for all oil field chemicals.

Samples of all chemicals are analyzed at the CQAC prior to being sent out to the fields to ensure that they meet Saudi Aramco's strict and exact specifications.

The Chiller Plant, the main construction of which was part of Phase I, was expanded as part of Phase II construction, and features a custom-design cooling tower which aids water circulation and heat absorption.

Saudi Aramco Senior Scientist Allan Fox has been involved with the R&DC project since 1997, working with other company scientists as well as engineers and contractors to create the company's newest scientific facility.

"This project used some new technology, including electronic review of the construction plans for some parts of the process, noted Fox. "Everything was very high-tech."

One area where high-tech was definitely put to the test was in air quality.

"Having a facility of this size, which requires air that is 100 percent replaced, was a unique challenge," noted Fox. "We are dealing with a huge volume of air that cannot be recirculated due to possible chemical contamination."

"Because of this, we are constantly pulling new air in, cooling it and then sending it out," he added.

Due to this need for replaced air, the R&DC has a cooling system with a capacity three-times that of other systems in Dhahran.

Another high-tech solution incorporated into the R&DC was a sophisticated early warning system. More than 15,000 data points continually monitor variables including temperature, airflow, air rate and quality. Along with these sensors, heat and smoke detectors are also fed into a main computer within the facility to be monitored and acted upon.

Not only does the system ensure safety and improved reliability, but it also cuts down on unscheduled downtime, thus increasing facility-wide efficiency.

Construction of a new Technical Exchange Center was added to the expansion project's scope during 2004, and completion is scheduled in the first quarter of 2005.

With the Phase II expansion, the center is now even better equipped to meet its mandate: to help maintain Saudi Aramco's leading position in the hydrocarbons industry by using innovative applied research to develop cutting-edge technology and processes. Nearly a third of the company's United States-issued patents have been awarded to R&D Center scientists.

Saudi Aramco's sharp emphasis on research and development reflect the company's continuing and far-reaching commitment to meeting future global demands for energy, creating technology-based business ventures and identifying new revenue streams that promote the development of the local economy.

R&DC scientists, across myriad disciplines and often in collaboration with outside partners, are working hard to capture growth opportunities for hydrocarbons, protect future markets for crude oil and generate new businesses. The center is undertaking joint projects with in-Kingdom and regional research centers, is participating in joint industrial projects and is teaming up with international universities and research institutes.

Company scientists are busy seeking answers to a host of questions crucial to the industry: How can petroleum

Lab technician specialist Abdulrahman Al-Nowaishi (at computer) and lab technician Marwan Al-Dossary perform a Nuclear Magnetic Resonance (NMR) analysis.

Company scientists are busy seeking answers to a host of questions crucial to the industry: How can petroleum fuels burn cleaner and more efficiently? How can heavy crude oils yield lighter products? What are the best ways to combat corrosion? How can more oil and gas be produced from reservoirs?

fuels burn cleaner and more efficiently? How can heavy crude oils yield lighter products? What are the best ways to combat corrosion? How can more oil and gas be produced from reservoirs?

In support of the company's exploration and producing operations, the center's scientists develop laboratorybased solutions, adapt transfer technologies and provide advanced technical services in petrophysics, hydrocarbon phase behavior, drilling fluids, oil-field cement, geochemistry, simulation and other areas. Researchers study the behavior of hydrocarbon reservoirs, perform geochemical rock assessments and look for ways to improve well productivity.

Ensuring reliability and peak performance of company assets is a critical goal, and the center's corrosion program is a cornerstone of this focus, through its investigation of control methods, condition monitoring and materials performance. Research activities also pursue development of coatings, drilling-fluid polymers, and non-metallic and composite materials for use in operations areas.

The center also conducts vital environmental research, and its scientists are recognized as leading regional authorities on ground-water contamination and remediation, and seawater, marine life and soils management. Long-range eco-studies include waste-land reclamation and research into the Kingdom's water and ground resources. Also under study are the biogradation of hydrocarbon wastes and the development of micro-organism technology in oil-field and related industrial operations.

Now, and in the years to come, the center will continue its pioneering research and seek out new technologies to leverage oil and gas resources to enhance company profitability and expand the Kingdom's economy. Benefits will accrue to the Saudi people while helping to ensure the secure and responsible stewardship of the Kingdom's hydrocarbon resources for the world's burgeoning needs.

The center also pursues advances aligned with four longterm targets: sustaining oil's use in transportation, expanding oil's use as a feedstock in the chemicals industry, positioning oil to take advantage of power generation applications and exploring new markets for oil. To these ends, research topics include enhanced oil recovery and reservoir appraisal, next-generation clean-fuel formulations, and identification of new oil uses.

A decade ago, Saudi Aramco became one of the first oil companies to use scanning computerized tomography (SCT), a medical imaging technique, to evaluate oil-producing rocks. Today, the center analyzes thousands of feet of core samples for improved reservoir characterization and fluid flow visualization.

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Other state-of-the-art analytical capabilities at the center are: powder x-ray diffraction to examine the physiochemical makeup of unknown solids, EDXRF spectrometry for scaling / mass spectrometry to study molecules, environmental scanning electron microscopy for very-high magnification imaging, and nuclear magnetic resonance spectroscopy for studying organic compounds.

During the past few years, the center completed water treatment and corrosion cost-reduction studies that identified significant savings through the use of new technologies, such as nano-filtration membranes, oil-based composite materials and new highperformance coatings. Also under way are investigations of next-generation petroleum fuel formulations and pioneering work on fuel chemistries suitable for emerging engine propulsion systems, plus a long-term focus on economical ways to convert oil to hydrogen for transportation applications, as well as stationary heat, power and electricity generation.

Another project seeks to increase olefin yields using a novel high-severity, fluid-cracking technology - a process that has been successfully piloted at Ras Tanura Refinery in collaboration with Japanese organizations.

The company continued working in the area of biotechnology to search for uses of micro-organisms to process crude oil and to provide cost-effective environmental remediation solutions. New DNA sequencing and quicker micro-organism identification tools have allowed these organisms to be studied in much greater detail.

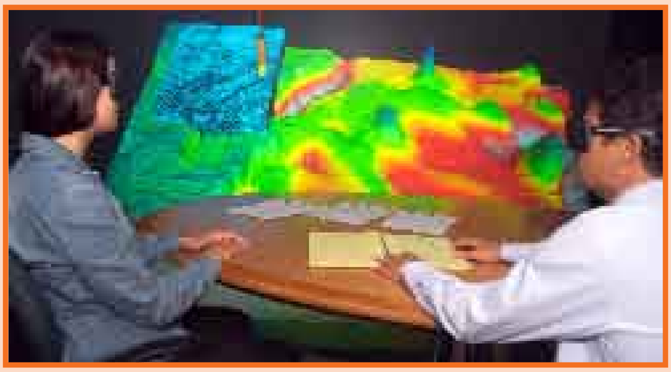
Current research projects also seek to utilize new sequestration technology to reduce industrial carbon emissions and to develop technological solutions that reduce emissions from automotive vehicles, including decarbonization of petroleum fuels and pre-combustion removal and recovery, as well as post-combustion remediation for internal combustion engines.

Specialized administrators manage the portfolio of intellectual assets and know-how that is emerging from the company's R&D work, investigating ways that in-house research and technology might be commercialized through the sale of proprietary solutions and licensing rights or the development of stand-alone technology businesses and partnerships with third parties. Technology-based business opportunities currently are being pursued in the manufacture of oleo-resinous paints and coatings, and oil-field performance additives, such as corrosion inhibitors and highperformance nonmetallic materials.

Saudi Aramco's expanded R&D capability positions the company well to consolidate its role in the international petroleum industry today and to enhance and widen its capabilities and reliability in the future in meeting global energy needs — and growing the economy of the Kingdom.

Some of Saudi Aramco's RD&C Technological Achievements

Seismic process patents: Our tradition of innovation in exploration continued in 2005 with the application for seismic process patents based on technology developed in-house. The patented technology involves the application of Anisotropic Magnetic Susceptibility (AMS) to microfracture characterization in the Unayzah reservoir. Two patents were submitted, one for the well-site application of the AMS technology to field-scale characterization of fractures, which will reduce the need for coring and imaging of reservoirs. The other patent submission deals with improving the quality of seismic pre-stack data.



In 2005, the company migrated the entire conventional seismic processing environment from a proprietary IBM supercomputer to more cost-effective Linux clusters with more than 600 terabytes (1TB equals 1 trillion bytes) of storage.

Smart well and Intelligent fields: Smart well systems and down-hole sensors are part of a larger strategy to develop Intelligent Fields, an approach that combines real-time monitoring and timely reactions to changing well and reservoir conditions to optimize production and reservoir management. A study conducted by a consultancy company, in conjunction with oil and gas companies, suggests that the Intelligent Field concept could significantly improve recovery factors, reduce capital expenditures, and reduce downtime and operations costs.

In 2005 Saudi Aramco successfully installed in the Shaybah field the first Smart Well with a hydraulic down-hole flow control system in Saudi Arabia. The well, a maximum reservoir contact (MRC) multi-lateral type with a total reservoir contact of 5.4 mi/8.7 km, was provided with a smart well system to improve management of the reservoir and extend the life of the well. Future smart well systems are planned for the Shaybah field.

The Haradh-III increment, brought onstream in early 2006, relies exclusively on multi-lateral MRC producing wells, and includes 15 wells with smart well systems.

Overall, the company completed 24 smart well installations in 2005 (versus two the year before), and 55 MRC wells, more than double the year before. These technologies are yielding significant results. In Haradh, a tri-lateral well with near-complete water cut was outfitted with a smart well system that controlled fluid entry into the motherbore, reducing the water cut to 24 percent and making the well a 6,000 bpd producer.

In addition, we successfully developed two low-cost methods for converting existing single horizontal wells to multi-lateral wells complete with smart well systems. Both conversion techniques have delivered up to a five-fold increase in well Productivity Index (PI), while reducing the cost and number of rig days compared with drilling a new well.

Log-while-drilling (LWD): Once remaining oil is identified, horizontal wells (often of the multi-lateral type) are guided to the optimal location by using advance log-while-drilling (LWD) techniques. Well placement with LWD measurements is used in all drilling applications: onshore and offshore, for shallow oil or deep gas.

Some of Saudi Aramco's RD&C

Under-balanced drilling: Equally important as the company's production wells are its water injection wells, which help maintain reservoir pressure and increase oil recovery rates. We have adapted the process of under-balanced drilling to eliminate formation damage and improve injectivity, thereby eliminating the need for post-drilling acid stimulation. This technique is, simply, drilling while the well is flowing, which allows formation fluids to flow into the wellbore, thus eliminating the formation damage mechanism. Other benefits include higher average initial injection rates, faster drilling times, and lower drilling and completion costs.

A total of 10 power water injectors were drilled under-balanced in the Hawiyah and South 'Uthmaniyah areas of the Ghawar field. The knowledge gained from drilling water injection wells under-balanced was applied to under-balanced drilling of oil producing wells at year's end.

Production equalizer technology: This technology allows a uniform production profile along the entire length of a horizontal well, increasing well production and improving reservoir sweep efficacy.

Multi-phase flow meters: In the offshore Safaniya and Zuluf fields, 39 multi-phase flow meters have been installed in wells to replace the test barges currently in use. The multi-phase flow meters are compact and can be operated remotely. In addition, unlike the barges, they are unaffected by weather conditions or water depth and allow for greater testing efficiency. In 2005, 65 of the meters were commissioned in Northern Area Oil Operations fields, with 13 more installed in 2006.

Geosteering Operations Center (GOC): To further exploit the technological gains of horizontal, multi-lateral and MRC wells, we opened our Geosteering Operations Center (GOC) in 2005. Located in the Exploration and Petroleum Engineering Center (EXPEC), teams of geologists and engineers remotely guide drilling activities in real time, around the clock, helping ensure that every well is optimally situated.

Not only has Saudi Aramco become an industry leader in completing multi-lateral wells, it is a leader in actively evaluating and implementing new technologies for better planning and monitoring these complex wells. Techniques such as resistivity and carbon-oxygen

Technological Achievements

reservoir saturation logs are used to evaluate water-flood efficiency and identify remaining oil in place.

Monitoring the performance of multi-lateral wells is a challenge, and one that has been met by extensive cooperation between us and our service companies. In one example, we are the first in the industry able to monitor water/oil/gas flow profiles in short radius horizontal wells.

3-D visualization centers: Saudi Aramco's 3-D visualization centers have undergone constant refinement since their inception, and in 2005, the centers were upgraded to the latest digital technology. New visualization techniques were developed for exploration and production, including seamless data integration between processing and interpretation, and super large 3-D seismic volume interpretation.

Operations Coordination Center (OCC): Tracking the movement of oil, gas and refined products from wellhead to tanker is enormously complex, but made easier and more efficient with the state-of-the-art data video wall in the company's Operations Coordination Center (OCC). The new video wall, a masterpiece of technology and the largest used in either the hydrocarbon or power industries, displays the company's crude oil, refined products, gas and NGL networks, terminals planning and scheduling, and electrical power distribution grid, all in real time.

The data display, 10 ft/3 m tall and more than 200 ft/61 m wide, facilitates the management of the entire system and helps optimize facility capacities and inventories to enhance revenues. The data wall allows quick detection of potential problems, and can also display live video from the field, geographical data, system drawings, satellite images, ship movements, and many other types of information.

Petrobras R&D Cent

Technological know-how is a strategic imperative for sustaining self-sufficiency in Brazilian oil production. Petrobras' Research and Development Center (Cenpes) Leopoldo Américo Miguez de Mello, pictured above is located on the Ilha do Fundão campus of the Federal University of Rio de Janeiro (UFRJ) and is responsible for anticipating and meeting the technological needs of all of Petrobras' operational areas.

Cenpes has 1,569 staff of which 350 members hold Master's degrees and 130 researchers with PhD qualifications. The center runs technological programs in Research and Development (R&D) and Basic Engineering (BE). The integration of the Center with the 2015 Strategic Plan's targets has resulted in a number of contributions to the Company's activities.

Among them are the basic projects for the P-34 and P-50 platforms, which are hallmarks of sustained self-sufficiency.

In 2005 Cenpes gave priority to three lines of production research: improving the production of heavy oil in an offshore environment; achieving technological advances in ultra-deep water areas; and the minimizing of the decline of mature onshore and offshore oil fields. In its efforts to improve production technology, one of Cenpes' objectives is to reduce costs for the Company.

Horizontal wells are one of Cenpes' technological contributions for enhancing production as they increase the flow of oil out of offshore fields by up to a factor of five – thus making Petrobras' large projects

ter

economically feasible. The use of artificial oil lifting equipment, installed at a depth of 2,000 meters, has also been a decisive factor for the development of heavy oil production.

The continuity of the Deep Water Technological Program (Procap) is in line with the priorities that Cenpes has established. The objective of the program is to anticipate solutions for production in the Marlim Leste and Albacora Leste fields, in the next stages of Roncador and Marlim Sul fields, in the deep water blocks in the Santos and Espírito Santo Basins and in fields found in up to 3,000 meters of water depth.

In the fields of natural gas, thermoelectric generation and renewable energy sources, Cenpes participates in efforts to consolidate Petrobras as an integrated energy company.

Cenpes restructured its exploration R&D program in 2005. Previously the focus was on joint projects with Brazilian universities, now research has a central focus on the identification of exploration targets with a high degree of probability of an accumulation of oil and the detection of the exploration risks in ultra-deep waters and onshore basins. As a result, Cenpes' participation in solving Petrobras's specific challenges has grown.

Restructuring led to the creation of the Basin Modeling Program (Promob) and a Geophysics Department. Promob is aimed at running geological simulations designed to reduce exploration risks. The new department will intensify the development of computer applications, emphasizing 4D seismic imaging used to explore areas with complex geological compositions.

Beside reducing costs and optimizing Petrobras' investments, Cenpes' programs seek to achieve high levels of operational reliability, safety excellence and the preservation of the environment. For the Company's downstream and refining activities, one of the main R&D programs strives to adjust Petrobras' refineries to the characteristics of heavy oil in view of the increase production of this type of oil in Brazil.

Technologies to be applied in processes, products and services also are under development by Cenpes, including the formulation of fuels with lower environmental impact. Another line of research is aimed at the development of solutions to increase the useful life of the Company's pipeline network and to reduce operating costs and transportation risks.

In the field of natural gas, thermoelectric power generation and renewable fuels, Cenpes is a part of Petrobras' overall efforts to consolidate itself as an integrated energy company. Besides working on innovations for expanding the use of gas, in order to boost gas consumption to 78 million m3/day in 2010, Cenpes is developing programs to enable the Company's operations to achieve environmental excellence and sustainability and become eco-efficient. Furthermore, it seeks technologies that will make it possible to optimize the use of renewable sources of energy, satisfying the business targets of a number of segments within the Company.

Cenpes' basic engineering area participated in seven large projects in 2005, including natural gas production projects in the Santos Basin and heavy oil production projects in the Jubarte field in the Campos Basin.

In downstream activities, it was involved in projects at RPBC, Replan and Repar encompassing improvements in fuel quality, the reduction of polluting emissions and expansion of heavy oil refining operations. The Center also developed the new formulation of Podium gasoline in Argentina and continued its research for the production of biodiesel fuel.

Cenpes carried out a number of relationship activities with its stakeholders, strengthening the role of the Company as a technological leader and adding value to the brand. The Center launched a second edition of the Petrobras Technology Prize, created in 2004 to encourage the work of researchers and students in the field of oil and gas. For their innovative contributions to the Company's oil, gas and energy sectors, the authors of 27 projects that were selected during the first edition of the Prize received their awards in October.

Petrobras has initiated expansion of Cenpes in view of the new research demands that have emerged in fields such as the environment, gas and energy. New facilities, totaling 88.7 thousand m2, will be built on its land directly in front of the current buildings. The new building will contain effluent treatment and recycling stations and other technological resources, incorporated into the project according to the eco-efficiency concept.

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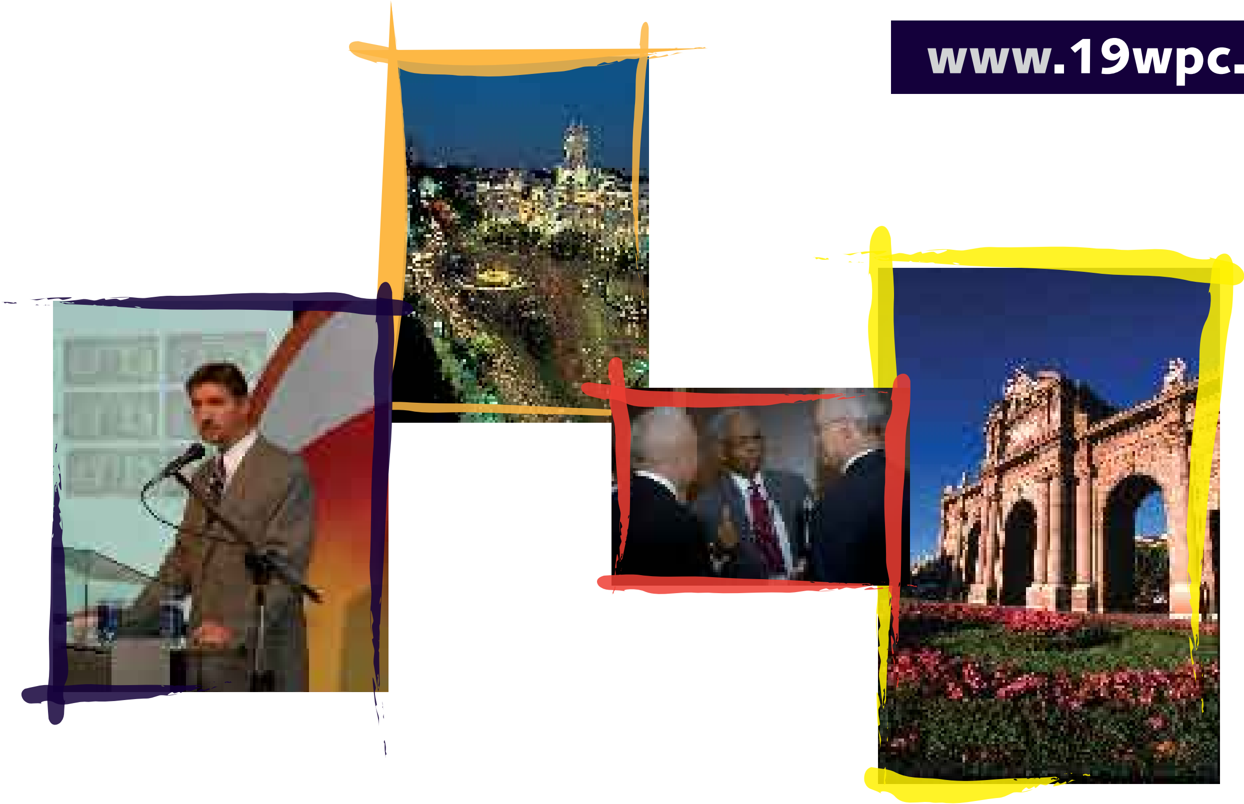

Spain welcomes the 19th World Petroleum Congress

29th June – 3rd July 2008

Feria de Madrid, Madrid

SPAIN MADRID 2008

19TH WORLD PETROLEUM CONGRESS

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Enormous projects now a

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specialty for Saudi Aramco

By John Palmer & Timir Mukherjee

In a global project environment where many large projects struggle to meet their cost and schedule targets, Saudi Aramco has been successfully executing its world-class mega projects with evershorter schedules, and well within budget.

Of the five mega projects executed in the last 10 years, two were recipients of the Project Management Institute's prestigious Project of the Year award, and one was honored at the 2005 International Petroleum Technology Conference.

Saudi Aramco is currently executing a series of new mega projects that will help meet the world-wide energy demand increases and ensure the company's leadership position for years to come. Huge new gas processing plants, facilities for capturing valuable petrochemical feedstock, and new crude oil production facilities are all a part of Saudi Aramco's ambitious domestic capital program to increase oil supplies and support.

Collectively, the Hawiyah, Khursaniyah, Khurais, Shaybah and Manifa programs will by 2011 increase revenue to the Kingdom, and promote the local economy by increasing oil production capacity by 2.85 million barrels per day (bpd), sales gas by 1.4 billion cubic feet per day (cfd), ethane production by 450 million cfd, and condensate by 325,000 bpd. All these projects are being executed on demanding schedules and within budget without a significant increase in company personnel while expanding the Saudi Arabian procurement and construction content of the projects.

This article will illustrate how this is being achieved. A key factor in the company's mega-projects success has been the broad cooperation of corporate Project Management personnel with internal stakeholders and contractors to deliver these projects. The cooperative spirit means that integrated teams resolve technical issues swiftly, optimize scope, streamline design reviews and achieve full control of the quality and schedule. Another major contributor to the success of these projects has been the use of best practices - in value engineering, constructability, planning for startup, benchmarking, scope definition and control, and the formal use of lessons learned - to promote excellence.

Saudi Aramco is fully dedicated to supporting Saudi Arabia's role as the leading provider of energy to the world, and history has demonstrated its success. The company will continue to build on its achievements through innovation, solid integration and a strong will to meet future challenges. Today, the company's mega projects are executed using international engineering firms for preliminary engineering and international EPC (engineering, procurement and construction) contractors for detailed engineering, procurement and construction, in tandem with local subcontractors. Engineered materials are purchased from international suppliers and local manufacturers when possible. Smaller projects (up to $600 million) are now predominantly engineered and built using local contractors.

Mega Project History

Saudi Aramco has a 70-year history of successful project execution. Its facilities tend to be very large compared to 16 Saudi Aramco Dimensions similar facilities worldwide. For example, the company's recent gas-oil separation plants (GOSPs) routinely process 300,000 bpd of crude to produce oil, water, and gas from wells averaging 5,000 - 10,000 bpd each. Pipelines ranging up to 60 inches in diameter transport the oil to terminals.

Enormous projects were the order of the day early in the company's history, with constantly pressing needs to build new GOSPs, water injection facilities to maintain reservoir pressure, pipelines, oil stabilization units and export terminals. Major capacity expansions were built in the mid-1970's. Until the late 1970s, projects in Saudi Aramco were managed by operations organizations working through major international EPC companies.

In 1977, Aramco started managing its projects with an internal organization, using Program Management Contractors. The first mega project was a very large gas collection and distribution program - known as the Master Gas System - to eliminate natural-gas flaring at the wellhead and provide Saudi Arabia with natural gas as a commercial resource. At that time, with expenditures running about $3.5 billion per year (2002 equivalent), the Project Management organization had six general managers and 19 departments to manage the gas program and multiple smaller projects.

In 1988, Arabian American Oil Company (Aramco) became Saudi Aramco, as the original U.S. partners were bought out by the Saudi Arabian Government. This change was accompanied by increased hiring of Saudi nationals. In the late 1980s, the company started using lump-sum turnkey (LSTK) contracts for the largest projects, and local contractors for smaller projects. There were no more mega projects until the early 1990's.

Modern Mega Projects

Since 1998, Saudi Aramco has completed five mega projects. The Ras Tanura Refinery Upgrade Project was first, and the company learned many valuable lessons from it. The other four were completed below budget and on or ahead of aggressive schedules, with three. Of five company mega projects in the last 10 years, two received the Project Management Institute's prestigious Project of the Year award. Transporting the enormous

Haradh GOSP

Hawiyah groundbreaking

vessels required for mega projects and placing them on-site is a massive logistical undertaking.

Special, ultra-strong vehicles are needed to move the vessels, and sometimes electrical power lines have to be temporarily disconnected or rerouted along roadways so vessels can pass safely.

Saudi Aramco Dimensions Ras Tanura Refinery Upgrade Project (1991–1998)

The RTR Upgrade Project changed the refinery configuration from a 300,000-bpd topping plant to a full conversion refinery including a hydrocracker, a visbreaker, a naphtha hydrotreater and atmospheric catalytic conversion reformer (the largest in the world at the time). Utility upgrades included a hydrogen plant, new steam system and water disposal.

Shaybah Field Development (1995–1998)

The Shaybah Field facilities were designed to process 500,000 bpd of Arabian Extra Light crude from the Shaybah field, deep in the Rub' al-Khali (Empty Quarter) desert. The oil was shipped from the field to Abqaiq Plants in a new 640-kilometer pipeline. Because of the field's remoteness, produced water and gas are reinjected into the reservoir to maintain pressure. The entire field had to be self sufficient, so the scope included cogeneration, a Boeing 737-capable airport, residential and industrial facilities, and a 400-km road through the desert.

Hawiyah Gas Plant (1997–2001)

The Hawiyah Gas Plant provided facilities to process 1.6 billion cfd of nonassociated sour gas from the highpressure Khuff and Jauf gas reservoirs on the south end of the Ghawar field. Gas plant facilities included gas-condensate separation, acid-gas removal, dehydration and sales gas recompression. Auxiliary facilities included wellhead connection and gas gathering, a gas transmission pipeline to the Master Gas System (MGS) and expansion of the MGS, sulfur recovery and truck shipment facilities, condensate transport and injection into the crude gathering system for transport to Ras Tanura Refinery, local maintenance and plant management facilities, and construction of a new road to the plant.

Haradh Gas Plant(1999–2003)

The Haradh Gas Plant has a design capacity of 1.6 billion cfd of combined raw feed of Khuff sour and sweet gas and Unayzah sweet gas to deliver 1.5 billion cfd of dry sweet gas to Saudi Arabia's Master Gas System. The plant consists of two gas-sweetening and three sulfur-recovery trains, two condensate stabilizers, two sourwater strippers and four gas processing trains for gas dehydration, dew-point control and sales gas compression. The plant recovers 170,000 bpd of hydrocarbon condensate and 90 metric tons per day of elemental sulfur. Auxiliary facilities included: well-head connection and gas gathering; a 42”– 56” diameter, 395-km gas transmission pipeline to the Master Gas System and expansion of the MGS; sulfur recovery and truck shipment facilities; condensate transport and injection into the crude gathering system for transport to Ras Tanura Refinery; local maintenance and plant management facilities; and construction of a new access road and an airstrip for the plant.

Qatif Field Development (2001–2004)

The Qatif Program provided facilities for 500,000 bpd of Arabian Light and Medium crude oil from onshore and 300,000 bpd from offshore. This was first Saudi Aramco facility to combine production of Arabian Extra Light, Light and Medium grades. The facilities were also designed to process 370 million standard cubic feet per day (scfd) of associated gas and 40,000 bpd of condensate.

All crude is desalted, stabilized and processed, then shipped to Ju‘aymah and Ras Tanura terminals for direct export. The gas is processed at Berri Gas Plant. The facilities included three new GOSPs, five new and 10 upgraded offshore platforms, a major expansion of Berri Gas Plant, 34 drilling islands, and a 140-megawatt (MW) Cogeneration Plant, providing steam heat for oil dehydration and power for offshore electric submersible pumps. Pipeline work included all gathering lines including offshore, and shipping lines for oil, gas and condensate.

Mega Projects - Top 10

Megaprojects in Saudi Aramco are generally defined as projects or programs exceeding $1 billion in value. The projects listed here are the company’s largest to date.

Hawiyah NGL Recovery Program (2003–2008)

The Hawiyah NGL Recovery Plant will process 4 billion standard cubic feet per day of sales gas from Hawiyah and Haradh Gas Plants to yield 310,000 bpd of ethane and natural gas liquids. The program will also expand the existing Hawiyah Gas Plant by 800 million cfd; install or expand pipelines for product shipments to Jubail and NGL to Ju‘aymah Gas Plant, and expand Ju‘aymah NGL fractionation facilities.


Khurs 76

Khursaniyah Field Development (2005–2007)

The Khursaniyah Program Facilities will process 500,000 bpd of Arabian Light crude oil and process 1 billion standard cubic feet per day of associated gas in a new grass roots gas plant. The output of the gas plant will include 280,000 bpd of condensate. The new facilities will also include new industrial support facilities. Due to the increased international demand for oil, Saudi Aramco decided to accelerate the development of these fields using new contracting strategies for the GOSP and the gas plant.

EPC contractors provided proposals based on an enhanced design basis and uplifts for engineering and procurement with a provision to convert the contracts to LSTK. Preliminary engineering, detailed design and procurement were done on a reimbursable basis to expedite the work.

Zamil Debutanizer

Khurais Field Development (2005–2009)

The Khurais program will build facilities for 1.2 million bpd of ArabianLight crude through a new Central Processing Facility (CPF), the largest of its kind in Saudi Arabia, near the town of Khurais. A new gas plant will treat the associated gas, producing 70,000 bpd of condensate and 420 million cfd of gas. The program will also provide 4.5 million bpd of seawater for injection to support the increased production from Khurais and Ghawar fields. The seawater injection pipeline network will consist of 920 kilometers of 48"–60" pipe. In addition, the program will also increase the existing East/West NGL pipeline capacity from 425,000 bpd to 555,000 bpd to manage the increased NGL produced at Khurais. Other pipeline work includes all of the oil gathering and water injection distribution and sour gas to Shedgum Gas Plant. Infrastructure work includes an air strip, residential facilities for up to 1,000 personnel, and an industrial complex to handle facility maintenance.

Shaybah Field Expansion (2005–2008)

The Shaybah crude expansion program is designed to increase Arabian Extra Light oil production capacity from the current 500,000 bpd to 750,000 bpd. The program includes installation of a new GOSP and expansion of the gas compression and injection facilities. A major oil pipeline loop will provide the increased oil transport capacity.

Manifa Field Development (2006–2011)

Under the Manifa program, Saudi Aramco plans to install central facilities at Manifa to process 900,000 barrels per day of Arabian Heavy crude oil. The Manifa Central Processing Facilities (CPF) will include gas and oil separation, wet crude handling, gas compression, gas conditioning, crude oil stabilization, produced water disposal and water injection facilities. The CPF will be designed to process 900 mbcd of crude oil; approximately 120 million scfd of associated gas, 50 mbcd of hydrocarbon condensate will be produced as result of this crude increment. The gas and condensate will be processed at Khursaniyah Gas Plant, and the crude will be transported to Ju'aymah Terminal for export. This program is challenging primarily because of the location of the Manifa field in shallow water in the western Arabian Gulf, requiring a 41-km asphalted causeway and 27 drilling pads in the shallow water.

This shallow bay contains the most prolific shrimping area in Saudi Arabia, and all precautions will be taken to maintain this vital resource for the country. The program will include installation of four oil-producing offshore platforms with 10 producing and two evaluation wells each, and seven water-injection platforms with 10 water injectors each. Electric submersible pumps will provide artificial lift for production, which will be shipped without processing for multiphase flow transportation to the causeway and shore-based CPF.

The entire Shaybahoilfield complex had to be self-sufficient, so the scopeincluded a Boeing 737-capable airport of them winning major awards. There were two dominant contributing factors to these successes:

• Communication factors: commitment from Corporate Management; CEO meetings; clear, common goals for the extended project team; lessons learned from previous projects.

• Organizational factors: formal implementation of best practices; a culture of continuous improvement; project team continuity; and successful contracting strategies.

Many of these factors are applied to the whole project system. With the increased demand for oil, Saudi Aramco has significantly increased its capital program, with six active corporate mega projects and three joint-venture mega projects. The company continues to set aggressive targets.

Factors contributing to success

The Ras Tanura Refinery Upgrade Program, started in 1991 and completed in 1998, was a watershed project in many respects. This $1.3 billion project was the first major expansion of the RT Refinery, which started refining oil in 1947. There were very few personnel in the company that had managed any mega projects, much less a complex refinery project, so experienced industry engineers were hired to help.

The company was also moving away from doing its own inspection to requiring contractors to inspect their own work. The project, though ultimately successful, was completed nearly two years behind schedule. The company learned from a multitude of mistakes on this project that it must:

• Assure that all stakeholders are completely aligned;

• Provide very clear project scopes and minimize scope changes after the Design Basis;

• Clearly state the quality requirements in the contract, 22 Saudi Aramco Dimensions not in an attachment;

• Keep management and key technical personnel on the job for the entire project.

Another mega undertaking, the Shaybah project, was started in 1995 and completed just 36 months later, on time and on budget, despite the amazing logistical challenges of building the company's first major project in the deep desert. On this project, project management professionals learned from success: minimal scope changes; well defined scope; tight communication internally and externally; and alignment of all of stakeholders.

The last significant learning step was benchmarking. A project system benchmark study of 30 projects was conducted by IPA (Independent Project Analysis) in 2000, showing that the company's projects were taking 60 percent longer than the industry as a whole and cost almost 30 percent more. The company began to incorporate this learning into change.


Juaymah Debutanizer

Zamil Debutanizer

Improving the Program

Change started with Total Quality Management in 1994, with quality teams and enthusiasm. PM personnel were reluctant to change much until the learning from the two above projects and the benchmarking hit home. From 1998 to 2002, several programs were instituted that made the changes permanent and actually changed the culture to one of continuous improvement:

• A lessons-learned system was established starting in 1995, and added to the knowledge base of project personnel. The company also joined the United States Construction Industry Institute (CII) to take advantage of their best practices and sponsored a chapter of the Project Management Institute in the Arabian Gulf. All of these changes began to increase the level of expertise. Changes have reduced average project schedules from an average of 48 months to 35 months;

• A Value Engineering Unit was formed after early successes showed that VE could significantly reduce project costs. Five people were trained and certified, and the unit continues today;

• Project Cost and Schedule performance targets were instituted in 1999 for on-time and on-budget completions, value engineering and value improvements. Recording value improvements (improvement ideas proposed by team members) acknowledged their contribution and provided incentives for finding ways to save money. This effort was enhanced by the advent of a balanced scorecard (BSC) for projects starting in 2002, when several other performance measures were added;

• A standard contract schedule for quality, introduced in 2000, significantly improved project quality. Further quality improvements, especially for local construction contractors, were promoted with a project quality measure for the BSC, focusing on adherence to requirements, and in 2002, requiring conformance to ISO 9001 and related documents;

• After several years of moderate success asking project teams to implement CII best practices and the lessons learned program, Project Management established a Best Practices group in 2002 to formally implement these concepts. This group of experienced personnel works with project teams in formal, facilitated sessions to optimize the value of selected best practices.

The result of these changes is that average project schedules have been reduced from an average of 48 months (from start of preliminary engineering to mechanical completion) for projects started in the early to mid-1990s to an average of 35 months in 2006. About 50 new projects start each year.

On-time performance has increased from 40–50 percent in the late 1990s to 80–90 percent for the last five years. On-budget performance (including contingency) has increased from 50–60 percent to 80–90 percent. Project quality has improved substantially, and start-up time has decreased to less than one month for almost all projects. Safety performance for construction contractors has also improved substantially, with less than one lost-time incident per 10 million man-hours in each of the last four years. It is important to note that this statistic is not comparable with U.S. statistics because there are no OSHA regulations; minor injuries and off-site traffic accidents are often not recorded.
Since 1998, VE studies have saved over $2 billion - roughly 7 percent of project value, and value improvements initiated by the project team or contractors has exceeded $1.8 billion.

Further Improvement

Saudi Aramco conducted its second IPA system benchmark in early 2004 for 30 projects that started during 1999–2003. The results showed improvement from the original study in 2000, with average schedules about 25 percent longer than industry and costs about 15 percent higher. However, it identified multiple specific areas for improvement. Consequently, the company launched a Corporate Capital Program Best in Class initiative with 23 of the 24 Administrative Areas participating. Nine major improvement areas were identified, and the initiatives are all moving into the implementation phase.

These initiatives are expected to have a great impact on cost and schedule performance of all Saudi Aramco projects:

• Greater use of Innovative Contracting Strategies, which focus on converted LSTK, using reimbursable engineering and procurement and then converting to a regular lump-sum contract at 50–70 percent of detailed design;

• Standardized Component Design. The first effort was a standardized substation design using precast walls and roof with top-entry electrical wiring, allowing a slab floor

Storage tank offloading

Khurs 70

and experienced erection subcontractors. This design will save design time and about 3–4 months in substation construction;

• Increased accountability during the design basis (IPA FEL 1 & 2) now uses a more formalized gate approval process. 24 Saudi Aramco Dimensions Since 1998, value engineering studies have saved over $2 billion;

• Project team integration for groups of small projects based on mega project success in this area;

• More rigorous review of plot-plan layouts and equipment peripherals and instrumentation;

• Procurement process improvements including standardized procurement systems for local contractors and requisition templates;

• Construction productivity improvements for local contractors who employ personnel from Third World countries with limited industrial experience. The initial focus is on reducing interruptions;

• Productivity improvement for local design contractors, focuses on construction feedback to the design process and design quality control;

• The Integrated Project Technology initiative will increase the use of information technology (IT) for improved project processes, data management and flow, and for program management reporting.

The extremely long delivery arm of cement-pumping equipment at the Khursaniyah site appears to be an appendage of an alien creature. The equipment is used to deliver cement to difficult-to-reach areas. Massive amounts of cement are used in mega projects.

Jack-up

Steering in the Right Dire

By Wajid Rasheed

Advances in rotary steering, logging technology and digitalization are bringing autonomous systems ever closer. Although systems capable of finding and accessing reservoirs on their own are still some years away, several types of rotary steerables exist today.

High-tech electronic solutions are sophisticated by nature, these systems are especially suited to costly complex designer wells. However, suppliers are offering a modular or combo approach which allows the degree of system sophistication to be determined by drilling engineers. This has already helped export some of the higher-end systems into certain intermediate cost shelf and onshore applications by tailoring certain BHA combos to well needs.

A different approach is being adopted by a number of smaller service providers who are developing simpler and more cost effective systems for the low rig cost market. The majority of these systems still rely upon electronics, but have fewer features such as lower DLS capability for instance and are aimed at 'simpler' lower cost wells. Simple or sophisticated - this much is clear - all systems generate cost savings and offer the potential to improve recovery from compartmentalized or horizontal reservoir sections.

But less clear is the criterion that makes one system 'better' than another. Reaching a consensus will always be contentious but an objective way of determining the best fit is to broadly 'match' rotary steerables with the varying dictates and expectations of deepwater, shelf or onshore drilling and completions. Drawing these variables together Figure 1 (on page 14) depicts deepwater, shelf and onshore sectors and matches technology appropriately.

Certainly, a rotary steerable system (RSS) must help reach the reservoir and optimize footage drilled within it but beyond this there are many reservoir and well dependent variables. For example, the Dogleg severity performance of a rotary steerable system should be matched with the complexity and number of targets involved. In complex designer wells, sophisticated systems shine. In less complex horizontal wells, simple systems suffice.

Similarly costs also drive system choice. It is well known that the tight economics of onshore or shelf assets cannot withstand high rig rates let alone expensive down-hole equipment. Here a match depends as much on reservoir needs (DLS required to reach optimal reservoirs) as it is driven by costs. Consider deepwater versus onshore trip costs. In the former an average round trip will cost $500,000. Yet, the same trip onshore hardly makes a tenth

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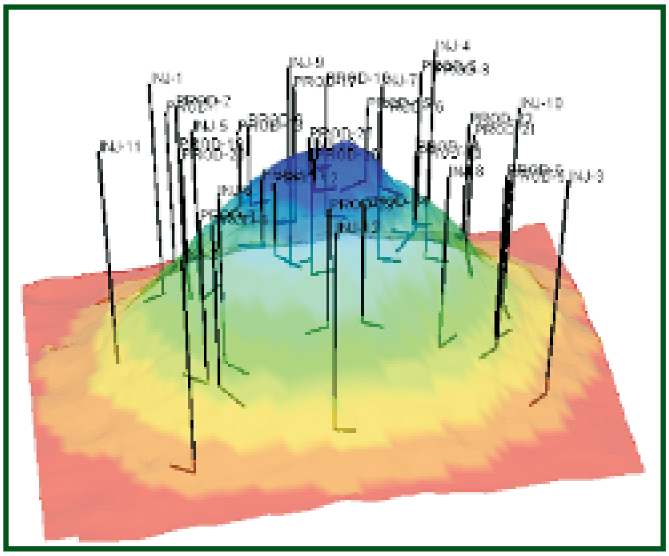


of this figure. In the first instance, it makes commercial sense to minimize trips. However, onshore it might make better commercial sense (depths and profile permitting) to induce trips by using conventional steering technology to line up sections and run in with rotary steerables where they have best effect.

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

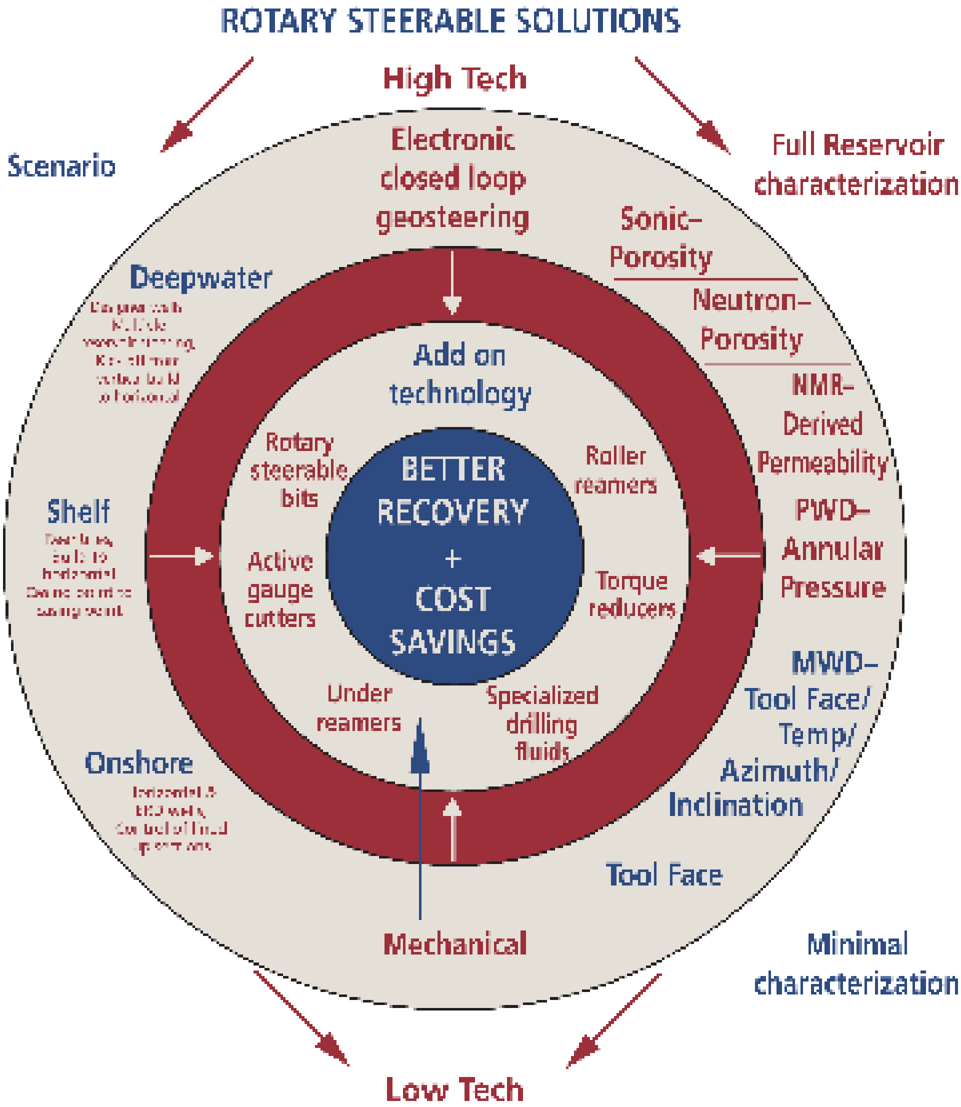
In these deepwater instances, a full range of reservoir characterization tools is also required. Sophisticated systems coupled with full logging capability reflect and meet deepwater frontier needs as offset data is often scarce and further asset development is dependent on data acquisition and interpretation. Therefore, the general rule is the more data acquisition and characterization the better. Data gathered 'while drilling' supplements the pre drill seismic package by increasing footage drilled in optimal reservoir zones.

Conversely, because mature assets are usually well characterized and offset data is plentiful, the same degree of data acquisition may be unnecessary. This makes mature or onshore fields ideal candidates for simpler rotary steerable tools. As we move down the characterization list, there is a diminished need for complete characterization. Intermediate or mature shelf assets may not require neutron magnetic resonance or sonic logging. While, in a marginal onshore context it is highly likely that a full logging while drilling suite becomes redundant. Little more than tool-face, azimuth, inclination, temperature and formation identification is required in this context. In exceptional onshore cases, the uncertainty associated with complex targets may require further logging but often a MWD plus Gamma system provides ample data.

In this way, technology can be pared down to bare essentials and costs lowered. What may have once been considered a marginal or mature field can be revisited with new economic parameters and perhaps be revitalized.

Add on Technology

Representing opportunities for reducing casing wear torque reducers can help overcome concerns of the effects of increased rotation on tubulars. Also roller



reamers aid BHA stabilization and reduce down-hole vibrations. While under-reamers, enable the diameter of production holes to be increased (especially important in deepwater scenarios where narrow pore pressure fracture gradients can jeopardize reservoir hole size) by allowing casing to be telescoped without sacrificing production. Also specialized drilling fluids exist to reduce torque and improve rotary drilling efficiency.

RSS Improve Drilling Effectiveness

RSS increase the effectiveness of drilling by improving reservoir exploitation. This comprises;

1. The certainty of precise inclination and azimuth control over the planned horizontal or directional section (the responsiveness of the system will be dependent on factors such as formation, the length of time a particular trend has been established and such like).

2. In cases an extension of the effective horizontal section drilled which would previously not have been possible using slide drilling. 1200' extensions as compared to offset have been documented in the US, NSea and Middle East.

Increasing Drilling Efficiency

The argument for increasing drilling efficiency is based on the following attributes of the RSS;

1. The elimination of difficulties associated with oriented drilling.

2. Improved hole cleaning as Sanchez et al detail. Rotary mechanical agitation of cuttings beds and the orbital motion of the drillstring means that cuttings are less likely to form cuttings beds as they are continuously exposed, agitated and circulated out. It is recognised that this leads to better hole cleaning. This in turn reduces the time spent circulating at section TD to improve hole condition.

3. Synergy with PDC bits. Orienting with a PDC bit is recognized as being difficult; this can limit optimal bit

The various rotary steerable systems available on the market today offer a host of benefits, with simple and sophisticated systems complementing one another. Each can be selected to match the full spectrum of needs and scenarios ranging from deepwater exploration frontiers to intermediate applications to mature onshore assets. There aren't many technologies capable of revolutionizing drilling and completions. Or making a startling difference to field economics. Rotary steerables are one of them.

choice in certain formation types. PDC bits can be used with a Rotary Steerable System to optimise bit selection. This has led to reduced rock bit trips, better ROP's and improved directional response. It is worth considering that the majority of horizontal sections appear to be drilled with PDC bits.

4. Increased average ROP. Rotary drilling consistently yields higher ROP leading to a reduced time in drilling the section.

5. Fewer trips, Wisenbaker concludes this is highly attractive in an under-balanced drilling situation as each trip saved obviates the need to kill the well using expensive kill mud.

6. Improved Borehole Geometry - Fewer instantaneous changes in well-bore curvature means a smoother well bore. This means reduced hole tortuosity and an improved well profile. This is because rotary - build or drop - trends take time to break. Therefore, well-bore curvature is smoothed out over entire sections. Consequently, casing can be set more easily and there is reduced potential for work-overs, and interrupted production. This highlights the reduction in Casing or Tubular wear due to smoother wellbores. There is also a reduced requirement for reaming. This is because of fewer transition ledges and less potential for keyseating. Lower well-bore tortuosity reduces the need for reaming to decrease tortuosity or well-bore curvature. Kristiansen et al link consistent gauge hole with improved resistivity readings.

7. Reduced Torque & Drag - as quantified by Mims. Less need for BHA Torque Reduction devices. Less need for mechanical Drill-string torque reduction devices such as NRDPP or Subs. Less need for drilling fluid based torque reduction such as polymer beads or other additives.

8. Literature shows reduced potential for mechanical & differential sticking.

9. The absence of a motor allows improved bit hydraulics, annular velocity and higher flow rates.

10. Ability to withstand bottom hole temperatures higher than 150 degrees centigrade dependent on each RSS .

The various rotary steerable systems available on the market today offer a host of benefits, with simple and sophisticated systems complementing one another. Each can be selected to match the full spectrum of needs and scenarios ranging from deepwater exploration frontiers to intermediate applications to mature onshore assets. There aren't many technologies capable of revolutionizing drilling and completions. Or making a startling difference to field economics. Rotary steerables are one of them.

What's in a

Nature's best OJ is sweet and light – as is its crude. However, not all the 200 odd naturally occurring crude 'varietals' are so blessed. This article lists oil and gas 'varietals' and explains how reservoir characteristics and behaviour shape commerciality.

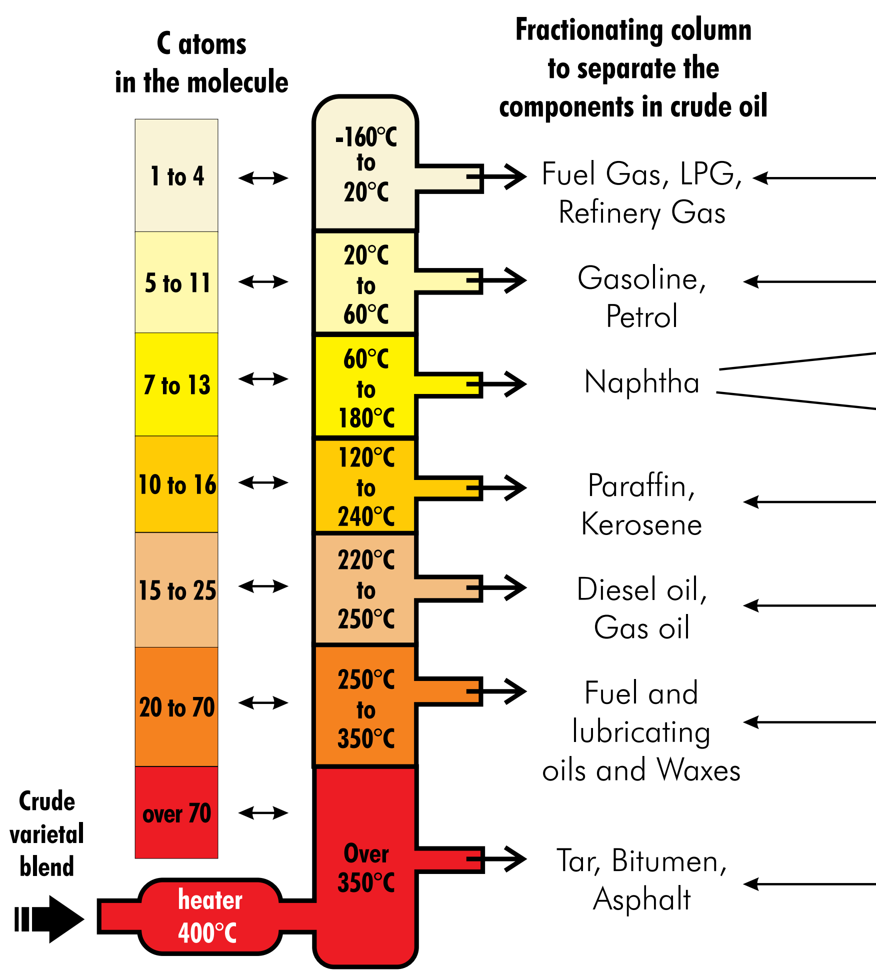
Based on an excerpt from The Hydrocarbon Highway written by Wajid Rasheed

Asphalt, bitumen and crude oil are all terms that describe different forms of petroleum that can be found in a barrel of 'oil'. Petroleum then is an umbrella term that is commonly used to describe all naturally occurring hydrocarbons as well as refined products or derivatives thereof. However, as Petroleum is a chemical compound made up of Hydrogen and Carbon, the classification Hydrocarbon is more appropriate.

Hydrocarbons in their natural state are found at a given depth in a complex inter-play of different molecular forms, different phases and ratios and are also likely to contain impurities and co-exist with water. Impurities can be metallic and non-metallic such as Vanadium and Hydrogen Sulphide and can be introduced at any time during the formation of Hydrocarbons over millions of years. Water with differing levels of salinity and salts co-exists with Hydrocarbons in their natural state and can also be introduced at any time during the formation process. Therefore, any reservoir management or production strategy will start by considering these factors and seek to simulate their behaviour over time in order to determine how best to produce a particular crude-oil accumulation.

The range can be appreciated by considering Methane Gas (CH_4), Petrol (C_5H_{12} to C_7H_{16})

Oil & Gas Types, Ap



a barrel?

and Asphaltene ($C_{80}H_{162}$+). Many characteristics such as density, viscosity and flammability are determined by molecular weights. Further details are found in the Chapter on Refining.

Oil varies in nature from the extremely light (relative density around 0.75 that of water), low viscosity fluids (less than that of water) in deep reservoirs, to very heavy viscous types with a relative density close to that of water, a viscosity 100 to 100,000 times that of water, and usually found in shallow reservoirs. Oil may also contain asphaltenes, waxes and sulphur compounds. Reservoirs have been found containing almost all types of hydrocarbons. Reservoirs are typically heterogenous structures that can be linked to other reservoirs or compartmentalised. Variations include pressure, temperature, depth, thickness, and sealing faults.

Reservoir Fluid States

Reservoirs are found at depths that vary from the surface of the Earth to shallow depths (2,000ft+) to deeper than (25,000ft+). Pressure and temperature conditions also vary between the near ambient for shallow reservoirs to temperatures above 250c (400° K) and pressures sometimes over 20,000 psi for deep reservoirs. Reservoir fluids are complex gas-liquid systems, existing as both non-aqueous and aqueous mixtures otherwise known as multi-phase immiscible fluids. Depending on the composition of the mixture and the pressure and temperature of the reservoir, hydrocarbons underground may be present initially as:

- liquid only - oil reservoir
- gas only - gas or gas/condensate reservoir
- gas overlying liquid - oil reservoir with gas cap, or gas reservoir with oil ring

Hydrocarbon Production

Production of hydrocarbons from an underground accumulation to the surface involves a reduction in pressure and temperature.

plications & Derivatives

Primary Applications

- Methane, Ethane, Butane, Propane LNG, CNG, Butane, Propane Bottled Gas, Aerosol Propellants
- Pentane – Octane Petroleum Spirit (Gasoline) Automotive Fuel
- Light Naphta
- Heavy Naphta
- Decane-HexaDecane, Jet-Kero, Kerosene Aviation / Jet fuel, Diesel Heating Fuel
- Automotive, Train, Marine & Bunker Fuel
- Tetracontane, Heating Oil, Lubricating Oils, Waxes, Polishes
- Asphaltane, Surface Coating for Roads and Roofs

Secondary Applications & Derivatives

- Production of Alkenes - Used to form plastics (polythene, polypropene, polystyrene and polyvinylchloride PVC) and Alcohols (Ethanol).
- Production of Arenes - Benzene (Steam & Catalytic Reforming), Toluene & Xylene.
- Subjected to Various Cracking Processes to produce Lighter Naphta and Gasoline.

As a result, hydrocarbons originally present as only liquid will separate into liquid and gas at the surface, and hydrocarbons originally present as gas underground will generally produce some liquid at the surface. The separation of gas and liquid at the surface is done mechanically using de-gassing facilities and the volumes of liquid and gas are measured separately. The behavior of reservoir fluids is grounded in the laws of physical chemistry for perfect gases and the phase changes in gas-liquid systems.

Oil

Crude oil varietals can be found in many colours from almost transparent to light yellow to light brown to dark black, with density and viscosity generally increasing with color intensity. For example, black oil is often viscous (hard-to-pour) while light yellow oils are of low viscosity (runny). Where petroleum is unable to flow in atmospheric conditions, it can be referred to as heavy oil, tar or tar shales. The term 'Liquids' or crude refers to petroleum in its 'crude oil' state that can generally flow in atmospheric conditions.

Sweet & light

Sweet crude has less than 0.5% sulphur content – up this figure and it turns 'sour'. Light crude has a density of 22° (degrees) or more using the American Petroleum Institute's (API) specific gravity scale and has light hydrocarbon fractions. Heavy crude is more complex with higher densities and lower API gravities.

Technologists quibble on when crude gets heavy; some say this happens at 25°API or less and others say 20°API or less. However, what is important is that finding heavy or light crude oil depends entirely on cap rock and permeability, as this will prevent oil and gas from leaking to surface. In Venezuela, oil deposits are close to surface with the lighter fractions having been washed away or evaporated over the years, and just the heavier residue is left.

Sour as a skunk

Sour crude with its high sulphur content sells below its sweet counterpart - the gap can be $10 or more. The gap exists because sour crude requires more processing and there is a lack of sour refineries worldwide. Consequently, a preference for sweeter crudes exists. The naturally occurring sulphur compounds or 'mercaptans' present in sour crude are powerfully smelly; also found in garlic oils and skunk excretions. The malodorous mercaptans are by-products of decaying organic matter and they must be treated which adds to refining cost. Getting rid of sulphur, water, chlorides and other such impurities improves quality, increases value and stretches the world's oil reserves but it also adds to cost.

Gas

Methane is the most abundant component of what is known as natural gas. The second most abundant component is ethane. Ethane can be liquefied and sold as fuel, but it is mostly used as a petrochemical feedstock. Propane and butane are also found in natural gas, albeit in smaller amounts. They are commonly separated and sold as natural gas liquids (NGLs). This is due to the fact that they have comparatively higher energy content per cubic foot 2,500 Btu for propane and 3,250 Btu for butane while methane has just over 1,000 Btu per cubic foot.

Gas Condensate or Wet Gas

Gas condensate or Wet Gas are hydrocarbons which are gaseous in the reservoir but which, when temperature and pressure are reduced, partially condense to yield condensate in liquid form. They are usually of low-density and high-API gravity and generally co-exist with natural gas.

For EP purposes, the physical properties of the fluids are characterized ie color, gravity, viscosity, bubble point pressure, gas oil ratio, interfacial compressibility, pour-point, and kerosene content. For downstream purposes, the hydrocarbon chemistry needs to be fully determined, with actual compositions and distillation base fraction description important.

Condensates usually have an API of 45 ° and above. The liquids that condense (6-60 m3/m3, 30-300 bbl/MMscf) are almost transparent or light yellow and can be refined in a way similar to very light crude oil.

The production of condensate reservoirs is complicated due to changes in reservoir pressure. Gas may be converted to liquid if the reservoir pressure drops below the dew point during production. Reservoir pressure can be maintained by fluid injection if gas production is preferable to liquid production. If the condensation occurs in the reservoir the reservoir fluid is termed a gas condensate fluid. This isothermal condensation behavior is opposite to normal experience and the phenomenon is known as retrograde condensation. Gas condensate reservoirs are an important class of hydrocarbon accumulation.

Natural gas condensate is typically composed of pentane, hexane, heptane and octane.

The Effects of Changing Molecular Weight

On average the carbon content of oil is 84%-87% weight and the hydrogen content is 11%-14% weight. Oil viscosity as we have noted is a prime determinant of producibility and refinability. We have seen that Hydrocarbons exist in varying forms and compounds. The number of these compounds, increase dramatically with isomers, which are different arrangements of the same number of atoms. In the case of paraffin hexane, C_6 there are 5 isomers, for C_{10} there are 75, and for C_{30} over 4 billion. Although laboratory analyses of the reservoir hydrocarbons can profile all compounds containing as many as 20 carbon atoms, it is usually sufficient to profile compounds containing up to 6 or 7 atoms, with a catch-all number being used to represent the total proportion of heavier molecules that are present.

Analysis is usually presented in terms of C_1, C_2, Cn+ with n often being 7, 12 or 20. Compounds that are not expressed are usually treated as a composite fraction characterized by a molecular weight, density and /or a boiling point.

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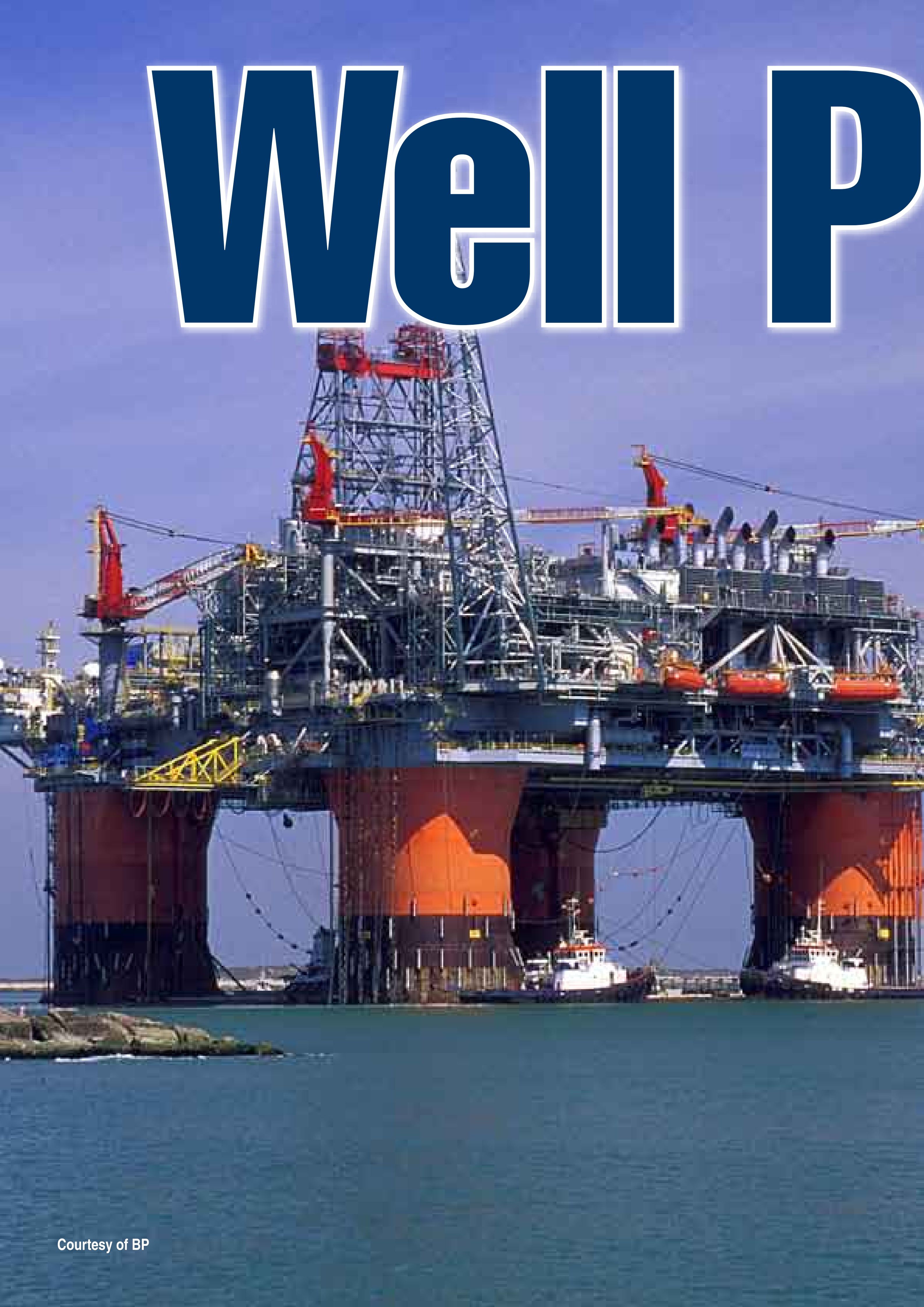
Well P



Courtesy of BP

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PART 2

The second article based on excerpts from the book Hydrocarbon Highway

By Wajid Rasheed

Coring

Formation core samples maybe taken. These are the most important way of examining formations and any oil bearing strata. Mostly, cores are used with a "core barrel" which drills formations. As the core barrel is rotated, it cuts a cylindrical core a few inches in diameter that is received in a tube above the core-cutting bit. A complete round trip is required for each core taken. The second is a sidewall sampler in which a small explosive charge is fired to ram a small cylinder into the wall of the hole. When the tool is pulled out of the hole, the small core samples come out with the tool. Up to thirty of the small samples can be taken at any desired depth. This provides positive real evidence of cross-flow, permeability and porosity. Lab tests are complex and can include Fluorescence (TSF) Gas Chromatography.

Oil can be found in cores as 3-D seismic surveys offers much enhanced imaging of subsurface fluid flow. Cores usually measure between 3 to 4 meters in length.

Sampling and Screening of Cores

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

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

Drilling to Total Depth

The final section of the hole is what the operating company hopes will be the production hole. But before long, the formation of interest (the pay zone, the oil sand, or the

The final section of the hole is what the operating company hopes will be the production hole. But before long, the formation of interest (the pay zone, the oil sand, or the formation that is supposed to contain hydrocarbons) will be penetrated by the hole.

formation that is supposed to contain hydrocarbons) will be penetrated by the hole. It is now make or break time - "Does this well contain enough oil or gas to make it worthwhile to run the final production string of casing and complete the well?"

After the operating company carefully considers all the data obtained from the various tests it has ordered to be run on the formation or formations of interest, a decision is made on whether to set production casing and complete the well or plug and abandon it. If the decision is to abandon it, the hole is considered to be dry, that is, not capable of producing oil or gas in commercial quantities. In other words, some oil or gas may be present but not in amounts great enough to justify the expense of completing the well. Therefore, several cement plugs will be set in the well to seal it off more or less permanently. However, sometimes wells that were plugged and abandoned as dry in the past may be reopened and produced if the price of oil or gas has become more favorable. The cost of plugging and abandoning a well may only be a few thousand dollars. Contrast that cost with the price of setting a production string of casing - $50,000 or more. Therefore, the operator's decision is not always easy and is invariably oil or gas price driven.

Setting Production Casing

If the operating company decides to set casing, casing will be brought to the well and for one final time, the casing and cementing crew run and cement a string of casing. Usually, the production casing is set and cemented through the pay zone; that is, the hole is drilled to a depth beyond the producing formation, and the casing is set to a point near the bottom of the hole. As a result, the casing and cement actually seal off the producing zone-but only temporarily. After the production string is cemented, the drilling contractor has almost finished his job except for a few final touches.

Cementing

After the casing string is run, the next task is cementing the casing in place. An oil-well specialist cementing service company is usually called in for this job. A good cementing job is crucial to the longevity of the well and incorporates many factors incl. annular volumes,

Since the pay zone is sealed off by the production string and cement, perforations must be made in order for the oil or gas to flow into the wellbore. Perforations are simply holes that are made through the casing and cement and extend some distance into the formation. The most common method of perforating incorporates shaped-charge explosives (similar to those used in armor-piercing shells).

formation-cement-wellbore interaction, slurry and set properties at any density, high or low. Cement behaviour at different pressure, temperature and loading conditions.

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

Perforating

Since the pay zone is sealed off by the production string and cement, perforations must be made in order for the oil or gas to flow into the wellbore. Perforations are simply holes that are made through the casing and cement and extend some distance into the formation. The most common method of perforating incorporates shaped-charge explosives (similar to those used in armor-piercing shells).

Acidizing

Sometime, however, petroleum exists in a formation but is unable to flow readily into the well because the formation has very low permeability. If the formation is composed of rocks that dissolve upon being contacted by acid, such as limestone or dolomite, then a technique known as acidizing may be required. Acidizing is usually performed by an acidizing service company and may be done before the rig is moved off the well; or it can also be done after the rig is moved away. In any case, the acidizing operation consists of pumping appropriately sized volumes of acid down the well. The acid travels down the tubing, enters the perforations, and contacts the formation. Continued pumping forces the acid into the formation where it etches channels - channels that provide a way for the formation's oil or gas to enter the well through the perforations.

Fracturing

When sandstone rocks contain oil or gas in commercial quantities but the permeability is too low to permit good recovery, a process called fracturing may be used to increase permeability to a practical level. Basically, to fracture a formation, a fracturing service company pumps a specially blended fluid down the well and into the formation under great pressure. Pumping continues until the formation literally cracks open.