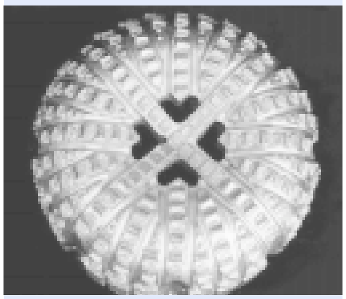
Advanced DRILLING, Completion & Stimulation Systems Program

Enabling Cost-Effective Domestic Oil and Gas Exploration and Production

OIL AND GAS RD&D PROGRAMS

Advanced drilling, completion, and stimulation techniques can help unlock domestic oil and gas resources.



Drilling a well involves much more than making a hole. It entails the integration of complex technologies, requiring the producer to make individual decisions related to unexpected pressure regimes, practices, and rock formations. The resulting well is the sole conduit to move fluids from a reservoir to the surface – a conduit that must last at least 50 years and be flexible enough in design to allow for application of future technologies.

Drilling operators must confront and solve extremely difficult technical, safety, and control problems as they bore through layers of subsurface rock to access oil- or gas-bearing strata. Furthermore, drilling must be done in a way that protects the geologic formation, the ultimate productive capacity of the well, and the surface environment. Drilling problems must first be diagnosed using the information or data that is transmitted from the bottom of the well to the surface, where the information is collected on the rig floor.

Depending on the depth of the well, this time lag can consume valuable time needed to address the problem – either technical or geological – before it becomes worse and/or causes drilling operations to stop. Drilling a well involves all types of technical, geological, and economic risks. The greatest economic risk occurs when drilling operations must be halted after time and cost has been invested. This is the nature of the challenge faced during the drilling process, and the primary reason for developing advanced drilling technologies.

When a well has been drilled and lined with pipe, the connection between the geological formation and the well must be established. Completion includes installing suitable tubing or casing, cementing this casing using rock section isolation devices, and perforating the casing to access the producing zones. In some reservoirs, the geological conditions dictate that stimulation processes be applied to improve reservoir permeability or flow conductivity, facilitating production through the wellbore. Therefore, there are many technologies involved with minimizing complications during the drilling process.

To facilitate exploration and production, DOE invests in research to develop new technologies. In partnership with industry, National Laboratories, and universities, DOE develops tools and techniques that reduce the costs and risks of drilling and support services. DOE also develops methods to reduce potential damage to the geologic formation, and to enhance environmental protection. Drilling technologies that are under development consist of non-damaging fluids and advanced hardware for high-efficiency directional drilling, offering faster rock penetration rates and reduced costs.

Advanced Drilling, Completion, and Stimulation Systems Program

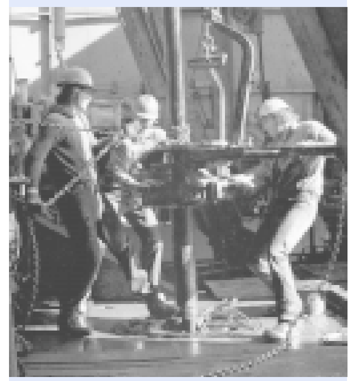
Leading the Way Toward Faster, Deeper, Cheaper, and Cleaner Drilling Systems

DOE has a long history of investment in drilling research. For example, since DOE supported pioneering efforts on measurement-while-drilling (MWD) in the 1970s, this technology has revolutionized drilling operations. The first system to transmit drill bit location by sending pressure pulses through drilling mud was developed by DOE and Teleco, Inc. Today, this mud pulse telemetry has become standard in the industry, saving hundreds of millions of dollars in time and labor.

In 1992, the Department reorganized the oil and gas program to make it more accessible to its stakeholders and to stimulate more joint projects with them. Since then, a number of notable contributions have been made, contributions that would not have been possible without the support of DOE. Examples are: the near-bit sensor, which has made it possible to acquire data from immediately behind the drill bit; Carbon Dioxide / Sand fracturing stimulation, making it possible to stimulate the formation using the liquid phase of the gas as a carrier fluid, and then recovering it in the gaseous phase; and air motors, based on DOE horizontal drilling technology, that are now being used for most new wells drilled in eastern U.S. gas formations.

In the next millennium, the program will continue to make strategic investments in a portfolio of projects that are focused on problems and challenges associated with the wellbore and the near-wellbore region. The Department will focus on making the strategic investments needed to enhance U.S. leadership in the development of "smart wells," such as: “zero footprint” drilling technologies, “rig-less” drilling, “self-drilling” well technology, “designer” stimulation technology, and “single well drainage” capabilities.

Advanced technologies enable access to our Nation’s oil and gas resources while preserving the environment.



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Government Role

Estimates indicate that 47 billion barrels of oil and 325 Tcf of gas are located offshore in Federal and State waters, and 430 Tcf of gas are located in diverse, geologically-complex formations onshore, some on Federal lands, which present unique technological challenges to the drilling phase of oil and gas exploration and production.

In the U.S., 85 percent of wells are drilled by independent oil and gas operators, over 90 percent of whom employ fewer than 20 people. Therefore, U.S. oil and gas production is dependent on the economic health of independent producers. Unfortunately, these companies do not have the resources needed to invest in the development of new technology required to address the challenges present in the various geologic environments that contain oil and gas. Therefore, the Federal Government sponsors research focused on developing advanced drilling technology.

The Federal Government is uniquely positioned to address the technological challenges that exacerbate the marginal economics associated with producing from complex geologic environments. DOE can assume more economic risk than independent producers and can serve as a catalyst in the development of advanced technologies. This is because, as soon as the technology is proven, DOE engages in strategic partnerships with private sector companies to bring these technologies to commercialization, and to the point at which independent producers can begin to use them.

Unlike U.S. businesses, it is DOE's mission to simultaneously ensure domestic energy security while protecting the environment. The private sector alone has little business incentive for this. But in partnership with DOE, the private business interest becomes apparent through the sharing of economic and technical risk. This is where the goals of DOE and the private sector become aligned and partnerships are formed.

Drilling Faster...

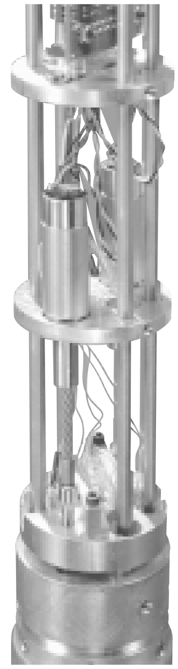
This program element addresses the need for increased efficiency during the drilling phase of energy production. Recognizing that drilling rig time is the most expensive part of operation (30 to 35 percent), the objective then becomes to increase the efficiency with which the well is drilled. This can involve reductions in equipment failure, extension of drill bit life, and reaching the target zone with the fewest number of course corrections possible. This can also involve efficiencies related to production equipment and waste management.

Drilling Deeper...

This aspect of the program addresses the varied and complex geologic environments that exist and affect the drilling phase. Drilling into these environments requires unique drilling strategies that use the specific characteristics of the geologic formation itself to assist in generating a hole. An example of this is the deeper, harder rock formations that contain natural gas. For those formations, the most efficient strategy is to focus on the brittle nature of the rock itself. When hit or hammered, this rock will break into large chips. This is a more effective drilling strategy than to crush and grind the rock into powder, as would be done using conventional roller cone bits. Other formations are sensitive to the type of drilling fluid used. In these cases, the best strategy is to use air as the drilling medium.

Drilling Cheaper...

There is still no substitute for drilling, at least, not yet. The goal, therefore, is to develop technology that will allow the most “cost-effective” drilling. Costs are measured in terms of the least impact on the environment, the longevity of the wellbore and all its components, and the long-term productivity of the wellbore. This means drilling a well with mechanical longevity that does not inhibit the entry of fluids from the reservoir, and that is placed at the precise location needed to achieve the ultimate recovery of oil and gas from a particular type of reservoir.



Advanced Tiltmeter

Success Story

Tiltmeter Awarded Honors

Tiltmeters are used to gain access to oil that is trapped in underground rock formations and to determine the orientation of hydrofractures.

An advancement in tiltmeter design was recognized as one of 1997’s most important technological breakthroughs. An “R&D 100” Award was presented to researchers from Lawrence Livermore National Laboratory and Pinnacle Technologies. Their work improved the range, cost, size, and efficiency of the oil field tiltmeter, now being marketed as the Pinnacle 5000. The annual award recognizes the year’s 100 most important, unique, and useful innovations. Considered a major indicator of successful technology transfer, the competition is the only one of its kind in the world.

Drilling Cleaner...

Another special focus of the program is minimizing the environmental impact of drilling activities. This can range from reducing the amount of surface disturbance that results from the drilling phase of energy production, to dealing with the final disposition of used drilling fluids, drill cuttings, and other waste generated by drilling activities. The use of small bore "slimhole" wells has led to a 75 percent reduction in the amount of surface disturbed and the amount of waste generated. Operating costs are also reduced by up to 50 percent. Furthermore, reduced volume and weight of equipment favors slimhole drilling use in sensitive environments, such as wetlands.

The goal is to develop drilling technologies that are environmentally "neutral," or even "friendly." After all, the drilling cuttings that are excavated from the well are natural materials, and the fluids used in the drilling process must be compatible with the rock to result in a productive well with a long life. Therefore, the basic elements for environmentally benign drilling technologies already are present.

Drilling for the 21st Century...

Finally, there is a need for highly futuristic technologies that would enable drilling without drilling rigs – systems that would have no "footprint." Also, there is a need for drilling systems that anticipate problems and apply the self-correcting adjustments needed to precisely place the wellbore, and that would enable the drilling process to be conducted from an office setting, instead of from a wellsite operation.

Recently, the National Aeronautical and Space Administration, has expressed interest in exploring if a habitable zone for micro-organisms exists under the surface of Mars. To answer this and other questions will require advanced drilling technologies that must withstand the extreme temperatures and remote location, be cost-efficient, and not impact the surface of the planet. Advanced technology that addresses these issues on Mars will also benefit drilling on Earth.

Laser drilling is another possible area of interest. Currently, the Gas Research Institute is studying the feasibility of adapting high-power laser technology, developed by the military for national defense, to drilling for oil and gas. GRI's initial goals are to establish a scientific basis for developing a commercial laser drilling system, and to determine the level of industry interest in pursuing future research. If sufficient industry interest is demonstrated, DOE also will consider a strategic investment in this emerging area.

Industry Issues

- *New concept drilling systems*
- *Drilling systems with high rate of penetration*
- *Underbalanced drilling systems*
- *Improved efficiency of drilling rig systems*
- *Advanced completion and stimulation systems to improve well productivity*
- *Advanced drilling fluids*
- *Reduction of formation damage*
- *Low-cost environmental compliance technologies*
- *Technology transfer*

Natural Gas & Oil Technology Partnership

The Natural Gas and Oil Technology Partnership (Partnership) provides a mechanism for the petroleum industry to collaborate with DOE's National Laboratories on near-term RD&D efforts to improve exploration and recovery of oil and gas. Through the Partnership, industry gains access to unique capabilities of the Laboratories in such areas as electronics, instrumentation, materials, computer hardware and software, engineering, systems analysis, physics, and expert systems.

The Partnership consists of four independently run forums: Oil and Gas Recovery Technology; Diagnostics and Imaging Technology; Drilling, Completion & Stimulation Technology; and Environmental Technology (includes oil processing). The Partnership stimulates, facilitates, and coordinates the development and rapid transfer of technology to industry. The program is industry-driven and leveraged by matching contributions.

Projects in the Drilling, Completion & Stimulation Technology Forum focus on development and demonstration of innovative drilling, perforation, and fracturing processes; subsurface instrumentation; and advanced computational software. This area of research was added to the Partnership in 1992, and its industry interface is through the Completion Engineering Association and the Drilling Engineering Association.

Project examples include:

- Coordinate an industry-wide tiltmeter mapping program to enhance and extend the imaging capabilities of tiltmeters, by: (1) optimizing tool design for deploying the tiltmeters to greater depths, (2) creating a more sophisticated signal processing package, and (3) creating a vertical string of tiltmeters for direct measurement of fracture geometry;

- Simulate multi-phase compressible fluid flow in a coiled-tubing drilling system, with emphasis on hydraulic/pneumatic power conversion, fluid dynamics, thermodynamics, heat transfer, and system optimization;
- Address specific problems related to the successful application of compressible fluids to coiled tubing, directional slimhole, and microhole drilling, including motor or hammer performance, cuttings transport, and bottomhole-assembly resonance and vibration in low-density, highly compressible drilling fluids; and
- Produce system models that support a feasibility investigation of applying underbalanced drilling to slimhole and microhole drilling.

Reduced Footprint

Reduced Environmental Footprint in Alaska North Slope

Drilling and production footprints in Arctic environments have been reduced dramatically in recent years. The reduction of land use has been achieved through improvements in drilling and waste management. Originally, wells were spaced about 120 feet apart. Advances in directional drilling and new drilling rig designs allow wells to be placed within 35 feet of each other, and in some cases, as close as 10 feet. This greatly reduces the surface area required for drilling. In addition, extended reach drilling technology allows drillers to reach targets up to three miles offshore, avoiding costly causeways and offshore artificial islands. Today, new production pads are up to 70 percent smaller than original Prudhoe pads, and spacing between wellheads has been reduced by 75 percent onshore, and over 90 percent offshore.

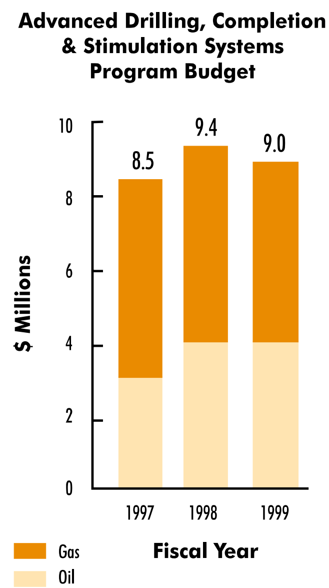
Another recent advance is the cutting grinder, which pulverizes rock cuttings to a flour-like consistency for mixture with the drilling muds. The mixture is reinjected into isolated geologic formations deep underground. This has eliminated the need for traditional reserve pits.

If the entire Prudhoe Bay oil field were built with today's technology, its footprint would be 64 percent smaller than its current size - the area impacted by drilling pads would be 74 percent smaller, roads would cover 58 percent less surface area, and oil and gas separating facilities would take up 50 percent less space.

A Partnership Accomplishment:

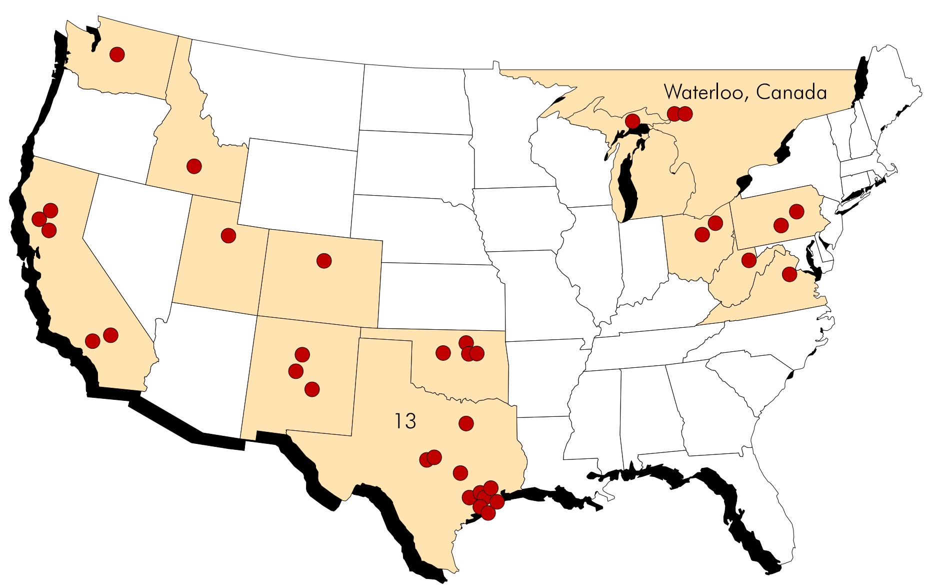
Extending Borehole Electromagnetic Imaging to Cased Wells: Borehole electromagnetic (EM) measurements can be used to monitor certain reservoir production processes (i.e., steamflooding and waterflooding) through steel casing. Previously, it was presumed that open-hole measurements were required due to large EM attenuation and phase shifts from ordinary metal casing. Recent laboratory measurements have indicated that this presumption may be unnecessary. The goal of this Partnership project was to improve subsurface imaging through steel casing.

Results showed that it is possible to make accurate crosshole measurements and the high-resolution imaging of electrical conductivity can be performed using those measurements. The upgraded system increased the transmitter moment from 1,000 to 3,000 Am^2 (Ampere times total coil area) with improved electronics. One major accomplishment from the field test was that data could be obtained even when both boreholes are steel cased. “Seeing” through ordinary metal casing is now possible in lower frequency ranges, which greatly reduces the cost of using this technology. This project will broaden the utility of EM imaging and allow additional production from mature reservoirs.



Project Sites

The Program currently involves 38 projects in 13 States and Canada.



Drivers

- Oil imports provide more than half of domestic consumption and gas imports supply 13 percent of our demand. There is a need to increase the recovery of domestic resources through advanced technologies that result in the fewest number of long-life wells.
- Environmental need to develop drilling technologies that do not disturb the surface environment, and that protect other subsurface natural resources, such as water.
- Current investment in longer-term, higher-risk technologies by the industry is declining.
- Advanced technologies are needed to offset low wellhead prices, which depress the domestic oil and gas industry – an industry that is critical to the Nation's economy.
- The increasing cost of environmental compliance increases the need for more benign technologies that will reduce surface disturbance and waste disposal.

Goals

- Reduce drilling costs.
- Reduce operating costs.
- Improve recovery efficiency.
- Increase the rate of penetration.
- Develop smart systems for unconventional reservoirs.
- Reduce formation damage caused by drilling and completion fluids.
- Provide enabling technologies for advanced smart drilling systems in all drilling environments.

Advanced Drilling, Completion & Stimulation Systems Program

Strategies

Drilling faster....

- Develop faster slimhole drilling systems for horizontal wells in hard limestone formations.
- Reduce rig downtime and the size of deep rigs.
- Improve economics for further expansion of rapid coiled tubing drilling technology to harder rock environments.

...deeper...

- Expand the use of underbalanced drilling systems to a greater variety of reservoir types.
- Improve stimulation and completion design capability for different formation types.

...cheaper...

- Reduce costs of drilling in shale formations, low permeability reservoirs, water sensitive reservoirs, and deepwater reservoirs.
- Develop drilling tools with better wear characteristics and more aggressive cutting structures.
- Reduce capital costs for wellsite fluid separators.
- Develop "high energy" perforation systems.
- Reduce overall drilling and casing cost by 50 percent.

...cleaner...

- Develop benign drilling technologies for use to increase access to productive lands using a small footprint.
- Eliminate and/or reduce cuttings disposal offshore.
- Use "smart wells" to increase access to productive lands with a small footprint.

Measures of Success

By 2010, DOE and industry partnerships will:

- Increase gas reserves by 13 Tcf;
- Add 24,000 jobs;
- Add $0.42 billion in tax revenues; and
- Increase gas production by 1 Tcf/year.

In 2015,

- Achieve cost saving of $375 million; and
- Increase oil production by 4 million barrels.

An appropriate role for the U. S. Government is to serve as a catalyst to industry to develop the next generation of drilling systems.

— National Research Council 1994

Meeting Industry Needs

The Advanced Drilling, Completion & Stimulation Systems Program is at the center of the Department's response to maintain the Nation's energy security. This is because oil and gas can only come to the surface for use to heat our homes, fuel our cars, and run our businesses through a well that must first be drilled. The following documents have captured this need and articulated the Department's role in this effort: National Petroleum Council (NPC) Study, *RD&D Needs of the Oil and Gas Industry* (1995), Petroleum Technology Transfer Council's *Technology and Related Needs of U.S. Oil and Natural Gas Producers* (1996), Report of the President's Committee of Advisors on Science and Technology (1997), and the *Comprehensive National Energy Strategy* (1998). All these documents reinforce that the impact of advanced technology on energy security is to reduce the cost of energy supply. Further, advanced technology will reduce the economic risk associated with drilling investments, and the Federal Government has an important role in ensuring our Nation's energy security by investing in advanced technology development.

Relationship to Other DOE Programs

Technologies developed through this program improve the efficiency of the entire oil and gas exploration and production effort, because decisions made during the drilling, completion, and stimulation phases affect the long-term productivity of the well. Furthermore, by minimizing use of fluids and surface disruption, the program upholds the environmental goals of the Oil and Gas RD&D Program.

Advances achieved in diagnostics and imaging technologies are particularly valuable to improving drilling methods, enabling identification of potential well locations, and reducing the risk of drilling a dry hole.

Advanced Drilling, Completion, and Stimulation Systems Program also participates in the National Advanced Drilling and Excavation Technologies (NADET) program activities. This program is currently managed by DOE's Office of Energy Efficiency and Renewable Energy, as part of its Geothermal Energy program. The NADET program will assist in the leveraged development of advanced drilling technology to lower costs and transfer these technologies to other industries.

Program Areas

The Advanced Drilling, Completion & Stimulation Systems Program consists of seven areas:

- Conventional Drilling System Efficiency
- Underbalanced Drilling (UBD) Systems
- New Concept Drilling Systems/Components
- Drilling Fluids and Cuttings Transport
- Sensors, Production Equipment and Systems
- Completion and Stimulation Systems & Processes
- Risk Issues

The Focus of Program Activities in These Areas are as Follows:

Conventional Drilling System Efficiency

RD&D within this project area includes product development for vertical, directional, and horizontal wells using new high rate of penetration drilling hardware, rig equipment, information systems, and other instrumentation submitted for improving drilling efficiency.

Underbalanced Drilling Systems

This program area addresses the development of technology for use in vertical, directional, and horizontal wells using new underbalanced hardware, models, equipment, and fluid systems.

Advanced Cuttings Transport Facility, located at the University of Tulsa, will provide industry with information on the behavior of compressible drilling fluids including foams, which are required to drill and complete wells in depleted onshore and normally pressured offshore oil reservoirs.

This program area addresses the development of technology for use in vertical, directional, and horizontal wells using new underbalanced hardware, models, equipment, and fluid systems. This is an important area because the drilling process itself has the potential to inhibit the flow of fluids to the wellbore. This "damage" is often caused by the use of heavy-weight fluid to control the influx of oil, gas, and water into the wellbore. Systems need to be efficient in excavating the well while preserving the future productivity of the well.

New Concept Drilling Systems/Components

RD&D within this program area includes revolutionary drilling system ideas, concepts, and prototypes that do not result in or depend on modification of conventional equipment or technology, and which result in significant economies of scale or high net-present-value/rate-of-return over the life cycle of the producing well.

Drilling Fluids and Cuttings Transport

This program is focused on reducing engineering and operating costs for drilling systems, thus improving economics and stimulating increased drilling in the U.S.

Success Story

Polycrystalline Diamond Drill Bits

One of the most important advances in drilling technology took place in 1986, with a breakthrough bonding technique that made polycrystalline diamond compact (PCD) drill bits commercially viable. Within one year of DOE's successful demonstration of the prototype drill bit, dozens of U.S. companies were applying the technology to manufacture the world's first commercial polycrystalline diamond drill bits. The PCD drill bit now accounts for one-third of the worldwide drill bit market, and sales are well above $200 million per year.

A new world record was set by this bit: 20,000 feet of drilling without a bit change. For time-critical drilling, into hard rock or deeper formations or in offshore operations, the PCD drill bit can save as much as $1 million per well. Today, U.S. companies sell more than 4,000 of these diamond drill bits each year.

The hydrocarbon resources at underwater depths greater than 7,000 feet are significant, and much of the technology to reach those resources is still under development. All of the projects are attempting to extend well life through pre-planning and designs for multiple use. The focus of many projects is to address the problems associated with such operations.

Sensors, Production Equipment and Systems

Refined sensing and separation technologies, suitable to the challenging offshore environment, will be investigated. Most of the new offshore developments are equally effective in reducing operation costs for onshore operations.

Completion and Stimulation Systems & Processes

This program area addresses the development of hardware and technology to permit enhanced production efficiency over the life cycle of the well.

Risk Issues

The program goal is to improve the economics and success rates for drilling by developing and disseminating advanced, risk-based, decision management concepts for oil and gas fields.

Highlights of Program Activities

Steerable Air Percussion System

Smith International is developing a steerable air percussion drilling system, which has the potential to more than double the rate of penetration over conventional drilling systems in the curved section of horizontal wells. The key to this system is developing a hammer drill that rotates the bit independently of drill string rotation. The benefits of a system of this type would be increased efficiency and lower cost when drilling through deeper, harder rock reservoirs containing vast amounts of natural gas. Such a system can be operated similarly to current drilling motors with bent sub assemblies for directional control. Wireline tools will initially be used to provide directional information; however, future work will include use of mud pulse telemetry to steer tools for real-time directional control information. Future work will also include rotation of the drilling assembly to maintain hole angle; this will allow drilling of the entire horizontal section of the borehole at a higher penetration rate and with less formation damage.

Advanced Mud Hammer

Novatek is developing a truly advanced hammer drilling system for use in drilling mud environments. The basic tool has a number of advanced features, in addition to the diamond-hardened mud hammer itself:

- a rotary vane motor to rotate the hammer drill;
- an advanced hammer/rotary bit to drill both hard and semi-soft formations (or soft formations with very hard stringers);
- a sequenced high-pressure jet-assist for a novel approach to directional control;
- an integral electric engine to convert hydraulic power to electric power for downhole instruments;
- a casing-while-drilling system based on the capabilities of a new, rugged, diamond-hardened thrust bearing; and
- a seismic “look-ahead” system, based on the high energy hammer impacts as the seismic source. This system will be the first of its kind to provide a truly “smart” drilling system capable of high penetration rates and significant overall cost savings.

High Power Slimhole Drilling System

A mud motor-based drilling system utilizing a slimhole multi-lobe downhole drilling motor (four-five configuration), and a hybrid Thermally Stable Polycrystalline (TSP)/PCD drill bit, has demonstrated in laboratory testing to be capable of providing and utilizing significantly more power downhole for drilling than conventional mud motor systems. The new bit was designed specifically for the increased power available, and it has been modified to be both aggressive and long-running in soft and hard formations. A demonstration is planned at a recognized field test facility to further compare this system to those currently available. Several service companies have agreed to provide systems based on the new design as part of their inventory, following further successful comparison testing of the high power motor and hybrid bit system.

Multiple Fracturing Pumps

High Pressure Coiled Tubing Drilling System

In partnership with Maurer Engineering and its industry advisory committee (consisting of ARCO, BJ Services, Dowell Schlumberger, Halliburton, Marathon, Quality Tubing, and Stewart and Stevenson), ONGPT has initiated design and development of an advanced high-pressure coiled tubing drilling system. Because coiled tubing is a continuous pipe, all noises associated with conventional drilling pipes are avoided. The noise level of coiled tubing drilling is 25 percent lower than conventional drilling. Due to its smaller size, it also uses 80 percent less fuel and emits 88 percent less sulfur dioxide compared to traditional rotary drilling.

As described in the January 1998 issue of *World Oil*, coiled tubing drilling has experienced an over ten-fold increase in utilization, from 30 wells drilled in 1993 to over 400 wells drilled in 1996.

The objective of this research is to add high-pressure jet-assist to the already effective coiled tubing drilling concept, to further extend its performance and utilization. An advantage of the coiled tubing is that it eliminates leakage and other design problems associated with previous attempts to use jointed drill pipe for high-pressure drilling. If successful, this system has the potential to significantly increase the cost-effectiveness and utilization of coiled tubing drilling systems.

High Temperature Logging-While-Drilling System

Sperry-Sun Drilling Services is working to extend the range of operation of current logging-while-drilling systems, from a nominal 150ºC (302ºF) to 175ºC (342ºF), with a minimum of 100 hours mean time between failures. The system will include both density and neutron porosity devices, in addition to resistivity. This development will materially enhance exploration capabilities in deep gas trends, such as those encountered in the deep Austin Chalk formation of Louisiana and Texas.

High Temperature Measurement-While-Drilling System

Maurer Engineering and its partner Halliburton Energy Services are developing a high-temperature measurement-while-drilling system capable of providing basic directional and lithologic information for high-temperature environments, up to an operating temperature of 195ºC (383ºF). Development of this system represents the latest attempt to approach the 200ºC (392ºF) “barrier” for electronic systems currently available in the oil field. It draws on sophisticated quality control techniques and potentially will benefit from the most recent developments in electronics and active cooling systems. At a minimum, this development will further extend the current maximum operating temperatures for deep MWD drilling from 175°C (342ºF) to 195°C.

Hydraulic Pulse Drilling System

Tempress Technologies is investigating the potential of hydraulic pulse drilling. Investigations are attempting to enhance deep drilling (greater than 5,000 feet), where penetration rates normally decrease because of high bottomhole pressures caused by the mud column. Instantaneous negative mud pressure spikes achieved in testing have been adequate to result in failure of pressurized formation samples. If successful, this will be an enabling technology for conventional rig systems, further increasing the life of these conventional units.

New Aggressive TSP Cutter Designs

DOE is investigating new high-strength TSP diamond cutter designs for advanced drag bits, in partnership with Technology International, Inc. (TII) and the Gas Research Institute. These cutters were made possible by new bonding processes being developed by TII, Jet Propulsion Laboratory, and Colorado School of Mines. The new cutter designs are uniquely durable, experiencing significantly less wear than the conventional full round shape. A new kerfing cutter, designed for continuous self-sharpening, has provided a more efficient method for cutting rock. Commercial drill bit manufacturers already have initiated testing on some of the new designs. These enhanced TSP drag bits should last longer and drill faster than conventional bits.

Microwave Processed Components and Bottomhole Assembly Hardening

Many of today's downhole components utilized in high performance drilling systems require varying degrees of hardening and/or roller cone configuration considerations in their fabrication. Synthetic diamond is usually the material of choice for hardening because of its durability in a wide range of environments, and because of the development of a number of technologies that have enabled the bonding of the material to various surfaces. Pennsylvania State University and Dennis Tool Company are developing a new process for bonding synthetic diamond to metals by utilizing microwave energy to provide the heat necessary to achieve the bond. In the microwave process, the heat is generated internally within the material instead of originating from external sources; and there is almost 100 percent conversion of electromagnetic energy into heat, largely within the sample itself. Utilization of this technology will potentially result in dramatically faster manufacturing of a wide range of higher quality synthetic diamond products. Many hours of processing time are often reduced to less than 15 minutes through this technology.

New Non-Damaging Drilling and Completion Fluids

In an effort to enhance economics of current exploration and development drilling, Texas Engineering Experiment Station at Texas A&M University is developing improved drilling and completion fluids, based on a new kinetic mathematical model for accurately predicting the behavior of new materials under downhole conditions. New drilling and completion fluids will be designed to develop a “removable” filtercake. The resulting reduction in formation damage is anticipated to result in significantly improved well productivity.

Downhole Fluid Analyzer

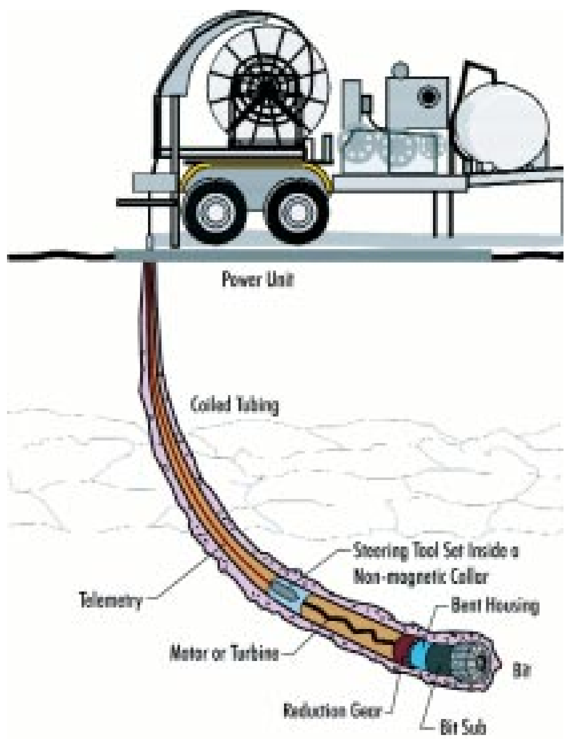
To reduce production costs, APS Technology is investigating “intelligent” completion systems. One component essential to any advanced completion system is information regarding the type of fluids being produced. The downhole fluid analyzer promises to provide that information. It is being designed to measure downhole fluid fractions in real-time without interfering with production. The system will employ permanent remote sensing and fiber optics to provide information to the surface in real-time, and to allow for optimized production decisions. Technologies such as this are supportive of industry initiatives, e.g., the Baker Hughes concept of the “downhole factory,” where only marketable fluids will be brought to the surface.

Russian Drilling Study

In an effort to investigate all potential resources for reducing drilling costs, Maurer Engineering will extend its previous study, *Former-U.S.S.R. R&D on Novel Drilling Techniques*, to focus on aluminum drill pipe and retractable bits. These systems, or derivatives of their components, could potentially enable technologies for some of today's more sophisticated offshore systems to reduce drilling and tripping time. The objective of this effort is to give U.S. industry access to more detailed evaluations of these Russian technologies.

Compact 3-Phase Separator

Compact 3-phase (gas, oil, and water) separator R&D performed by the University of Tulsa/Louisiana State University will continue to focus on the complex multiphase hydrodynamic flow behavior in a 3-phase gas liquid cylindrical cyclone (GLCC). The experimental and computational fluid dynamics simulation results will be integrated with a mechanistic model. Designs for meeting industrial criteria for field application and facilitating easy technology transfer will be incorporated into a model, and a high-pressure field pilot test will be conducted.



MICRODRILLING TECHNOLOGY

Drill bit attached to thin steel coil could revolutionize underground oil and gas exploration.

Fracture Fluid Characterization

The University of Oklahoma rheology research study will maximize understanding of fracture fluid technology results by industry. Fluid rheology RD&D studies, to date, have shown that effective viscosity measurements of cross-linked gels by standard industry tests are in error by as much as 250 percent. Similarly, perforation friction loss of crosslinked fluids was found to be significantly higher than reported by standard industry measurements. To better study these fluids under dynamic conditions, a prototype high-pressure simulator has been built and tested to prove the feasibility of the Fracture Fluid Characterization Facility concept. Additional tests will be conducted with the new high-pressure test cell on a number of fluids in various downhole stimulation environments to complete the study.

Perforation Dynamics

Lawrence Livermore National Laboratory (LLNL) is evaluating conventional-shaped charge perforating systems. This project is part of a larger effort in collaboration with major U.S. gas storage and service companies, Pennsylvania State University, and the University of Illinois (Chicago). The project aims to devise and evaluate means for improving the state-of-the-art method of perforating porous, gas bearing geologic formations.

Surface equipment for 2-phase separation (gas and liquid) that is operated in Southern Oklahoma by Chevron. DOE is currently experimenting with a 3-phase separator.

Success Story

New Microdrilling Technology

Los Alamos National Laboratory researchers are currently testing new microdrilling technology that may revolutionize the way underground resource exploration is conducted in the 21st century. Several major oil companies are also contributing financial or technical support for this technology development.

The technology consists of a standard mining drill bit and oil field drillout turbine attached to a steel coil that is 1 inch in diameter. Conventional production well drills used today can be anywhere from 6 inches to more than a foot in diameter.

Microdrilling systems will occupy a space roughly one-twentieth that of a typical rig and will cost about 90 percent less. Microdrilling realizes additional savings because it requires only about a barrel of fluid per 1,000 feet of drilling to lubricate the bit and motor and remove dirt, whereas conventional drilling requires about 40 barrels of fluid per 1,000 feet.

The microdrilling technology is currently undergoing the first phase of testing at Fenton Hill, a site located about 40 miles northwest of Los Alamos. Thus far, the results have been encouraging. Los Alamos researchers hope to be able to drill down to a target depth of 6,000 feet within the next three to five years.

Computational analysis performed by LLNL in Fiscal Year 1998 suggests that penetration of a shaped charge jet can be enhanced by at least 25 percent, by imploding the liner in a high-pressure light gas atmosphere. Experiments will be performed at Halliburton's Alvarado, Texas test facility to verify the computational analyses. Complementary projects will be conducted by Pennsylvania State University and the University of Illinois to measure the permeability field of a fluid-saturated sandstone before and after perforation, and to compare these results with a model based on the hydrodynamic simulation.

Advanced Tiltmeter Development

Commercialization of downhole tiltmeters for real-time diagnostics of fracture stimulations has been the focus of a number of recent technical publications. Lawrence Livermore National Laboratory (LLNL) is working to improve the current capabilities of this new technology. The primary objective of the program is to design, develop, and test an advanced borehole tiltmeter that can operate in high temperatures, at 125°C (257°F), and in deviated wells. The 125°C circuit boards are complete and the first production run has been made. Software that controls the tiltmeter has been updated to accommodate the circuit changes necessary for the high-temperature board. LLNL has also completed a design for an innovative self-leveling mechanism that will enable installation in highly deviated, or horizontal wells. The first prototype of this mechanism is nearing completion. These two advances broaden the environments in which downhole tiltmeters can be used. This technology is anticipated to significantly impact the effectiveness of stimulations designed for unconventional reservoirs, where permeability is often highly directional.

Ultra-Slimhole and Microdrilling Systems and Components

Los Alamos National Laboratory (LANL) is currently conducting a study to analyze, model, simulate (where justified), and demonstrate ultraslimhole and microdrilling systems and components that are compatible with coiled tubing-deployed directional drilling using multi-phase underbalanced fluids. From these analyses, modified and new drilling system concepts will be developed, which are customized and optimized to support directional drilling with real-time steering using low density, compressible drilling fluids. The study's focus is on effective bottom-hole power conversion to maximize power to the bit and minimize bottomhole assembly (BHA) vibrations in low density fluids. Both percussion drilling and high rate-of-penetration rotary drag bit systems are the primary focus areas.

The program is being run in concert with the Drilling Engineering Association (DEA) Project DEA-101, “Air/Mist/Foam and

Underbalanced Drilling Technology Development and Evaluation." The DEA-101 project is run by Maurer Engineering, Inc. (MEI), and the MEI test facility will be modified for studies associated with this project. Other participants are: DeepLook Consortium, Mobil Technology Company, Roper Pump, and the University of Tulsa.

Coiled Tubing Buckling Prediction Model

Unlike current models that predict helical buckling in coiled tubing used for vertical wellbores using straight pipe, this model includes an intermediate stage referred to as "snaking," which can occur prior to helical buckling. The model also addresses buckling in slanted and curved section of the well, and acknowledges the pre-bent condition of coiled tubing in the calculations. To date, most of the predictions resulting from the model have been within 16 percent of the experimental results. It is estimated that as many as 30 percent of the deviated wells drilled with coiled tubing would see improvement if this model were consulted prior to drilling.

Modeling of Downhole Positive Displacement Drill Motors

Downhole positive displacement motors generally based on the progressive cavity concept have been designed by trial and error. The model developed here for the power section presents criteria for comparing these empirical designs with the ideal drill motor.

It is known that progressive cavity drill motors are not very efficient when used with energized fluids. This model also can be used to suggest better designs for the power section when used with energized fluids. Based on the results of this study, almost 100 percent of the applications for use with progressive cavity drill motors with energized fluids could be improved by redesigning the power section.

Cuttings Transport Facility

A one-of-a-kind, high-temperature, high-pressure field scale facility has been designed for the study of drill cuttings transport by energized fluids. This facility will consist of six major elements: the basic flow loop capable of high-pressure flow; testing at high-temperatures; cuttings transport; the introduction of gas for the creation of energized fluids; the ability to change the angle of the drilling section to simulate deviated wellbores; and the use of eccentric and concentric drillpipe rotation configurations. The first element capable of high-pressure flow is in place and is being used to test the rheology and stability of emulsion-based muds. The ability to fully characterize these fluids has potential for significant environmental benefits. (See photo on page 1-13.)