The oil industry’s push toward greater efficiency and more integrated services is profoundly impacting marine support activities. New concepts and designs that offer an expanded range of capabilities from a single vessel rather than multiple boats and barges are rapidly transforming the face of well workover and remediation operations. This article describes how innovative approaches are solving logistics and performance problems that have challenged offshore operators and service providers for decades.

In today’s oil field, delivering cost-effective solutions to difficult problems is paramount. As oil companies continue their intense drive to lower finding and producing costs and increase efficiency in every facet of operations, service companies are working closely with them as proactive solution-providers. Success hinges on exploiting the new business relationships that have sprouted and thrived during the past few years, typified by a proliferation of alliances and integrated services contracts. At the core of these initiatives are alignment of fundamental goals and an unparalleled application of cutting-edge technology targeted at productivity enhancement.1

Cooperative operator-service company programs are closely examining the cost-effectiveness of oilfield equipment used throughout the field development cycle. Radically different approaches are being adopted to reduce logistical complexity and nonproductive time, deficiencies associated with many long-standing practices. This is particularly true for well construction, intervention and remediation where a combination of innovative thinking and technical advances is ushering in a new era of performance from offshore barges and lift boats. Former single-purpose or limited-use vessels are being retrofitted to enhance efficiency and upgraded to add capabilities. Purpose-built vessels, which can swiftly deliver a wide spectrum of services, with fewer constraints and with a smaller cadre of highly skilled personnel, are being designed and commissioned in key oil-producing regions worldwide.

To put it simply, today you can have a Swiss Army knife at your disposal instead of a common penknife.

Progress in the Lake

Lake Maracaibo, Venezuela remains one of the most prolific oil-producing areas of the world—contributing over 1.5 million BOPD (240,000 m³/d) to help satisfy the ever-increasing global demand for energy. This represents more than 50% of the 2.9 million BOPD (460,800 m³/d) produced by Venezuela. Lake Maracaibo is also home to a unique field development scheme of over 11,000 wells and a unique set of well maintenance problems.

State-owned Petroleos de Venezuela SA (PDVSA) has committed to more than dou-

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ble oil production capacity by the year 2005 with an impressive assembly of drilling and workover programs. Three-dimensional seismic mapping of the entire Lake, completed in 1994, paved the way for a new, intensive exploration campaign that has already led to several important light-oil discoveries.\(^2\)

PdVSA’s programs are being complemented by aggressive efforts from international oil companies, including Mobil, Enron, British Petroleum, Shell, Amoco, Maxus, Conoco and Elf Aquitaine, as they develop acreage acquired in recent offerings. Earlier this year, Venezuela leased acreage in the first bidding round since it reopened to foreign investment in 1993. Profit-sharing contracts covering exploration on eight tracts with a combined area of 18,000 km\(^2\) [6950 square miles] were awarded. Undiscovered oil reserves in the newly assigned areas are projected at 7 to 23 billion bbl [1 to 3.6 billion m\(^3\)].\(^3\)

Lagoven, the company that along with sister affiliates Maraven and Corpoven constitute PdVSA, has seized the initiative with a vengeance. In 1994, for example, 77 million bbl [12 million m\(^3\)] of light crude were added to reserves with three major discoveries in the Lake that helped boost Lagoven’s production. Currently, Lagoven maintains over 8000 wells and produces about 730,000 BOPD [116,000 m\(^3\)/d] from 4940 active wells mainly in the eastern sector of the Lake (right). Water depths in the sector average about 60 ft [18 m] and well depths average around 4000 ft [1220 m].

Of the total number of wells, nearly 1000 are presently shut-in, and as many as 4000 require some type of workover operation. As the fields in this area of the Lake have matured, the need for more frequent and
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Evolution in well workover practices. The logistical and coordination problems and excessive downtime currently experienced using single-service barges can be solved by integrated, multipurpose vessels capable of more rapid, efficient, less costly operations.

Complex workover and remediation procedures have grown accordingly.

Although wells in Lake Maracaibo are technically “offshore,” many operations are reminiscent of land development. Flat-bottom barges with cantilevered derrick sets are used for drilling. Historically, Lagoven built drilling barges up to 220 ft [67 m] in length and then adapted them for a range of workover functions. An array of separate barges, outfitted to provide one or two specialty services each, such as cementing and coiled tubing, supports the drilling and workover barges. Currently, Lagoven owns 11 out of 28 barges and three jackups servicing its sector of the Lake.

When well construction or intervention tasks call for multiple barges in a prearranged sequence, the logistics of barge scheduling and positioning are complicated and inefficient. Time spent waiting for the next barge to arrive is often excessive. Lake Maracaibo is prone to rapid weather fluctuations, further impeding operations since most barges have minimal tolerance to waves. Delays waiting for weather to improve increase nonproductive time. The scene evokes visions of a queue of rain-delayed jets awaiting takeoff at a major airport. These constraints, and having a limited fleet of service vessels, restrict rig-based workovers to about 400 per year, far fewer than needed.

Lagoven’s efforts to sustain production from depleting zones and increase overall hydrocarbon recovery rely heavily on well reentries and workovers. Lagoven views this as the most economical way to enhance hydrocarbon production and stop its primary nemesis—water production.

This, in turn, has prompted a rethinking about how workovers should be performed. An evaluation of existing deficiencies and benefits from an integrated services approach convinced Lagoven to propose multipurpose barges for delivering a suite of services from a single vessel. Smaller, more flexible and cost-effective, these vessels solve scheduling problems and eliminate the excessive downtime plaguing current operations (above).

The changeover will, of necessity, be evolutionary. The progression from dedicated, single-use barges to custom-designed, multipurpose vessels is currently passing through an interim stage—barge retrofitting.

More Than a Cosmetic Makeover

For several years, service companies have sporadically reconfigured—or retrofitted—drilling and specialty service barges to increase functionality by adding dedicated equipment. These attempts represented the first valid steps toward more efficient well workover services. Today, efforts are more directed and less experimental.

A notable effort by Dowell, based on work in the late 1980s when barges were first outfitted with coiled tubing units, has helped bolster confidence in coiled tubing drilling on the Lake. A 140-ft [43-m] barge was specially configured to support either conventional or coiled tubing drilling. To date, nearly 50 wells have been drilled from the barge with coiled tubing. Initially,
hole sizes were 37⁄8-in. diameter. Now, wells are being drilled through shallow gas areas with diameters as great as 123⁄4 in. Well casing, up to 103⁄4 in. in diameter, is run and cemented with the same unit. The success of this approach paved the way for the even more ambitious efforts that followed.

Recently, two barges in the Lagoven fleet—Lagoven 405 and Lagoven 406—were retrofitted. Lagoven 406 (LV-406), a cantilevered drilling barge with on-board derrick set and wireline logging unit, was the first vessel with hoisting and rotating capabilities to be retrofitted (above). Working alongside Lagoven, Schlumberger Oilfield Services, with Sedco Forex as project manager, reconfigured the barge in order to provide integrated services.

The barge was delivered for retrofitting in mid-February 1996 and equipped with a 1.5-in. diameter coiled tubing unit (control cabin, power pack, reel and injector head), WASP water and sand proportioning mixer for blending gravel pack slurries, fluid filtering system, silo, displacement tanks and recirculating pump—replacing the bare pipe racks on the deck of LV-406 (right).
Upgraded piping and new systems for air, water, fuel and electricity were added. During the construction phase, a premium was placed on efficient use of deck space. Since the reconfiguration primarily involved coiled tubing and pumping equipment, a team of experienced Dowell engineers was appointed to define an optimal deck arrangement (left).

Although over 100,000 lbm [45,360 kg] were added to the vessel, the excellent load-bearing capacity of LV-406 ensured that variable deck load limits were not exceeded. A comprehensive stability analysis conducted by a naval architect confirmed that vessel stability would not be compromised.

The reconfigured barge was placed in operation in mid-April 1996 (below left). In its first few months of operation, the retrofitted LV-406 has mainly performed horizontal well cleanouts and cement plug placements with coiled tubing, as well as wireline operations, including perforating and setting bridge plugs or permanent packers.

Previously, cleanouts of produced sand required use of larger diameter drillpipe or contracting for a separate coiled tubing barge to work in tandem with LV-406. The former was expensive and time-consuming; the latter meant dealing with ever-present scheduling and positioning problems. With two barges, the well would often sand up again after cleanout, before the rig could be repositioned to install a prepacked sand-control screen.

With the retrofitted LV-406, however, cleanout of a 3000-ft [914-m] horizontal section typically requires only 17 hours compared to 36 hours with multiple barge operations, a savings of 53%. Worked-over wells now produce sand-free.

According to Francisco Gamarra, Drilling and Workover Manager for Lagoven’s Tia Juana District and Alexis Sanchez, Workover Engineer in charge of LV-406, $220,000 and 15 days were saved working over the first 10 wells.

“With everything now on the same barge, multiple barge moves have been eliminated and logistics have improved significantly,” says Gamarra. “We have taken a major step forward in the quality and efficiency of our operations. Cross-training between coiled tubing and conventional workover experts
has reduced rig-up time. Based on this success, we plan to convert our remaining barges over the next three years.”

Designing the Ultimate Toolkit
Retrofitting has its place as a logical, intermediate measure. The long-term goal, however, is a fleet of versatile, purpose-built vessels. “We don’t have a single mindset on how to accomplish this. We are willing to listen to the innovative ideas service companies are proposing,” Gamarra indicates.

Designing vessels for the stringent workover and intervention activities expected in the future requires an exhaustive analysis of the parameters affecting practices on the Lake. What basic vessel structure should be used? How can deck equipment best be integrated to maximize functionality and efficiency? Reconfiguration of LV-406 provided invaluable experience in the definition and selection process—highlighting what worked and what didn’t. The assessment required three iterations, with each revision giving a tighter, more cost-effective design.

The result is a new vessel concept called PRISA—a Spanish term which translates “to do things quickly”—symbolizing the objective established at the outset. PRISA is envisioned as the solution to Lagoven’s workover and intervention needs for the future—a multipurpose unit that reduces logistical complexity, improves operational flexibility and efficiency, and decreases time spent waiting on weather.

Two design variations are possible. The first is a barge style, 180 ft [55 m] in length with a 4000-ft² [370-m²] deck, capable of operating in water depths to 150 ft [46 m], wave heights to 6 ft [1.8 m] and surface currents to 2 knots (above right).

The second is a self-propelled, lift-boat style, 180 ft long with a 6000-ft² [558-m²] deck, able to operate in water depths to 100 ft [30 m] (right). This configuration is bottom-supported for better stability over a wider range of environmental conditions.

□Barge configuration. Starting with a clean slate, Schlumberger engineers designed a customized vessel—PRISA—to fulfill the well workover and intervention needs of Lagoven. The efficient, compact design affords modular flexibility and adheres to stringent quality, health, safety and environmental guidelines. The barge version of PRISA is shown with a modified cantilevered derrick, supplemented by a coiled tubing unit for reentry and underbalanced drilling.

□Lift-boat configuration. This self-propelled version of PRISA is equipped with bow and stern thrusters to permit easy mobilization and precise positioning.
Services in both configurations include:
- conventional well repair and workover, including workover fluid services
- conventional reentry drilling and snubbing (barge configuration only)
- coiled tubing drilling, including underbalanced air or foam drilling with quick changeover to conventional drilling and pulling mode in the barge configuration
- measurements- and logging-while-drilling
- wireline logging and perforating
- pumping mud, cement, acid, gravel packs and completion fluids
- slick-line operations.

But the design goes further, providing capabilities for reentry and production improvement drilling of short-radius horizontal sections and multilaterals (see “Reentry Drilling Gives New Life to Aging Fields,” page 4) from existing wellbores with casing sizes up to 7 in. [18 cm] (above). These techniques will proliferate rapidly as crucial elements in the long-term production improvement strategy for Lake Maracaibo. Late in 1996, Lagoven plans to drill two wells using multilateral technology. For 1997, this number jumps to 25.

PRISA includes an integral, cantilevered derrick and major support facilities—mooring system, crane, living quarters, power generation, and fluid pumping and storage equipment. The deck space is readily accessible by the main crane, allowing efficient placement of service modules. Hydraulic and power units support multiple applications.

Automation and process control maximize productivity during running, tripping and pulling of completion equipment. A central control cabin monitors functions in the derrick and on the drill floor, as well as electric and slick-line operations.

In stark contrast to existing vessels, PRISA simplifies logistics and enhances onboard operator-service company coordination, allowing rapid, sequenced operations. The stable platform and an advanced positioning system decrease waiting-on-weather time. Better equipment layout, modular construction and tighter organization of deck personnel reduce nonproductive time. Quality, health, safety and environmental performance improves, combined with lower operating and maintenance costs—overall, an impressive list of benefits. Lagoven currently envisions construction of up to six such vessels to support its production enhancement initiative.

Indonesia and West Africa: Reflecting Similar Needs
The well workover and intervention market in Indonesia is sizable. As primary fields mature, they require increased attention. Estimates indicate that this market will grow in the near term, with yearly workover targets of 500 wells or more.

Today, there simply aren’t enough service vessels. Oil companies plan workovers using the available, diverse assortment of...
Performance and reliability in compact packaging have epitomized the last decade of computer and electronics breakthroughs. In similar fashion, technical innovations are streamlining oilfield equipment, decreasing failure rates and delivering increasingly accurate data more rapidly. Whether it’s onboard processing for seismic surveys, revolutionary downhole wireline logging tools, or integrated fluid mixing and blending systems, an insistence on speed, quality and versatility is permeating the industry.

Offshore well construction, maintenance and intervention services that require vessel support are being closely scrutinized. These tasks can be performed more efficiently and cost-effectively with multipurpose service vessels—MPSVs—than with an assembly of traditional, single-service units. With the number of deviated, horizontal and multilateral wells mushrooming, and revisited reservoirs requiring more complex well completion schemes, custom-designed vessels are increasingly viewed as the preferred equipment of choice.

Multipurpose service vessels provide the service company with an arsenal of capabilities and integrated platforms for delivering a veritable smorgasbord of services. At the same time, they offer oil companies more options for improving hydrocarbon recovery and extending the life expectancies of offshore wells. The MPSV is a win-win solution for both parties.

In late 1995, a self-propelled MPSV, Irish Sea Pioneer, was commissioned by Halliburton Energy Services for well workover and intervention activities in the BHP Petroleum Liverpool Bay field off the west coast of England. It is the largest such vessel built to date and underscores the benefits that operators and service companies alike perceive in the MPSV concept.1

The MPSV initiative within Schlumberger is a natural outgrowth of the drive toward integrating services and supplying value-added solutions in direct response to client needs. Defining specifications for and designing the first-generation MPSVs required the combined strengths and expertise of the Schlumberger Oilfield Services companies—led by Sedco Forex for vessel management and drilling expertise, Anadrill for directional drilling and measurements-while-drilling services, Wireline & Testing for logging and well testing services, and Dowell for pumping, fluids engineering and coiled tubing services.

The resulting design adheres to the fundamental quality, health, safety and environmental tenets being applied uniformly by Schlumberger worldwide and conforms to standards established by regulating organizations, including the American Bureau of Shipping and International Maritime Organization, and initiatives such as Safety Of Life At Sea.

The chosen blueprint is a jackup-style vessel—properly termed a lift boat—with four, 300-ft [91-m] legs (above). The vessel is self-propelled at speeds up to 6 knots, compared to jacks that are towed at a sluggish 1 to 2 knots by tugboats. It is smaller than a normal jackup, requires less steel and is sleeker than the flat-bottom barges typically used in areas like Lake Maracaibo. The MPSV is equipped with four legs. This configuration saves time during vessel moves, improves safety, reduces maintenance costs and provides greater space for equipment on and below the main deck.

The MPSV has a streamlined bow and stern to minimize hull resistance, and utilizes state-of-the-art azimuthal thrusters for precise station keeping and maneuverability. It can be used safely in water depths as shallow as 10 ft [3 m] or as deep as 170 ft [52 m] and is stable in 60-knot winds and 29-ft [9-m] waves. Fully-retractable spud cans are integrated into the hull design, minimizing drag during transit. Top and bottom jetting capabilities aid removal when leaving location.

The MPSV is self-elevating with leg-jacking speeds of 6 to 8 ft/min [1.8 to 2.4 m/min], five times faster than a conventional jackup. A power-generation system that isolates propulsion functions from jacking functions ensures that the

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vessel can maintain accurate position, even in high currents, during jack-
ing operations and when adjacent to wellheads.

The 6000-ft² deck is open, usable and supports a 1.5 million-lbm [0.7 million-kg] deck load with the legs elevated and a 1.0 million-lbm [0.5 million-kg] load at other times. Twin 100-ton cranes with 120-ft [37-m] booms are capable of moving equipment modules onto and around the vessel, and are qualified for major lifts directly to and from attended platforms or wellheads. The cranes revolve a full 360° without interference from the legs, increasing flexibility and reducing deck space requirements.

To permit extended, 24-hour operation, accommodations and water production facilities are provided for up to 60 people, as operations dictate. Additional personnel can be housed in temporary modules on the main deck, if necessary. Quarters are located for ready access to the helideck and lifeboats or life rafts.

MPSV services cover the spectrum from routine, daily repair and maintenance on wells and platforms to short or extended well tests, horizontal production logging and acid stimulation with coiled tubing, and drilling mud treatment. The MPSV can be equipped as an early production system during the initial stages of field development, allowing operators to fully evaluate reservoir potential while generating immediate cash flow.

A single process-control system, ergonomically designed primary control cabin and modular, integrated equipment layout simplify operations, improve safety and permit staffing by a smaller cadre of multiskilled personnel than with a random assortment of single-purpose vessels.

Modularity allows rapid, easy customization. In the extended-well-testing mode, the vessel is outfitted with production separators, surge tanks or knock-out drums, export and reinjection pumps, a special logging cabin, a twin, high-pressure pumping skid, flare boom and burner (top).

For horizontal production logging, a coiled tubing unit—including power pack, reel and injector head—blender, a twin, high-pressure pumping skid, production pump, and surge tank or knock-out drum are used (bottom). For acid stimulation, a pressure-swing absorption nitrogen unit and acid storage tank are added. Other coiled tubing applications—nitrogen lift, logging and cementing—can be accommodated easily. Electric or hydraulic high-volume, high-pressure pumps can be added to extend the operating range of coiled tubing and snubbing units.

For well repair activities, a cantilever, mast and hoisting facilities, mud pumps, fluid storage tanks and mud treatment skids are provided. The cantilever offers versatility by permitting direct positioning over the wellhead. The MPSV can also serve as a diving-support vessel or as a temporary logistics and supply vessel for platforms or other offshore facilities.

Currently, MPSVs based on this design are being evaluated for diverse areas, such as the Gulf of Mexico, west coast of Africa, Malaysia and Indonesia.
boats and barges, and must live with the technical and operational restrictions inherent in their designs. High-efficiency, flexible units—at least four just to satisfy the demands of major international players—are desperately needed both to increase workover frequency and to optimize scheduling.

The majority of today's fleet are floaters, mainly flat-top barges. Historically, these were the cheapest to build and operate while offering modest flexibility. But they have severe limitations, require substantial marine support—up to three auxiliary boats for moving and positioning—and large crews, 50% greater staffing than for efficient vessels. They are also highly sensitive to weather, often unusable if swells exceed a few feet. Nonproductive time rigging up, rigging down and waiting on weather runs as high as 40 to 50%. These barges can interface only with platforms equipped with a derrick set or designed to accommodate a rig or coiled tubing unit. This lack of formance restricts certain operations and promotes substandard quality and safety.

With a purpose-built intervention unit, capabilities to run completions, perforate and clean up wells—common practices in many parts of the world, but currently difficult to impossible in Indonesia—can be added. Today, importing specialized units for these purposes is an option, but usually prohibitive due to mobilization costs and incompatibilities with platform designs.

A Schlumberger study outlines the ideal solution: a versatile, self-propelled, multipurpose service vessel—or MPSV—to minimize transport time and the amount of marine support needed (see "A New Generation of Capabilities," page 41). Modular construction allows fit-for-purpose equipment sets to be placed and changed out rapidly and efficiently on deck, reducing rig-up and rig-down time. The vessel has a working deck at the same level as those on production platforms to minimize lost time and eliminate the need to transfer equipment from barge to platform. The vessel's deck accommodates most service equipment for greater efficiency, safety and improved communications. Staffing is reduced through multitasking and cross-training in several services.

The vessel is capable of running and pulling completions and can incorporate a derrick with rotating capabilities to drill out cement, mill windows and washover downhole equipment. Onboard living quarters and support facilities allow 24-hour operation.

A generalized strategy, based on MPSVs, is emerging to satisfy the burgeoning needs of the Indonesian workover market. Eventually, when service vessel capabilities expand sufficiently, there will be an additional benefit—the size, complexity and cost of production platforms will decrease substantially since fewer, lighter facilities will be needed.

Similar well servicing challenges and opportunities exist off the west coast of Africa. Here, MPSVs will have to meet the rigorous demands of a wide range of clients and incorporate servicing modules for well testing, early production facilities, wireline logging and coiled tubing.

This means more deck space, variable load capacity, hefty cranes, permanent onboard equipment and a large workshop to carry out maintenance and repair work on platforms and wellheads. Many such operations are currently performed by conventional drilling jackups at high day rates.

Like operations in Indonesia, a nearly identical MPSV concept provides the answer. Since it is designed to be moved frequently, mobilization is rapid and easy. Transit times and costs are reduced, and towing vessels are not required. To be financially attractive to operators, costs must be lower than for conventional drilling jackups. The MPSV is expected to bring greater functionality at considerably lower day rates.

Managing a Successful Changeover
The drive to eliminate core inefficiencies in equipment and operations is spreading globally as a result of open communications and teamwork between operators and service companies. The results are innovative concepts to solve industry problems that have lingered for decades.

Advances in offshore support vessel design and functionality are opening up new avenues for greater productivity and efficiency. The evolution from single-purpose to retrofitted designs and from integrated service vessels to custom-designed, multipurpose vessels has been a phased, but relatively rapid, one. While each oil-producing area has specialized needs that must be fully addressed during design, operators and service companies are realizing that a common strategy, MPSVs, can be the ultimate answer—a versatile toolkit for well intervention.

Implementation, however, is the real challenge. It will require investing capital in new equipment, instilling an across-the-board commitment to quality and efficiency in offshore servicing, and training a large number of multiskilled teams to staff these vessels. The potential rewards in terms of productivity enhancement and improved field economics, however, are enormous.

—DEO