Reservoir LIFE Extension Program

Encouraging Production of Remaining Oil and Gas

OIL AND GAS RD&D PROGRAMS

RESERVOIR LIFE

One hundred forty years after the discovery of oil and the birth of the U.S. oil and gas industry, petroleum resources remaining in the ground are still double the amount producers have extracted. Recovering these remaining oil and gas resources poses formidable technical and financial challenges.

Many oil fields are in danger of being abandoned, even though they retain one-half to two-thirds of their original oil. The high capital cost of drilling wells and the difficulty of restoring production leases makes it unlikely that abandoned fields will ever be reopened, even if future oil prices increase significantly. Premature abandonment of wells, in effect, permanently cuts off access to valuable oil assets.

By the year 2015, an estimated one-half of the gas produced in the U.S. is projected to come from low permeability and other unconventional reservoirs. In many reservoirs producing natural gas, previously unrecognized gas-producing zones can be brought into production, thereby extending the life of these gas reservoirs.

DOE, in partnership with the U.S. oil and gas industry, supports the development of innovative and cost-effective technologies that can recover oil and gas from hard to produce resources and extend the productive life of domestic reservoirs. By encouraging advances in oil and gas recovery technologies and facilitating their transfer to producers, DOE can help increase production from U.S. oil and gas resources, help to slow the rate of premature abandonment, and reduce our reliance on energy imports.

Reservoir Life Extension Program

Current U.S. oil production is 6.3 million barrels of oil per day. Of this, 37 percent is produced by primary recovery. In mature oil fields, the contribution of primary recovery declines each year, while the contribution of secondary and tertiary recovery increases over time.

Advanced recovery technologies can slow the premature abandonment of U.S. oil and gas wells.

Lower-cost, advanced technologies and efficient development strategies, if widely applied by the Nation's oil and gas producers, are estimated to be capable of increasing the yield of tertiary oil recovery by up to one million barrels of oil per day, and the annual yield of natural gas by up to 6 Tcf per year by the year 2015.

Typically, only about one-third of the oil discovered can be produced economically. Production at most petroleum reservoirs includes three distinct elements: primary, secondary, and tertiary recovery. Tertiary oil recovery is also known as improved oil recovery (IOR), or enhanced oil recovery (EOR).

Primary recovery refers to oil production when energy stored in the reservoir is sufficient to drive the oil through reservoir rock into a wellbore. As reservoir pressure declines with oil production rates, additional oil can be recovered using secondary recovery techniques. One such technology, waterflooding, displaces the oil and drives it to the wellbores of the producing wells.

Oil displacement in the reservoir is incomplete, however, even with secondary recovery processes. Tertiary oil recovery technologies – such as thermal, gas-miscible, chemical, or microbial methods – can provide additional production. Such technologies potentially could lead to substantially higher average recovery efficiency, approaching 50 percent of the "original-oil-in-place" in reservoirs that have "discovered but unrecovered" oil.

Although improved oil recovery technologies have significant potential to extend reservoir life, and have been successfully demonstrated in the laboratory and in the field since the early 1960s, their historically high cost has limited their widespread application. In the last decade, however, dramatic improvements in analytical and assessment tools have led to a greater understanding of reservoir geology and the physical and chemical processes governing multiphase flow in porous media. This understanding has led to the development of new technologies for reservoir life extension.

Secondary Gas Recovery Technologies

Reserve growth has emerged as a major component of the natural gas resource base in the past decade due to changed perceptions of gas mobility and recovery in heterogeneous and compartmentalized reservoirs. Past efforts in the Secondary Gas Recovery Program sought to encourage reserve growth by combining the technical expertise and research capabilities of DOE, the Gas Research Institute, the State of Texas, and various industry partners. The project has been operating for nine years and has been funded with $37 million. Of this, the Gas Research Institute has contributed $16.5 million. The project participants approach the Secondary Gas Recovery Program with the philosophy that: if more can be learned about the internal architecture of a mature, producing gas reservoir, then producers can target drilling efforts to capture some of the estimated 25 percent of recoverable gas now unattainable through conventional methods. This resource is simply bypassed for lack of true understanding of the geologic nature of the field. Principal components of the Secondary Gas Recovery Program are multidisciplinary reservoir characterization analysis and targeted application of innovative drilling technologies.

Advanced exploration and production technologies, such as 3-D seismic interpretation, modern quantitative well log analysis, state-of-art sequence stratigraphic and sedimentalogical interpretation, and crosswell seismic tomography, provide a better “snapshot” of the internal architecture of producing gas reservoirs. Such technologies help producers understand how gas reservoirs are compartmentalized. With this information, drilling efforts can be targeted to reach new production zones or bypassed compartments.

Success Story

Secondary Gas Recovery

Lifting the geologic veil, that has until now obscured gas pools in producing reservoirs in southwest Texas, has had dramatic economic results. With the application of technologies developed through the Secondary Gas Recovery project, proved natural gas reserves increased by about 4 Tcf in the Gulf Coast alone, and industry gas well completions are up 24 percent compared to 1993. Gross production revenues from secondary gas reserves are expected to approach $1.4 billion. Projected incremental gas production from 1993 to 2000 is 2.6 Tcf. Project results have tremendous potential to be replicated in other regions.

A multidisciplinary study of the Ellenburger Group Reservoirs, in a 176 square mile study area in West Texas that included a modern 3-D seismic data set, demonstrated that, despite great depth (greater than 18,000 feet), a remarkably detailed structural interpretation in a complicated tectonic terrain is possible. Although production in the target formation was found to be controlled by natural fractures (an unexpected discovery) and in pressure communication, reservoirs above the Ellenburger are compartmentalized and provide recompletion opportunities in abandoned Ellenburger wells.

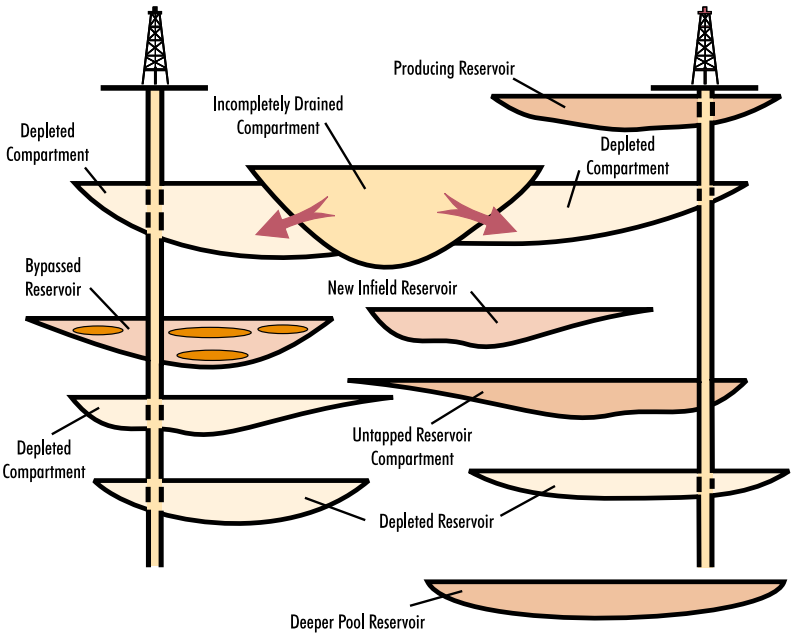
Correct reservoir characterization directs the type of drilling most appropriate for any one reservoir. When applicable, new, smaller bore drills can be used, which minimize the surface area needed for drilling and reduce the impact on the environment. Advanced reservoir characterization also allows producers to determine whether wells can be drilled in one location and completed several miles away, again protecting the surface environment while allowing recovery of valuable oil and gas resources deep within the earth.

Like the Reservoir Class Program, the Secondary Gas Recovery Program also conducts field demonstrations at producing wells, a strategy that reduces risk to producers.

The magnitude of the work and the degree of industry co-funding determines the actual amount of public funding required for any one field demonstration. Industry partners provided additional cash or in-kind contributions. In every field demonstration, industry's dollar-value contribution significantly exceeded the combined DOE and Gas Research Institute funding.

Secondary gas recovery demonstrations were initiated in South Texas and later shifted to the Southern Midcontinent and Permian Basins. Demonstrations have been conducted at these Texas gas fields: Stratton, Lake Creek, McAllen Ranch, Agua Dulce, North McFaddin, Boonsville, and Lockridge-Waha. In 1997, the testing of secondary gas recovery methodologies and field demonstrations occurred in the Appalachian Basin, and in 1998 there was an initiative to investigate the secondary gas recovery in the Gulf of Mexico.

Field demonstrations of advanced reservoir characterization techniques and focused drilling have been completed or are underway at locations where gas reservoirs have been deposited in fluvial, fluvial deltaic, and carbonate environments. Although numerous other reservoir environments exist, these three promise to yield the greatest increases in production after application of new technologies. Each field study is conducted by a team of six to ten people representing expertise from core disciplines. Knowledge gained from each field study is promptly transferred to industry through an extensive and intensive technology transfer program component. Key industry beneficiaries include the thousands of small independent oil and gas operators who now manage the majority of the Nation's onshore hydrocarbon-producing properties.



Many of the old gas fields contain new infield reservoirs, incompletely drained reservoir compartments, and bypassed reservoirs.

Secondary gas recovery optimization practices, developed onshore in the Gulf Coast, Mid-continent, and Permian basins, are now being taken offshore in the Northern Gulf of Mexico, a prime location to continue the trend of reserve growth through the application of advanced reservoir characterization. The Gulf of Mexico basin, which is geologically-complex (heterogeneous both vertically and horizontally), is estimated to contain about 11 percent of the world's known production of natural gas. In 1994, the Gulf of Mexico accounted for approximately 26 percent of the natural gas produced in the entire United States.

The offshore Northern Gulf of Mexico is a mature producing province, with nearly 10,000 gas and oil producing reservoirs in more than 1,000 fields. An enormous resource target remains in place with an established infrastructure of platforms and pipelines. However, the extremely high cost of developing and operating natural gas production offshore requires a greater scientific understanding of the remaining resource to accurately and economically target development programs.

The next phase of the program will use advanced reservoir characterization principles to predict the value of recoverable but currently bypassed resources of a major gas field through a multidisciplinary reservoir characterization study. The selected field will contain reservoirs with varied depositional styles, types of heterogeneity, and large unrecovered gas resource targets. These characteristics will ensure that the knowledge gained during this project will have maximum potential for technology transfer to other offshore fields.

Success in this effort could impact a major segment of the larger independent oil and gas companies operating in the Gulf of Mexico by providing the tools and methodology to identify and characterize bypassed natural gas within active producing fields and reservoirs. Also, it is anticipated that the application of technologies and methodologies developed through the Secondary Gas Recovery Program will lead to increased success in locating and producing resources in the high-cost offshore environment. This effectively will increase gas reserves and maximize recovery of the Nation's resource potential in one of the world's most prolific hydrocarbon producing basins.

Technology Development with Independents

ONGPT, through its field office, the National Petroleum Technology Office, has developed a program to help small producers who lack resources to try unfamiliar technologies or novel, unproven approaches to extend economic production and increase ultimate recovery from domestic oil and gas fields. As much as $1 million is targeted to small operators with less than 50 employees. Financial assistance of up to $75,000 must be matched by the producers, and projects usually last from six months to two years. The program focuses on solving specific production problems, faced by smaller independent operators, in every aspect of oil and gas field operations, from improved reservoir characterization to reservoir management and environmental compliance. Since the program began in 1995, there have been 22 projects funded in exploration, drilling, improved oil recovery, fluid lifting problems, well stimulation, excessive water production, and a variety of wellbore problems. Eighteen of the 22 projects were considered successful and are being evaluated. The following are two project examples and their benefits.

Gel Polymer Treatment: The Bartlesville sand, produced from the Bird Creek field in Tulsa County, Oklahoma, is widely known as a high water producing interval, and it was targeted for improvement by Kenneth Y. Park, an independent oil operator from Skiatook, Oklahoma. Water channeling and excessive water production are common problems found in the lower member of the Bartlesville sand. These high water and low oil production problems must be remedied to allow profitable operations to occur.

Goals of this project were to: (1) inject a cross-linked-gel polymer mixture into the lower portion of six producing wells; (2) return four previously shut-in wells to production after similar treatments; and (3) monitor oil and water production of the lease to evaluate the success of the treatments. Following wellbore cleanups with small volumes of acid, the six wells were treated with a high molecular weight and partially hydrolyzed polyacrylamide polymer mixed with a chromium cross-linking agent. An ammonium salt was used to prevent swelling of the formation clay during the remedial operations.

Four of the six producing wells were shut-in before treatment and became productive following the treatment. The two other treated wells showed production improvements. The oil production rate from the lease tripled to 18 barrels per day, while water production doubled. Total well productivity increased twofold, while water-to-oil ratios were reduced for the wells in question. This type of treatment for stripper wells was found to be effective, and the value of the incremental oil obtained is in excess of the total project cost of $96,000.

Microbial Treatment: The Speir Operating Company, Albion, Illinois, conducted a cost-shared project with DOE to evaluate the effectiveness of microbial well treatments for cleaning up producing and injection wells. This project, located near Evansville, Posey County, Indiana, produces from the Cypress limestone at 2,200 feet. Paraffin and sulfide scale precipitation was impeding production and injection by plugging perforations and tubing.

The project involved the planned treatment of nine producers and two injectors with microbial agents for well bore cleanup and remediation during this program. Following well bore cleanups with small volumes of acid, the wells were produced for one month before the microbial treatments began. Wells were then injected with five barrels of warm water, followed by ten gallons of microbes and nutrients, then displaced with a 20-barrel warm water flush.

Treatments were repeated monthly for six months. Oil production for these wells tripled from 7 to 21 barrels of oil per day, while injection well pressures declined to one-third of their previous levels. Producing wells began unloading sulfide scale, paraffin, and oil-water-paraffin emulsion, as they cleaned up and produced. Incremental oil obtained was sufficient to pay out the total project cost of about $98,000.

Gas Stripper Well Revitalization

ONGPT has started a five-year stripper gas well revitalization program to extend the productive life of active low-rate wells. The program will conduct engineering assessment of wells to determine candidate areas for restimulation tests, and evaluate via field tests the effect of revitalization efforts. Stripper gas wells, owned exclusively by independent producers, are those in which production rates have declined to less than 60 Mcf per day.

According to the Interstate Oil and Gas Compact Commission, 4,914 stripper gas wells were plugged or abandoned in 1997. Any new insight on how to prolong their operating life, or operating guidelines that could be developed to re-energize the stripper gas well production, could significantly increase their contribution to domestic gas supply, which currently is 5 percent of U.S. gas production.

The program will acquire and analyze production data from gas stripper wells to determine reservoir conditions that are responsible for the rapidly declining production rates. For example, factors contributing to abnormal decline rates could be: wellbore damage from precipitates in produced water; decreased near-wellbore permeability, or so called "skin effect;" or other geological or production conditions. As a result, simple corrective measures may be sufficient to increase gas production. The program will take a "regional approach" based on number of stripper wells, production of stripper wells, and number of abandonments in various stripper well regions of the Nation (e.g., Eastern, Southwest, and Midcontinent). During the first year of this program, one State from each region will be investigated.

Technology Transfer with PTTC

Petroleum Technology Transfer Council (PTTC) was initiated in 1994 by the Independent Petroleum Association of America, along with State producer associations, and other industry groups. PTTC transfers technology to independent producers from government agencies, universities, National Laboratories, and service and supply companies. PTTC, supported with funds from industry and ONGPT, assists operators to reduce finding costs, improve operations, increase oil and gas recovery, and comply with environmental regulations.

PTTC is one of the major technology transfer arms for ONGPT's oil and gas RD&D program. This non-profit organization has established an impressive national network that links the public and private research and development community with domestic oil and gas producers. PTTC has 10 fully functional Regional Resource Centers located in West Virginia, Illinois, Alabama, Louisiana, Kansas, Oklahoma, Texas, New Mexico, Colorado, and California. All of the centers are linked through the Internet to provide electronic transfer of information.

PTTC has developed a highly successful technology workshop program on practical solutions that are immediately applicable to the field. Over the last four years, PTTC has held more than 325 workshops attended by over 12,500 participants. Of this total, nearly two-thirds are from the oil and gas industry. Independent producers are increasingly accessing PTTC's Internet websites for information.

Its quarterly newsletter, *PTTC Network News*, is distributed to over 6,000 readers, over 50 percent of whom are from oil and gas exploration and production companies. In 1997, PTTC won the National Energy Resources Organization award for significant achievements in energy.

Some examples of PTTC successes, as expressed by companies who benefitted from PTTC technology transfer, are as follows:

- Advanced hydraulic fracturing and micro-seismic fracture mapping in East Texas tight gas sand play saved $4.5 million in 1997 (Union Pacific Resources Company, Fort Worth, Texas);
- Improved water control increased oil production by as much as 60 percent in the Nebo-Hemphill field (Hunt Oil Corporation, LaSalle Parish, Louisiana);
- Polymer gel application prevented premature well abandonment and saved at least 13 wells (Polymer Systems, Inc., Hays, Kansas);
- Formation Micro-Imager log technology reduced risk in Pleasant Home field coring and provided savings of $15,000 to $25,000 per well (Longleaf Energy Co., Brewton, Alabama); and
- Waterflooding and additional drilling in Appleton field could result in eight percent increase in oil production, 400,000 barrels of new reserves, and two to three years of field life extension (Smacko, Ltd., Brewton, Alabama).