The Beginning of the End: A Review of Abandonment and Decommissioning Practices

The oil and gas industry anticipates growing activity in well-abandonment and platform-decommissioning operations. Technically sound well-abandonment practices are essential for long-term environmental protection, especially as regulations become more stringent and complex. Although advanced technologies and techniques bring new meaning to the “permanent” aspects of abandonment work, operators seek to minimize abandonment and decommissioning costs because these expenses are not recouped.

The life of a well comprises numerous stages. The discovery of a new accumulation of oil or gas after months or years of exploration and drilling invigorates the responsible technical team. Achieving first production is another uplifting milestone. Successful enhanced-recovery operations can make the waning stages of production financially and technically rewarding. The stage that no one seems to enjoy facing is the final cessation of production and the abandonment of wells and production facilities. Although abandonment is supposed to mean permanent termination, the effects of some abandonment practices can be felt for many more years than the relatively brief producing life of the average well.

Well abandons are becoming increasingly frequent as aging fields reach their productive and economic limits. The cost of decommissioning the world’s 6500 offshore platforms is estimated at $29 to $40 billion over the next three decades. Onshore, tens of thousands of wells must be abandoned someday.

Responsible operators now seek to balance environmental responsibilities with the profit demands of shareholders. Shoddy plugging and abandonment (P&A) operations are expensive to remediate and exact a toll on both the environment and the reputation of the company. Local P&A mishaps can affect the reputation of the entire oil and gas industry. With those issues in mind, many operators are upgrading their well- and field-abandonment procedures to ensure that abandoned reservoirs truly are permanently sealed and facilities properly decommissioned. In this article, we review P&A and decommissioning practices, explain how sound abandonment practices protect the environment and discuss new technologies that reinforce the meaning of the “permanent” part of abandonment work. We also discuss permanent-abandonment challenges and practices, and examine well- and platform-abandonment operations in Oman, Canada, the Gulf of Mexico and the North Sea.
Wellbore-Abandonment Challenges and Solutions

The key goal of any well abandonment is the permanent isolation of all subsurface formations penetrated by the well. Although sealing depleted reservoirs is an important concern in P&A procedures, ideal abandonment operations isolate both producing reservoirs and other fluid-bearing formations. Complete isolation prevents gas, oil or water from migrating to surface or flowing from one subsurface formation to another. Experts estimate that a high proportion of seals placed in wells may be faulty.²

Leaking seals pose risks to the environment—groundwater resources and the overlying land or sea—and must be repaired, but remedial plugging operations are difficult and expensive. Sealing a well correctly at the outset is far easier, even if the initial financial outlay appears high. Considering well abandonment at the earliest stages of the well design makes sense because the quality of the primary cement between the casing and formations is a key factor in successful well abandonment years later.³ For decades, oilfield engineers have recognized that Portland cement is the best material to seal abandoned wells. It is durable, reliable, available worldwide and relatively inexpensive. Complete removal of drilling mud and filter cake during primary-cementing operations decreases the risk of forming a microannulus or channel in the cement sheath, and improves bonding between rock formations, cement and casing. Bulk shrinkage of ordinary Portland cement slurry as it sets can create small cracks and gaps that can become flow paths.

Any deficiencies in primary cementing tend to affect long-term isolation performance. Wide fluctuations in downhole pressure and temperature can negatively affect cement integrity or cause debonding. Tectonic stresses also can fracture set cement. Regardless of the cause, loss of cement integrity can result in fluid migration, impairment of zonal isolation or casing collapse, even when high-quality cement is placed properly and initially provides a good seal.

Advanced, flexible cement provides greater long-term cement integrity than ordinary Portland cement.

---

*Primary cementing parameters that affect sealing. Incorrect cement density can result in hydrostatic imbalance. Poor mud- and filter-cake removal allows gas to flow up the annulus. Premature gelation leads to loss of hydrostatic pressure control. Excessive fluid loss allows gas to enter the slurry column. Highly permeable slurries provide poor zonal isolation and resistance to gas flow. Significant cement shrinkage and cement failure under stress create fractures and microannuli that transmit fluids. Poor bonding at cement-casing or cement-formation interfaces also can cause failure.*
cement because it resists stress cracking and microannulus formation. Introduced in 2000, FlexSTONE cementing technology incorporates an optimized distribution of flexible particles into the cement matrix to adapt to temperature and pressure variation, providing zonal isolation for the life of the well and beyond. The corrosion resistance, low permeability, flexibility and posthydration linear-expansion capabilities of FlexSTONE systems make them ideal primary cements and abandonment-quality cements (right).

If fluids are migrating from a well that must be abandoned, then the first challenge is to locate the fluid-migration path. Typically, subsurface fluids migrate through completion components, leaky plugs, deficient cement squeezes, or flaws in the primary cement sheath or the caprock—the relatively impermeable formation that encloses the reservoir. The caprock might be compromised by natural fracturing or by fracture-stimulation treatments. When multiple reservoirs exist, identifying which one is leaking enables targeted remediation. Knowing the condition of primary and secondary cement is vitally important. Personnel involved in abandonment must understand the geology, wellbore geometry and accessibility, downhole equipment and its condition, reservoir pressure and potential fluid-migration paths to abandon a well successfully (right).

2. While the estimates of the proportion of leaky seals vary widely from one region to another, in a survey initiated in 1993 in the Lloydminster area, western Canada, Husky Oil reported that 45% of surveyed wells suffer from gas-migration problems. On the basis of their research, the company estimated that remediation of these wells might cost $15,000 to $150,000. For more information: Schmitz RA, Cook TE, Ericson GMJ, Klebek MM, Robinson RS and Van Stempvoort DR. “A Risk Based Management Approach to the Problem of Gas Migration,” paper SPE 35849, presented at the International Conference on Health, Safety & Environment, New Orleans, Louisiana, USA, June 9-12, 1996.

3. Primary cement is the initial cement sheath placed around a casing or liner string. The main objectives of primary cementing operations include zonal isolation to prevent migration of fluids in the annulus, support for the casing or liner string, and protection of the casing string from corrosive formation fluids. For more on primary cementing: Bonett A and Pafitis D. “Getting to the Root of Gas Migration,” Oilfield Review 8, no. 1 (Spring 1996): 36–49.


5. Isotope analysis of gas from two formations in the Lloydminster area demonstrated that the shallower formation was more prone to gas-migration problems. For more information about this example: Schmitz et al, reference 2.
Another challenge in P&A procedures is that relevant documents detailing the life of the well, such as well logs and schematic diagrams, might not be accessible. Information about the geology might be lost or unavailable because of the time that elapses between first production and well abandonment. This time frame can be decades. Also, it is common for wells to change ownership.

Operators also must strictly adhere to local well-abandonment regulations (below). In some regions, regulators grant permits for specific abandonment procedures and observe key stages of the operations. Compliance requires careful planning and coordination, which, for some operators, may be facilitated by specialized databases and software.

Regulations have changed considerably over the years, and keeping track of them requires engineering, environmental, legal and safety expertise.

In many regions, there are rules and regulations in place that constitute the requirements for well abandonment. In areas where the regulatory authorities do not supply minimum standards, operators tend to follow their own internal standards. Most of these standards are similar because many originated in the North Sea, where environmental-protection goals significantly influence operations.

### Examples of P&A Regulations

<table>
<thead>
<tr>
<th>Texas, USA¹</th>
<th>Albertas, Canada²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well abandonment regulations specify:</td>
<td>Openhole and cased-hole abandonment require:</td>
</tr>
<tr>
<td>• Written notice of intent to plug and proposed procedures</td>
<td>• Regulatory preapproval</td>
</tr>
<tr>
<td>• Commencement of plugging operations within specified time limits</td>
<td>• Plans that meet regulatory standards, including special requirements in oil sands and areas having gas-migration problems</td>
</tr>
<tr>
<td>• Plugging by the Railroad Commission of Texas and reimbursement by the operator under certain conditions</td>
<td>• Compliance with timing and notification requirements</td>
</tr>
</tbody>
</table>


^ Examples of well-abandonment regulations. Designed to protect water and hydrocarbon resources, some regulations include standards for the type of cement used and the locations of cement plugs in the well, how deeply below surface the casing must be cut, and how the well location should be marked. Returning the surface to a pristine condition also is part of the job. In areas not subject to regulation, operators generally follow their own guidelines.

### Rigless Wellbore Abandonment

Preparation is a key ingredient in well abandonment, including a thorough assessment of the near-wellbore geology and the unique mechanical condition of the well. In a straightforward case, well abandonment begins with cleaning the production tubing and cementing, or squeezing, the production perforations. After the tubing above the production packer is perforated, cement is circulated between the tubing and casing. At shallower casing-shoe levels, multiwell perforations are shot and cement is circulated in all open annuli to achieve a wall-to-wall cement barrier. Finally, the tubing is perforated at a shallow depth—perhaps 150 m (490 ft)—and a surface cement plug is placed. When all cement plugs have been placed and tested, the wellhead and casing stump are removed.

In reality, most abandonment operations are much more complicated. Multiwell onshore-abandonment programs demonstrate both the complexity of the operations and the gains in efficiency and cost savings achieved when using a coiled tubing unit instead of a workover or drilling rig.

Although pioneered on land in 1983 in the Prudhoe Bay field, Alaska, USA, rigless well-workover procedures using coiled tubing units have been adapted for abandonment operations worldwide. Rigless abandonment operations also have been performed offshore for more than a decade, but removing production facilities generally requires mobilizing heavy lifting equipment (see “Field Abandonment and Platform Decommissioning,” page 37).

There are clear advantages to rigless abandonment using a coiled tubing unit for a multi-well abandonment program. The equipment costs less offshore and often is much easier to mobilize; onshore, its value lies in time savings over a comparable hoist operation. Coiled tubing allows precise placement of cement plugs, even in deviated wells. Also, coiled tubing operations can be performed without killing the well or removing the production tubing or wellhead.

In several depleted oil and gas fields onshore Oman, Petroleum Development Oman LLC (PDO) initiated a multiwell abandonment program with Schlumberger (next page). The primary concern was to properly abandon all producing zones and protect aquifers while minimizing cost and risk.

PDO began its rigless abandonment project in November 2000 following a research report on permanent plugging materials and rigless applications. After an initial literature study, a review of the PDO well inventory revealed 60 redundant exploration wells located throughout their concessions. PDO decided to begin the 60-well abandonment project in southern Oman, where formation pressure regimes are mainly at or below hydrostatic levels.

PDO prepared the scope of work and equipment requirements for the contract tender, and soon realized that the complexity and variety of the abandonment activities required an integrated services approach. A key element of this rigless abandonment program would be coordinating all well services to maximize efficiency. Ideally, the lead contractor would perform at least 80% of the work, and preferably could perform the two most critical activities, perforating and cementing.

PDO developed five main criteria for optimal rigless abandonment performance:

- **Supermobile equipment**—All equipment, including a mobile camp, would be mounted on wheels to allow faster relocation, given the fact that the units must move every four to six days.
- **Self-supported operations**—The contractor takes care of nearly all activities, such as supplying materials, transport and subcontractor services, with minimal operator involvement.

PDO supplies only programming, air transport, communication facilities, some mud chemicals and a site representative.
**Dry location concept, also known as zero discharge**—No fluids are drained on or near the wellsite. This eliminates the possibility of repairing or rebuilding waste pits at abandonment locations. Although fluid circulation and dumping are inevitable during the job, all fluids are stored in tanks. Dry locations speed up the abandonment and restoration job by approximately ten days per well because no time is spent cleaning a waste pit or waiting for the location to dry. Previously, this required as much as several months.

**One-stop job**—Each wellsite is visited only once and the entire abandonment job must be completed at that time. Any return to the site substantially delays the next operation.

**Minimum mileage**—Equipment moves are optimized to reduce move time and optimize transport. With the PDO concessions covering approximately 41,000 square miles [110,000 square kilometers], executing the moves in accordance with health, safety and environment (HSE) guidelines is a crucial requirement. From September through December 2001, 18 wells were abandoned, with typical savings of 30% over previous abandonment procedures. The wells were up to 25 years old and produced approximately ten days per well because no time is spent cleaning a waste pit or waiting for the location to dry. Previously, this required as much as several months.

Though the lessons learned from each well were incorporated into subsequent operations, procedures could change significantly from one well to the next. Typically, the need for these changes became clear only after the first entry into a well. Thus, abandonment work differs greatly from new-well engineering, where forward planning is possible. Abandoning old wells requires an initial plan plus constant communication between field and base once the job commences, since the status of the well at surface and downhole differs for each well. For these reasons, seasoned site representatives and experienced, dedicated contractor staff are required to cope with the constant changes dictated by well conditions.

Challenges encountered to date included heavy, thick crude oil in the production tubing and “A” annulus—the space between the tubing and the first string of casing—that made it impossible to run wireline. Corrosion of the outer casing of some wells required additional plugging through the outer annulus of each well. Some wells had more than one annulus, requiring perforations through overlapping, concentric casing strings. On the other hand, some wells had good injectivity, which simplified downhole discharge by bullheading the cleaning slugs into the formation. Bullheading saved time and effort compared with handling the cleaning slugs at surface. All these situations created a need for detailed programming for each individual well.

Common to all abandonments, however, is the requirement to perform the operation flawlessly the first time and to protect the environment at all stages of the operation. Accordingly, all locations are kept “dry” to speed restoration to their natural state. All waste fluids must be removed for safe disposal at PDO-designated areas, except for excess cement, which is nonhazardous. Fluids used on site are stored in tanks. Since there are no rigid governmental abandonment directives in place, the applicable PDO abandonment policy and standards are developed in line with the United Kingdom Offshore Operators Association (UKOOA) standards set for North Sea operations and similar Dutch government-accepted standards.

---


10. Bullheading refers to the technique of forcibly pumping fluids into a formation. In addition to fluid-disposal operations, bullheading may be performed when formation fluids have entered the wellbore during a well-control event or when normal circulation cannot occur, such as after a borehole collapse. During bullheading operations, the fluid usually enters the weakest formation.
Abandonment of the Jisr-1 well, located in southern Oman, represents an average degree of difficulty for the PDO well-abandonment program (right). The operation began as a coiled tubing rig was moved on location (next page, top). Because the well was 12 years old, all valves on the Christmas tree were back up with new valves, and coiled tubing blowout preventers were rigged up to ensure well control. Gas-detection and other safety equipment was installed before entering the cellar.11

Next, the tubing-hanger plug, used for temporary well suspension, was removed. The production tubing and "A" annulus were cleaned by jetting cleaning fluids down the tubing and up the annulus. The cleaning fluid contains surfactants and acids that remove sludge, oil and paraffin. Cleaning is critically important because seals within the wellbore can shift if sludge or other material moves after setting cement plugs. Also, cement will not form a perfect hydraulic seal with materials that are coated with hydrocarbon.

The production tubing and 9%-in. casing sump were cleaned with a high-pressure jetting tool run on coiled tubing. The tubing and the "A" annulus were then displaced with 11.4-kPa/m (0.5-psf/ft) salt brine. High-pressure jetting has proved to be an effective, environmentally friendly method for cleaning the tubing and sump, as waste generation is kept to a minimum. In cases of heavy-oil contamination, light crude and TubeCLEAN slugs are pumped and bullheaded through the perforations where possible. These were not required on Well Jisr-1, where a 2-m³ [13-bbl] surfactant wash, with a 10-minute contact time, was considered sufficient to clean the "A" annulus.

With coiled tubing, the operations team set a bentonite spacer on bottom to serve as a base for the cement plug. On Jisr-1, the perforations were shot 342 m [1122 ft] above the base cement plug. The PDO requirement is to set the reservoir-isolation plug from 50 m [164 ft] below the lower perforation to 50 m above the top reservoir. To comply with this requirement at minimum cost, a 280-m [920-ft] bentonite spacer was spotted on bottom as a filler. The first cement plug was set through coiled tubing across the perforations. A second plug was set higher in the wellbore, opposite the 13%-in. casing shoe, after a bridge plug was set inside the 3%-in. production tubing using coiled tubing. The 3%-in. tubing and 9%-in. casing were perforated and a wall-to-wall cement plug was placed. Next, a bridge plug was set at 155 m [508 ft], and the tubing was perforated at 150 m. Finally, the surface cement plug was pumped. In contrast to procedures for the previous cement plugs, PDO abandonment standards do not require pressure-testing of the surface plug.

In most of the wells in this abandonment program, the cells are about 2.6 m [8.5 ft] deep. Once the wellhead was cut 50 cm [1.6 ft] above the cellar floor, a 10-mm [0.4-in] thick steel plate was welded to the stomp, and a small pole with the well number was installed to mark the location above the surface. Then, the cellar was temporarily filled with sand until final site restoration. The operation concluded with rigging down the coiled tubing unit, and moving the severed wellhead assembly and all junk from the location (next page, bottom). This operation took five days, including a two-day rig move. Placing cement plugs consumed much of the remaining time. Rig moves for closely spaced wells typically require 6 to 10 hours. Moves greater than 15 km [9.3 miles] require relocating the work camp.

This multwell abandonment program will continue through much of 2002. The most complicated abandonment operations are scheduled late in the program to capitalize on the experiences of the previous operations. Other challenges continue to be addressed by the operations teams. Because unit moves consume a substantial part of the operational time, achieving the "supermobile" equipment goal and using multifunctional, fit-for-purpose equipment will...
increase efficiency. In addition, the major, daily activity is placing cement plugs in the wellbore, so there is considerable interest in developing short but safe cement-setting times.

In an operation such as rigless abandonment, where the benefits are in the time saved, long waiting-on-cement (WOC) times are a major hurdle. Slurry recipes are modified frequently to reduce pumping and thickening times as field experience increases. Current conventional through-coil slurries have 3-hour pump times and have been tagged, or contacted, in 11 hours. UniSLURRY formulations are being considered to reduce this time even more. UniSLURRY systems can be used for all cementing operations over a wide temperature and density range, addressing most oilfield cementing requirements. The UniSLURRY family consists of solid and liquid fluid-loss additives and liquid retarders. Their versatility simplifies the logistics of cementing operations by reducing the number and quantity of additives that have to be transported and, eventually, stored at the wellsite. The additives synergistically reduce overall additive concentrations while maintaining slurry quality.

As the operation teams prepare to abandon the most challenging wells, PDO is considering the use of flexible systems from the CemSTONE family. FlexSTONE long-term zonal isolation technology is expected to increase resistance to cracking under changing field conditions and provide an abandonment-quality plug that will last longer than ordinary cement plugs. Another advantage of the FlexSTONE slurry system is that it can be designed to expand, which eliminates any possible bulk shrinkage that might lead to loss of isolation. The expansion and flexibility will ensure excellent bonding with the casing and prevent the development of a microannulus between casing and cement plug so the well remains properly abandoned over time. An added improvement is faster compressive-strength development for slurries based on optimized particle-size distributions, such as FlexSTONE systems, than for conventional slurries, reducing the WOC time for pressure-testing the plugs. Laboratory tests have confirmed the faster compressive-strength development. The FlexSTONE system is one of many new systems that will be employed over the course of the PDO abandonment project.

11. The cellar is a pit located below the drilling rig that holds the casinghead and casing spools. The depth of the cellar allows access to the master valves of the Christmas tree from ground level.

^ Typical P&A site in Oman. Mobile equipment, such as the coiled tubing rig (orange), allows P&A jobs to be completed in about five days (top). Camels visit the sites from time to time (bottom).

^ Typical restored desert location in Oman after well abandonment.
Reduced-density LiteCRETE slurries are a possible solution for interaquifer isolation, where heavy fluid losses make the use of conventional slurries impractical. The use of dropped propellant and pelletized bentonite to isolate well sections that are below the reach of conventional coiled tubing, either because of borehole restrictions or depth, is also being investigated. The use of resins to seal 1/8-in. pressure-transmitting systems and control lines has been successfully yard-tested and is awaiting a suitable candidate well for a full field test. This procedure will permit wells with control lines to be abandoned without a rig, rather than using a rig to pull the completion. The development of resins also may lead to short, low-volume plugs with quick setting times that will replace expensive inflatable packers and mechanical bridge plugs.

Remediation of Imperfect Abandonments

In some cases, the initial well-abandonment procedures fail to seal the reservoir completely or permanently, and remedial operations must be undertaken. This is particularly troublesome in gas wells because gas can pass through micron-scale leaks easily. Even high-quality primary cements sometimes fail to seal microannuli at pipe-cement or cement-formation interfaces. Remediation is essential for protection of groundwater resources.

Perhaps the most persistent efforts to seal small gas vents in onshore wells are occurring in western Canada. PanCanadian Energy Corporation, for example, is working steadily to improve all aspects of its well-cementing operations; recently, it has focused on optimizing remedial cementing for permanent well abandonment. Working with Schlumberger, PanCanadian has sealed vent flows in abandoned gas wells in Alberta using an ultralow-rate squeeze-cementing technique.

In a well in the Killam North field, two squeeze attempts failed to stop gas migration to surface. Another well in Bantry field also had been squeezed twice without success (above left). Both wells were permanently abandoned after successful ultralow-rate squeeze operations with advanced cementing technology.

A key ingredient in sealing the gas vents was the SqueezeCRETE remedial cementing solution, which uses optimized particle-size distributions to penetrate and fill minute gaps. The extremely low set-cement permeability and resistance to cracking enhance the performance of SqueezeCRETE technology.
Prior to use of new cementing technology in the field, laboratory testing of ordinary microcement and SqueezeCRETE systems demonstrated that the ordinary microcement lost water rapidly and penetrated only a short distance in the narrow slot before forming a bridge. In contrast, the SqueezeCRETE system evenly penetrated the full 225-mm (8.9-in.) length of the apparatus without fingering or bridging (previous page, bottom).

The ultralow-rate squeeze process required pumping rates as low as 5 L/min [0.03 bbl/min] to limit friction pressure and place as much slurry in the gap as possible. The SqueezeCRETE water content is much lower than typical Portland cement slurries, so the solid particles fill the voids readily without having to apply moderately high pressure to force water from the slurry. Maintaining a relatively low pressure reduces the potential for casing or tubing to expand as slurry is pumped through and then to relax as pressure is released. Even minor casing-shape changes during cementing operations can form a microannulus. Pumping continued as the cement set so that gas could not migrate into the cement.

Subsequent gas-migration tests of the Killam North and Bantry field wells confirmed that the gas vents had been sealed and that the wells met regulatory requirements for abandonment. Because tens of thousands of gas wells must be abandoned in western Canada alone, and many others worldwide, innovative cement-remediation technology and techniques may become increasingly important for successful permanent abandonment of wells with gas leaks.

Field Abandonment and Platform Decommissioning

Once individual wellbores have been plugged and abandoned, the pipelines, facilities and other structures in the field must be decommissioned and removed. The surface site must be returned to a pristine condition. These operations can be challenging onshore; in offshore environments, especially in deep water, P&A and decommissioning procedures can become monumental endeavors that require careful coordination of several specialized crews.

Offshore production-platform decommissioning is subject to extensive regulation worldwide. Decisions about when and how to decommission platforms involve complicated issues of environmental protection, safety and cost. Limited availability of heavy-lift equipment necessitates significant advance planning to remove platforms. Operations typically are scheduled to avoid rough weather.

Offshore field abandonment and platform decommissioning encompass abandonment of each well in the field. Permeable subsurface formations are isolated permanently from each other and the surface. Each well is plugged and the casing is cut at some depth below the seabed, as specified by local regulations. Pipelines also must be decommissioned and removed. The pipelines may be reused, sold as scrap or treated as waste.

Next, surface facilities and other structures are decommissioned, which may involve partial or complete removal or toppling in place. This may begin with removing the platform deck or topsides, followed by removing the supporting structure, known as the jacket, or the entire structure may be removed in one piece. Depending on the method selected, extensive diving operations may be necessary to cut the structure into pieces. Finally, the seabed must be remediated.

Typically, platform removal is the most expensive part of decommissioning operations because of the expensive lifting equipment that must be mobilized. Ongoing advancements in lifting technology should make platform removal safer, quicker and easier. Most offshore platforms are customized, so decommissioning operations are tailored for the specific configuration and conditions.

Maureen Platform Refloating

The Maureen platform, installed in the UK sector of the North Sea in 1983 by operator Phillips Petroleum Company United Kingdom Limited and partners, was designed with recycling in mind. Because of the marginal reserves of the Maureen field, the platform was built to be refloated, moved and installed to produce oil from another field after depleting the Maureen field (above). In 2001, after eight years of planning and...
preparation, the platform was refloated and relo-
cated successfully to Norway, where it awaits
reuse or dismantling.22

Unique among North Sea production platforms, the Maureen platform rested on a steel-gravity
structure rather than the more common concrete-
gravity structure; its three storage tanks served
as legs for the platform.23 The storage tanks
double as ballast tanks when the platform is
towed. Its facilities integrate all equipment nec-
essary to drill, produce and store oil while also
accommodating personnel. The main platform
components—the steel-gravity structure and the
deck—were constructed onshore and mated
near the shore before being towed to the field.

An articulated loading column (ALC) was
installed to move oil into tankers because a
pipeline to shore was uneconomic.

The platform supported 13 production
wells and seven water-injection wells in the
Maureen field, which produced 223 million bbl
(3.5 million m³) of oil between 1983 and 1999.24
In addition, a single subsea well in the Moira
field was tied back to the Maureen platform. As
production declined, Phillips began to study
decommissioning options.

Platform decommissioning typically involves
multiple operations.25 Before any operations
begin, regulatory agencies require proof that the
abandonment plans will meet environmental and
safety standards. The first step is to cease produc-
tion and abandon each well. Next, the platform
is decommissioned, after which it may be
dismantled and removed. The size, water depth
and structural condition of the platform strongly
influence dismantling and removal plans. The
most common options for offshore platform
decommissioning include total or partial removal,
topping in place or reuse. As in most offshore
operations, equipment availability and weather
are critical factors. Following decommissioning
operations, the site must be surveyed to ensure
navigational safety and environmental protection.

Total removal of offshore facilities leaves the
seabed free of debris, which is desirable for fish-
ing but tends to be expensive. Partial removal
reduces cost, but necessitates careful surveying
of the remaining structure to ensure navigational
safety. This option currently is open only to structures greater than 10,000 metric tonnes [11,000 tons] in the OSPAR Commission area.26 Toppling a platform in place, which will be discussed later, is considerably less expensive than removal, but is illegal in North Sea and northeast Atlantic Ocean areas under OSPAR regulations. The operation would have to ensure that the platform is devoid of environmental hazards and falls as intended. Some well-maintained platforms are left in place or moved to another location for possible reuse.

Studies of the Maureen platform revealed more than 60 possible removal options. Of these, six were considered achievable, and each of those required reflating the platform before subsequent disposal operations. Computer simulations of reflating operations, including issues such as metal fatigue, confirmed that the operations could be performed safely.27 The studies confirmed that reusing the platform was feasible, even after more than 18 years of production, because of the excellent maintenance of the facilities.28

All the wells were abandoned and the conductors and risers cut before reflating the platform. Seawater in the storage tanks was pumped out to provide buoyancy. Reflating operations began with water injection below the platform to lift the structure from the seabed. Aker Offshore Partner performed the reflating operation in about 60 hours without incident (previous page). Operational arrangements included preparing extensive contingency plans—particularly to provide additional buoyancy if necessary—and constant monitoring of ascent rate and tank pressures to achieve the desired draft for towing.

Despite marketing the platform worldwide for several years, Phillips has been unable to identify a full reuse option for Maureen that satisfies its five criteria—regulatory, technical, commercial, environmental and scheduling. Partial reuse options also have been evaluated, with the most viable being a proposal from Aker to turn the bases of the platform and parts of the ALC into a deepwater quay at Stord, Norway.

Toppling an Offshore Platform

In some regions, platforms may be abandoned in place to form an “artificial reef.” Toppling a platform in place requires significant preparatory work to ensure safety and care for the environment. In the Main Pass area, Block 254, in the Gulf of Mexico, the production platform was toppled in place in August 2000 (above right). The
Toppling a platform in place. These time-lapse photographs show the controlled sinking of the platform, which took 37 seconds from first motion to complete submergence.
operations, which took several months of planning and coordination by operator Unocal, involved contractors for marine operations, engineering and diving services.

From the start, Unocal worked with several agencies to be sure that all operations would comply with existing regulations. The company also decided at an early stage not to use explosives to topple the platform because of the abundant marine life in the area. Next, the team had to prepare for all aspects of decommissioning and topping operations.

The platform, which sat in 280 ft [85 m] of water, was installed in 1975. Six wells produced to tanks mounted on the decks, so there was no pipeline to abandon. However, the company sought to topple the deck and jacket together, an operation not attempted previously in the area.

The platform was decommissioned in 1998, with personnel staying on the platform throughout the operations to ensure safety once navigational aids were removed. Divers worked for 205 hours, completing their work in 26 days.

At that point, the platform was ready for topping with horizontal force provided by an anchor-handling vessel equipped with two 500-ton [181-tonne] winches. The initial attempts failed because of problems with the rigging system, so the crew deballasted subsea drill-water tanks to reduce the horizontal topping force required. The third attempt succeeded in toppling the platform, which submerged completely within 37 seconds (previous page). Divers surveyed and videotaped the toppled platform to confirm its location and a buoy was installed to mark its location (below left).

There has been at least one case in which wells and a platform were abandoned after a cargo ship collided with a platform. In an accident in the Gulf of Suez in 1989, the wellheads and the platform were damaged to the degree that they were declared a total loss. The operator’s key objectives were to control the wells, minimize pollution and decommission the damaged structures safely. Scaffolding erected over the mangled platform allowed workers to safely access valves, so oil spills were halted within one week of the accident. After the top deck of the platform was removed, a drilling rig was mobilized to support well-abandonment operations. Finally, two and a half years later, the rest of the platform was decommissioned. This exceptional event underscores the need for contingency planning in case wells or platforms must be abandoned prematurely.

**Abandonments Ahead**

The conceptual “life of a well” clearly extends beyond the production phase. Ideally, modern well-abandonment procedures isolate subsurface formations forever. Oil and gas producers recognize the importance of true permanent abandonment, which begins with well design, continues through primary cementing and concludes with fit-for-purpose well-abandonment procedures. Creating a common budget for each of these operations at the beginning of a project helps ensure that they are carried out properly.

Field abandonment, which typically involves more than one well, requires close coordination of many different operations to ensure subsurface isolation of each well, removal of surface equipment and facilities, and restoration of the surface to a pristine condition. With new technologies for primary and remedial cementing, perforating, and cement evaluation in addition to coiled tubing and slickline intervention, Schlumberger and E&P companies are ready to tackle the many well- and field-abandonment projects ahead.

—GMG

---