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.

Government Role

The problem of continuously declining oil production in the United States (since 1970) is well documented. An associated national problem is that of steadily increasing abandonments of oil and gas wells, caused by their insufficient productivity. Not only can abandoned wells create environmentally-sensitive disposal problems (in itself a Federal and a State role), but the abandoned wells preclude reservoir access even if the economics and technology improve sufficiently to warrant their reopening. Proper abandonment requires plugging wells with cement such that they can never be redrilled economically. This, on average, leaves approximately one-half of the residual oil and about one-third of natural gas unrecoverable – a major waste of national assets. This problem requires urgent national attention.

Advanced technologies can extend the life of maturing oil and gas reservoirs and yield significant additional volumes of oil and gas. DOE's Reservoir Life Extension Program, conducted in partnership with industry, supports research, development, and demonstration of promising technologies, and encourages their transfer to U.S. producers. The independent producers do not conduct their own research, yet they produce about 40 percent of oil and 66 percent of natural gas in the United States. In this case, a little help goes a long way.

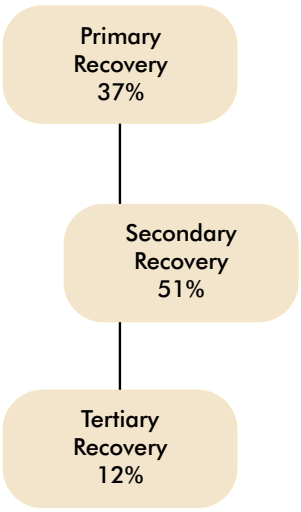
Two such programs have been very successful: the Reservoir Class Program and the Secondary Gas Recovery Program. Both are highly cost-shared with industry, and both address the application of advanced technology, advanced reservoir management, and recovery of the discovered but unrecovered oil and gas reserves. This is being accomplished in partnership with the private sector, universities, and the National Laboratories. Direct participation of the industry assures rapid and effective technology transfer through the Natural Gas and Oil Technology Partnership and the Petroleum Technology Transfer Council. In the process, the imminent abandonments of many oil and gas wells are postponed, and valuable resources are recovered.

Problems associated with more efficient or complete gas recovery are somewhat different. In low permeability formations, natural fractures create channels for gas to flow through the rock formation to production wells. However, they often cause gas to drain in irregular, elongated patterns, reducing the overall amount of gas that can be produced. In addition, natural fractures are not often intersected by vertical production wells. Current laws regarding the spacing of production wells often limit the recovery of gas. In Colorado, research by DOE, industry, and others has helped to change the well spacing to increase the amount of gas that can be recovered. Research conducted by the Texas Bureau of Economic Geology, on behalf of DOE and the Gas Research Institute, has also demonstrated that current production practices fail to recover a large portion of the gas-in-place. Even after 50 years of commercial production, substantial infield reserve growth exists in bypassed, incompletely drained, and untapped reservoir compartments, not to mention deeper pool potential in many fields. The DOE natural gas recovery program focuses on a more complete characterization of complex heterogeneous reservoirs to afford a more precise placement of new wells and recompletions in existing wells.

The Reservoir Life Extension Program supports RD&D of promising technologies in areas identified as priorities by the oil and gas industry. Some of this research taps the unique strengths of the National Laboratories. The National Laboratories are able to focus on high-risk technology developments, where long-term payoffs deter private companies from adequately investing on their own.

The National Petroleum Council, in its 1995 report, *Research, Development and Demonstration Needs of the Oil and Gas Industry*, identified reservoir life extension among its highest priority areas. The report listed well productivity, stimulation techniques, recompletion techniques, and reservoir management as key technology needs.

The 1995 report of the Secretary of Energy Advisory Board, *Task Force on Strategic Energy Research and Development*, recommended reservoir life extension technologies in secondary and tertiary oil recovery. These technologies included polymer-augmented waterfloods and polymer-gel profile modification; continuous steam injection and in-situ combustion techniques; continuous gas injection, cyclic, and water-alternating-gas injection; and micellar surfactant and alkaline surfactant polymer flooding.



U.S. oil production by recovery methods

Relation to Other DOE Programs

Today, there is an increasing need to transfer improved recovery technologies more effectively to domestic producers to slow the rate of premature oil and gas well abandonment, extend the life of mature reservoirs, and avoid the permanent loss of significant oil and gas reserves.

A recent study by the National Research Council, *Maintaining Oil Production from Marginal Fields: A Review of the Department of Energy's Reservoir Class Program (1996)*, found that, by the end of 2004, nearly 175,000 marginal wells and their associated production could be lost through premature abandonment.

Industry Issues

- *Research and policies to limit the decline of domestic oil production and to increase gas production*
- *Extending the life of oil and gas reservoirs with discovered, but unrecovered, reserves*
- *Reduced abandonment of oil and gas stripper wells*
- *Cost-effective secondary and tertiary oil and gas recovery technologies*
- *PC-compatible reservoir simulation software access through the Internet*
- *Access to technology and information about reservoir life extension through participation in topical seminars and workshops*

In 1997 alone, industry reported that more than 15,000 oil wells and 5,000 gas wells were abandoned. In addition, 100 to 150 offshore platforms are removed each year from the Outer Continental Shelf, and over 25 percent of the remaining platforms are more than 25 years old. A follow-up study by the Interstate Oil and Gas Compact Commission (IOGCC), entitled *Produce or Plug: The Dilemma over the Nation's Idle Oil and Gas Wells*, states that idle and orphan wells are of national concern and that efforts must be made to conserve the Nation's resources, enhance revenues, limit liability, and protect the environment.

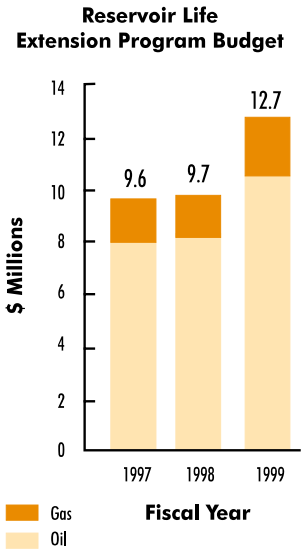
Many of these wells, oil and gas fields, and offshore platforms could yield additional oil and gas with current recovery technologies if technology transfer were more efficient. Because it is not economically feasible to renew production at an abandoned well, the loss of oil and gas resources due to abandonment is permanent.

ONGPT's Reservoir Life Extension Program, conducted in partnership with industry, supports research, development, and selective demonstrations of promising technologies. It also encourages their transfer to U.S. producers, particularly independent producers, who now account for about 40 percent of the oil and 66 percent of the gas production in the United States.

Potential Benefits

The $115 million reservoir class program enabled 29 projects that are expected to result in 500 million barrels of oil by 2002. The current market value of that oil is $6 billion (at $12/barrel). The 6 Tcf per year of additional gas recovery that is projected with advancements in technologies is worth $9 billion annually (at $1.50 per Mcf).

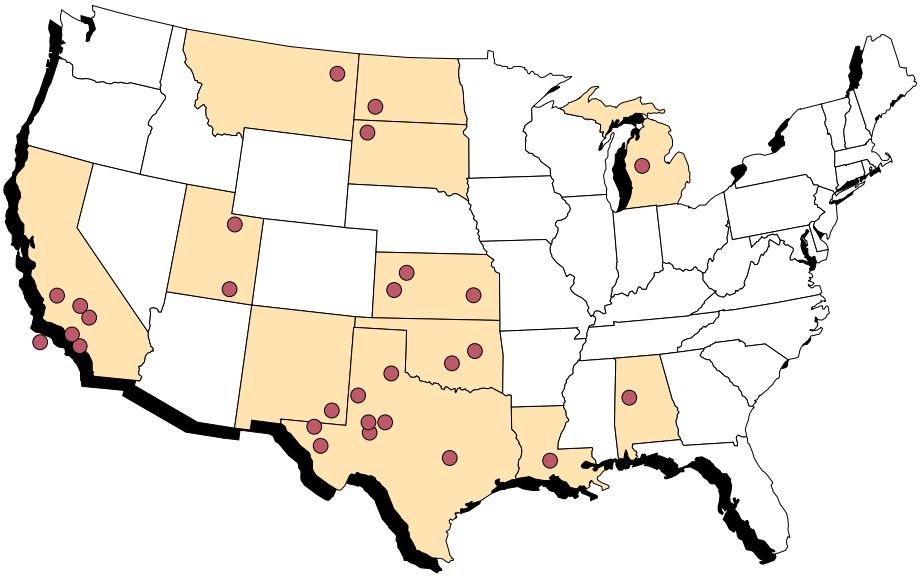
Individual projects within the Reservoir Life Extension Program are selected for their potential application throughout the domestic oil and gas industry. Research dollars are focused on those oil and gas reservoirs that have vast resource estimates, or are threatened by premature abandonment. Geologic class was chosen as the mechanism for clustering the oil and gas reservoirs immediately available for technology application. This assumes that reservoirs in the same geologic classes will experience similar technical barriers, and as a result, technology that has been successfully field tested for one reservoir in a geologic class should be suitable for another reservoir in a field of the same geologic class. Industry cost-sharing is almost 60 percent for reservoir class field demonstration and secondary gas recovery projects, which are conducted at actual producing sites.



RESERVOIR LIFE

Project Sites

The Program currently involves 28 projects in 12 States.



RESERVOIR LIFE

Drivers

- The Nation's energy security is at risk, with steadily increasing demand for transportation fuels and steadily declining domestic oil production.
- Rates of abandonment of oil and gas wells and offshore platforms are unacceptably high.
- Independent oil and gas producers (over 7,000 companies) conduct an increasing share of U.S. production activities. They have limited capital to conduct R&D and do not have the means to assume the perceived risk to try advanced technologies used by major companies.
- Recovery of additional large volumes of oil and gas requires improved extraction processes, sophisticated extraction numerical models, and improved reservoir management approaches.

Goals

- Make available to industry, by 2010, improved and new technologies helping to stabilize domestic oil recovery at current rates. Improved and new technologies will help to locate and produce gas from new resources and to recover additional gas from poorly drained and untapped reservoir compartments.
- Stabilize the abandonment rates of marginal oil and gas wells at current rates.
- Maximize oil and gas extraction through focused research and field testing of reservoir life extension technologies and technology transfer.
- Complete Reservoir Class Revisit Program, analyze results, and transfer lessons learned to industry.

Reservoir Life Extension Program

Strategies

- Conduct research to develop and demonstrate the tools and methodologies of known reservoir life extension processes.
  - Focus projects on mature oil and gas fields in danger of premature abandonment, and focus on opportunities to increase the recovery of oil and gas from Federal lands.
  - Revisit the Reservoir Class program to capitalize on the achievements of the successful Class I, II, and III demonstrations.
- Develop and demonstrate advanced production technologies to accelerate production from large U.S. gas resources.
- Expedite technology transfer to industry by: conducting pilot and field-scale demonstrations of proven laboratory technologies; and by working with industry associations, such as the PTTC, to provide focused technology workshops, information resource centers, and computer-based information.
- Support ongoing university and partnership research in critical Reservoir Life Extension areas (e.g., extraction technologies and recovery process modeling).
- Develop the scientific basis for major technology breakthroughs that are applicable to oil and gas, as well as to other related industries.

Measures of Success

- Stabilization of the rate of oil and gas well abandonments at the current level of 15,000 and 5,000 abandonments per year, respectively.
- Matching or exceeding the all-time historical record of the rate of enhanced oil recovery by the year 2005 (from the record 761,000 barrels per day in 1992).
- Arrest of overall decline in oil production by the year 2005.
- Production of new gas resources and additional gas from mature reserves.
- Increased use of program products by industry, particularly by independent oil and gas producers.
- Increased participation of oil and gas producers in technology transfer seminars and topical workshops.
- Establishment of a well-functioning regional network of PTTC resource centers with full support, and eventually, full funding by industry.

Technology transfer includes: technical assistance to solve a specific problem; training in advanced equipment, techniques, and processes; use of costly or unique facilities; access to patents and software; exchange of personnel; and cooperative research. Regardless of its form, technology transfer is the guiding strategy for the Reservoir Life Extension Program.

The ongoing Reservoir Class Program originally consisted of 32 projects in 14 states. Of these 32 projects, nine have been completed, three were stopped before completion, and 20 are ongoing. A new solicitation for the Reservoir Class Revisit is expected to fund 10 to 20 new projects that are smaller, have shorter periods of performance (3 to 5 years), and have higher industry cost-share percentages (up to 90 percent).

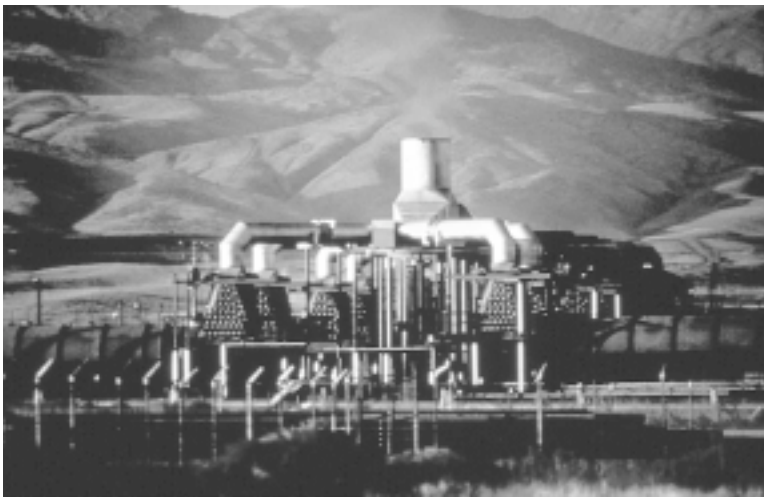
Main Program Areas

The Reservoir Life Extension Program efforts are organized in the following major areas:

- Reservoir Class Field Demonstrations;
- Secondary Gas Recovery Technologies;
- Technology Development with Independents;
- Gas Stripper Well Revitalization; and
- Gas Storage Technology (see Chapter 5 – Gas Storage Program).

The following pages highlight specific program accomplishments and suggest the range and variety of program activities.

Steam injection is the most common EOR process used today. This process is most often applied in reservoirs containing viscous, heavy oil, which does not flow at significant rates under normal reservoir pressures and temperatures.



Steam Generation Facility

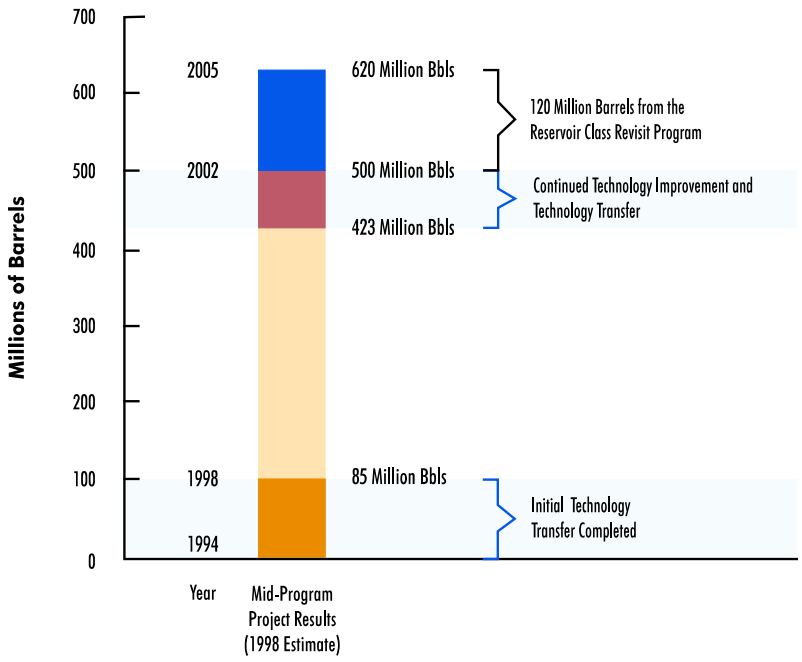
Reservoir Class Field Demonstrations

The trend toward abandonment of individual wells and fields must be turned around to prevent further loss of access to our Nation's valuable oil reserves. To demonstrate that today's reservoir life extension technologies are a highly cost-effective alternative to abandonment in real life situations, DOE launched the Reservoir Class Field Demonstration Program. This Program area represents the opportunity for in-the-field application of many improved and new reservoir life extension technologies.

The Program targets three groups of depositionally similar reservoirs, based on the premise that demonstrated methodologies and technologies that overcome specific producibility problems in representative reservoirs have a higher probability of being applicable to other members of the same class than to non-class reservoirs. The Program goal is to preserve access to reservoirs with high potential for increased production. The goals are being accomplished by conducting technology transfer activities that motivate operators to identify producibility problems and to apply underutilized technologies to overcome those problems.

The Reservoir Class Program was identified as a high priority program in 1989, and the background and technical rationale are documented in the April 1990 issue of the DOE Oil Research Program Implementation Plan. Originally, 10 reservoir classes were identified for further testing, but only three could be completed with available funds. From the outset, effective technology transfer has been a critical component of the Reservoir Class Program; and it remains so today.

Cumulative Production & Reserve Additions from the Reservoir Class Program



The Reservoir Class Revisit

This Reservoir Class Revisit Program will be much smaller than its predecessor. The projects also will be smaller. Independents and small operators will be encouraged to participate.

This Program will build on the technologies and successes demonstrated in the original Class Program, evaluate their effectiveness when applied to different oil-producing regions, and test new technologies. Technology transfer activities will help ensure that all Class Revisit successes can be implemented industry-wide. Industry cost-share will be increased from 55 to 90 percent.

The Class Revisit program will provide opportunities to: test the technological advances and critical hypotheses already made in Class I, II, and III reservoirs in more regions of the country; capitalize on the advances already made through technology transfer efforts; and further the relevance and industry recognition of the Federal oil program. There will be 10 to 20 more field test projects, but the total DOE funding is about one-half of the previous class budgets, and new projects will be considerably shorter in duration (3 to 5 years).

A commitment on the part of all program partners to technology transfer has been a critical factor in the program's success to date. Oil producers (including both small independent companies and major producers), universities, State agencies, service companies, consultants, and DOE have teamed up for development, application, and transfer efforts. Project results are also being fed into a national petroleum technology transfer network.

The original 32 Reservoir Class projects selected by DOE are in 15 States: Alabama, California, Colorado, Illinois, Kansas, Louisiana, Michigan, Mississippi, Montana,

Success Story

Inland Resources/Lomax Project

Within the Uinta Basin, the Green River Formation produces a paraffinic, low-energy crude from a highly heterogeneous reservoir. Because of unfavorable reservoir heterogeneity and crude characteristics, only a few early waterfloods, some 30 miles away from Inland's Monument Butte Unit, had been conducted. Inland Resources evaluated the performance of early waterfloods, determined that they would have been economic with current economic conditions, and compared Monument Butte Unit fluid and reservoir characteristics. Finding them to be comparable, Inland began waterflooding in the Monument Butte Unit, despite conventional reservoir engineering wisdom (and advice) indicating that the waterflood would not be successful. Production increased from 45 to 330 barrels/day, significantly better than expected.

Successful demonstration of waterflooding in a high paraffin oil reservoir added 2.4 million barrels of oil to the region's reserves. Because of this demonstration, neighboring companies initiated 11 new waterfloods with more than 300 wells, which are expected to add 45 million barrels of oil. Because these 11 projects cover only 13 percent of the area, widespread application of waterfloods could double or triple the region's reserves.

New Mexico, North Dakota, Oklahoma, Texas, Utah, and Wyoming. A single reservoir can be the site of more than one field demonstration project.

Fluvial Deltaic (Class I)

These reservoirs were formed in ancient river deltas and originally contained about 70 billion barrels of crude oil. Class I reservoirs now contain over 5 billion barrels of potentially recoverable oil; half of this oil is at risk of abandonment by 2010. In April 1992, 14 projects were selected representing nine states – Alabama, Colorado, Illinois, Kansas, Louisiana, Oklahoma, Texas, Utah, and Wyoming – and offshore Gulf of Mexico. Three projects were terminated during start-up as a result of economic problems, and six projects were completed successfully in 1998. The final four projects will be completed by 2002.

Shallow-Shelf Carbonates (Class II)

Formed in shallow ocean shelves, these reservoirs originally contained more than 68 billion barrels of crude oil. Most of the remaining 48 billion barrels are at risk of being abandoned. Advanced technologies have the potential to recover an additional 5 billion barrels. Of the nine projects initiated in 1993, three are already completed and six are to be completed by 2001. The projects are in eight states: Kansas, Michigan, Montana, New Mexico, North Dakota, Oklahoma, Texas, and Utah.

Slope Basin (Class III)

Created from sediment deposited in deep ocean slope and basin areas, these reservoirs are estimated to have originally contained nearly 60 billion barrels of light and heavy crude oil. Most of the remaining 44 billion barrels are in danger of being abandoned unless more sophisticated techniques are widely deployed. Advanced technologies have the potential to recover an additional 5 billion barrels. Nine projects were awarded in three states: California (onshore and offshore on the Outer Continental Shelf), New Mexico, and Texas. All are scheduled for completion by 2002.

Success Story

Diversified Operating Corp. Project

The Cretaceous "D" sand of the Sooner Unit in northeast Colorado has good primary recovery, but disappointing waterflooding performance. The majority of waterflooding projects have produced only about 20 percent of the original-oil-in-place (OOIP), due to low porosity, highly variable permeability, and poor reservoir management practices. Under a Class I project, Diversified Operating Corp. demonstrated the cost-effectiveness of geologically-targeted infill drilling and improved reservoir management to increase waterflooding recovery in the Sooner Unit.

The project has yielded 200 barrels of oil per day above pre-project estimates, and has boosted projections of OOIP from 5.9 million to 6.9 million barrels through refined seismic studies. Recovery has been boosted from 15 percent of OOIP to 20 percent by mid-1996. Ultimate recovery may be 30 percent. In the Denver-Julesburg basin, the use of 3-D seismic data analysis to identify reservoir architecture and tailor well spacing and injection patterns to the reservoir compartments can be applied to increase waterflooding recovery. As a result of this field demonstration project, 13 new seismic surveys have been shot in the "D" sand in nearby formations. The 3-D seismic data has been made available to interested parties through the Regional Lead Office of the PTTC in Golden, Colorado.

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.

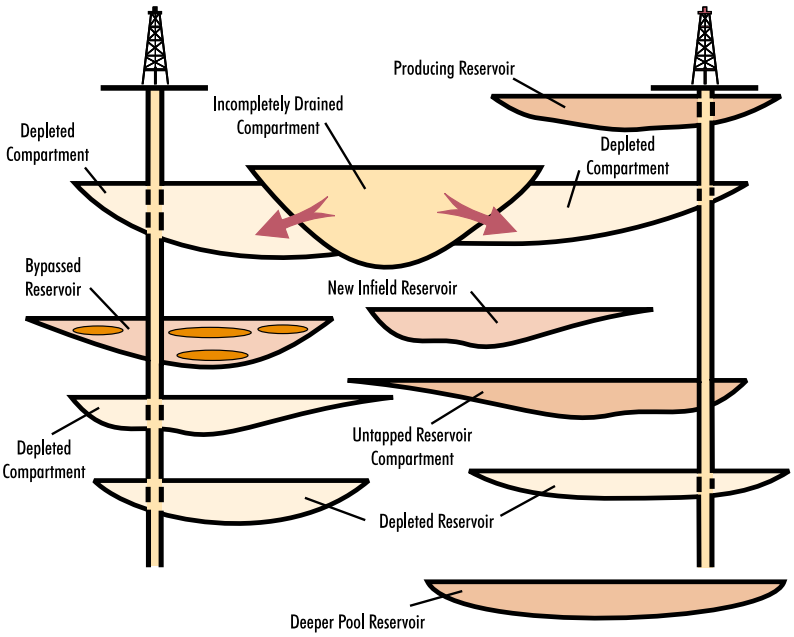
Correct reservoir characterization directs the type of drilling most appropriate for any one reservoir. When applicable, new, smaller bore drills can be used, which minimize the surface area needed for drilling and reduce the impact on the environment. Advanced reservoir characterization also allows 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).