

# Reservoir, drilling and real-time technologies increase Saudi Aramco reserves, production

By Wajid Rasheed, contributing editor

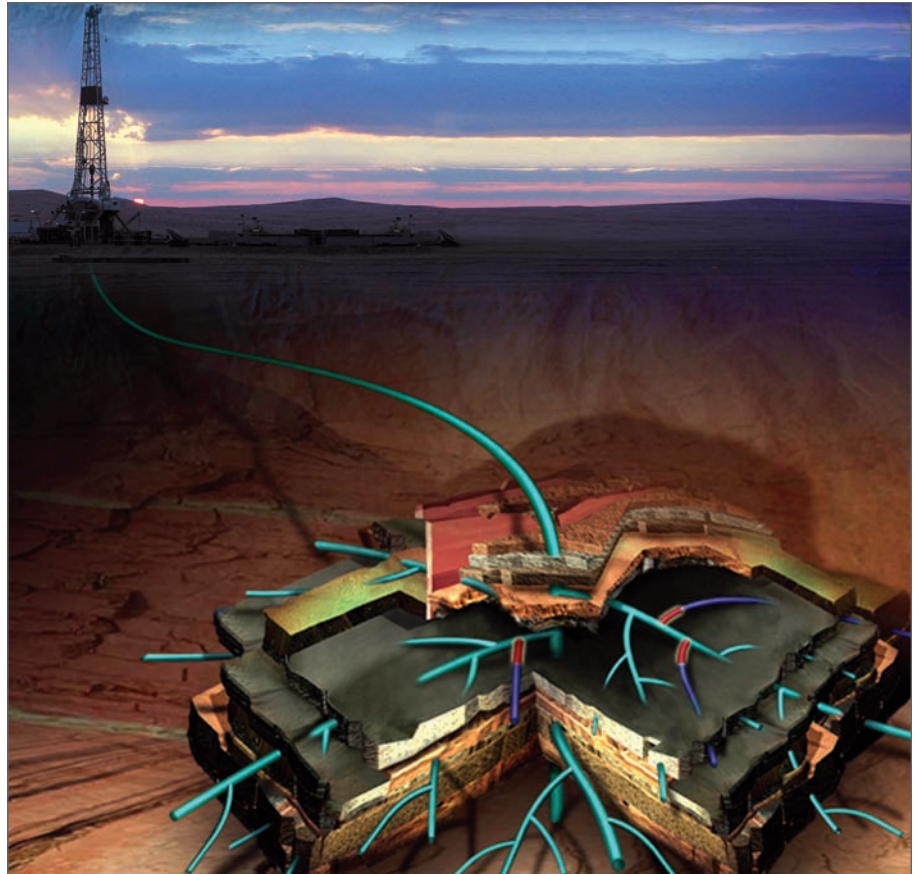
COMMONLY CITED AS the largest oil company in the world and a “swing” producer in times of crisis, Saudi Aramco faces more challenges than your average operator. Not only does it need to replenish reserves and maintain production output, but whereas other oil companies can acquire reserves through stocks, for Saudi Aramco the only way to add reserves and production is through the “bit.”

With some of the largest and most prolific reservoirs worldwide, such as Ghawar, Saudi Aramco’s acreage comprises green and brown fields located both onshore and offshore. Challenges associated with this acreage involve accessing deep oil and gas accumulations located in vast and complex carbonate reservoirs, a requirement for enhanced oil recovery and managing remote operations.

Abdallah S Jumah, president and CEO of Saudi Aramco, 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, as well as the operational challenges that we face during the execution of our activities, pose unique challenges and require solutions that cannot be brought in from anywhere in the world.”

For Saudi Aramco, recognition of the role of research and development (R&D) in meeting these challenges came about as other oil companies were shedding R&D as non-core activities. The company has created a world-class Research, Development Centre (RDC) in Dhahran with extensive laboratory and testing facilities, as well as a field engineering base at the Exploration and Petroleum Engineering Center (EXPEC). Benefit – patented commercial technologies in seismic and other niches.

Overseen by Saudi Aramco’s Engineering and Operations Services business line, the RDC is well-equipped to help maintain Saudi Aramco’s leading position in the industry by the research and development of technology and processes. Illustrating this, the centre accommodates 330 employees (75% of whom are Saudis) spread over 34,500 sq m, and 210 laboratory modules, which



Saudi Aramco photo

**Saudi Aramco is an industry leader in multilateral wells. More than 80% of its wells drilled in 2006 were horizontal wells with either single or multiple lateral sections.**

can be combined or separated. Nearly a third of the company’s United States-issued patents have been awarded to R&D Center scientists.

Typically, technologies have been developed via internal R&D and research agreements and through projects with service companies. Technologies are extensively tested in laboratory facilities before being field-proven. This approach has placed Saudi Aramco at the forefront of carbonate reservoir characterization and seismic processes, drilling technologies such as multilateral well architecture and geosteering in complex clastic and carbonate reservoirs and real-time visualization centres for down-hole measurements and optimal well placement.

EXPEC has become one of the largest upstream earth-science and engineering centers in the industry. It now provides technical expertise and special services in-house in all facets of engineering and

producing operations. EXPEC computing capacity has reached 34 teraflops, or 34 trillion floating point operations per second, which is a 300-fold increase in capacity since 1999. The seismic processing environment in the EXPEC Computer Center continues to grow, and in 2006, the company completed the largest disk installation and seismic data migration in the center’s history. A total of 650 terabytes of new storage was installed for conventional seismic processing.

Improvements in seismic processes and reservoir characterization have led to more accurate models that help Saudi Aramco plan its wells with greater accuracy. Improvements in visualization and real-time monitoring have enabled geosteering, which, combined with multilaterals, enable Saudi Aramco to increase footage drilled in productive zones. Here we look at these technologies in greater detail.

## RESERVOIR CHARACTERIZATION AND SEISMIC

Geo-scientific and engineering professionals now routinely construct 3-D models of oil and gas fields using a combination of software developed both internally and by service companies. Not only does this dramatically reduce the time it takes to characterize reservoirs and build models, it also enables geoscientists and reservoir engineers to work together during all stages of field development.

**Seismic process patents:** A major patented technology involves the application of Anisotropic Magnetic Susceptibility (AMS) for 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 deals with Edge Preserving Smoothing (EPS), a noise-attenuation technique that reduces certain types of noise without damaging the edges of the signal. Result – a much clearer picture of oil in place.

## DRILLING TECHNOLOGIES

The term Maximum Reservoir Contact (MRC) neatly describes the function of horizontal and multilateral wells. Once oil is identified, horizontal wells with multilateral branches are guided to optimal reservoir zones using advanced measurement-while-drilling (MWD) or logging-while-drilling (LWD). Well placement based on while-drilling measurements is applied in all types of drilling from onshore to offshore, and for shallow oil or deep gas targets. Formation evaluation in horizontal wells is generally a challenge because many factors can affect formation resistivity such as shoulder beds, anisotropy, borehole size and mud filtrate invasion. To ensure that well objectives are delivered, deep directional resistivity tools can be run to provide real-time measurements capable of detecting reservoir boundaries, maximize the net horizontal length drilled in the reservoir, and reduce the risk of missing oil-bearing zones.

Building on this, Saudi Aramco has successfully developed two low-cost methods for converting existing single horizontal wells to multilateral 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.

Smart wells using downhole sensors also help provide real-time monitoring and enable timely reactions to changing well and reservoir conditions to optimize production and reservoir management. In 2005, in the Shaybah field, Saudi Aramco successfully installed the first Smart Well in Saudi Arabia with a hydraulic downhole flow control with a MRC multilateral well with a total reservoir contact of 5.4 miles (8.7 km). The Haradh-III increment, brought onstream in early 2006, relies exclusively on multilateral MRC 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% and making the well a 6,000 bpd producer.

**Underbalanced drilling:** Equally as important as the company's production wells are its water injection wells, which help maintain reservoir pressure and increase oil recovery rates. Saudi Aramco has adapted underbalanced drilling to eliminate formation damage and improve injectivity, thereby eliminating the need for post-drilling acid stimulation. This technique allows formation fluids to flow into the wellbore, thus eliminating formation damage. 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 underbalanced in the Hawiyah and South Uthmaniyah areas of the Ghawar field. The knowledge gained from drilling underbalanced water injection wells was applied to drilling of oil producing wells in 2006.

## VISUALIZATION, REAL-TIME CENTRES

Saudi Aramco's 3-D visualization centres have undergone constant refinement since their inception and are equipped with the latest digital technology. New visualization techniques were developed for exploration and production, including seamless data integration between pro-

# Saudi Aramco Numbers

## 2006 New Drilled Wells

Oil wells: 333 (294 onshore, 39 offshore)

Gas wells: 35 onshore

**Total recompletions: 125 onshore, 47 offshore**

## Workovers

Gas wells: 5 onshore

Oil wells: 126 onshore 69 offshore

Total oil well workovers: 195

**Total workovers: 200**

Saudi Aramco manages more than 60 oil and gas fields, including the world's largest field, Ghawar, and the largest offshore field, Safaniya.

As of 1 January 2007, conventional crude oil reserves in the company's fields were 259.9 billion bbls. That quantity is about a quarter of the world's known total.

Reserves of gas tallied 248.5 trillion standard cu ft.

*Source Saudi Aramco Annual Review 2006.*

cessing and interpretation, and super-large 3-D seismic volume interpretation.

## REAL-TIME MONITORING OF DRILLING WELLS AND SEISMIC DATA ACQUISITION

Greater precision of well positioning is being achieved using satellite relayed real-time downhole measurements. These data are sent directly from LWD and MWD borehole tools and is also employed by all seismic crews. This has greatly improved communication between the Dhahran operational office and field operations. It has been used in the Shu'aiba reservoir in Shaybah field



Dhahran RDC

Saudi Aramco photo

## Increased Rig Count

The challenge is not just drilling and completing wells, at a time when worldwide demand for drilling rigs is at historic highs — drilling equipment is in short supply too. Despite this, Saudi Aramco has increased its drilling rig count by 26%, from 90 to 113 rigs by the end of 2006.

The total rig count was six exploration rigs and 75 development rigs (65 onshore and 10 offshore). Additionally, the company ran 32 workover rigs (24 onshore and eight offshore). It drilled 368 new development wells and 13 exploration wells and performed 206 re-entries and 136 workovers.

and the Arab-D reservoir in the Haradh area and has provided geoscientists with immediate data which is compared with existing reservoir models using powerful 2-D and 3-D visualization software. When there is a significant deviation from the expected reservoir quality or pre-planned well path, immediate geo-steering from drilling rig changes the well path so footage drilled is maximised within the optimal reservoir zone.

Techniques such as resistivity and carbon-oxygen reservoir saturation logs are used to evaluate water-flood efficiency and identify remaining oil in place. Monitoring the performance of multilateral wells has been achieved by cooperation between Saudi Aramco and its service companies. Exemplifying this is the fact that Saudi Aramco became the first in the industry able to monitor water/oil/gas flow profiles in short radius horizontal wells.

To further exploit the technological gains of MRC wells, Saudi Aramco uses a Geosteering Operations Center (GOC) located within EXPEC. Teams of geologists and service company engineers remotely guide drilling activities in real time, around the clock, helping to ensure that every well is optimally placed.

Consequently, not only has Saudi Aramco become an industry leader in completing multilateral wells, it has also become a leader in actively evaluating and implementing new technologies for better planning and monitoring such wells.

By using 3-D reservoir visualization combined with drilling technologies and real-time measurements, Saudi Aramco geoscientists and drilling engineers are planning well paths and drilling more footage across the reservoir zone. That's a proven way of keeping reserves and production up.

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*References: Production and Reserves data sourced from Saudi Aramco Annual Review 2006*

*Ghawar Arab-D Reservoir: Porous Shoaling-upward Carbonate Cycles, Saudi Arabia Lindsay et al Saudi Aramco*

*Saudi Aramco Dimensions Magazines Winter 2004*

*Saudi Arabia Oil and Gas Issue 2 Saudi Aramco and Petrobras Research Centres*

*SPE 105187 HARADH-III: Industry's Largest Field Development Using Maximum Reservoir Contact Wells, Smart Well Completions and I Field Concept Al-Kaabi, Saudi Aramco*

*SPE 105606 Optimising development well placement within Geological Uncertainty using sector model Yuen et al, Saudi Aramco* ♀