GEO ENERGY RESEARCH AND DEVELOPMENT:
TECHNOLOGY TRANSFER

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Geo Energy Technology Department II

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Abstract

Sandia Geo Energy Programs related to geothermal, coal, oil and gas, and synfuel resources have provided a useful mechanism for transferring laboratory technologies to private industry. Significant transfer of hardware, computer programs, diagnostics and instrumentation, advanced materials, and in situ process understanding has occurred through US/DOE supported programs in the past five years. The text briefly reviews the technology transfer procedures and summarizes 32 items that have been transferred and another 20 technologies that are now being considered for possible transfer to industry. A major factor in successful transfer has been personal interactions between Sandia engineers and the technical staff from private industry during all aspects of the technology development.

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SANDIA R&D - PROGRAM MATRIX

	PROGRAM AREAS					
	1700	4200	4300	4400	4500	4700
R&D AREAS	NUCLEAR SECURITY SYSTEMS	PULSED ENERGY	WEAPON SYSTEMS	NUCLEAR FUEL CYCLE	WASTE MANAGEMENT	ENERGY PROGRAMS
1000 - FIELD ENGR WEAPON'S ANAL PROCESS LABS DEVELOPMENT TESTING						
2000 - ELECTRONICS ELECTROCHEMICAL COMPUTING						
5000 - SOLID STATE SCI ENGR SCI SYSTEM SCI MATERIALS SCI						
6900 - APPLIED RES

Matrix system provides an effective mechanism for utilizing advanced weapons technologies to meet energy and other non-weapon needs.

GEO ENERGY TECHNOLOGY: TRANSFER FROM SANDIA TO INDUSTRY

Recognition that mechanical switching devices could never meet the increasing demands of communication networks, Bell Telephone Labs initiated a research program resulting in the now ubiquitous transistor. This successful development with the ensuing transfer of multiple technologies to many industries is a recognized achievement of this century and details are well documented [e.g., References 1,2]. This concept of research directed to solve a problem with a requirement of transferring results to a manufacturing facility has been passed down from Bell Laboratories to Sandia for developing the sophisticated, high reliability components needed for nuclear weapon systems. Since all the weapon components are produced by captive private industry, all advanced technology has to be transferred effectively from the government laboratory to industrial process lines on defined schedules.

When the energy shortage had serious national security implications and the national laboratories were asked to assist development of solutions, Sandia made a conscious decision to apply its technology base to resolve problems then existing in the fossil and geothermal energy producing communities rather than to develop new energy producing concepts. This decision required intimate interactions with industry personnel from the research labs to field operations. The decision also implied, in many cases, an understanding of the economics, definition of a development schedule and a product that would be adopted by private industry.

This report is a summary of those results from the Geo Energy (geothermal, fossil and synfuels) Programs at Sandia. The following briefly reviews technology transfer concepts, how they were evolved by Sandia, and then summarizes the technology that has been or is being transferred. Composition of the industrial advisory panels and some relevant references are included in the appendix for general information. This report will hopefully demonstrate that government laboratories and private industry can work effectively to solve national problems and the results can catalyze further industry-laboratory interactions.

GEO ENERGY RESEARCH AND DEVELOPMENT:
TECHNOLOGY TRANSFER

Large government investments in R&D result in many developments that have potential application in U.S. industry. The mechanism of transferring this technology has been the subject of books [3-5], conferences [6,7] and many papers. NASA [8] has implemented a major technology transfer program including state, university and industry applications centers, a computer software and management center, a distribution of NASA Tech Briefs and applications teams. Nevertheless, the amount of spinoff technology from all government R&D has been disappointing considering the total federal investments [9]. A number of reasons for limited spinoff are given in Table 1.

As mentioned earlier, Sandia chose to use their capabilities to directly transfer technology to energy producing industries. A number of mechanisms have been suggested for transferring technology; some are listed in Table 2. However, with all the rhetoric, modeling and analyses, one fact keeps being repeated:

"The key to successful technology transfer lies not in procedures, but people." [12]

"...feedback, direct personal links...direct contacts" [13]

"The real problem is that we ignore the human involvement." [14]

Technology transfer is "movement of people... agents versus agencies." [15]

"In fact, it appears that the early establishment of a strong innovator -- manufacturer linkage -- strong enough so that the manufacturer becomes the co-inventor -- is one of the keys to successful transfer of federal laboratory technology." [16]

Successful transfer requires "a champion." [14]

To assure strong communication links, extensive industrial interaction is designed into all programs as outlined in Table 3. The "Stages of Development" are standard for an R&D program with the exception of a continuing system and economic analyses through the development activities to:

- . Identify critical areas requiring R&D plus those that have the most potential for influencing costs

Table 1. Impediments to technology transfer from national laboratories

Lag Time:	An approximate six-year lag time [10] exists between the actual transfer operation and visible industry use.
<hr/>	
Mission Goals:	Mission-oriented laboratories have defined goals (e.g., reliable weapons, safe waste disposal, etc). Attempts to transfer technology to other industries detract from those goals and do not improve the viability of the labs.
<hr/>	
Program Termination:	Successful transfer of technology terminates an R&D program with no assurance of combining support for a researcher; i.e., the researcher works himself out of a job.
<hr/>	
Visibility:	Direct transfer of technology needed to meet mission goals is usually not considered a spinoff to industry; secondary applications of this technology may not be visible.
<hr/>	
Not Technical:	The mechanics of transfer are difficult, expensive, and not usually technically challenging.
<hr/>	
Solution Oriented:	Most scientists work in a discipline-oriented environment (solid state, shock wave, circuit design...), not a problem-oriented environment. Thus, they have many solutions searching for problems.
<hr/>	
Incentives:	No incentives exist to encourage transfer efforts. However, NASA's actions were legislated and the recent Stevenson-Wydler Act [11] requires other federal agencies to make a conscientious effort to transfer technologies.

Table 2. Mechanisms of technology transfer

Most Effective

Spinoff Industry

People Transfer to Industry

Joint Government-Industry Development and Test*

Government Development - Joint Test*

Workshops

Design Given to Industry

Publications and Presentations

Data Banks

*Frequently involve R&D contracts from government to industry

Table 3. Technology transfer processes

Activity	Stages of Development				Transfer
	Evaluation	Feasibility	Development	Verification	
System and Economic Analyses Industry Review (continues to end of program)	Math & Lab Models Basic Research Define Boundary Conditions	Build & Test Prototypes Lab & Initial Field Tests	Viable Prototype Field Test & Evaluation	Design, Manufacture and Test in Commercial Application	
Advisory Panel	Establish	Continued Involvement in Critique, Joint Tests, Potential Users

- . Involve industry to understand commercial constraints and incentives
- . Develop realistic schedules and goals
- . Provide a rationale for shutting down a program if results cannot be justified
- . Identify new areas for needed R&D

Advisory panels of industrial personnel, plus academic and government experts provide semi-annual critiques of the programs, identify capabilities for joint endeavors and become personally involved in technologies of interest to their firms. None of the panel members have, nor expect contracts from the programs they advise. Industry has been most supportive in these interactions; advisory panel members who have supported Sandia programs are listed in the appendix.

The funding sequences obviously vary with different projects, but it is important that projects be carried through the verification stage to assure transfer. The industrial funding has typically been to support the advisory panels, provide hardware or computer analyses specific to a given development, offer test or operational facilities to evaluate prototype equipment and supply the design and manufacturing support for building final hardware parts.

The following chapter summarizes the results of this methodology as applied to the geotechnology programs.

GEO ENERGY TECHNOLOGY TRANSFER

The effective transfer of technology occurs for many reasons and in several ways. A new concept -- hardware, computer program, material -- that has an economic or market advantage, will be readily transferred. Such a transfer is obvious and easy to document. In some cases, a technology exists but industry is reluctant to pick it up because of the risk involved in modifying an existing plant or procedure. In the case where that technology exists at a federal laboratory, some directed research can catalyze adoption of that technology by industry. Since the technology does exist, the catalytic role of a laboratory may be difficult to quantify. When technology transferred consists of information or understanding, the transfer usually cannot be quantified. Such "inventions" have many fathers. Industrial personnel will also have been thinking along similar lines due to past contacts and the new concept is undoubtedly an evolution of many peoples' thoughts.

The following discussion is divided into these three categories: New Concepts, Risk Removal and Understanding. Again, there will be fuzzy boundaries between the areas with potential overlap. The results described are those by Sandia researchers and contractors. In most outside contracts, a Sandia engineer or scientist was involved in research on one aspect of the project to maintain technical expertise in that area and contribute to the problem's solution.

Technology Transferred

New Concepts

Drilling, Completions and Mining: The following activities are all oriented to accessing resources including geothermal, oil and gas, coal and minerals.

- . Developed computer code to place polycrystalline diamond compact cutters on bit to optimize cutter life. Code now used by several major bit companies (Reed, PCI, Smith, Security).
- . Developed process for diffusion bonding of PDCs to bit studs. Pressure Coring Inc. is now applying this technology.
- . Developed (with Hydronautics, Inc.) cavitating jets to enhance cutting and cleaning ability of bi-cone and tri-cone bits. Nozzles now available in Smith A-1 bits.

- . Developed and field tested new high-temperature drilling fluid using sepiolite clay. Formulation now available from NL Baroid.
- . Developed (with L'Garde) high-temperature elastomers for "O" ring applications. Now available through L'Garde, Precision Rubber, and Parker Seal Company.
- . Developed (by Pacer Industries) high-temperature lubricant for roller-cone bearings. Marketed by Pacer Industries as Geobond™.
- . Identified stabilizing agents and detergents for making aqueous foams stable at high temperature. Foamair is using results in foam drilling and Chevron in foam drive for enhanced oil recovery.
- . Low invasion organic and water-based coring fluids developed for sampling depleted oil reservoirs are now in use by Pressure Coring Inc. and Christensen.

Diagnostics: The major portion of diagnostics R&D has been oriented toward instrumentation and analyses of in situ processes as enhanced oil recovery, oil shale retorting, underground coal gasification and stimulation, and to the evaluation of reservoirs by improved logging tools. Emphasis was also on high temperature electronics and capabilities.

- . Quartz crystal transducer research led to new company, Quartex, and establishment of lab at Schlumberger.
- . New thick film resistor inks and discrete resistors for hybrid use at high temperature were developed and marketed by Cermalloy, DuPont, Craddock and Corning.
- . Development of new circuits, materials, rotating transformer, acoustic transducers and other improvements are being incorporated into the borehole televiewer by Simplec, the original manufacturer, and by Hot Hole Instruments, a new company established to provide high temperature field instrumentation.

- Monitoring of in situ temperatures, pressures, flows and gas compositions is combined with retort model calculations, for oil shale retorting by Geokinetics and Occidental Oil Shale.
- X-radiography for catalyst level monitoring developed, built and installed at HRI for coal liquefaction processing; Lummus and others requesting similar diagnostics and manufacturing technology being transferred to JR Sheppard.

Processes: Hardware or concepts to improve processes have been developed with major emphases on enhanced oil recovery and stimulation.

- Development and test of a downhole steam generator for enhanced oil recovery is a new concept that has provided technology for five firms currently marketing generators; one of the firms, Enhanced Energy Systems, is a new company.
- Development of advanced packer designs for high temperatures resulted in marketing of new designs by Baker, L'Garde and Foster-Miller.
- Developed and demonstrated the tailored pulse loading concept for creating multiple fractures for well stimulation. Currently offered as a commercial service through several companies.

Risk Removal

Drilling, Completions and Mining:

- Catalyzed design and use of bits using polycrystalline diamond compact (PDC) cutters. Prior to Sandia involvement, there were no commercial PDC bit manufacturers in the United States; now there are fifteen-plus companies marketing PDC bits (PCI, Stratabit, Davis Hicks, Security, Christensen, American Coldset, etc.).
- Developed (with Drilling Research Labs) new seals and materials for tri-cone bits which enable survival at geothermal temperatures. Program cost shared with Reed Tool Company.

Figure 1. Downhole Steam Generator Concept -- Steam is used to recover heavy oils in oil reservoirs and tar sands. The downhole generator has advantages over surface boilers of high thermal efficiencies, reduced air pollutants and more rapid recovery of oil.

Figure 2. Downhole Steam Generator -- The generator is being installed in a well in conjunction with the City of Long Beach, California.

- Redesigned (with DOWDCO) a pressure coring system for higher pressure use, to recover a longer core, with improved seals, and to incorporate a core orientation device; is in commercial use and resulted in establishment of a new company, Pressure Coring Inc.

Diagnostics:

- Developed 275°C hybrid circuitry for: voltage regulators, line drivers, pulse stretchers, and voltage-to-frequency converters. Products are now available from Teledyne-Philbrick.
- Developed a multiplexer (GE marketing) and an op-amp (Harris marketing) for use to 275°C in downhole logging tools.
- Demonstrated (with Gearhart Industries) the application of hybrid microcircuit technology to logging tool instrumentation; adopted for use by Gearhart and Schlumberger.
- Design changes on clock bearings and lubricants now used in slick line logging tools transferred to Kuster Tool and Geophysical Research; also a new company, Thermodurics, established.
- Developed several advanced instrumentation techniques for in situ process monitoring; the tilt meter concept for determining fracture propagation direction was jointly developed by and currently marketed by Fracture Technology, Inc., and others.

Processes:

- Verification of insulation effectiveness on downhole tubular goods resulted in a new injection string insulation system by GE and catalyzed work on new downhole pipe insulation concepts by several companies.
- Identification of catalytic effects by pyrite and other minerals in coal provided major impetus to DOE programs in disposable and slurry phase catalysts. Being evaluated by Gulf, Exxon and Mobil.

Figure 3. High Temperature Electronics -- The high temperature hybrid micro-circuits (upper unit) operate to 275°C, are more compact than conventional circuitry (middle unit) and have high reliability. These circuits are packed in a Gearhart temperature logging tool (lower unit).

Figure 4. Logging a Geothermal Well -- Operation of the high temperature electronics was confirmed by logging Union's geothermal wells.

Information

Drilling, Completions and Mining:

- . Software for analyzing casing stress and failure in geothermal environments adapted by Union and Aminol.

Diagnostics:

- . Improved performance of Corioles mass flow meters by changing tube radii being incorporated in new models by Micromotion, Inc.

Processes:

- . Verification of low temperature coal dissolution reactions enhancing shift of all direct liquefaction processes to "two-stage" processes.
- . Measured residence times and catalyst deactivation rates in H coal PDU; resulted in changes in operating procedures and data interpretation for H-coal process.
- . Development of novel, slurry phase catalysts initiated research on advanced catalysts for two-stage liquefaction at Amoco, American Cyanamide and Lummus/Cities Service.
- . Identification of the formation and loss of low boiling hydrocarbon fuels in oil shale retorting; now being recovered by Geokinetics.

Technology with Potential for Transfer

Extensive interactions with advisory panels and industry assures that many program aspects are in the process of being transferred. The technologies listed in this section have received industrial interest and many should be transferred within a year.

New Concepts

Drilling, Completions, and Mining:

- . Designed and built high-temperature/high-pressure viscometer for evaluating drilling fluids at geothermal conditions. Prototypes now being used by Texas Tech University. Industry requests from Shell, Chevron, and Union.

- . Application of an inertial navigation system to the spatial mapping of wellbores. Field test of prototype tool scheduled for February 1982. Exxon and Scientific Drilling Controls currently developing hardware; Sperry Sun and Eastman Whipstock following. Patent problems delaying transfer of electronic design, packaging techniques and associated software.
- . Design (with Engelhard) of inert gas generator which cleans diesel exhaust gas for use as a substitute for air (when air drilling) to reduce drill pipe corrosion. Companies such as Western Air Drilling and Foster-Miller Associates considering marketing.
- . Waterjet descaling system for cleaning scale for geothermal wells. Uses cavitating jets, minimizing casing damage and permitting well to flow while being cleaned. Also being considered for under-reaming geothermal wells to increase productivity.
- . Waterjet drill for providing horizontal wellbores in coal seams for methane drainage, in situ gasification or other processes.
- . Reamer bits modified to use polycrystalline diamond compact cutters and Sandia developed wear sensors (to indicate hole gage) to be evaluated in field tests.
- . Completed development of roof bolt drill bits which significantly improve penetration rates and bit life over conventional bits; being evaluated by General Electric, Kennametal and Bendix.

Diagnostics:

- . Development of a long-life, high-power electrical switching device for use at elevated temperature. Sprytron tube is being modified to operate as SCR for primary use in cement-bond logging tool.
- . Development of a 300°C sheathed monocable which is resistant to geothermal environment. Halpen Engineering to deliver 15,000 feet of sheathed monocable to Sandia in March 1982. Other private companies have initiated development and marketing activities.
- . Downhole, periodic seismic source for in situ, geophysical exploration of geothermal and oil or gas reservoirs, mineral resources and in situ processes.

- . Development of high temperature probes for monitoring convection in magma bodies being considered for use in monitoring steel making processes.
- . Magnetic tracer for process diagnostics requested by Lummus and Exxon.
- . Electrical potential and borehole seismic methods developed for determining fracture orientation and geometry is being documented and being considered for adoption by industry.
- . Remote, underwater seismic equipment with an automated acoustic communications link has been developed and successfully used; detailed designs being disseminated to industry.

Processes:

- . Titanium Diboride hard coatings as valve trim for Air Products and Exxon; for hardened thermocouple wells by Stearns-Rogers.
- . Currently developing and demonstrating technologies to recover gas from lenticular, tight gas sand reservoirs in an extensive field experiment in Colorado; joint industry-Sandia effort constantly transferring technology.

Risk Removal

Drilling, Completions and Mining:

- . Seals capable for sealing high-speed turbine/motor bearing packages at geothermal conditions. The HPCR-SF design has operated for 200 hours under laboratory conditions.
- . Guidelines for the design of hydraulic configurations to improve cutter cooling and bottomhole cleaning being assessed by industry.
- . Developing understanding of coal and rock cutting energetics through laboratory tests and finite element analyses for advanced rock and coal cutting systems.

Processes:

- Research on low temperature coal liquefaction mechanisms and catalyst deactivation processes originated a concept of low severity coal liquefaction now being considered for H-coal and the new two-stage liquefaction processes.

SUMMARY

The unclassified, energy related, industry oriented Department of Energy Programs at Sandia have provided an excellent mechanism to effectively transfer many of our technologies from government to industry. The strong research base in insitu diagnostics (from weapons testing), transport processes and materials for hostile environments is being coupled with a directed systems approach to get new concepts into the private sector. A recent conference [17] on high temperature electronics, after all federal funding on the project had ceased, attracted over 350 attendees with industry asking to present papers and display new wares. This termination of a geothermal logging instrumentation program signaled the advent of a new industrial move into high temperature electronics for use in the logging of deep gas wells and geothermal resources, for monitoring controls and environments inside nuclear reactor containment vessels, for warning of jet flameout in aircraft engines and many other new applications.

Details of the transferred technology, presented in the previous text, can be summarized in facts:

- . Five new companies have been established based on these technology developments.
- . Over thirty engineers and scientists, involved in these energy programs, have joined industry at industry's initiative.
- . A new perspective of electronics use in hostile environments and for describing in situ processes has been initiated.
- . Capabilities were made available to monitor and evaluate national problems as coal mine fires in Pennsylvania and Colorado, volcanic hazards at Mt. St. Helens, and oil storage problems at the Strategic Petroleum Reserve sites.

The technology transfer has been largely from the base developed in the weapons programs to the energy sector, but transfer has also occurred in the other direction. Work on special crystallographic cuts of quartz crystals to minimize temperature effects for the evaluation of geopressured resources has resulted in quartz tuning forks for weapon's timer applications. Work initiated on gallium phosphide and arsenide semiconductor devices for high temperature diodes is being applied to use in radiation hardened circuits for weapons.

The success of these programs reinforce the lessons of past technology transfer studies that person-to-person interactions are essential to effective transfer. These interactions are generally well supported by industry as evidenced by the advisory panels and many joint programs. As the energy programs phase out of the federal budgets, new methods will have to be developed to maintain the existing communications. Unfortunately, these new methods have not yet been identified.

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APPENDIX A

ADVISORY PANELS

Geothermal Technology Program Industry Advisory Panel

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Larry Diamond, Vice President, Technical Services, Dyna-Drill
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Paul Durning, Union Oil
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High Temperature Logging Instrumentation Panel

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Bruce Blackman, Electrical R&D Department, Halliburton Services
R. A. Broding, Amoco Production Company Research Center
Jan Brown, Schlumberger Doll Research
John T. Byrne, Interstate Electronics
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John Moore, Consolidated Natural Gas Services Corp.
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Alfred Schlemmer, Texas Eastern Gas Pipeline Corp.
Stanley Whitford, Natural Gas Pipeline Co. of America
Charles Nathan, New Mexico Energy Institute

APPENDIX B

MAJOR PUBLICATIONS

Coal

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APPENDIX C

EXHIBITS

OIL AND GAS RESEARCH AND DEVELOPMENT

ENHANCED OIL RECOVERY

EXTENSION OF STEAM DRIVE TECHNOLOGY

UNCONVENTIONAL GAS RESOURCES

UNDERSTANDING AND EVALUATION OF STIMULATION TECHNOLOGY

DRILLING TECHNOLOGY

IMPROVEMENTS IN DRILLING SYSTEM PERFORMANCE

OFFSHORE TECHNOLOGY

CHARACTERIZATION OF GEOTECHNICAL ENVIRONMENTS

SANDIA OIL AND GAS RESEARCH AREAS

SYNTHETIC FUELS RESEARCH AND DEVELOPMENT

COAL LIQUEFACTION

IMPROVE DIRECT LIQUEFACTION PROCESSES

COAL GASIFICATION

COAL-CHAR

EXAMINE MINERAL CATALYTIC EFFECTS

IN SITU COAL GASIFICATION

ESTABLISH PROCESS RELIABILITY

OIL SHALE

ADVANCE MODIFIED IN SITU TECHNOLOGY

SANDIA RESEARCH AREAS IN SYNTHETIC FUEL DEVELOPMENT

GEOTHERMAL TECHNOLOGY PROGRAM

DEVELOPMENT OF ADVANCED DRILLING, COMPLETION, AND LOGGING SYSTEMS FOR ACCESSING THE GEOTHERMAL RESOURCE

ROCK MECHANICS

CAVITATION RESEARCH

WELLBORE INSTRUMENTATION

HIGH SPEED STRATAPAX[®] BITS

**AQUEOUS FOAM
PROPERTIES RESEARCH**

EFFECT OF PRESSURE ON AQUEOUS FOAM CELL SIZE
LIQUID VOLUME FRACTION - 0.05

**LOST CIRCULATION
MATERIAL EVALUATION**

Sandia National Laboratories

GEOTHERMAL TECHNOLOGY RESEARCH AREAS

MAGMA ENERGY RESEARCH

GOAL: TO DETERMINE THE SCIENTIFIC FEASIBILITY
OF MAGMA ENERGY UTILIZATION

ACTIVITIES: LAVA LAKE FIELD EXPERIMENTS
LABORATORY CONVECTION
EXPERIMENTS IN FURNACES
MAGMA CHARACTERIZATION
STUDIES

FY81 ACCOMPLISHMENTS:

DRILLED INTO 1100 °C MELT AND
SUCCESSFULLY OPERATED FIRST
OPEN HEAT EXCHANGER
IN MOLTEN BASALT

MEASURED SEISMIC TRANSMISSION
SIGNATURE THROUGH A MELT LENSE

TECHNICAL TRANSFER NEW COMPANIES ESTABLISHED

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	THERMODURICS	HIGH TEMPERATURE UPGRADING OF SLICK LINE INSTRUMENTS
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	PETROLEUM CONCEPTS. INC.	DRILL BIT FABRICATION
ENHANCED OIL RECOVERY	ENHANCED ENERGY SYSTEMS	DOWNHOLE STEAM GENERATORS
MULTI-FRAC DEVELOPMENT	TAILORED PULSE LOADING. INC.	FRACTURING SERVICE

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	VENERUSO	GEARHART, IND	LOGGING TOOL DEVELOPMENT
DRILLING TECHNOLOGY	VARNADO, McFALL, WESENBERG	N L PETROLEUM SERVICES	MEASUREMENTS WHILE DRILLING TECHNOLOGY
	ST CLAIR	EXXON	DRILLING - MECHANICAL DESIGN
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	POLITO	PRITSKER & ASSOC.	SYSTEMS ANALYSES
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MULT FRAC DEVELOPMENT	STOLLER, REECE, SCHMIDT	TAILORED PULSE LOADING	FRACTURE SERVICES
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