International

Middle East

Client

Petroleum Development Oman

Location

Muscat, Oman

Qarn Alam Steam Project

Project Highlights

- Developed conceptual design studies for water supply and steam generation to recover heavy oil
- Several key issues drove the project: water conservation, energy efficiency, risk management, equipment reuse, and project management
- Implemented flexible work schedules to accommodate international, cross time zone communications

Project Description

The Sultanate of Oman, the legendary home of Sinbad the Sailor, is located on the southeastern tip of the Arabian Peninsula. It is bordered by the Straits of Hormuz (the entrance to the Persian Gulf) to the north, the Arabian Sea to the east, the United Arab Emirates and Saudi Arabia to the west, and the Republic of Yemen to the south.

As in many countries in this part of the world, oil and gas productions represent a vital part of the Omani economy, accounting for some 40 percent of its gross domestic product and more than 70 percent of its export revenues. However, unlike some of its larger neighbors, who are blessed with enormous deposits of low-cost, light oil, Oman is a relatively small country with finite reserves and maturing oilfields. Maintaining production under these circumstances presents a significant challenge for the country's dominant energy company, Petroleum Development Oman (PDO), which is owned jointly by the Omani Government and Royal Dutch Shell.

Fortunately, the country has sizeable reserves of largely unexploited heavy oil in the hot, arid regions of the interior. Shell's experience using enhanced oil recovery techniques to produce heavy oil in California and Alberta led PDO to experiment with steam injection technology at its Qarn Alam field. The success of this pilot project encouraged PDO to proceed with plans to develop a full-scale commercial steam injection project, the first known use of this technology in the Middle East.

One of the key challenges of the project was finding an adequate water supply of suitable quality to produce the required 19,842 tons/day (or 18,000 tonnes/day) of steam. Because of our considerable experience in water supply and treatment for heavy oil projects in western Canada, PDO retained CH2M HILL to undertake conceptual design studies for water supply and steam generation for this heavy oil recovery project.

Unique Project Features and Challenges

Several features of this project presented some unique technical and logistical challenges.

Water Conservation – Potable water is a scarce and precious commodity in this desert region. Only brackish (saline), non-potable water sources were considered as potential supplies for the project, and considerable effort was made to ensure highly efficient use of even these limited resources.

Energy Efficiency – To meet its growing electrical power demands, while minimizing greenhouse gas emissions from this project, PDO plans to utilize cogeneration to produce both electricity and steam. Gas turbines will be used for power generation, and heat recovery steam generators will extract waste heat from the turbine exhaust gases to provide most of the project's steam requirements.

Risk Management – Given the remote project location and the need for high system reliability, the emphasis was on selecting technologies with which local experience existed and adopting a sparing philosophy that provided backup for critical process equipment.

Equipment Reuse – Efforts were made to integrate reuse of high value process equipment from the existing pilot plant into the commercial-scale development. This not only provided opportunities to reduce capital cost, but also facilitated the use of equipment with which operators were familiar.

Project Management – PDO's project team was situated in Muscat, Oman, while the core CH2M HILL team was based in Calgary, with specialists distributed in three offices, spanning 12 hours of total time zone difference.

The workweek in Oman runs from Saturday to Wednesday, further exacerbating the challenges of business communication with our North American team. The team relied heavily on electronic tools to efficiently generate, deliver, and review over 100 work products in a four-month period. Flexible work schedules facilitated regular communication between the client and consultant teams.

Water Supply and Treatment

Because of the need to conserve all supplies of fresh water for domestic use, only saline, non-potable water sources were considered as potential candidates for this project. The project team evaluated three water supply options:

- Desalinating seawater and pumping it nearly 200 km via a new pipeline;
- Developing a local brackish groundwater supply, which would also require desalination before use;
- Recycling low-quality "produced" water (the oily formation brine recovered with the oil), which would require de-oiling and desalination as well.

Using the local supply of brackish groundwater (which is about two-thirds as salty as seawater) offered the advantages of lowest cost and lowest technical risk. To minimize the demands placed on this limited, albeit low-quality resource, significant efforts were made to ensure its most efficient use.

Reverse osmosis (RO) will desalinate the brackish groundwater, providing approximately 70 percent recovery of the feedwater as high-quality permeate. The 30 percent reject stream containing the concentrated salts normally would be disposed of as a waste.

However, to provide maximum recovery of useable water, the RO reject will be further processed in a mechanical vapor compression (MVC) evaporator to recover high-quality distillate, resulting in an overall water recovery efficiency of greater than 90 percent.

An MVC evaporator was used to desalinate groundwater for the existing pilot plant. Reusing the existing equipment in this modified application for the commercial project is an effective way to provide significantly improved water utilization efficiency, while minimizing additional capital cost and integrating a process technology with which PDO operators are familiar.

While the produced water currently recovered with the oil is too saline to reuse for steam generation, reservoir modeling predicts that the salinity will decline in future due to the connate water dilution with condensing steam. Provision has been made to recycle produced water in the later stages of the oil recovery project. This will reduce the reliance on brackish groundwater to meet the incremental water requirements of future phases.

Power and Steam Generation

PDO owns and operates its own power generation and distribution system, which is interconnected with the national grid operated by the Ministry of Electricity and Water. Power loads in both PDO and the country are forecast to grow significantly over the next ten years.

This projected load growth, combined with the Omani Government's initiative to privatize power generation, provided an opportunity to locate new power plants strategically, so that their waste heat can be used for steam generation. Since the energy input requirements of a steam injection project represent the highest component of the operating cost, generating steam with waste heat provides a tremendous savings in the total production cost per barrel of oil recovered. Reducing the amount of natural gas burned also dramatically reduces the quantity of greenhouse gas emissions that the project would otherwise create and conserves the gas for future, higher value uses.

PDO intends to separate the development of the Qarn Alam project into three phases to meet the projected growth in power demand. Whereas the first two phases will be timed to meet PDO's own power needs, it is anticipated that the power production from Phase 3 will be exported to the national grid.

Natural gas burning in gas turbines will produce the power. The hot, turbine exhaust gas will then be passed through heat recovery steam generators (HRSGs) to produce most of the project's steam requirements. To meet the heat requirements of the reservoir, existing, direct-fired oilfield steam generators used in the pilot phase will be integrated into the commercial project.

Project Delivery

Effective communication is key to the successful delivery of any project. When client and consultant teams are separated by up to 12 hours of time difference, and work different days of the week, it is particularly challenging to ensure that everyone is kept fully informed and that the work proceeds in a timely, efficient manner.

PDO helped tremendously by ensuring the CH2M HILL team was properly chartered at the outset of the project. They accomplished this by first developing a thorough, design basis document incorporating all the information the CH2M HILL team needed to undertake the studies. The project was then kicked off with an intensive, full-week orientation session in Oman that included a

project briefing, a site visit, and detailed, collaborative work planning to ensure expectations, constraints, and procedures were fully understood.

CH2M HILL had a large quantity of work to complete in only four months. The work was executed in four sequential stages, with key milestone review points between each stage. Each stage was further broken down into several distinct tasks, each with a well defined work product or deliverable, for example, technical memoranda, drawings, and cost estimates. A target date was established to complete over 100 work products, making it possible to track and report the progress of the project on a weekly basis. This ensured that each stage of the work was completed on time.

The differences in time zone and workweek were actually used to the team's advantage. If questions and requests for information were e-mailed by the close of business one day, the team on the other side the world had a full day to respond, and a reply could often be received overnight. CH2M HILL produced all work products electronically, e-mailing each week's deliverables to PDO by close-of-business on Fridays.

This provided the client with a set of documents to review when their workweek began in Muscat on Saturday morning. Initial review comments were often received in Calgary by Monday morning, allowing the team to maintain the demanding project schedule with virtually no delays attributable to waiting for client feedback.

The project team monitored and responded to e-mail communication with PDO seven days a week. Weekly phone communication facilitated discussions of key issues and ongoing progress reviews. Face-to-face technical review meetings were held at key project milestones, alternating between Calgary and Muscat.

Project Successes

PDO and CH2M HILL forged a true partnership to successfully deliver this technically and logistically challenging assignment that represents the many attributes of an award-winning project.

Innovation and Technology Advancement

- This project represents the first known use of steam injection technology for heavy oil recovery in the Middle East, demonstrating successful transfer of North American technology to a developing nation.
- The coupling of two desalination processes (reverse osmosis and distillation) represents a unique application of these technologies, providing an economical water supply for the project and a highly-efficient use of a limited resource.

Added Value

- The ability to incorporate and reuse existing process equipment from the pilot plant into new applications in the commercial project (MVC evaporator and steam generators) helped reduce the capital cost, while providing technology with which operators are familiar.
- Using cogeneration to synergistically supply PDO's and the country's growing electrical demands, while meeting the project's steam requirements,

provides highly efficient energy use, dramatically reducing the cost of enhanced oil recovery.

Degree of Difficulty

- The harsh site conditions—especially the lack of fresh water supplies and extreme summer temperatures—imposed particularly difficult challenges to developing an enhanced oil recovery project at this site. These were overcome by employing desalination technologies that made it possible to use a low quality water supply and did not rely on ambient cooling to recover distillate.

- The logistical and administrative challenges created by the physical separation of the client and consultant teams were overcome by:

  - a strong commitment by both teams to maintaining a high degree of communication;
  - utilizing electronic tools to facilitate work products production, delivery, and review; and
  - effectively exploiting differences in time zones and workweeks as advantages, rather than impediments, to maintaining the project schedule.

Risk Management

- PDO used pilot testing to demonstrate each component of the project—water treatment, steam generation and injection, and reservoir response—removing much of the uncertainty associated in applying new technology.

- The project will not rely upon a water supply for which there is a competing or higher value use and will utilize several other environmental protection measures, thereby mitigating the risk of public opposition and project delays due to regulatory hurdles.

Social Benefits

- The project will help develop an economically important petroleum resource for Oman while supporting the country's goals of citizen education, training, and job creation. The experience gained with early application of enhanced oil recovery in the region also will give PDO staff the opportunity to develop core competencies with the technology, important for the future development of Oman's natural resources.

- The project will develop these resources without depleting the region's limited reserves of fresh water. The highly efficient use of low quality brackish water, with ultimate conversion to recycled produced water, protects and preserves the scarce supplies of fresh water for domestic use.

- Electricity and steam cogeneration will not only provide the power supply necessary for ongoing growth, but will enable PDO to minimize the greenhouse gas emissions from the project by developing this oilfield almost exclusively with energy derived from waste heat.