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Oil and Gas Technology Transfer Activities and
Potential in Eight Major Producing States

Volume 1

July 1993

Work Performed Under Contract No. DE-FG22-91BC14818

Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

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ACKNOWLEDGEMENTS

"Oil and Gas Technology Transfer Activities and Potential in Eight Major Producing States" is the second report of the "Project on Oil and Gas Technology Transfer", being conducted by the Interstate Oil and Gas Compact Commission (the Compact). This second phase was initiated by grant from the U.S. Department of Energy, Bartlesville Project Office (BPO), to the Compact. Special acknowledgement to Mr. Thomas C. Wesson, BPO Director, Mr. Fred Burtch, EOR Program Manager, and to Mr. Herbert A. Tiedemann, BPO Project Manager for Technology Transfer, is extended for their encouragement, participation, and assistance.

ICF Resources Incorporated, of Fairfax, Virginia, served as the Compact's principal consultant responsible for the profile analyses, interpretation, and report preparation. Mr. Peter M. Crawford, Project Manager, directed day-to-day activities and carried out the majority of key activities. Mr. Jerry P. Brashear, Senior Vice President, served as program director responsible for overall program design. Ms. Maureen O'Brien, Research Assistant, and Mr. Jeff Enright, Analyst, also assisted in the research, writing, and analyses. Administrative support and text presentation services were provided by Ms. Barbara Jones and Ms. Patricia Kipp. Mr. Robert V. Cooper, Associate Director of the Compact, supervised the direction of the project and assisted me in providing liaison and coordination among the participating organizations.

The Compact also wishes to acknowledge those state, regional, and national organizations which provided information and assistance without which this project could not have been completed. They include:

California: University of California at Berkeley; University of Southern California; Conservation Commission of California Oil and Gas Producers; California Independent Petroleum Association; Pacific Oil Conference; California Resources Agency; Stanford University; Western States Petroleum Association; Independent Oil Producers' Agency;

Illinois: Illinois Department of Natural Resource; Illinois State Geological Survey; Illinois Oil and Gas Association;

Kansas: Kansas Geological Society; Kansas Geological Survey; University of Kansas; University of Kansas Tertiary Oil Recovery Project; University of Kansas Energy Research Center; Kansas Corporation Commission; Kansas Independent Oil and Gas Association;

Louisiana: Louisiana State University; Louisiana Geological Survey; Louisiana Tech University; Louisiana Department of Natural Resources; Louisiana Mid-Continent Oil and Gas Association; Louisiana Independent Oil and Gas Association;

New Mexico: New Mexico Institute of Mining and Technology; New Mexico Energy, Minerals, and Natural Resources Department; Eastern New Mexico University; New Mexico Junior College; New Mexico Petroleum Recovery Research Center;

Oklahoma: University of Oklahoma; University of Oklahoma Center for Reservoir Characterization; Sarkey's Energy Center; University of Tulsa; Oklahoma Geological Survey; Oklahoma Independent Petroleum Association; Oklahoma Corporation Commission;

Texas: University of Texas at Austin, University of Texas at Austin, Center of Petroleum and Geosystems Engineering; Railroad Commission of Texas; Houston Advanced Research Center; Texas A&M University; Texas Independent Producers and Royalty Owners Association; Texas Tech University; Bureau of Economic Geology;

Wyoming: University of Wyoming; Casper College; Enhanced Oil Recovery Institute; Western Research Institute; Petroleum Association of Wyoming; Wyoming Oil and Gas Commission; and Independent Petroleum Association of Mountain States.

The Compact would also like to thank other national-level organizations including Sandia National Laboratory, Los Alamos National Laboratory, Society of Petroleum Engineers, American Association of Petroleum Geologists, Independent Petroleum Association of America, and the *ad hoc* Petroleum Technology Transfer Council for their valuable inputs and contributions to this effort.

W. Timothy Dowd
Executive Director
Interstate Oil and Gas Compact Commission

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EXECUTIVE SUMMARY

In 1990, the Interstate Oil and Gas Compact Commission (the Compact) performed a study that identified the structure and deficiencies of the system by which oil and gas producers receive information about the potential of new technologies and communicate their problems and technology needs back to the research community. The conclusions of that work were that major integrated companies have significantly more and better sources of technology information than independent producers. The majors also have significantly better mechanisms for communicating problems to the research and development (R&D) community. As a consequence, the Compact recommended analyzing potential mechanisms to improve technology transfer channels for independents and to accelerate independents' acceptance and use of existing and emerging technologies.

Building on this work, the Compact, with a grant from the U.S. Department of Energy, has reviewed specific technology transfer organizations in each of eight major oil producing states to identify specific R&D and technology transfer organizations, characterize their existing activities, and identify potential future activities that could be performed to enhance technology transfer to oil and gas producers. The profiles were developed based on information received from organizations, follow-up interviews, site visits and conversations, and participation in their sponsored technology transfer activities. The results of this effort are reported in this volume. In addition, the Compact has also developed a framework for the development of evaluation methodologies to determine the effectiveness of technology transfer programs in performing their intended functions and in achieving desired

impacts in the producing community. The results of that work are provided in a separate volume.

The eight states analyzed and profiled by the Compact were selected on the basis of known remaining oil-in-place. They are: California, Illinois, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming. A "technology transfer profile" has been prepared for each of these states. The profiles describe recent oil and gas industry trends in the state and detail the current technology transfer functions of each public and private R&D and technology transfer organization. The profiles also describe each organization's potential for expanded, coordinated participation in technology transfer. In each state, the project analyzed state organizations, including the oil and gas regulatory agency, the geological survey, and state-funded universities. The project also analyzed private college and university programs, industry organizations, and established technology transfer programs.

Throughout the project, the Compact also observed the technology transfer related roles and functions of, and interactions between national organizations. The organizations include industry trade associations, professional societies, the Department of Energy's oil R&D program, and some of the national laboratories. The focus here was to identify mechanisms through which state level and national level organizations interact or could interact to provide an integrated technology transfer system.

Although the primary intent of this effort was to develop the state technology transfer profiles, the Compact has made numerous observations and conclusions about the roles and potential of specific classes of state and national

organizations, technology transfer approaches, and current and potential interactions between the state and national level organizations and the producing industry.

CONCLUSIONS ABOUT STATE-LEVEL ORGANIZATIONS

Within the states, there is an increasing level of interest in technology transfer by all of the relevant participants including producers, state agencies, universities, and industry associations. However, significant gaps in addressing priority problems and gaps in interaction between the various organizations still exist. These gaps are to the detriment of achieving state and national goals to improve oil and gas production.

In each state, the regulatory agencies play an important role in collecting, analyzing, and providing data and information about both the producing industry and the environment in which the industry is working. Because of their regulatory role, however, it is difficult for these agencies to interact closely with producers to advocate technology approaches.

Conversely, state geological surveys, whose role is to characterize the state's resources and assist, as appropriate, in their commercial development, have taken an active role in some states. Geologic surveys are researching, developing, and promoting the application of innovative geoscientific analytical tools for improved reservoir characterization and improved oil and gas extraction technologies in order to enhance production. Increasingly, the geological surveys are bridging the disciplinary gaps between geologists and engineers to perform integrated research and development activities that result in useful products for and approaches to the industry. In several states, the geological surveys are located in or interact with the academic, R&D, and industry-cooperative efforts of the state university.

In several states, the university geoscience and petroleum engineering academic, research, and industry cooperative efforts are increasingly interactive. Many are trying to reduce the

impacts of declining enrollments in disciplinary academic programs on their capacity to perform research and development. Several state universities have developed separate research institutes to address specific research topics of interest to industry and to provide a forum for interdisciplinary research. These institutes and related consortia research activities help to leverage limited university and industry research budgets and to share ideas and breakthroughs without breach of anti-trust concerns. In both state and private universities, concerns were voiced about the continued future availability of state, federal, and/or private industry funding to assist in the development and maintenance of technology transfer activities.

In several states, including Kansas, New Mexico, and Illinois, highly problem-focused, producer-oriented technology transfer programs have existed for several years to address high priority, high impact problems of the producing community. These organizations (the Kansas Tertiary Oil Recovery Project [TORP], the New Mexico Petroleum Recovery Research Center [PRRC], and the Illinois Oil and Gas Association and Illinois Geological Survey) have been successful because they focus on problems and solutions and because they work on a one-to-one basis with producers. They cooperate with the industry associations and other research and technology organizations on a highly cooperative and interactive basis. Since the Compact's 1990 report, these organizations have continued to serve the industry, and have modified their approaches and activities to adapt to changing needs and priorities.

In addition, during the past two years, the Texas Independent Producers and Royalty Owners Association (TIPRO) and the Texas Bureau of Economic Geology have begun significant needs assessment and workshop efforts to improve technology transfer to oil and gas producers in the state of Texas. TIPRO is also planning to implement an Improved Recovery Information System to provide information and technical assistance to producers throughout the state.

In all of the producing states reviewed, the industry trade associations have become increasingly interested in technology transfer. At the behest of their national association, they are preparing to work with the state agencies, geological surveys, university programs, professional societies, and service and consulting entities in the state to develop integrated technology transfer programs. These programs are intended to meet the technology needs of producers, provide feedback to the research community, and sustain or increase production in the states. The state organizations have expressed support for and interest in the development of a national technology transfer "umbrella" organization to coordinate activities between states as well as within them.

CONCLUSIONS ABOUT NATIONAL ORGANIZATIONS

National organizations, including producer and other industry associations, professional societies, the federal oil R&D program, and the national labs are important participants in the technology transfer process. While their previous roles have not been sufficient to fully serve the needs and requirement of the producing industry in sustaining or increasing domestic production, recent efforts and initiatives reflect their growing realization, interest, and acceptance of their potential in stimulating improved technology transfer in the producing community.

Specifically, the Independent Petroleum Association of America has led an industry-wide initiative to form a Petroleum Technology Transfer Council (PTTC). This Council, led by the industry with the participation of universities, professional societies, state agencies, and geological surveys, intends to develop an "umbrella organization" to help integrate and coordinate activities within and among the states to improve technology transfer. The industry associations' move to go beyond their policy and regulatory agendas to embrace the role and importance of technology in improving production is a major advancement.

The Department of Energy has also expanded the focus of its research program. DOE has organized it to address high-priority problems in specific geological operating environments. The program is developing an expanded approach to technology transfer to effectively communicate the results of DOE research to the producing community. It ensures that producers are aware of and have access to other technologies in the market that can help them defer abandonments, sustain or increase production, and extend the economic life of their reservoirs. DOE's programs are increasingly developing and implementing mechanisms to learn of the priority needs of the producing community and to ensure that the program remains relevant.

The national laboratories have expressed an interest in and have taken some initial steps toward working with the producing industry to apply knowledge and technology developed in the labs' defense missions to improved reservoir characterization, oil and gas extraction, and well servicing. To the extent that these activities are economically viable and consistent with the priorities and needs of the producing industry and the focused DOE program, they should be encouraged.

OVERALL CONCLUSIONS

The increasing interest and activity at all levels in the area of oil and gas technology transfer is to be applauded. However, significant problems remain at all levels. Only an integrated and systematic approach to technology transfer can solve and avoid these problems. Even with improved interest and participation, the potential remains for significantly greater participation, including funding, by all levels and by all classes of participants.

With the exception of a few states noted above, there is a lack of a single entity in most states to provide technology transfer leadership, direction, coordination of activities, and leveraging of limited financial and human resources and facilities. This major gap exists as well at the national level, although the PTTC

concept offers significant potential to resolve it in the future.

Some organizations participating in the technology transfer process have not effectively planned their activities to identify the priority problems, to differentiate audiences, or to appropriately target technology transfer mechanisms to address these specific problems and audiences. In some cases, these errors have rendered the effort ineffective beyond stimulating greater interest and awareness. For technology transfer to be effective it must be highly focused.

There is a significant need for the development and application of consistent approaches to the technology transfer process in general and to the performance of specific functions and processes. Areas requiring attention include:

- Audience identification
- Problem identification and prioritization
- Needs analysis
- Technology assessment and appraisal
- Problem- and audience-focused technology transfer mechanisms and approaches
- Feedback of problems to the research community
- Evaluation of technology transfer effectiveness.

The development and application of consistent approaches to all of these functions by state and national organizations in the technology transfer process can result in significantly greater effectiveness in individual efforts as well as synergistic benefits to all efforts and participants.

There is significant potential for improved interaction between state and local programs and national industry-led programs with the federal oil program. The products and results of DOE's

refocused efforts will have significant applications for producers (the end-users of technology) as well as intermediaries and packagers of technology and technology information and other non-federal research and development organizations. If the industry is successful in developing a technology transfer "umbrella" organization, it could be highly effective in coordinating interactions between the federal program and initiatives in the producing states.

All of the organizations that could expand their participation and interaction in the technology transfer process face constraints related to staffing, facilities, and funding. Greater interaction and coordination at the state and national levels can help to leverage these resources and apply them more efficiently. However, if accelerated and increasingly focused technology transfer functions are to achieve their full potential, additional resources will have to be found and committed to the effort. The states and the federal government will benefit from increased oil and gas production in a variety of ways, including increased economic activity and revenues. Once plans and budgets are clearly developed for such integrated programs and activities, the states and the federal government should seriously consider providing appropriate levels of financial assistance.

RECOMMENDATIONS

The Compact recommends significantly expanded state participation in the technology transfer process, including greater coordination among state organizations including the regulatory agencies, geological surveys, and state universities. The Compact further recommends concerted efforts to improve interaction among these state organizations and other private sector industry, educational, research and technology transfer organizations. All of these organizations should work in an integrated fashion to coordinate activities and information with the federal oil program.

Working together, all of these organizations should integrate problem identification and

prioritization functions with technology transfer activities to ensure that the highest priority problems are being addressed, that the appropriate target audiences are being reached, and that the oil and gas resources of the state and the nation are explored and produced with the greatest efficiency and benefit.

Chapter 1

INTRODUCTION

The Interstate Oil and Gas Compact Commission ("the Compact") is the organization of the Governors of the oil and gas producing states. Since its inception in 1935, the Compact has been committed to conserving the nation's oil and gas resources. The Compact achieves this goal by developing programs and policies to prevent the waste of these resources due to inefficient production or premature abandonment in the reservoir.

Through the Compact, the producing states strive to assure consistent state regulation. Member states develop model or uniform policies that foster maximum efficient production of the resource while protecting the environment. Recently, the Compact has conducted numerous studies of the effects of various tax incentives and research policies to defer premature abandonments and to stimulate deployment of current and emerging improved oil recovery processes.

The Compact encourages a strong public/private partnership between the producing industry, the states, the federal government, and the research community to ensure that public and private resources are efficiently applied to address the highest priority problems. The partnership also seeks to ensure that current technologies and products of R&D are "transferred" to oil and gas producers in the most efficient and expeditious manner.

In 1988, recognizing the beginning of significant shifts in the structure of the domestic oil producing industry, the Department of Energy (DOE) provided the Compact with an assistance grant to:

- Examine the structure of the producing industry
- Identify how technology information and industry needs are communicated between the oil and gas R&D organizations and major and independent producers
- Recommend how improvements could be made in the technology transfer structure to benefit producers and complement DOE's evolving oil R&D program.

The Compact's report, published in 1990, suggested enhancements for DOE's own technology transfer efforts, recognizing DOE's intention to change the focus and mission of its oil R&D program. Whereas the focus of the R&D program had been toward long-term, high-risk scientific research limited to proof-of-concept, the refocused program would also stress:

- Near-term technology transfer to retain economic access to reservoirs and sustain production
- Applied field research and demonstration projects for emerging technologies
- Supporting lab and field research activities to develop new technologies and advancements in geosciences.

The Compact's 1988-1990 study concluded that previous federal technology transfer functions had been successful in communicating

the results of DOE's scientific research to its appropriate target audience, primarily university and industry researchers and applied technology developers. However, the same approaches and mechanisms would *not* be fully effective in transferring current and emerging technology solutions from the new mission-oriented, problem-focused program directly to the producing community and especially not to less technologically inclined independent producers.

The Compact reported that the most promising approaches to improving technology transfer efforts would include:

- Immediate "packaging" and transfer of existing technologies to sustain production and defer abandonments in the near-term
- Expanded roles for industry associations to encourage technology awareness and deployment by their members
- Improved coordination and integration of R&D needs analysis and technology transfer functions between industry, government, academia, and other R&D and technology transfer organizations
- Development of state-federal-industry cooperative technology outreach projects in producing states.

Having defined the broad technology transfer and "feedback" channels used by various sectors of the U.S. oil and gas R&D and production communities and having suggested improvements in these channels, the Compact determined that it would be necessary to identify and profile the current roles of specific existing R&D and technology transfer organizations and to identify additional organizations that could participate in enhancing technology transfer channels in major producing states. The Compact also recognized a need to be able to test the effectiveness of these technology transfer approaches in the near term, as opposed to waiting to see if domestic oil production would increase in the long run.

In response to the Compact's 1990 report and recommendations, DOE provided the Compact with a new grant to extend its analyses of technology transfer approaches, through the performance of two specific tasks:

- Task 1. Development of Technology Transfer Profiles of Eight Major Producing States
- Task 2. Development of a Framework for a Technology Transfer Evaluation Methodology.

Task 1 involved profiling the state agencies, research universities, and industry organizations in eight lower-48 states with the largest known remaining oil-in-place. The purpose of this task was to identify and assess current organizations engaged in technology transfer activities and to identify other potential organizations that could participate effectively in expanded public and private technology transfer activities. The results of this research are provided in the following discussion and analysis and in eight detailed state profiles which are provided in the Appendix of this volume.

Task 2 sought to develop a framework for establishing an evaluation methodology to determine the effectiveness of the technology transfer program and specific mechanisms in delivering technology information to the producing community, changing attitudes towards technology, and motivating industry decision-makers to deploy new technology in improved recovery projects. The framework for the technology transfer evaluation methodology is presented in a separate volume.

GOALS OF THIS ACTIVITY

In preparing profiles of current and potential technology transfer organizations in the states with the largest remaining oil in place, the Compact has identified both opportunities and constraints to integrated technology transfer effort in the major producing states:

- The profiles offer suggestions for each reviewed state for improved coordination of information dissemination and technology transfer to oil and gas producers, including the relationships between state-funded academic institutions, private institutions, state regulatory agencies, and the state geologic survey.
- By analyzing the state profiles comparatively, one can identify achievements, gaps, and opportunities within each state's research and technology transfer structure.
- Finally, the state profiles help to identify the areas and functions that could be included in the design of a cooperative state/federal technology transfer element within the framework of the expanded federal oil research and technology transfer program.

BENEFITS TO THE STATES AND THE NATION

States will obtain an overview of the technology transfer efforts within their borders from which potential links and synergies for improving program effectiveness can be determined. Recommendations are provided for improving technology transfer in each profiled state. In addition, the profiles can assist DOE in distinguishing the impacts of state activities on federal efforts and identifying the areas in which directed federal efforts can be most effective.

The states, the producing sector, and the federal program all stand to gain even greater benefits from the development of an effective evaluation methodology. The methodology provides public and private program managers with a means to assess the effectiveness of R&D and technology transfer programs in transferring information and technology to operators in the producing states. The methodology will allow rapid determination of problems and will assist in correcting deficiencies in the technology transfer program.

For states and the private sector, the evaluation methodology also assures a viable feedback loop to the federal research program through which both may express their needs and concerns. DOE will be able to more effectively direct results of federally funded RD&D and supporting R&D to end-users. The evaluation methodology and associated feedback loops will also provide information on areas to which the research should be directed.

This work provides an essential interim step to the development of a more cohesive national technology transfer program. The information and methodology provided will assist DOE program managers in formulating an effective technology transfer plan. By maximizing the effectiveness of federal technology transfer efforts in the oil research program, the near- and mid-term goals of the oil research program can be more readily achieved, and national goals of increased domestic oil and gas production may be attained.

Chapter 2

BACKGROUND

NATIONAL CONDITIONS COMPELLING IMPROVED TECHNOLOGY TRANSFER

The U.S. oil and natural gas exploration and producing industries are now at a cross-roads. Future directions will largely depend on the public policy decisions made by a new Administration and a new Congress at the national level, by the governors and legislatures of the oil- and gas-producing states, and by the strategic decisions of America's oil and gas producers. Each faces the challenge of achieving a suite of interrelated goals and objectives.

Specifically, government and private interests must determine how the U.S. can best supply its near-term and long-term energy needs while avoiding supply interruptions, avoiding price shocks and dislocations, protecting the environment, ensuring responsible stewardship of natural resources, reducing import dependence, and ensuring the security of supply.

Amid calls for a rapid transition from petroleum-derived refined products to natural gas and alternative and renewable fuels, particularly in the transportation sectors, pragmatic federal and state policy makers and industry leaders recognize that a rapid transition is impracticable and that a smooth transition will only occur over a period of several decades. Government and industry are intensifying their focus on conducting research and development and building infrastructure to accommodate a transition to alternative energy sources. At the same time, however, they must both continue to face the challenge of ensuring adequate domestic supplies of liquid fossil fuels to meet the nation's needs throughout and beyond the transition period.

Exploration and Production Trends

The urgency of these decisions is at once amplified and complicated by the maturity and accelerating decline of the domestic oil- and gas-producing industry and by sectoral shifts of responsibility and activity from the major integrated petroleum companies to independent oil and gas producers.

Reduced finding rates, high operating costs, increasing costs of regulatory compliance, concerns about future environmental liabilities, and shifts in world markets are causing major integrated producers to shift their exploration and development focus. Many are leaving the U.S. lower-48 state resource base in favor of lower-cost, higher-promise, foreign resources. These producers are reducing their exploration and production (E&P) profile significantly and are focusing on importing purchased crudes and refined products.

The lower-48 oil resource base is mature. U.S. companies have produced almost one-third of all oil ever discovered. Between 1985 and 1991, crude oil production dropped over 17 percent and proved crude oil reserves fell by over 13 percent. In 1990, enhanced oil recovery (EOR) methods (thermal, CO₂, and chemical) were used to produce more than nine percent of the U.S. crude oil.

Since 1982, lower-48 onshore reserve additions attributable to new field discoveries have decreased from nine percent to just over one percent. While the lack of new field discoveries is partly attributable to lower prices and a decrease in exploratory activity, it is also an indicator of the maturity of the resource.

Over the course of the past decade, the well abandonment rate increased by over 160 percent. The prevention of premature well abandonments is crucial for maximal production of the oil resource because it ensures economic access to oil that may be producible using advanced recovery technologies.

Decreasing production and reserves have naturally led to reduced extraction industry revenues and employment and reductions in related economic activity. Declining industry activity has also caused significant reductions in state and federal royalty, severance, and income tax revenues.

Structural Changes

The accelerating departure of the major integrated companies from the lower-48 resource base represents a fundamental change in the structure of the exploration and producing industry.

Of particular note is the coming change in the structure of markets for producing properties. Independent producers have traditionally outperformed the major producing companies in lower-48 onshore exploration success. Majors, however, have had the capital and related resources to perform intensively focused, high-quality research and development in geosciences, reservoir characterization, and improved oil and gas recovery processes.

Frequently, independents sell newly discovered reserves to a more technically sophisticated major company for development and production. With the major companies departing the Lower-48 resource base, this secondary market for properties discovered and/or produced by independents is shrinking or disappearing. Consequently, the requirement for independents to become more technologically sophisticated is significantly increased.

OPPORTUNITIES AND POTENTIAL

The accelerating departure of the majors also presents an opportunity for independents. As majors begin to divest themselves of their

domestic E&P operations, many have placed significant blocks of producing properties in the lower-48 on the market for acquisition by large and mid-size independent producers. This transition offers significant opportunities and enormous technological and financial challenges. Independents must have the means to analyze, value, and select the offerings with the greatest potential and fewest potential liabilities. They must also have both the access to existing and emerging technologies and the ability to apply the technology. As the majors and large industry service companies have been the primary developers of these improved recovery technologies, a smooth transition within the domestic producing industry is necessarily predicated by effective technology transfer.

The opportunity and the challenges are indeed significant. While the lower-48 resource base is mature, even excluding the undiscovered oil resource base, more than two-thirds of all oil discovered in the U.S. will remain in the reservoir after current conventional and improved recovery technologies have been applied. This remaining oil resource contains more than 340 billion barrels of oil trapped in the reservoir by viscous and capillary forces or unswept by conventional waterflooding or enhanced recovery processes (Figure 2-1).

Figure 2-1
U.S. Domestic Oil Resource

Figure 2-2
Potential Reserves Additions from
Enhanced Oil Recovery and Advanced Secondary Recovery

If improvements in geoscientific understanding and improved reservoir description and oil recovery processes currently being developed in government and industry R&D programs can contact even ten percent of this remaining resource, U.S. proved reserves could more than double. (Figure 2-2)

Constraints

This opportunity is clouded, however, by accelerating well and reservoir abandonments which threaten the economic viability of applying current and emerging improved recovery technologies (Figure 2-3). The threat of abandonments imposes a significant level of *urgency* not only on the performance of focused R&D but on the development and implementation of effective technology transfer mechanisms to ensure that domestic oil and gas producers have the greatest possible *awareness* of and *access* to technologies that could increase the ultimate recoverability of oil from their reservoirs and potential acquisition targets.

As the major producing companies have significantly curtailed R&D expenditures focused on the Lower-48 oil resource base, state and federal policy-makers have recognized that it is no longer necessarily true that "If it needs to be done, industry will do it." The Compact's 1990 analysis demonstrated that the sources of technology information available to majors--including their own labs, the major service companies, and university and federally funded research--are quite numerous. However, technology transfer channels to independent producers are less numerous and far less direct (Figure 2-4). Further, the channels to which independents were found to avail themselves typically lacked any direct feedback channels to the research community through which to convey needs, recommendations, or criticisms (Figure 2-5). Consequently, "improved aggressive technology transfer" has been recognized as an essential element of any effective R&D program intended to sustain or increase production.

Figure 2-3
Projected Abandonment of Known Oil Resources

Figure 2-4
Producer Sources of Technology Information

Information about available exploration and production technologies: where they can be found, how to use them, and the expected benefits from their use, needs to be communicated to appropriate audiences. In addition, any *new* R&D effort must have technology transfer as an integral component in order to fully achieve the program's goals.

STATE AND FEDERAL INTERESTS

Both the producing states and the federal government have much at stake in the ongoing restructuring of the lower-48 exploration and producing industry. The states, as the stewards of the subsurface mineral resources that lay

Figure 2-5
Current Technology Transfer Channels and Potential Links Through Use of Associations and State Agencies

within their borders, have a responsibility to see that the resource is produced efficiently without waste or harm to the surrounding environment. The largest producing states also have a clear financial and fiduciary interest in that severance and production taxes from oil production and related income taxes and economic activity contribute significantly to the state revenue base.

The federal government has a responsibility to ensure that the nation's energy needs are met effectively at the lowest cost to the economy, that energy prices are stable, and that energy supplies are secure. Further, as the steward of natural resources on federal lands and offshore, the federal government has a responsibility to see that resources are developed efficiently. The federal Treasury has a significant interest as well in sustaining a viable exploration and producing industry in the United States. Increased domestic oil production reduces imports of oil and refined products, improves the U.S. trade balance, provides capital for domestic reinvestment, sustains jobs, and sustains tax revenue. A robust domestic E&P industry also helps to sustain infrastructure that provides significant oil field equipment and product exports to foreign markets and trading partners.

FEDERAL RESPONSE

In response, the Department of Energy has recently made an important shift in its oil

research program. DOE is expanding its focus from long-term high-risk R&D, limited to the point of "proof-of-concept", to a highly focused program of R&D and technology transfer activities that is focused on near-term, mid-term, and long-term needs. It includes domestic oil production, demonstration projects, field research projects, and supporting field and laboratory research and development activities.

According to DOE's 1990 Oil Research Program Implementation Plan, the program is focused on high-priority problems encountered in specific classes of reservoirs which have been prioritized according to the quantity of remaining recoverable oil in place and the estimated timing and urgency of reservoir abandonment.

If this program is to be successful, effective technology transfer to the producing community is an essential requirement. The Department of Energy has undertaken an effort to develop an effective and on-going technology transfer program.

The near-term, mid-term, and long-term elements of the new federal R&D program, including demonstration projects, field R&D and supporting R&D, are planned and structured using a systems approach. The system, portrayed hypothetically in Figure 2-6, includes inputs, processes, outputs, and an ongoing assessment function to keep the program focused on achieving impacts that address the real needs and concerns of the producing community.

In this context, technology transfer can be viewed as a sub-system of the larger federal oil R&D program system. It should be recognized, however, that DOE's oil R&D and technology transfer program does not encompass the entire producing industry, nor is its technology transfer process restricted to the transfer of federally-funded R&D products or performance by federal entities.

Figure 2-6
DOE/FE Oil Research Program

Technology transfer occurs where the research program interfaces with the larger external environment. As such, the technology transfer system is not only a conduit of technologies and information emanating from the DOE and private research and development programs, but also a conduit or feedback loop to convey information about industry needs and the adequacy of DOE functions and products back to the design and assessment elements of the federal program.

These concepts are discussed in greater detail in Volume II of this report. In the absence of a formal federal technology transfer plan for the oil program, the concept of the program as a system provides an adequate framework for determining which technology transfer functions might be performed by the federal program, which might be performed cooperatively by external parties and the federal program, and which would be best performed exclusively by non-federal entities. By comparing the realm of possibilities in each of these categories against the results of our state profiles, one can begin to determine where the opportunities are for greater cooperation between the federal program and non-federal participants.

Chapter 3

APPROACH TO STATE TECHNOLOGY TRANSFER PROFILES AND ANALYSIS

State technology transfer profiles were researched and prepared for the eight lower-48 states having the largest known remaining recoverable oil-in-place. This number was arrived at based on an assumption that characterization of several of the largest states would capture the realm of *potential* technology transfer activities and ultimately provide a sufficient base against which to compare other states to identify gaps, and to suggest opportunities.

Eight of the top ten states, ranked by remaining oil resource (Table 3-1), were selected to be profiled: California, Illinois, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming. Illinois was selected over Ohio because of the noteworthy oil

technology transfer efforts *already* underway in the state. Information on Illinois technology transfer efforts provided important data for assessing and comparing technology transfer programs and making recommendations. The selection of the states to be profiled was made by the Compact with the concurrence of the Department of Energy's Bartlesville Project Office.

Once the states to be profiled were identified, a research and data collection protocol was established to ensure that all key participants in the state's producing industry were contacted and provided an opportunity for input to the profile. A contact list of oil and gas entities was created for each state. The

Table 3-1
States Having the Largest Remaining Oil Resources
Remaining Mobile and Immobile Oil in Place (Bil. Bbls)

<u>State</u>	<u>OOIP*</u>	<u>Mobile</u>	<u>Immobile</u>	<u>ROIP**</u>
Texas	154.7	35.0	68.0	103.0
California	84.7	26.8	35.8	62.6
Oklahoma	39.0	6.2	20.1	26.3
Louisiana	41.2	7.2	15.2	22.4
Wyoming	16.7	3.9	7.5	11.4
Kansas	16.3	2.4	8.7	11.1
New Mexico	14.9	3.3	7.7	11.0
Ohio	7.3	NA	NA	6.3
Illinois	9.1	1.5	4.4	5.9
Pennsylvania	6.6	0.8	4.5	5.3

Totals may not add due to rounding

* Original oil-in-place
** Remaining oil-in-place
Sources: American Petroleum Institute, *Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979*; Energy Information Administration, *U.S. Crude Oil, Natural Gas and Natural Gas Liquids Annual Report*; DOE/BPO 1991.

project team attempted to identify the key oil and gas personnel in the state regulatory commission, the state geological survey, public and private university research programs, and known industry associations and related industry organizations. An initial list was compiled and then refined by ICF Resources staff and the Compact project director.

Each contact was sent a letter briefly describing the project and requesting descriptive information about any oil and gas related R&D and technology transfer efforts in which they were involved. As the project progressed, additional contacts were added to the contact list and sent requests for information. Project staff made follow-up phone calls to solicit additional responses and information. Where appropriate, and as scheduling and funding permitted, interviews and site visits were conducted to expand understanding of the activities and effectiveness of various technology transfer organizations.

In addition to the organization-specific data collected through mailings, interviews, and site-visits, a statistical profile was prepared for each state in order to place the discussion of current and potential technology transfer functions into an appropriate context. Information for each state was gathered to describe recent trends and conditions, including:

- Crude oil and natural gas resources
- Remaining recoverable oil resource by reservoir class
- Annual and cumulative production
- Current proved oil and gas reserves
- Producing wells and stripper wells
- Annual wellhead prices, value of production, and severance taxes
- Extraction sector industry employment.

Project staff also conducted limited literature reviews to identify current events and developments in oil and gas technology transfer. Publications, such as the *American Oil and Gas Reporter*, *Oil & Gas Journal*, *AAPG Explorer*, *Improved Recovery Week*, *Inside Energy with Federal Lands*, the *Federal Technology Transfer Report*, industry association

newsletters, Society of Petroleum Engineers presentations and papers, and major newspapers, were all monitored for important information on current or planned technology transfer activities. The resulting data provided essential background to the preparation of state profiles and also helped direct the questions asked during interviews and site visits.

Project staff monitored or participated directly in actual technology transfer activities in several of the states. Attendance at workshops and seminars held by state oil and gas entities provided staff with the opportunity for first-hand analysis of technology transfer activities, including an opportunity to determine the effectiveness of industry contact and technology transfer approaches and mechanisms.

In Texas, for example, project staff attended several of the Texas Independent Producers and Royalty Owners Association (TIPRO) problem identification "forums" to observe operator participation and reaction and to evaluate the effectiveness of the problem identification and needs analysis format.

Project staff also attended the first of a series of follow-up workshops intended to provide technology solutions to priority problems and needs that were identified by producers in the forums. Workshops and seminars held by the University of Kansas Energy Center, KU/TORP, the Illinois Oil and Gas Association (IOGA), the Illinois State Geologic Survey (ISGS), and the Society of Petroleum Engineers (SPE) were also observed and analyzed.

Technology transfer functions, performance, and potential in each state were reviewed and analyzed with an eye toward determining the following:

- Functions performed and services offered by each organization
- Comprehensiveness of problem solving/technology transfer approach
- Problem identification and prioritization approaches
- Needs analysis approaches
- Technology appraisal and assessment

- Problem-focused R&D (demand pull vs. technology push)
- Breadth/focus of technology and information dissemination functions
- Methods of targeting technology transfer functions and content to specific problems and audiences
- Mechanisms for soliciting or encouraging feedback or communication of technology problems to the R&D community
- Levels of activity and participation of R&D, technology transfer, and industry organizations
- Levels of participation and support by producers
- Diversity of participation
- Coordination of activities among organizations
- Current or potential interaction or coordination with Federal oil and gas and geoscience R&D programs
- Current or potential roles of state agencies in R&D and technology transfer.

Overall conclusions regarding these analysis factors are presented in Chapter 6 following the discussions of state and national organizations. State-by-state conclusions are presented in the individual state profiles in Part II of this volume.

REVIEW OF PARTICIPATION IN NATIONAL TECHNOLOGY TRANSFER PROCESSES

Organizations in many of the states analyzed are becoming involved in cooperative efforts not only within their states, but also at the national and

regional levels. This is particularly true of producer associations, professional societies, and university academic and research organizations. Therefore, as part of the profile preparation process, project staff also researched and inquired into the level of interaction between the programs being reviewed and other institutions within the state and national R&D or technology transfer organizations operating outside the state.

By far, the most significant effort to develop a national technology transfer coordinating organization is a Petroleum Technology Transfer Council (PTTC) that is being formed under the leadership of the Independent Petroleum Association of America in concert with more than 40 cooperating state and regional industry associations. This *ad hoc* organization, directed by oil and gas producers, is an attempt to bring the producing industry, industry R&D organizations, academic R&D programs, professional societies, state geological surveys, and state oil and gas regulatory agencies together under a single "umbrella" organization. The Council will provide a forum in which organizations will coordinate and cooperate in identifying and prioritizing the needs of producers and providing problem-focused, prioritized technology transfer services to oil and gas producers throughout the United States.

Project staff monitored the Independent Petroleum Association of America's (IPAA) efforts to develop this national technology transfer "umbrella" organization and the subsequent activities of the organization. Planning meetings were observed, and support was provided as part of the Compact's participation in the effort. Understanding this approach to the national technology transfer organization as it relates to various state efforts is essential for a complete picture of state and federal cooperation on an effective program reaching appropriate audiences.

Chapter 4

OBSERVATIONS ABOUT ROLES AND POTENTIAL OF R&D AND TECHNOLOGY TRANSFER ORGANIZATIONS IN THE STATES

Each of the eight states analyzed by the Compact are unique. They differ in terms of operating conditions, industry organization, governmental functions related to the industry, and research and technology transfer organizations and resources. Nonetheless, all of the states have a basic framework of functions and organizations related to the oil and gas producing industry. Specifically, each state has a:

- State oil and gas regulatory commission or division
- State geologic survey
- Oil and gas producer association(s)
- State and/or private university petroleum engineering, technology, and/or

Table 4-1
Technology Transfer Functions of State Organizations

	Current or Potential Oil and Gas Technology Transfer Functions																			
	Data & Publications					Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance			
	Reservoir Data	Product. Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	Consortia	R&D Reports	Processes	Equipment	Software	Trouble Shooting
State Organizations																				
State Oil and Gas Commissions	C	C	C		P	C	C							C						C
State Geologic Surveys	C		C	C	C	C	C	C	C	C	P	C	P		C	C			C	C
Universities					C	C	C	C	C		P	P	C		C	C	C	C	C	P
Industry Associations			C	C				C	C		P	P	P	C					P	P
TT Organizations*		C	C		C	C	C	C	C	C	C	C	C	P	C	C	C	C	C	C
C = Currently performs																				
P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints																				

*As in KS, TX, IL, and NM

geoscience teaching and/or research programs.

In addition, in at least four of the eight states reviewed, specific technology transfer organizations have been planned or established.

Each state reviewed also has local, state, and/or regional chapters of professional societies such as the Society of Petroleum Engineers (SPE), American Association of Petroleum Geologists (AAPG), Society of Exploration Geophysicists (SEG), and Society of Independent Petroleum Earth Scientists (SIPES).

Each organization is governed by a national organization. Therefore, a discussion of the roles and potential of professional societies is contained in the following chapter, which addresses a select group of national organizations involved in the technology transfer process. Trade associations that represent other elements of the oil and gas industry, such as service companies, equipment manufacturers, and consultants, are not addressed.

The collective results of the Compact's analysis of technology transfer organizations and functions in eight states provide a solid basis for making observations about the current and potential roles and functions of specific kinds of organizations in the oil and gas technology transfer process, including their unique strengths and weaknesses (see Table 1). The results also identify key constraints of organizations that should be considered in planning and focusing specific technology transfer programs and functions.

STATE OIL AND GAS REGULATORY COMMISSIONS OR DIVISIONS

In general, the role of the oil and gas regulatory agency in each state is to:

- Ensure that oil and gas resources are being explored and produced efficiently, within prescribed limits

- Ensure that drilling, completion, and injection practices are employed so that groundwater supplies are not contaminated
- Protect the correlative rights of lease and mineral rights owners from unfair encroachment
- Protect the mineral interests of the state.

Many state agencies define "conservation" of the resource in terms of prevention of its waste through premature abandonment in the reservoir due to inefficient production or reservoir management. While this broad charter may vary from state to state, it generally defines the boundaries of specific activities performed by the state agency.

In fulfilling their roles, the state agencies conduct a variety of activities and provide numerous services to the producing industry:

- Primarily, they are responsible for reviewing and issuing permits for exploratory or development drilling, production, injection, and well abandonment activities in the state. They also monitor and enforce compliance with permits and state regulations.
- They collect, maintain, and disseminate data on well permits, wells drilled (completed or dry holes), wells plugged, oil and gas production, reserves, and injection volumes, among other categories. Many state agencies also maintain well logs.
- In many instances, state agencies also provide or coordinate educational instruction for the producing industry in order to communicate safety measures and changes in operating and environmental regulations and to offer approaches to record keeping and regulatory compliance.

- Many state agencies issue newsletters and other publications to the producing industry to inform them of regulatory developments and trends in the oil and gas community.
- State agencies typically *do not* perform oil and gas extraction research or other R&D activities. Hence, they are not a source of new technology. Through their project review and permitting function, however, they do observe and comment on innovative technical approaches being applied in the reservoir and often encourage producers to consider improved technologies to maximize the efficient production from a specific well or reservoir.
- Also, by virtue of their hands-on knowledge of industry practices and conditions throughout the state, these agencies provide information and guidance to state governors, legislative bodies, and related regulatory bodies about regulatory and reporting requirements and their impacts on oil and gas activity.

Constraints

One might anticipate that the state agency could perform focused technology transfer functions to keep the industry attuned to and aware of state-of-the-art practices in exploration, drilling, production, reservoir management and environmental protection. However, the state agencies face significant constraints to performing these functions.

Budget, Staffing, and Facilities: Like many other publicly funded institutions, most state oil and gas regulatory agencies are significantly constrained by limited staffing, budgets, and facilities. Several of the states are struggling to modernize their facilities and capabilities to collect, manage, and disseminate accurate data and analyses while performing their required duties. As abandonment rates continue to

increase and environmental and other regulatory requirements are expanded, the demands on increasingly limited resources are growing. Without significantly expanded funding and staffing, state agencies could not adopt a broader technology transfer function.

Public Commitment: Levels of public commitment to oil and gas exploration, development, and production also vary from state to state, depending on the relative importance of the producing sector to the state's economy. In Texas, for example, where the industry still plays a major role, the public, the legislature, and elected officials provide significant funding support to both the regulatory and the conservation functions of the Railroad Commission of Texas. In California, however, even with a substantial producing industry, the diversity of the economic base, a host of environmental issues, and a lack of strong public support for the industry make oil and gas production and support for conservation efforts a lesser priority.

Producer Perceptions: Technology transfer, to be effective, requires that the problem identification and needs analysis functions be performed before specific technical advice or assistance can be given. This requires aggressive outreach to the producing community and open discussion with operators about actual geological and engineering conditions in the reservoir. Because of the agency's regulatory and permitting function, some producers are uncomfortable in speaking frankly to regulatory agency personnel.

These constraints are in addition to other prescribed limits on the scope of activities that may be dictated by the charter of the agency.

Potential

Although it is difficult to envision a state regulatory agency in a *lead* position coordinating technology transfer to oil and gas producers, state agencies can, nonetheless, play an important role. Much of their potential lies in the expansion or enhancement of existing roles.

- Data collection, analysis, and dissemination functions can be automated in a "user-friendly" fashion to enable producers to dial in to the agency by computer, to identify, sort, and obtain the public data from their remote locations.
- State agencies can require or make explicit existing guidelines for "post-mortem" case studies of applications of new technologies and processes that are applied to improve production from a reservoir (including reasons for their successes or failures). The state can disseminate these case studies to producers and other interested parties such as consultants or service company personnel.
- Through its annual reports, newsletters, and other publications, a state agency can help make operators aware of technologies being applied in the state to address specific problems encountered in specific classes of reservoirs. Newsletters can also help to inform producers as to the availability of seminars or training on new technology applications for exploration, production, or reservoir management.
- The states can leverage their resources and improve technical efficiency in oil field operations through expanded coordination with producer associations and with other state and private entities including the geologic surveys, university teaching and R&D programs, and local chapters of the national professional societies. This interaction could work to focus industry attention on areas of opportunity and to focus R&D and technology transfer efforts on high-priority, high-payoff problems.

STATE GEOLOGICAL SURVEYS

The general mission of state geological surveys is to characterize and map the states'

surface and subsurface geologic features and mineral resources, including oil and natural gas among other energy and non-energy resources. In some cases, the principal impetus behind the geologic survey's work is to help steward efficient commercial development of a state's mineral resources. In other cases however, the focus of the Survey's mission is elsewhere, such as plate tectonics for earthquake prediction in California. Complementing the roles of the state regulatory agencies, however, the geologic surveys *are* specifically chartered to perform research and conduct studies and to advise public officials and decision makers. Conversely, they generally have no regulatory function.

The roles and activities of the geologic surveys studied vary considerably as they relate to oil and gas resources. In general, though, the geological surveys offer the following functions and services:

- Collection, maintenance, and dissemination of well logs and reservoir data
- Storage and maintenance of cutting samples and core samples
- Surface feature mapping
- Subsurface mapping
- Atlases of state, basin, or regional oil and gas resources
- 3-D reservoir modeling
- Reservoir studies
- Interpretive assistance to operators
- Field trips to significant outcrops and other features
- Lectures and short courses on oil and gas geology and technology.

Within their log libraries and cuttings and cores collections, the state geological surveys

have a wealth of data that is critical to the development of reliable 3-D models of the reservoirs and to the understanding of permeability variations and other heterogeneities in the reservoirs. This improved understanding is key to planning reservoir development and improving the predictability of improved recovery processes in the reservoir.

In line with the nature of their research and analytical roles, many of the state geological surveys have established relationships with the academic research community. Many of the geologic surveys reviewed by the IOGCC are located on or near the campus of the state university. Several, in fact, are operated for the state by the university. This provides proximity to research performed at the university's teaching and research departments.

In several of the states, the geological surveys are performing interdisciplinary research with in-house petroleum engineering teaching or research staffs or in cooperation with university and/or industry engineering personnel. This trend toward interdisciplinary research offers significant potential for new insights to the reservoirs and development of new technologies and applications to improve ultimate recovery of oil and gas resources.

The state geologic surveys have a long history of working with producers, large and small, to provide essential data and to help interpret the data in the appropriate context. In several states, survey personnel have engaged in formal and informal interactions with producers to determine high-priority needs in specific environments and to focus elements of their research to address these problems. In cases where the survey has had information, knowledge, or analytical tools to assist producers in resolving problems, they have provided it, often as part of workshops or seminars for the producing industry.

In several of the states, the geologic survey has actually entered into cooperative agreements with industry-led research consortia to study specific problems or opportunities. Of note is

the Oklahoma Geological Survey's interaction with the University of Oklahoma Center for Reservoir Characterization and British Petroleum (BP) to analyze a major outcrop and to operate a field laboratory. In other instances, the geological surveys also provide formal training and other functions to producing companies on a contractual basis.

Constraints

Funding, Staff, and Facilities: As with the state conservation agencies, the geological surveys are constrained in the level and nature of activities they may perform by funding, staffing, facilities, and competing priorities between the survey and the state. While relative levels of staffing and funding vary considerably across the eight state surveys analyzed, all appear to be struggling to maintain essential functions and services within the finite bounds of their funding constraints. In many cases, funding constraints were also coupled with absolute constraints in facilities, space, and equipment. Of concern is that funding, staffing, and facility constraints have made surveys, state agencies, state universities, and technology transfer programs competitors rather than partners in the search for research dollars, staffing, and recognition.

Research Priorities: A significant constraint is that of priority. In several states, while the budget and staffing levels appear fairly strong, the proportion and absolute number of personnel devoted to oil and gas geology is minuscule. This reflects a focus on other areas of geological science or on other minerals and resources of the state.

Disciplinary Focus: State geological surveys are also constrained in focus along disciplinary lines. While geological expertise enables survey personnel to characterize a given reservoir with increasing clarity, accuracy and dimension, the knowledge base of the geologist may not be sufficient to determine or design the application of technologies to address geologic constraints. In some states, however, there is an increasing integration of geology and reservoir engineering expertise in R&D and demonstration efforts

intended to maximize success in exploring, drilling, and producing oil and gas resources.

Potential

Among the state agencies, the state geological survey has the most significant potential to function as key participants in technology transfer from the research community to oil and gas producers. By virtue of its research function, its relatively low cost to use, and its lack of regulatory authority, the geological survey is a trusted source of interpretative assistance and information for small and medium-sized producing companies as well as an important information source for many of the larger integrated companies.

To improve this function, like the state regulatory agencies, state geological surveys can move more aggressively to automate their data collections, making data more readily available to the exploration and production community through user-friendly, on-line databases, and to expand publication and distribution of printed data, maps, case studies, and related information.

Geological surveys can also work more closely with universities and other entities to develop and disseminate computer applications for 3-D reservoir modeling and characterization and integration with engineered reservoir simulators. They can also provide interpretive analysis services to the producing community.

Geological surveys can also work cooperatively with other research, technology transfer, and industry organizations to sponsor, host, conduct, or provide technical insight to problem identification and technical solution exchanges with the producing community.

UNIVERSITY PROGRAMS

Colleges and universities perform several essential functions in support of research and technology transfer that benefit the domestic and international oil and gas exploration and producing industry. The scope and intensity of university programs and their potential to expand their roles differ considerably however,

depending on a broad range of factors: size, enrollments, location, state or private funding status, endowments, and missions and goals, among others.

In all colleges and universities, the primary mission of the institution is to educate students and to provide a setting in which study and research can expand knowledge and foster innovation. In many state-funded institutions, there is also an explicit mission to support economic development of the state through education and research focused on the state's unique industry and resources. University programs tend to be of three broad types: academic (teaching) programs, research programs, and industry-cooperative research and development programs. These exclude specific technology transfer programs which are addressed separately below.

Academic Programs

Perhaps the most important function performed by colleges and universities in service to the oil and gas producing industry, has been the education of undergraduate and graduate level students who will ultimately work in the industry. Academic programs that ultimately serve the industry include: geoscientific disciplines (such as Earth Sciences, Geology, and Geophysics) and engineering disciplines (such as Petroleum Engineering, Reservoir Engineering, and, more broadly, Chemical Engineering). Each of these broad disciplines encompasses a variety of specialties as well.

Several associate and baccalaureate level degree programs also offer training programs in the *hands-on* application of technology used in oil and gas exploration and production. The graduates of all of these programs typically seek employment in the oil and gas exploration, producing, and related support industries in the United States, and increasingly abroad as the major integrated companies reduce U.S. Lower-48 state operations and expand overseas.

Research Programs

College and university instructors, professors, and graduate students typically split

their time between teaching and performing research in their chosen disciplines and specialties. This research helps the teaching faculty and the graduate researchers to perform at the state of the art and contribute to the advancement of the discipline and its practical applications in industry.

The focus, organization, and end-products of research functions depend largely on the educational institution, the research project's source of funding, and the interests and requirements of the faculty member or graduate student directing the effort. Even at the most richly endowed universities, the research may be sponsored or co-funded by the federal government, foreign entities, or major U.S. producers or service companies. In some cases, the direction of the research may be mandated by a solicitation or request from the funding organization for research and development in a specific area. In other cases, researchers may solicit industry or government funding to perform work in a specific area of interest to the researcher.

Because of the role of disciplinary graduate-level research projects in documenting the academic performance of the student researcher(s), the products of graduate research tend to be relatively narrowly focused dissertations, reports, and articles that document advancements in the knowledge base or the contribution of new chemicals, technologies, or analytical approaches to future operations. In many cases, the results of graduate student or faculty research provide insight to specific pieces of the larger intellectual puzzle that must be solved in order to understand a larger problem in reservoir characterization or production techniques. In these instances, the direct product of the R&D may be of significant interest to other researchers, but may have little immediate value to the producing industry.

Increasingly, albeit slowly, interdisciplinary research combining the skills and knowledge bases of engineering, geology, and geophysics is occurring at the graduate research level of major research universities. As this trend progresses,

there is significant potential for improved understanding of the varied structure and composition of subsurface reservoirs to help improve the design and predictability of exploration and extraction technologies in specific classes of reservoirs.

Through the teaching function, as well as through the publication of academic papers and journal articles, presentations before professional societies, and interaction with other students and researchers, the knowledge base and technical and intellectual advances of the universities are ultimately transferred to industry.

Cooperative Research and Consortia

In addition to industry support of graduate research programs, many larger universities have developed dedicated and specialized research institutes with the explicit role of performing applied research to develop improved approaches and technologies to enhance exploration, reservoir characterization, oil and gas production, and cost-effective environmental protection and regulatory compliance. While these institutes may use graduate student personnel and include teaching faculty to assist research efforts, they typically also engage full-time research professors and technical personnel.

The research institutes work directly with exploration and producing companies and service companies to perform highly focused research that results in specific technology applications. In many cases, these applications may be targeted to adapting an existing technology to perform in a unique operating environment.

The funding mechanisms for these institutes and their projects vary significantly. Typically, they rely on direct grants from industry. Increasingly, as major producing companies and service companies pare back their in-house research focused on U.S. lower-48 resources, industry funding is being leveraged through the formation of R&D consortia. These consortia of two or more U.S. or foreign companies fund research focused on the development of a specific technology or an approach to solving a specific problem in a defined operating setting.

The consortium may fund the research institute to perform the R&D activity and deliver the results to the sponsors. In many cases, members of the consortium may provide personnel to assist in the research and learn from the process as well as the result.

The technology transfer processes of these university-industry consortia are increasingly open. In the previous decade, the competitive nature of major producing companies in the United States caused research results to be kept highly proprietary to the originating or sponsoring company. However, the new realities of the producing industry are fostering significantly greater cooperation and interaction. In the consortium setting, sponsoring companies receive competitive advantage by:

- Participating directly in the research and development effort through personnel assignments or exchanges
- Receiving interim reports and advance notice of research findings
- Receiving the results and accompanying reports and products immediately upon their completion
- Having a significant lead-time to apply the results and advances before results are published or publicly disseminated in research journals, professional society meetings, or the trade press
- Limited or exclusive marketing licensing and royalty agreements.

The consortium process provides an effective mechanism for resolving problems while leveraging increasingly constrained R&D funds, taking advantage of synergies, and avoiding anti-trust concerns. Numerous specific examples and variations of the increasingly prevalent consortium mechanism were observed in the geosciences, in petroleum engineering disciplines, and in interdisciplinary efforts in the states analyzed. These efforts also included

public-private-academic consortia. They are described in greater detail in the state technology transfer profiles in Part II of this volume.

Constraints

While the university teaching and research programs play an important role in training personnel, performing oil and gas geoscience and engineering research functions, and leveraging research dollars and resources, they are constrained in the roles that they can perform in future focused technology transfer to the producing community.

Limitations by Charter: Many private colleges and universities are constrained by charters that stipulate that their primary mission must be one of educating enrolled students. Clearly, performance of research and development of new technology serves that mission. In some cases, however, expanding beyond that role to take broader leadership roles in transferring practical technology and related information to the broader, non-academic producing community can be difficult to justify.

Restriction on Use of State Funds: Several states, including California, restrict the availability of state funds to private universities. Hence, there is little latitude or incentive to serve the inherent interests of the state by helping to educate the public and the producing industry as to improved recovery technologies. In California, this constraint eliminates both Stanford and USC from state funding.

Declining Enrollments: Since the 1986 oil price collapse, enrollments in U.S. private and public university petroleum engineering and hydrocarbon geoscience degree programs have declined dramatically. Prospective American students accurately perceived a severe reduction in U.S. oil and gas industry operations. Since then, the reduction in activities and down-sizing of U.S. oil and gas companies has displaced over 300,000 workers in the producing industry and severely limited job opportunities for graduates with bachelors or advanced degrees. This has further exacerbated the enrollment decline.

University teaching programs have, in turn, been faced with a choice of eliminating oil and gas related engineering and geoscience programs, reducing staff, reducing admission standards, and/or accepting larger numbers of foreign nationals who will take their knowledge back to their native countries upon completion of their education. The education of foreign nationals helps to sustain university teaching and research programs and makes valuable contributions to the domestic producing industry as many of the best and brightest choose to remain and work in the United States.

Permanent research institutes at the universities help to offset some of the impacts of declining enrollments on staffing. Nonetheless, reduced enrollments and projections of continuing negative enrollment trends in oil and gas related academic programs make it difficult for colleges and universities to commit to taking greater leadership or other roles in technology transfer without guarantees of long term assistance from other sources.

Continuity of Funding: State and private universities are motivated to initiate and/or participate in aggressive privately and publicly funded technology transfer functions. New programs cannot be initiated, however, without significant assurances of continuity of funding from one fiscal year to the next. If university programs are to take any lead role in coordinating technology transfer activities in a given state or region, there must be long-range assurances from academic and public and private funding sources as to continuing financial support. Otherwise, appropriate personnel and facilities cannot be attracted to or committed to the effort.

Research and Technology Transfer Focus: Much skill and knowledge exists in the university research and teaching programs and related technology institutes. The focus of interest and knowledge, however, is concentrated in the specific intellectual and scientific interests of the researchers or in the very specific needs of the company or companies who are funding the research.

To be effective in meeting the national goal of deferring well abandonments and maximizing the safe and economic producibility and production of the nation's oil resources, technology transfer programs need to focus on priority needs that offer significant production potential. They may also provide mechanisms to ensure that existing, commercially available solutions to other problems are known and accessible.

Unless university R&D is already focused on the priority needs and interests of local producers, university technology transfer programs will need to ensure that their technology transfer functions focus on packaged solutions to the priority needs of the producing industry rather than the intellectual interests of the university or the needs of the R&D sponsors.

Location: Many universities with established petroleum engineering and geology teaching and research programs are located at great distances from the offices or field sites of oil and gas producers. Unless specific mechanisms and staffs are developed in close proximity to the producers, this factor limits the ability of university staff to troubleshoot problems for producers. It also limits the access of producers to the data and knowledge resources of the university.

Potential

Clearly, the universities' academic programs, research programs, and institutes offer a wealth of knowledge, understanding, insight, capability, and facilities that can be applied to effectively transfer technology to oil and gas producers. This is especially true with the decline of many proprietary restrictions on disseminating the results of industry funded research.

Workshops and Seminars: The knowledge and expertise of university research personnel can contribute significantly to the *content* of seminars to make producers aware of the existence and availability of existing and emerging technological solutions to clearly defined problems and requirements. University

research personnel can also participate effectively in focused workshops intended to teach producers how improved exploration, extraction, and reservoir management technologies and approaches are applied in the reservoir. To be effective, however, presentation of the materials must be "applied" rather than theoretical or academic. University programs can also participate effectively in packaging technologies to address a specific problem in a specific operating setting.

Publications: Publication of theoretical or academic research results will continue to be of considerable use to other researchers, allowing accretions of knowledge to move forward until tangible products or improvements in geoscientific or technical understanding and approaches are achieved. University programs also have significant potential to publish "producer-friendly" accounts of field research projects and demonstration projects conducted by the university in cooperation with industry or government sponsors.

Resource Centers: University researchers and technology specialists can interact effectively with the producing community through the establishment of technology information resource centers at existing facilities in or near oil and gas producing areas. Such centers could offer access to data, analytical tools and software, and publications, and provide "troubleshooting" assistance, project planning services, and unbiased expert referrals.

Cooperative Efforts: Universities have a significant role to play in emerging regional and national cooperative efforts that seek to take advantage of potential synergies of combining the best attributes of several classes of R&D performers and intermediary developers and suppliers of technology in an integrated technology transfer network to serve the producing community. The role of universities will likely include not only the provision of expertise, technical information, and technology advances, but also assistance in direct technology transfer mechanisms.

OIL AND GAS PRODUCER ASSOCIATIONS

In addition to the state agencies, the oil and gas producing industry in each state and region is served by one or more industry trade association(s). These associations are funded by the producing industry with the sole purpose of serving the needs and interests of the producing industry. Producing companies become members in the associations because they recognize the synergistic benefits of pooling financial resources and leveraging their ability to commit time and effort to resolving key problems and issues.

Producer associations exist at several geographic levels -- local, state, regional or national. Different associations at each level may also address different sectors of the producing industry. Specifically, major integrated companies are served at the national level by the American Petroleum Institute (API) and, to some extent, by the Mid-Continent Oil and Gas Association (MCOGA). Independent producers are served at the national level by the Independent Petroleum Association of America (IPAA). API and MCOGA have regional and local chapters as well. IPAA works at the state and regional levels through independent cooperating associations. Many of these state and regional cooperating associations also interact with one another through a committee known as the Liaison Committee of Cooperating Oil and Gas Associations. The roles and functions of the *national* associations are addressed in the following chapter.

Until recently, the state-level industry associations have had a relatively narrow technical mission in serving the producing industry. They have focused on economic, regulatory, and environmental factors affecting exploration and production in the United States and in their specific geographic areas of interest. Much of their activity has involved representing producer views before state legislatures and regulatory agencies, and, to a more limited extent, before the U.S. Congress and federal agencies. Typically, producer concerns on national issues have been coordinated and addressed by national associations.

Industry associations at the regional, state, and local levels, interact with their membership and provide services to them through a variety of established structures, functions, and forums, including:

- Monthly newsletters or magazines
- Correspondence and mailings
- Monthly or quarterly meetings (luncheons, breakfasts, etc.)
- Annual meetings or conferences
- Committees and subcommittees
- Special meetings and task forces on specific issues.

These mechanisms offer a potentially effective, highly targeted infrastructure for reaching producers, particularly medium and small independent producers who may not be reached through other current technology transfer mechanisms.

Constraints

Producer associations have a unique perspective and unique access to the nation's oil and gas producers, large and small. There is a clear opportunity for them to perform an expanded role in the technology transfer process. Nonetheless, they are faced by several constraints, most of which can be overcome relatively easily.

Lack of a Clear Technology Focus: Until recently, producer associations, particularly independents, have assumed an advocacy role and have declined to address the continuing technological education needs of their membership. Technology education has not been part of the mission.

For the majors, the lack of industry association focus on technology has not been of particularly significant concern. Majors tend to have their own internal R&D laboratories and infrastructure to address priority needs. They

use service companies and other R&D organizations to address other needs. As such, association participation in technology transfer has not been warranted. API has, however, sponsored an extensive program of training in safety and regulatory compliance to industry personnel.

The lack of focus on extraction technologies by independent producer associations reflects, in part, the propensity of independents to explore and discover resources and to sell portions of these discovered reserves to major integrated companies. It also reflects a tendency to plug and abandon wells after primary production and waterflooding reach their economic limits rather than invest in unpredictable, high-cost, high-risk advanced recovery processes.

Funding: Given the continuing oil production decline and relatively low current prices, the budgets of state and regional associations are relatively tight. Funding levels for cooperating independent oil and gas associations vary considerably from organization to organization. Most independent producer associations have a base of annual dues and seek contributions to provide additional needed operating revenues. It is unlikely, therefore, that significant additional funding for technology transfer activities will be available to producer associations until technology transfer functions have proven their worth to producers and producer contributions increase. Nonetheless, independent producer associations have expressed a desire to participate, to offer access to their membership, and to provide in-kind and direct funding assistance where possible to expand technology transfer functions. Seed money grants may be required.

Staffing Constraints: Consistent with their levels of funding, staffing of state and local producer associations is typically tight. With significant exceptions, many of the cooperating associations are staffed only by an executive director and limited clerical support. Due to the nature of their current functions, which is primarily the representation of producer interests before government bodies, the staffs of the state

and regional independent producer associations are also generally non-technical. As such, they do not have sufficient technical expertise to accurately identify high-priority problems and needs or to design focused technology transfer functions to address them. To expand their technology transfer roles they will need to rely on the expertise of the universities, state geologic surveys, and technical and analytical consultants.

Potential

While producer associations at the state and regional levels do face significant constraints, they have, perhaps, the single greatest potential to make producers aware of and interested in the potential of technology to increase ultimate production, reduce operating costs, improve regulatory compliance, and to extend the economic life of their wells and fields.

Increasing Interest: As exploratory drilling activity is discovering fewer fields and smaller fields and majors producing companies are departing the lower-48 resource base to take advantage of lower-cost foreign opportunities, independent producers are increasingly recognizing a need to improve the efficiency of their existing operations and to consider the potential of existing and emerging technologies to extend the economic life of their producing wells and fields, even as they continue to explore. Consequently, since the mid-1980s, independent producer associations have slowly begun to pay increased attention to the role of technology. In several states they are active participants (as hosts and reporters) in emerging technology transfer programs focused on independents.

Access To Producers: While university R&D programs and state geologic surveys (as well as service companies and other entities) can offer technology information and assistance to producers, the industry associations are, quite literally, the only organizations that can bring producers to the technology. By targeting producer association membership, technology transfer activities can be certain to address the companies that are most likely to become

interested in investing in and applying improved technologies.

Trust Of Producers: Industry associations also have the potential to give credibility to federal- or state-assisted technology transfer efforts. This element is key in persuading producers to attend meetings and to openly share information about problems encountered in surface or sub-surface operations or successes or failures with field projects.

Existing Infrastructure/Mechanisms: In addition to these key factors, the industry associations already have an existing infrastructure for identifying, contacting, and communicating with independent producers. If near-term goals are to be effectively met, technology transfer programs do not have time to build a new infrastructure from the ground up. As hosts and co-sponsors, however, industry associations can significantly assist technology outreach functions and generate significant input and feedback from producers as to their R&D and technology needs, the effectiveness of technology transfer mechanisms and activities, and the effectiveness of new technologies.

CONCLUSIONS ABOUT STATE AND LOCAL R&D AND TECHNOLOGY TRANSFER ORGANIZATIONS

Each type of organization reviewed has important contributions to make to the technology transfer process. All have significant constraints both in the content of information or assistance they can provide and in the scope and extent of services they can provide and support. In each state, an evaluation of the roles and motivations and limitations of each organizational type begins to explain why and where there are significant gaps in the R&D and in the technology transfer process.

Considerable potential exists in each state reviewed for significant improvements in the technology transfer process. Much of this potential lies in coordination and cooperation between and among the various organizations in the state that perform research, disseminate data,

information, or technology, or that serve the oil and gas producing industry. Even with increased cooperation and integration of activities, however, insufficient funding and human resources threaten the potential for research and development activities and focused technology transfer efforts to achieve the full production and cost-reduction potential of existing and emerging technologies.

Among the eight states reviewed, there is significant evidence in several that coordination of research and technology transfer activities is improving and that priority needs of the producing industry are being considered in planning and focusing research. Of particular note are the combined efforts of the University of Kansas' Tertiary Oil Recovery Project and the KU Energy Research Center; the Illinois Geological Survey and the Illinois Oil and Gas Association; the New Mexico Petroleum Recovery Research Center; the University of Oklahoma, the Oklahoma Geological Survey, and

the Oklahoma Independent Producers Association; and the Texas Bureau of Economic Geology and the Texas Independent Producers and Royalty Owners Association.

Each state has an organization or institution that could take the lead in convening an integrated technology transfer program that takes advantage of the synergies of all of the related organizations in the state. It is clearly in each state's best interest to act prudently to ensure a vital petroleum industry in the state that maximizes economic production of the resource while protecting the environment. In each state, at least three potential organizations to lead coordinated technology transfer activities are managed by the state: the oil and gas regulatory agency, the state geological survey, and the state university. State legislatures and governors have the authority to require the integration and coordination of activities among and between state agencies and to direct their interactions with other non-state organizations.

Chapter 5

OBSERVATIONS ABOUT R&D AND TECHNOLOGY TRANSFER ORGANIZATIONS AT THE NATIONAL LEVEL

The Compact's analysis identified several national organizations that perform important roles and functions in petroleum research and technology transfer. These include industry trade associations, professional societies, the federal oil program, the national labs, and an emerging industry-coordinated technology transfer organization. Although these are not "state" organizations per se, they do have current and potential impacts on the technology transfer

functions performed by organizations within the states. Their roles, constraints, and potential are briefly discussed in the following pages and summarized in Table 5-1, below.

INDUSTRY ASSOCIATIONS

As in the states, trade associations at the national level provide information services to their members, and they represent their

Table 5-1
Technology Transfer Functions of National Organizations

	Current or Potential Oil and Gas Technology Transfer Functions																								
	Data & Publications					Meetings/Seminars				Workshops				R&D/Analysis				Project Assistance				Cooperative Efforts			
	Reservoir Data	Produc. Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	Consortia	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals		Project Assistance	Project Design	Engineering
National Organizations																									
Associations		C	C				C	C			P	P	P	P						P	P	P			P
Professional Societies			C	C	C	C	C	C	C	C	P	C	C			C	C	C	C		P				P
Petroleum Technology Transfer Council	P	P	P	P	P	P	P		P		P	P	P	P		P	P	P	P	P	P	P	P	P	C
Department of Energy	C	C	P	P	P	C	P	P	C		P	P	P		C	C	C	C	C		P				C
National Labs	C				P	P						P			C	C	C	C	C	P	P	C			C
C = Currently performs																									
P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints																									

members' policy, legislative, and regulatory interests before the Department of Energy, other elements of the Executive Branch, and Congress. Several trade associations serve the oil industry, including producer associations, oil field service industry associations, and equipment manufacturer associations, among others.

Producer Associations

The oil and gas extraction sector of the petroleum industry is served by three national associations:

- The American Petroleum Institute (API) and the Mid-Continent Oil and Gas Association primarily serve the major integrated companies and the largest independent producers.
- The Independent Petroleum Association of America (IPAA) serves independent producers, ranging from the large and technically sophisticated companies to small, less technologically inclined producers.

Although the major producer associations are better funded than the independents, they provide a similar range of services (in addition to advocacy) to their memberships, albeit at different scales. Services include:

- Collection and analysis of industry statistics and economic data
- Publication of newsletters and magazines
- Sponsorship and coordination of periodic seminars, symposia, and membership meetings
- Sponsorship of regulatory workshops and conferences
- Coordination of task forces to address special issues or concerns.

All of these capabilities could be effectively applied to improve technology transfer to producers.

Constraints

Producer associations, by virtue of their history, roles, functions, and legal status face limited constraints (e.g. focus and budget) to expanding their roles in technology transfer. None, however, appear to be insurmountable.

Lack of Technology Focus: The major integrated companies and the very large independents have internal R&D departments and/or access to information and technology from service companies, consultants, universities, and other research organizations. Consequently, their national associations have tended to minimize continuing education in technology applications, geosciences, engineering, or reservoir management in the services they offer. API has taken a very active role in studying the energy and economic effects environmental regulation and in offering producers insight on how to comply with changing regulation. However, it is unlikely that API or Mid-Continent will adopt technology transfer as a primary mission in the foreseeable future.

Independent producers have typically relied on exploratory successes and sales of reserves to majors. Hence, IPAA has traditionally focused its activities on tax, economic, regulatory, and legislative issues. IPAA has left technology concerns to the majors and has relied on industry service companies to provide technology to independents. Although IPAA has had an Improved Recovery Committee for many years, its activities have not (until recently) been a major focal point of the overall organization.

With the downturn in industry activity, association memberships are declining and budgets are being reduced, further constraining their ability to participate in technology transfer. As producers see the benefits of association technology transfer functions, however, memberships, dues, and contributions can all be expected to increase.

Potential

National producer associations have significant capacity and potential to play a major role in future technology transfer efforts.

Increasingly, these associations are expanding their focus to include technology transfer.

Operator Confidence and Trust: One of the most important factors in achieving effective technology transfer is having the trust and confidence of the producer. By design, producer associations are operated and funded by producers with the specific mission of serving their needs. Hence, they are uniquely suited to the mission of technology transfer.

Existing Infrastructure: Each national producer association has an established infrastructure and network for contacting and communicating information to domestic oil and gas producers. These networks and databases also allow associations to target producers in specific size classes, geographic regions, and operating environments.

Because of their established rapport and their ability to target and contact specific segments of the producing community, producer associations represent an important, yet, until recently, inactive, channel for conducting technology transfer. While suppliers and service companies are sometimes seen as "salespeople" trying to push technology, and are often mistrusted by smaller or less technically sophisticated producers, the producer associations are uniquely situated to deliver the technology to the producers in an environment directed and controlled by producers or their representatives.

Input and Feedback to R&D Programs: Producer associations at the national level, through their national and regional organizations, have effective network mechanisms for soliciting and receiving input from their members as to their priority needs and concerns. Existing networks can also be used to provide a single authoritative voice to communicate the needs and concerns of producers to public and private research and technology transfer organizations, as well as to federal and state organizations, regulators and policy makers, and the financial community.

Expanded Opportunities for Independents: Independent producers are increasingly inheriting responsibility for discovering and producing new oil resources in the lower-48 states and for stewarding efficient production of known remaining resources. Companies are offering large blocks of properties for acquisition by independents, but these opportunities also carry a measure of risk. Many have significant incremental production potential while others may not. Ultimately, the risk must be evaluated on the basis of economic, technical, and regulatory factors. Independent producer associations could perform valuable functions in:

- Informing independent producers of acquisition opportunities
- Communicating the availability, potential, and risks of new E&P technologies and approaches to improve production, extend the economic life of wells, and defer abandonments
- Assisting producers in learning how to analyze the potential of improved recovery technologies in specific operating environments.

Unlike state and regional associations, national producer organizations are not overly constrained by parochial interests. Thus, they can perform an essential leadership role in:

- Coordinating the technology transfer activities of state and regional producer organizations
- Performing unbiased evaluation of the effectiveness of state and regional activities and efforts
- Identifying effective and successful approaches to technology transfer that could be applied in other states and regions
- Leveraging and maximizing the benefits to the industry of limited expenditures

for technology transfer and related industry assistance efforts

- Serving as a single point of contact for other public and private organizations involved in the technology transfer process
- Establishing access to and credibility with other associations, professional societies, and state organizations.

Other Industry Associations

In addition to producer associations, numerous associations represent other segments of the petroleum community and have an impact on the producing sector:

- The Petroleum Equipment Suppliers Association represents the manufacturers of oil and gas exploration, drilling, and extraction materials and equipment
- The Association of Oilwell Servicing Contractors (AOSC) represents large and small workover and well service companies
- The National Ocean Industries Association represents the special concerns and needs of offshore oil and gas operators.

An additional association of interest is the American Association of State Geologists (AASG). While this association does not directly serve producers, it does serve as the formal organization of the Directors of the state geological surveys in each of the fifty states. The state profiles have clearly identified the state geological surveys as key current and future participants in integrated technology transfer efforts. AASG serves as an effective coordinator and forum for sharing the concerns and innovative approaches of the geological surveys of individual states so they may contribute to meeting the needs of the nation as a whole.

While these associations have not been investigated in detail as part of this study, it is

clear that they could also play significantly expanded roles in working with the national producer associations and related R&D organizations to accelerate and improve the effectiveness of technology transfer to U.S. petroleum producers.

PROFESSIONAL SOCIETIES

The nation's petroleum-related professional societies have long been among the most effective forums for technology transfer and information sharing in the petroleum community. Unlike industry trade associations (which serve as advocacy and member service organizations), professional societies serve the "disciplinary" interests of the members of a specific profession. They are, by definition, dedicated to advancing and communicating advancements in the state-of-the-art of the specific disciplines around which they are organized. Key petroleum industry professional societies include: the Society of Petroleum Engineers (SPE); the American Association of Petroleum Geologists (AAPG); the Society of Exploration Geophysicists (SEG); and the Society of Independent Professional Earth Scientists (SIPES).

The professional societies achieve their mission and goals through a variety of functions, all of which are designed to communicate new ideas to their membership or foster interaction and discussion among their members (Table 5-1). Professional societies offer an extensive suite of publications, including books and manuals, periodicals, journals, and highly focused topical reports and technical papers. Through this mechanism, they provide a critical outlet for the dissemination of data, results, and analyses of research performed in industry, academic, and government laboratories and in the field.

National and regional conferences, technical expositions, and symposia are held by the professional societies on a regular basis. These meetings provide forums for short presentations of papers on economics, policy, research breakthroughs, new technologies, and case studies of field projects. The presentations and handouts of the papers themselves are intended

to provide sufficient information to stimulate awareness of and interest in the project and to inform interested parties as to where they may find additional information about the research and its applications.

The professional societies take an active role and interest in the continuing professional education of their members. To fulfill this element of their mission, the societies offer an extensive roster of short courses, training sessions, and in-depth video-taped courses to their members. Courses are offered during their annual and regional meetings, as well as through the local and regional chapters of the societies. Importantly, these meetings provide forums in which researchers and industry professionals can get together and exchange ideas, experiences, successes, and failures.

Several of the petroleum-related professional society conferences and symposia at the national and regional level are co-sponsored by the Department of Energy, Gas Research Institute, or other research organizations. Of particular note is the bi-annual SPE-DOE Enhanced Oil Recovery Symposium held in Tulsa, Oklahoma. This meeting has been a highly effective forum for more than 10 years in communicating advancements in improved oil recovery technology to the producing industry.

Constraints

As with other research and technology transfer organizations, the professional societies face significant constraints in continuing or expanding their roles and services to the petroleum research community and the producing industry.

Declining Memberships: With the oil price decline, declining lower-48 exploration and production activity, and the resulting down-sizing of domestic operations of the major integrated oil companies, hundreds of thousands of jobs have been lost in the petroleum extraction sector. Even as the largest professional societies (SPE and AAPG) have expanded their scope to embrace the international petroleum community, memberships in the professional societies and

participation in their meetings and conferences have declined. In turn, revenues from membership and meetings fees have also been reduced, limiting the societies' latitude in expanding their roles and focuses.

Minimal Interdisciplinary Activity: By definition, the professional societies are focused on a particular discipline. Therefore, there is a lack of interdisciplinary efforts to consider petroleum engineering, geoscience, and geophysical research results together as a whole or to integrate their results and present them as "packages" of technology solutions. This reflects, in part, a history of schisms between the geoscience and engineering disciplines and professions.

Recently, SPE, AAPG, and SEG have begun to feature highlights of each organization's efforts and developments at the others' annual meetings in sessions called "The Best of AAPG" or "The Best of SPE" or "The Best of SEG". In addition, some of the research reported has also become more interdisciplinary. Particularly in the areas of geosciences and geophysics, researchers are beginning to demonstrate how disciplinary advances in these areas can be combined with petroleum engineering to improve the performance and predictability of drilling and production techniques in specific operating environments.

Target Audiences: Much of the technical information communicated by the professional societies in papers and presentations focuses on relatively narrow advances in theory. While the information is generally sufficient to enable other researchers to create new or improved products or develop technology applications, it is typically not presented or packaged in such a way as to enable a producer to immediately apply it to analyze a problem or implement the solution.

Hence, the audience for much of the information provided in technical sessions is more appropriately targeted to the personnel of major integrated companies, technically sophisticated independents, service companies, or university research programs rather than to less

technically sophisticated mid-sized or small independent producers.

The professional societies seek to balance this focus in their larger annual and regional meetings by sponsoring or hosting extensive technology expositions. Providers of equipment, chemicals, processes, and analytical and consulting services use the expositions to demonstrate in a hands-on fashion their capabilities and the potential applications of their technologies.

Interaction With Associations: There has been little direct interaction or coordination of activities between the professional societies and the producer associations discussed above at the national level. This is due, in part, to the associations' focus on regulatory concerns as well as to the societies' disciplinary focus and the theoretical nature of much of their products. It is also a function of the limited financial and personnel resources of both sets of organizations. To a great extent, however, this is also due to the fact that the organizations were established independently of one another to perform different functions. There has been little impetus to motivate coordination or interaction between the respective groups.

Potential

The professional societies perform a critical and highly laudable role in the research and technology transfer sector of the petroleum community. Recognizing their constraints, they have significant potential to expand their participation and effectiveness in technology transfer to domestic oil and gas producers.

Access to Researchers, Producers, and Intermediaries: Through their extensive membership rosters, databases of exhibitors, and other contact mechanisms, the professional societies have an established infrastructure for making contact with producers and the researchers and intermediary technology and service organizations that serve them.

Educational Services: Through their established mechanisms for the development of

short-courses and more detailed educational curriculum, the professional societies have the facilities and the ability to assist in the development of hands-on and remote education and training materials and courses to teach specific audiences about the potential of new technologies and approaches to address specific problems in distinct operating environments. Such efforts, if performed in coordination with industry associations and other technology transfer organizations, could be highly effective.

Interdisciplinary Forums: Professional societies could also improve their effectiveness by developing and implementing broader interdisciplinary efforts that relate geoscience, engineering, and other advancements to demonstrate specific applications. Of particular usefulness would be efforts to encourage greater interaction between the disciplines through the sponsorship of interdisciplinary forums focused on specific technical problems and/or specific geologic classes, fostering greater one-to-one interaction between the geoscientific and engineering sectors.

Coordination with Other Organizations: Several professional societies have expressed interest in participating actively in a national organization to promote coordination of producers, industry associations, professional societies, university R&D programs, state agencies and geological surveys, and federal R&D efforts. The purpose of this organization would be to help prioritize research and technology transfer efforts and to leverage the limited resources of all of the participants to generate beneficial synergistic effects.

PETROLEUM TECHNOLOGY TRANSFER COUNCIL

Many public and private research and technology transfer organizations recognize the need for a coordinated technology transfer effort to help domestic oil and gas producers to respond to the challenges and opportunities of the changing domestic industry structure. In 1991, the Independent Petroleum Association of America began to examine the potential of

forming a single national "umbrella" organization to coordinate and accelerate the effective transfer and improved availability of data, analytical tools, and technology information to independents and other domestic producers. Since then, working with university R&D and technology transfer programs, professional societies, service companies, state geological surveys, state regulatory agencies, the U.S. Department of Energy, and the Interstate Oil and Gas Compact Commission, IPAA has succeeded in developing a concept for an industry-driven umbrella organization that is embraced by virtually the entire petroleum community.

To separate this organization from the government relations functions of IPAA, the organization will be separately chartered as a non-profit educational organization to be known as the Petroleum Technology Transfer Council (PTTC). In 1992, the Department of Energy requested the PTTC to organize an ad hoc group to prepare a report to DOE on the technology transfer needs of the producing community and recommended approaches for achieving them. A report is expected in April 1993.

In general, the PTTC intends to establish a unified approach and framework for conducting problem-focused technology transfer activities in all of the oil producing states and regions of the nation. These activities will include:

- Problem identification and prioritization
- Focused workshops and short-courses to present packages of solutions to resolve high-priority problems and teach operators how to analyze and apply them
- The design and implementation of resource centers at existing institutions to provide producers with direct and remote access to data and technology information, case studies, analytical tools, trouble-shooting assistance, and unbiased referrals to consultants and service companies who can assist them
- The provision of effective channels to communicate the technical needs and priorities of the producing community back to public and private research organizations and decision makers.

As a new organization, the PTTC will face a variety of constraints and hurdles. These include the need to retain a small full-time staff and the need to secure funding commitments from private and public sources. Once these constraints are overcome and organizational details are finalized, the PTTC has a significant opportunity to make a positive impact on domestic oil and gas production.

FEDERAL ORGANIZATIONS

The federal government continues to take an increasingly active role in performing and funding research and technology transfer activities intended to sustain or increase domestic oil and gas production.

Federal Oil Research Program

Until recently, the Department of Energy's oil research program was focused on addressing gaps in needed long-term, high-risk geoscience and engineering research that were not being addressed by industry. The results of the research were communicated, through a variety of functions, to appropriate target audiences, largely other researchers who could convert them to applications. Specifically, the oil program's technology transfer mechanisms included:

- Distribution of data and statistics
- Publication and distribution of R&D technical reports and quarterly abstracts of R&D progress
- Distribution of predictive models, reservoir simulators, and other software and analytical tools
- Distribution of information about R&D products that resulted from DOE-funded research

- Co-sponsorship with the Society of Petroleum Engineers of a biennial SPE/DOE Enhanced Oil Recovery Symposium.

Constraints

These functions served the program's target audiences well. However, by virtue of its limited mission and budget, the oil program was constrained from seeking to effect technology transfer to broader audiences or to transfer products and results other than those developed by the program or its contractors. This constraint particularly impacted the program's ability to address high-priority near-term needs of producers.

Potential

Recognizing the potential impacts of accelerated well and field abandonments, unstable prices, investor uncertainty, and more stringent environmental regulation, the Department of Energy's Office of Fossil Energy began implementation of a new oil research program strategy in 1990. The new program plan calls for focused, aggressive technology transfer in the near-term to slow the rate of abandonments and encourage application of existing technologies to maximize ultimate recovery. This plan includes field demonstration projects, as well as other DOE and technology transfer functions.

The plan also calls for highly focused supporting laboratory and field research and demonstration efforts to develop and transfer emerging technologies, approaches, and advances in geoscientific understanding in the mid-term (within 10 years). Finally, the plan continues support for problem-focused, longer-range, high-risk research and development activities to be performed by universities, laboratories, and others that can develop and transfer new advances in the future.

As part of its new oil research program, the Department of Energy has refocused the activities of its Bartlesville (Oklahoma) research facility. DOE plans to assist or perform elements of the program's research and to assist

in the aggressive technology transfer of the results of DOE-sponsored or DOE-performed R&D activities and demonstration projects. A new managing and operating (M&O) contractor will soon be put in place to operate the facility and operate the national oil and related programs.

The department is still in the process of defining its technology transfer mission, goals, and activities, with the expanded use of the Bartlesville research center, the M&O contractor, and explicit technology transfer requirements for recipients of DOE contracts and grants from the oil program. Through this transition, DOE can significantly expand its direct and indirect technology transfer functions. DOE will also be able to explicitly target technology transfer mechanisms to address distinct problems and audiences with appropriate technological and analytical solutions.

In addition to the improvements in the program's current technology transfer roles and approaches, DOE has the potential to add to its technology transfer mechanisms through:

- Expanded publications, including focused newsletters or magazines, case studies, and comparative project analyses
- An expanded program of seminars and symposia to make producers aware of the products of DOE efforts and the applications of technology advances
- Sponsorship of focused problem identification
- Focused technology outreach functions, such as lectures, seminars, and problem- and setting-specific solution workshops.

DOE also has the potential to foster broader awareness of, confidence in, and application of technology that is developed through the DOE research program. This can be achieved through enhancement of DOE's existing approaches for design, publication, and distribution of reports of the program's research and analytical efforts.

The program's technology transfer function could also provide unbiased referrals to operators and others seeking assistance in troubleshooting problems or in designing and implementing improved recovery processes in their reservoirs. Many of these mechanisms can be designed and implemented directly by the Department through its field staff or its program M&O contractor. Other mechanisms will have to be contracted to other R&D or technology transfer organizations.

In addition to those functions performed directly by the federal program or assisted by the DOE program, other external R&D and technology transfer organizations exist. With its expanded mission and program capabilities through the use of the Bartlesville facility, DOE can play an active and important role in encouraging and participating in cooperative technology transfer efforts that take advantage of the synergies between service companies, professional societies, industry associations, universities, state geological surveys, and other entities.

National Laboratories

Several of the national laboratories, initially established to support the nation's defense technology needs, have developed capabilities in geosciences and in engineering that may have direct applications to improving exploration, drilling, and extraction efficiency in the United States. In recent years, the national labs have opened their doors to the exploration and producing community, large and small, to offer assistance in resolving technical problems in deep, hot, or fractured reservoirs.

The Office of Fossil Energy within DOE has established an Oil Recovery Technology Partnership (ORTP) with two of the laboratories, Sandia National Lab and Los Alamos National Lab, both in New Mexico. The ORTP has allowed producing companies to bring problems related to drilling, completions, and fractured reservoirs to the labs, to be addressed on a cost-shared basis.

Through recent acts of Congress, the labs have also been authorized to enter into

cooperative R&D agreements (CRADAs) and "work for others" agreements with private organizations to perform research and provide technical assistance to resolve geoscience and engineering problems faced by the E&P community. The purpose of these acts is to foster "technology transfer" in the sense of transferring knowledge from one industry to another, as opposed to transferring knowledge and technology from a developer or contributor to an end-user.

Constraints

The labs and the ORTP are constrained in expanding their services to the oil and gas community by numerous factors including staffing and funding, limited industry awareness of the labs' services and possible application of defense technologies, and concerns about competing with private sector service and consulting companies to serve a shrinking domestic market.

Potential

With increased staffing and funding, the labs could play an expanded role in technology transfer to the oil and gas E&P industry. The labs must first, however, demonstrate an understanding of the problems and conditions faced by producers in specific operating environments. They must also inventory and make available to the public the specific kinds of technology and expertise developed by the labs that may have applications to E&P problems.

The labs have always been highly mission focused, establishing interdisciplinary teams to resolve specific problems or to develop essential technologies. Once their missions and limits are defined, the labs have the potential to assist or complement the research activities performed by the oil program at the Bartlesville research facility or by universities, service companies, or other contractors.

Currently, the labs and the ORTP are conducting technology transfer through the use of cooperative R&D agreements, industry-lab consortia, and "work-for-others" mechanisms. These vehicles, however, provide for immediate

technology transfer to a very limited audience of project sponsors. Broader transfer of the project results must be focused on the appropriate target audience and conducted through appropriate mechanisms. The labs have the potential for broader technology transfer if they clearly communicate the scope of the capabilities and experience to the producing industry and if they establish effective mechanisms to communicate the results of their oil and gas related projects to a broader spectrum of producers.

CONCLUSIONS

The national organizations can significantly improve the effectiveness of technology transfer to the producing community and the responsiveness of the research community to the priority needs of the industry. By working together and in cooperation with state and regional organizations, they can provide an integrated technology transfer network that will leverage their resources and take advantage of the potential synergies of each organization's unique skills and perspectives. Together, these organizations can provide the leadership and coordination that is needed to sustain efficient production of the nation's petroleum resources.

Chapter 6

GENERAL FINDINGS AND CONCLUSIONS

Based on the Compact's analyses of the producing industry and related research and development, technology transfer, and government organizations in eight major oil and gas producing states, the project team reached several general conclusions about:

- Trends in oil and gas research and technology transfer in the lower-48 states
- Effectiveness and deficiencies of existing technology transfer approaches
- Structural and substantive technology transfer needs of the petroleum production and research community at the state, regional, and national levels.

TRENDS IN OIL AND GAS TECHNOLOGY TRANSFER

The eight state profiles that follow these conclusions reflect the diverse structure, missions, staffing, funding, and constraints of the respective organizations that are engaged in petroleum research and development and technology and information dissemination within and among the states. When viewed comparatively, they also reflect differences in the geology and other attributes of each state's oil and gas resources and producing industry.

Virtually all of the states that were reviewed share common negative trends in oil production, reserves, extraction sector employment, value of production, and contributions of severance tax revenues to the state. Even the largest producing states are witnessing a dramatic shift in the composition of the producing industry from dominance by major integrated producers to increasing responsibility of independent producers for production of the state's remaining discovered and

undiscovered oil and gas resources. In most states a consolidation of the independent sector is also apparent, largely attributable to attrition among the smallest producers.

With the downsizing of the major integrated companies and consolidation and restructuring in the domestic producing industry, research staffs and budgets in the majors' labs are being reduced, research agendas are being pared back, and research focus is increasingly shifting to foreign resources and opportunities.

Further, with the loss of personnel to other industries, transfers of properties to new operators, and reductions in staffing, a significant amount of valuable data and expertise stands to be lost, perhaps forever, to the remaining producing industry.

Reduced employment opportunities in the domestic industry are causing similar reductions in enrollments in the nation's petroleum geoscience and engineering research universities, causing some programs to be dropped or severely curtailed.

Collectively, these trends and actions are reducing the nation's capacity to conduct needed research focused on the related geoscientific and engineering problems encountered in trying to maximize production of the oil and gas resources in America's diverse reservoir classes.

Increasing Levels of Technology Transfer Activity and Interest

In light of these and other factors, it is not surprising that since the Compact's 1990 technology transfer report, there has been a growing interest from major and independent producers in the potential of improved exploration and recovery technology and effective technology transfer. The technology enhances exploration and production

successes and efficiency, maximizes potential production levels, and assists in sustaining the nation's weakening domestic producing industry.

In 1988, the idea of industry or government coordinated technology transfer functions was met with apathy or opposition from most independent operators and producer associations. By 1992, however, concerted efforts to expand the use of currently existing technologies and to develop and transfer new technologies to address high-priority problems were increasingly accepted and demanded by the producing community and, in particular, independent producers.

Increasingly, research and development entities and other organizations with helpful information (e.g. geologic societies, etc.) have recognized the need to communicate the useful results and products of their research and that of others to the producers, operators, and royalty owners.

In three states, previously established technology transfer organizations continued and expanded their services to the producing community. The University of Kansas Tertiary Oil Recovery Project (TORP), the New Mexico Petroleum Recovery Research Center, and the Illinois Oil and Gas Association and Illinois State Geological Survey have all continued innovative, problem- and producer-focused research and technology transfer functions, and expanded them to encompass even greater interdisciplinary activities and services to producers.

In 1990, the Texas Independent Producers and Royalty Owners Association (TIPRO) built on its previous efforts and joined with the University of Texas' Bureau of Economic Geology to establish a program of needs identification forums and focused workshops to address priority needs. TIPRO is also planning an Improved Recovery Information System to be deployed at technical information centers that will serve oil and gas producers throughout the state.

In Oklahoma, the University of Oklahoma's Center for Reservoir Characterization Research entered into a highly innovative agreement with British Petroleum, the Oklahoma Geological Survey, and several petroleum research organizations to assume management of an integrated field study of

a major, geologically important reservoir outcrop. The Oklahoma Independent Producers Association also joined in an agreement with Gas Research Institute to engage the services of a natural gas field agent to provide hands-on technical assistance for producers in the state with priority problems.

In addition to Texas and Oklahoma, in each other state studied there was a growing realization by state-level producer trade associations of the importance of technology transfer functions and their need to participate. One association director went as far as to say "our association remains anxious for a practical, cost-effective program to provide our members with technology for enhancing production methods, etc."

These requirements are also being recognized and accepted by other regional and national industry organizations which are taking aggressive action to expand their traditional roles to ensure the domestic producing industry continues to operate at or near the state-of-the-art. Many state and regional associations have joined with the Independent Petroleum Association of America and other professional societies, universities, and R&D and technology transfer organizations to study the potential of a national technology transfer organization.

However, while interest has increased significantly, and a limited number of new activities and initiatives have begun, the level and quality of effort that is required for technology transfer to be effective in deferring premature abandonments and increasing production has not yet been achieved. Clearly some regions and states are moving faster than others. Overall, however, the process of aggressively transferring existing technology to producers and effectively soliciting and reporting information about their problems and R&D needs is still inadequate to meet the needs of the industry, the states, or the nation.

Greater Diversity of Participants and Roles

An encouraging observation of the Compact's recent effort is the greater diversity of participants who have become interested and involved in the petroleum technology transfer process since the Compact's 1988-1990 effort.

An effective integrated technology transfer program at the state or national level must identify and involve all of the essential participants, as appropriate, in the research, development, service, and producing community if it is to be fully effective. The program must recognize the special attributes, levels of technological sophistication, potential contributions, and or requirements of each class of participants -- whether direct end-users of technology, intermediary packagers or transferrers of technology, or developers of technology:

End-Users of Technology and Information

- Oil and gas producers
 - Majors
 - Large, medium and small independents

Intermediary Users or Providers

- Service companies
- Consultants
- Professional societies
- Industry associations
- State geological surveys
- State agencies
- Technology transfer organizations

R&D Performers and Technology Developers

- Industry labs
- Colleges and universities
- Consortia
- DOE's Oil Research Program

Major and independent producers, royalty owners, field personnel, producer associations, state agencies, geologic surveys, professional societies, and university R&D programs all have an interest in successful R&D and technology transfer. All have roles to play in the process. Each participant also brings different expectations and demands to the table. Balancing and coordinating these varying, and occasionally conflicting, functions as well as each entity's expectations and desires while ensuring that all interested parties are involved is a necessity of a successful program.

Greater Cooperation and Interaction in Technology Transfer

In 1990, the Compact reported that while there is a diversity of participants in the petroleum and related technology transfer community, there was

little effective interaction among them. In performing its present task, however, the Compact has noted significantly greater levels of cooperation and interaction between producers, researchers, technology transfer intermediaries, and government, both in research and in related technology transfer activities:

Cooperative R&D: With research budgets reduced, major companies are increasingly engaging universities and service companies in cooperative R&D projects.

Consortia: Producers and researchers are increasingly using consortia to leverage research dollars and take advantage of synergistic benefits of sharing their knowledge and insights. These consortia also enable joint research to be performed without fear of anti-trust actions.

Inter-disciplinary Research: Increasingly, independent producers, majors and research organizations are recognizing the benefits of interdisciplinary approaches to research, technology transfer, exploration, and production activities.

Reduced Competitiveness: Particularly as majors are downsizing and restructuring and expanding their involvement in cooperative R&D and consortia, there is reduced emphasis on keeping geoscientific and engineering research results proprietary. Increasingly, majors are recognizing that broader understanding of and ability to apply improved reservoir characterization and oil and gas recovery processes on the part of independents and others can create markets for properties they are trying to sell.

Cooperative R&D, consortia, and reduced R&D competitiveness are expanding the breadth of distribution of R&D and field results to others in the producing community.

Cooperative Technology Transfer Efforts: Realizing that accelerating abandonments, decreased reserve additions, and declining production in the lower-48 states is threatening the future of the industry, industry associations, universities, service companies, and producers are also working more cooperatively to ensure that solutions are available

for priority problems and that producers are aware of these solutions and are able to apply them in their operations.

Expanding Federal Role in Technology Transfer

The Compact has also been pleased to note an expanding federal interest and commitment to enhancing oil and gas technology transfer. DOE is currently examining additional technology transfer mechanisms that can be performed through the program and its Bartlesville research facility to aggressively transfer these products to the appropriate intermediaries and end-users. DOE is continuing to assist the national labs to transfer applications of their defense related research that could be useful in addressing oil-field problems through the DOE/National Labs Oil Recovery Technology Partnership.

DOE is also encouraging DOE-funded research organizations, other private R&D and technology transfer organizations, and state agencies to take a more cooperative and active role in the technology transfer process.

EFFECTIVENESS OF AND DEFICIENCIES IN EXISTING TECHNOLOGY TRANSFER APPROACHES

Although progress is being made in expanding interest and participation in technology transfer activities, several concerns must be addressed before the technology transfer process can fully meet the needs of the industry, the states, and the nation. These concerns include:

- Lack of effective local or national coordination
- Inconsistent or ineffective approaches to key technology transfer processes
- Limited failure to differentiate target audiences or effectively target technology transfer events and approaches activities to appropriate target audiences
- Lack of effective channels to solicit input or feedback from producing community to R&D community and policy makers.

As demonstrated, many kinds of organizations perform technology transfer functions. Each has its own specific mission or goal(s) and its own agenda. Although the situation is improving, there is still little state, regional, or national interaction or coordination among R&D and technology transfer organizations to:

- Establish and prioritize common technology transfer goals
- Focus activities on specific problems and audiences
- Ensure the use of effective technology transfer approaches
- Consistently apply approaches so that their impacts can be evaluated
- Communicate new approaches and program content among organizations
- Communicate the feedback from the target audiences back to the research and technology transfer community.

Understandably, much of the content of the technology transfer activities reflects the technical or research focus of the individual organization performing the activity. This subject matter may or may not correspond to the highest priority technical problems in the targeted region or of the targeted audience.

In some instances, organizations interested in participating in technology transfer have failed to adequately determine the audience for their activity or to package their information appropriately to communicate to a specific targeted audience. The end results have often been more self-serving to the host organizations than beneficial to the producing community. Greater coordination can help to avoid this.

The lack of coordination also contributes to occasional redundancy in activities, broad gaps in coverage of specific needs and audiences, and

inefficient allocation of technology transfer resources, including funding, staffing, technical materials, and facilities.

Coordinated and integrated planning by universities, professional societies, industry associations, and state geologic surveys can help to avoid these pitfalls and increase the benefits to the respective organizations and to the producing community as a whole.

STRUCTURAL AND SUBSTANTIVE NEEDS TO IMPROVE OIL AND GAS TECHNOLOGY TRANSFER

The Compact has identified several improvements that should be attained to help overcome the obstacles to effective oil and gas technology transfer.

Problem Identification and Needs Analysis

As noted above, much technology transfer activity is not adequately focused on priority problems or tailored to achieve maximum benefit to the appropriate audience(s). Because of the rate at which known remaining oil resources are being abandoned, such problem identification and prioritization is essential.

Technology transfer should begin with problem identification and prioritization, needs analysis, and technology appraisal. This process can identify high-priority problems, identify what is needed to resolve the problem, and determine whether information, technologies, or other solutions exist to address the problem.

Where solutions *do not* exist, the technology transfer organization can serve as an important conduit to report the problem and the perceived need back to the research community to be addressed, also prioritized on the basis of urgency and potential for sustaining or increasing production. Resulting technologies, information, and solutions can then be packaged for transfer to appropriate target audiences.

Where solutions *do* already exist, the technology transfer process, if effectively organized, can then (directly or through intermediaries) inform producers about the technology, its application in the reservoir,

and its potential to sustain or increase production or reduce operating costs.

Importantly, "problem identification" and "needs analysis" must not be confused. It is potentially misleading to ask a producer what technology is needed if the question is not problem focused. Using such an approach to determine the substance and focus of future technology transfer activities can render the future program ineffectual.

Effective problem identification, prioritization, needs analysis, and technology appraisal can serve as a highly effective basis for coordinating technology transfer organizations, identifying and selecting appropriate technology transfer approaches for specific audiences, and evaluating the effectiveness of the technology transfer process and approaches and the solutions being transferred.

Greater Participation At All Levels

While significant improvements have been made and more parties are actively interested in participating in the technology transfer process, still greater participation is required at all levels and functions in the process. This need extends beyond the sheer number of participants to include expanded commitment of funds, facilities, staffing and other resources to the technology transfer process.

Involved parties need to expand their traditional roles in the technology transfer process. In particular, a more proactive approach at all levels is not only possible but also necessary. In order to be successful, technology transfer needs to be a dynamic and on-going process. Remaining in reactive roles limits the effectiveness of the overall program and keeps technology transfer from achieving its full potential. When organizations expand beyond their traditional roles in the technology transfer process, positive benefits result. This expansion beyond traditional roles can be made by nearly all of the participants.

Research and development programs can do more to disseminate results than publishing papers in technical journals and making presentations at conferences and symposia. Often the results of research, development, or demonstration activities

need to be tailored to a level of technical sophistication that may be beneath that of a technical journal article or paper presentation. For example, operators and field personnel probably will not be interested in the theoretical basis for the work. Rather, they will want to know how the advance is applied in the reservoir.

Failures as well as successes need to be documented. Such documentation may offer suggestions and warnings to others undertaking similar work and may explain some problems experienced in the field.

Although they are increasingly active in the research and the technology transfer process, many state geological surveys can also take a much more proactive role in communicating their research and project results to the producing community and in informing producers of the range of services and information available at the surveys. To fulfill their potential, the geological surveys in all but the largest producing states will require additional staffing, funding and facilities.

Royalty owners, operators, and field personnel can also take a more proactive approach to technology transfer. Today, the primary technical information source for many independent producers is what they learn from other producers "over the back fence." However, by working together through their local industry associations and professional societies, producers can more systematically and effectively identify the priority, high-impact problems encountered in specific types of reservoirs existing in their regions. These industry organizations can effectively interact with public and private technology sources to organize functions to communicate existing solutions to producers working in the affected environments. Once effective communication channels and networks are established to transfer technology information, they can also be used to communicate problems and perceived technology needs back to the research community.

Beyond the local level, interaction between state and regional industry associations through the national associations or emerging technology transfer

organizations can provide an effective mechanism to share successes in one area with producers operating in similar environments elsewhere.

The Need for Consistent Approaches

Each state or region should take approaches to technology transfer functions that are consistent with those taken elsewhere. While varying geography, producing conditions, operator profiles, etc. will lead to differences, the basic approaches taken can be the same. Consistent approaches are necessary in order to allow comparisons between programs to evaluate efficacy and identify deficiencies in an objective manner. Taking similar approaches also allows the effective transfer of results from one state or region to another. Similar state programs will also facilitate interaction and compatibility with a national program. Disparate programs are unlikely to form a unified whole.

As mentioned above, the entire technology transfer effort will be constrained by limited resources, particularly funding and personnel. It is therefore essential that the resources be efficiently distributed and that their use be maximized. In order to efficiently distribute the resources, comparison and evaluation of the various programs is necessary. Objective comparison and evaluation is accomplished best when programs are similar. The legitimacy of program evaluation and comparison derives from acceptance by involved parties of the standards to be used for the evaluation or comparison. Without an accepted "yardstick," decisions on distribution could be subject to strenuous dispute by entities who feel they were slighted in some manner. Developing an objective standard is difficult, if not impossible, if the programs do not adopt consistent approaches to their technology transfer efforts.

Such evaluations and comparisons are also necessary for identifying weaknesses and deficiencies within state programs. Such identification is necessary for demanding accountability from managers for program efficiency and for the practical distribution of resources. As weaknesses and deficiencies are identified, resources can be appropriately directed to correct or change them. If a program is found to be consistently unproductive, it could be discontinued or modified. Again, an

objective standard is necessary for evaluation and comparison. Consistent programs are required for the formulation of an objective standard.

Consistent programs also allow for optimal and maximized use of limited resources. The evaluations and comparisons, while providing a basis for resource distribution and accountability, offer proven programs that could be applied in other states. Naturally, the details of a program will vary from state to state. Geologic settings, resource base, operator profile, number of involved organizations, and acceptance of the technology transfer program will all vary. The general approaches taken in one state, though, can be applied to another if the programs are consistent. In this manner, the most efficient and productive options can be applied.

The actual transfer of results and technologies to the producing community can be a complex venture because of the number of different levels on which it can occur. As mentioned above, there is a wide diversity of participants in the technology transfer process, each with their own set of expectations and goals which may conflict with the expectations and goals of other involved parties. Yet, none of these audiences can reasonably be ignored or forgotten. Each group of individuals will represent companies or organizations of different sizes, be comprised of individuals with different scopes of responsibilities within their company or organization, and have different levels of technical sophistication. These three levels--company size, position within company, and level of technical sophistication--need to be addressed, each by a potentially different technology transfer mechanism.

Consistent approaches also help to ensure that state and national programs will have compatible goals. Common application of programs are likely to lead to similar overall goals. For example, DOE has made prevention of premature abandonment of oil resources a goal of the national oil research program, and, by extension, of the emerging DOE technology transfer program. To this end, a reservoir classification program was established to prioritize reservoirs on the basis of remaining resource and threat of abandonment. If a state program does not

use these qualifications as a factor in prioritizing problems faced by producers and operators, it is possible that the programs can have conflicting priorities.

There are several areas where the maintenance of consistency is important:

- Problem identification and prioritization
- Analysis of technology needs
- Assessment of existing technology
- Technical and reservoir data collection
- Information dissemination and referrals
- Targeted technology transfer functions and content.

Applications in each of these areas provides states the opportunity to adapt each function as the program progresses. A program that works in one state or region could just as easily work in another if the programs are consistently applied. Rather than proceeding in a trial-by-error fashion, there is a wealth of practical experience in application upon which to draw.

Consistent approaches taken to as many areas of technology transfer as possible will make each state program as similar as possible. A national program can then be designed to ensure compatibility with all state programs in an efficient and equitable manner. Each state could then fit as an essential piece of the national program.

The use of consistent approaches greatly increases the potential for interaction with the federal program. The national program can be designed and adapted to allow for interaction with the state programs. This interaction is necessary to the development of a successful national technology transfer program as each state will have something to offer to the national whole. On the other hand, while state programs are an essential element of a national program, existence of a national program is the only way the whole system will work.

Increased Interaction With State Agencies

Greater interaction and participation of the states and state agencies is essential if maximum production of the oil resource base is to be achieved and if the related economic and financial benefits are to accrue to the states and their citizens. As noted above, the universities and geological surveys can play significantly expanded roles in providing technology information and assistance.

Need for A Lead Organizing Entity In Each State

Currently, there are several established organizations in each state that perform functions related to technology transfer. In a handful of states, a single, identifiable, and well organized entity serves as a coordinating point for addressing technical problems associated with oil and gas production. In these states, technology transfer activities are beginning to be highly focused and effective. In other states where there is little coordination between state agencies, the universities, or the producing industry, its associations, and the professional societies, technology transfer is notably less effective.

Successful technology transfer efforts occur when organizations go beyond traditional roles and adopt an aggressively proactive approach. The wide diversity of participants and their respective roles need to be coordinated and balanced. An organizing entity can synthesize organization's expectations and goals for the program and minimize conflicts and potential problems.

A single organizing entity could facilitate the process of identifying potential synergies of effort, evaluating areas of weakness, organizing programs to achieve the broadest range of result, and opening communications channels.

Open and easily accessible channels of communication are essential to maximizing the limited resources of the technology transfer program. A lead organization would facilitate communication between oil and gas producer, R&D, and technology transfer entities while, at the same time, ensuring that necessary exchanges of information and data are taking place. The organizer could serve as a clearinghouse of ideas and sources of information. The organizing entity could also be the hub of the

feedback loop to and from participants and the national technology transfer program.

An effective lead organization would have to be well situated within a state or region. Intimate knowledge of and respect within the oil and gas community of the state or region is essential to perform effectively in this capacity.

Having a single entity organizing and coordinating the technology transfer process also facilitates the organization of the national technology transfer program. Each state or region with a technology transfer program would ideally be a self-sustaining piece of the national technology transfer program. Each component would feed into the national program creating a unified whole. To accomplish this in the most effective and practical manner, consistent approaches to similar functions should be taken in each component.

The Compact perceives a real and urgent need for a single entity to be established, or perhaps designated, in each state to serve as a lead organization to coordinate the other organizations in the state to provide effective technology transfer. By taking a logical and systematic approach to the process, as described above, and by defining the roles, functions, and responsibilities of each party in the process (including producers), problems can be addressed, research can be focused, and needs can be effectively served. More importantly, from the perspective of the governors of the producing states, premature abandonments can be deferred, ultimate production levels can be enhanced, and resulting economic benefits to the state can be realized.

Need for A National Coordinating Organization

While state and regional level programs are important, the technology transfer picture is not complete without a program at the national level.

The most important roles a national technology transfer would serve would be like those of state-level lead organizations, only on a broader level. A national program would be able to identify possible synergies between state and regional programs and evaluate areas of weakness or need. Resources could be more equably distributed across states and regions

if a national organization which oversees all state and regional programs exists.

A national program could also establish feedback loops and communication links between various state and regional programs. Deficiencies among and between programs could be more easily identified in this manner. Perhaps more importantly, however, these linkages would facilitate the transfer of approaches and program results between state and regional programs. A national technology transfer program would keep its various components (i.e., state and regional programs) in contact with one another.

In addition, a national program is necessary to conduct functions that transcend state and regional borders. A good example of this would be technology transfer efforts associated with DOE's Program Opportunity Notice (PON) process. Recent PONs from DOE have focused on the demonstration of enhanced recovery technologies in reservoirs where the threat of abandonment is greatest. This program is not confined to one state or region. The results from the program will have broad applicability. A national program would be situated to transfer these results.

A national program could also serve as an external point of contact for working with DOE, Congress, and the Administration. As at the state and regional level, funding is often provided by agencies and entities which lack in-depth knowledge of the industry in general or the technology transfer program in particular. Providing the funding through a national program will facilitate the equitable and efficient distribution of funds to the appropriate areas. A central point of funding would also lessen competition for funding among state and regional programs and proposals. Providing the national program with the "power of the purse strings" also allows the program a degree of authority over state and regional programs while maintaining accountability with the funding entity.

A national program would serve as a point of contact for directives as well. Program changes on the part of DOE, Congress, or the Administration could be directed through the national program to the appropriate state and regional program, ensuring that

the directives reach all the necessary entities. Such a link would also be the point of feedback for concerns, complaints and questions from external entities.

A national program is therefore necessary on many different levels. It would facilitate synergies of experience and effort and the transfer of approaches and results, while ensuring that weaknesses and deficiencies in state programs are dealt with and that there are no gaps in information. The use of consistent approaches to technology transfer functions at the state and regional level allows interaction with the national program and assists in the maximization of limited resources. Finally, the national program provides an essential point of contact for funding and directives from DOE, Congress, and the Administration.

To be fully effective, the Compact believes that a national technology transfer organization is needed to leverage the resources of the industry, the producing states, and the federal government in ensuring that effective technology transfer is conducted in all of the producing states and regions. Working with state, regional, and national organizations such as an "umbrella" organization can help to develop a systematic approach to conducting and evaluating technology transfer that could then be applied in all of the producing states and regions. Such an organization could also provide an unbiased mechanism for comparing the results and impacts of technology transfer activities and refining approaches to address discovered deficiencies.

Under the leadership of the Independent Petroleum Association of America, the independent producing industry has developed a plan for a national Petroleum Technology Transfer Council (PTTC), operated by producers and open to participation of all state and regional industry associations, the state geological surveys, petroleum research universities, professional societies, and the states. The PTTC intends to develop and implement a program of problem identification workshops, technology transfer workshops, and technology information resource centers in all of the producing regions of the country. In December 1992, the Interstate Oil and Gas Compact Commission passed a resolution endorsing the concept of a national

technology transfer "umbrella" organization to coordinate the activities of these disparate groups and provide an integrated program of technology transfer to serve the producing industry.

Greater Interaction with Federal Oil R&D and Technology Transfer Functions

The current refocusing and expansion of the federal oil R&D program to address near- and mid-term needs of the producing industry presents significant opportunities to the producing industry, related organizations, and the states, including the current programs to cost-share technology demonstration projects in specific, high-priority reservoir classes.

The federal program is committed to expanding public and private technology transfer functions to ensure that current technology solutions to priority problems are known and accessible to the producing community. This includes technologies developed by DOE or its contractors as well as that produced by private industry.

The Compact believes that greater interaction between industry technology transfer functions and the federal program will result in increased opportunities to producers, expanded benefits to the states, and more effective dissemination of federal R&D results.

PART II

STATE TECHNOLOGY TRANSFER PROFILES

**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
CALIFORNIA**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR CALIFORNIA

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil Resources

Oil was first discovered in California in 1861. Through 1987, California had produced 18.8 billion barrels (BB) of oil, with 53.4 BB of California's 72.3 BB original-oil-in-place (OOIP), or 74%, still in the ground. With 4.7 BB in proved reserves, 48.7 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

Most of California's ROIP is found in onshore and offshore sandstone slope-basin reservoirs (Figure 2) with the remainder in eight other geologic classes. Over 47% is heavy oil (API gravity <20 degrees) and requires costly artificial lift and advanced recovery methods. The combination of lower prices

and increased costs of production makes heavy oil less economic and more price and market sensitive than light oil.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas Resources

In California, a full 70.2% of the 47.3 trillion cubic feet (Tcf) of original natural gas resources has been produced. Of the remaining 14.1 Tcf, less than 30% is proved reserves. These proved reserves are recoverable under existing economic and operating conditions. The remaining 9.9 Tcf of undiscovered reserves is broken up into probable, possible, and speculative reserves and includes the portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Figure 3. Natural Gas Resource

Production

Twenty-nine of California's 58 counties have some oil or gas production, and 17 produce oil (Figure 4). Most oil production is concentrated in seven counties in the Los Angeles and San Joaquin Basins with about 16% of California's production from offshore platforms in federal and state waters. Producing oil wells totalled 42,600 in 1991 with 98% on artificial lift. Just over 60% of the

Figure 4. Counties with Active Production

producing wells are stripper wells (versus the national average of over 75%). Stripper wells produce 10% of the state's annual production.

California crude oil production has declined steadily since peaking at 424 million barrels (MMB) in 1985 (Figure 5). Annual production levels dropped more than 17% to 350 MMB in 1991. Even in decline, California ranks third behind Texas and Louisiana, accounting for over 17% of lower-48 production.

Figure 5. Crude Oil Production

Natural gas production is also in decline. Production peaked in 1968 at 719.4 Bcf but fell to a 1980 level of 310 Bcf (Figure 6). With higher prices and demand in the early 1980's, production again increased to almost 500 Bcf in 1985. Natural gas prices then led a declining trend, in which gas production decreased by almost 50% between 1984 and 1991. Recent trends in California, and the nation, show natural gas prices and production on the rise. In 1991, gas production from state and federal offshore platforms accounted for 15.6% of state gas production.

Improved Oil Recovery

Since 1958, California's reservoirs have been a target for enhanced oil recovery (EOR) methods. Since that time, 155 EOR projects have been carried out in California, 136 of which are currently active. Over 163 MMB of production has been attributable to EOR. EOR projects currently account for 46% of California's crude oil production.

Figure 6. Natural Gas Production

A few projects have employed chemical EOR methods, such as alkaline or polymer flooding. Most have employed thermal EOR methods. Thermal EOR methods lower the viscosity of heavy oil to make it more producible, hence the predominance of thermal EOR projects in the state. Over 90% of thermal EOR projects involved steam injection. At least five additional EOR projects were known to be planned as of 1991: three steam projects, one steam and polymer flooding combination, and one hydrocarbon miscible project.

Oil and Gas Reserves

California accounts for approximately one-fifth of all crude oil resources discovered in the U.S. and one-fifth of current U.S. proved reserves. The state's oil and natural gas reserves were strongly affected by the 1986 price decline. Investments made in the early 1980's in exploratory efforts and the expected potential of EOR projects caused oil reserves to continue to increase through 1988. Since 1988, crude oil reserves have fallen almost a billion barrels from 5.9 to 4.9 BB (Figure 7). Some of this is due to temporary write-offs precipitated by regulatory and permitting problems. Nonetheless, reserves remained well below the 1985 level as producers have been unable to replace proved reserves.

From 1984 - 1991, the average wellhead price of California natural gas (in 1991 dollars) dropped by almost 50%. Recently, U.S. and California gas prices have begun to recover. Like oil reserves, Proved gas declined, but less steeply, falling more than 25% between 1983 and 1991 (Figure 8).

Figure 7. Crude Oil Reserves

Figure 8. Natural Gas Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce the remaining oil-in-place. California well abandonments fluctuated throughout the 1980's before sharply increasing due to the price decline. The drop in abandonments between 1986 and 1987 reflects in part, a change in state policy to allow wells to be placed on "temporarily abandoned" status for up to one year. The rule was instituted to give operators relief until prices improved and to protect vital resources from premature abandonment.

Since 1986, the rate of stripper wells abandoned increased by over 300%, reflecting not only low and unstable prices, but also more recently the threat of potential future liability for environmental damages from improperly maintained or plugged wells. Many smaller operators are choosing to plug and abandon wells rather than accept potential risks inherent with transferring them to a new owner. These figures do not account for the large number of wells that are either presently idle or temporarily abandoned (Figure 9).

Figure 9. Stripper Well Abandonments

Exploration

The number of active rotary rigs and the number of new wells drilled dropped sharply with lower oil prices. The total number of active rigs was down by almost 70% in 1991 from its peak in 1981, consistent with the national trend. The drilling of exploratory wells (wells drilled in unproven areas) and new-field wildcats (exploratory wells in previously unexplored areas) experienced a similar decline. Exploratory well drilling dropped almost 82% between 1981 and 1990, and wildcats fell by over 75% during the 1980's. New field discoveries and extensions have not replaced produced reserves. Even development well drilling, conducted in areas of proven production, fell by over 47% between 1984 and 1990.

Economic Impacts

These negative industry trends have significant economic impacts on the state. Employment in California's oil and gas extraction industry increased by more than a quarter from 1980 to 1984 during the

oil boom. In the next two years, it plummeted with the price decline back to the 1980 level. Between 1986 and 1991, extraction employment fell another 8%, representing a loss of almost 11,000 jobs since 1984 (Figure 10).

Figure 10. Oil and Gas Extraction Employment

Reduced production rates and continued price instability resulted in significant decreases in the wellhead value of both oil and natural gas production in the state. Crude oil production value is well below its decade high. Reductions in the value of production have severely impacted state revenues. After 1985, the revenues collected by the state through severance taxes on oil and natural gas production fell by almost 30%, in 1991 dollars, from \$543 million to \$390 million in 1991. Clearly, the state has a stake in maintaining a viable petroleum producing industry.

Production Incentives and Relief -- Both the state and federal government are trying to encourage stripper well production and avoid abandonments by allowing temporary abandonment status and federal royalty relief for stripper well operators. In 1992, independents were successful in winning limited relief from the federal alternative minimum tax (AMT). In 1990, the federal government also approved a 15 percent tax credit for new investment in enhanced oil recovery projects. Many states also offer a state tax incentive for improved recovery projects. California, however, is not among them.

Environmental Regulation -- Operators in California face some of the most stringent environmental regulations and the most activist citizenry in the nation. Prevailing attitudes oppose

oil and gas development, particularly offshore and in sensitive areas. While disposal of produced waters and wastes associated with oil and gas production remains at issue, air quality standards are of particular concern. Most of the EOR efforts in California are steam flooding projects. The emissions associated with steam generation for these projects are a continuing target of increasingly stringent environmental regulation. The cost of complying with these regulations could cause otherwise economic production to be shut in or lead to use of less convenient and often more expensive sources of steam.

California's outer continental shelf has enormous resource potential, but remains under a Federally mandated OCS drilling moratorium until after the year 2000, due to air and water quality concerns.

Major producing companies are accelerating their departure from the lower-48 resource base due to increased costs, lower finding rates, more stringent regulation, higher costs of compliance, and more promising opportunities overseas. As they divest themselves of their holdings, independent producers in California face both the opportunity for good investments and the challenge of acquiring properties that require significantly higher levels of technological sophistication to efficiently produce the resource. With California's offshore and heavy oil resources and special environmental conditions, the challenge to large, mid-size, and small independents is even greater.

II. R&D AND TECHNOLOGY TRANSFER

The need for broader and more effective technology transfer in California is clear. If companies are to maximize production of the California oil resource, state-of-the-art operations are essential. As the responsibility for producing the resource increasingly shifts to the independents, their access to and understanding of conventional and improved recovery technology, analytical tools, and related information and resources must be expanded.

In the *near-term*, technology transfer has the opportunity to deploy existing technologies to defer reservoir abandonments and preserve access to the reservoirs for application of even more efficient

emerging technologies. In the *mid-term*, technology transfer functions can ensure the broad deployment of emerging technologies and advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic research and development communities and the producing community as new technologies and processes are developed over the *long-term*.

Petroleum R&D and Technology Transfer Organizations

Numerous public and private entities in California currently perform oil and gas research, disseminate results, and offer technology assistance to oil and gas producers. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1) and suggestions on how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to California producers.

State Agencies

The California Department of Conservation, directed by Edward G. Heidig, includes the state's Division of Oil, Gas and Geothermal Resources (the lead regulatory agency for oil and gas production in the state) and the Division of Mines and Geology which includes the Office of the State Geologist, James F. Davis. While the **Division of Mines and Geology** performs extensive geological and geophysical mapping and analysis of the state's surface and subsurface physical characteristics, most of the directly petroleum-related analytical functions are carried out by the Division of Oil, Gas and Geothermal Resources.

The Division of Oil, Gas and Geothermal Resources, managed by Oil and Gas Supervisor William F. Guerard, Jr., is located in Sacramento and works closely and cooperatively with the producing industry. The Division maintains field operations and assistance offices in all of the state's major oil and gas producing regions. The Division performs regulatory functions and provides a host of other essential services to the industry and others associated with oil and gas production in California.

Services include providing base maps of oil and gas activities in the state and preparing technical reports and articles on the state's producing fields and reservoirs and special oil and gas recovery projects, including applications of improved recovery technologies. The Division also offers a series of video-taped training programs and historical information on the industry. In addition, the Division offers a series of "how-to" training manuals for blow-out prevention and for compliance with production/injection reporting requirements. The Division also sponsors workshops and programs to explain and discuss current and emerging federal and state governmental requirements and regulation of the producing industry. The Division works closely with the Conservation Committee of California Oil and Gas Producers (CCCOGP).

While the Division does not directly perform or sponsor R&D related to oil and gas exploration or recovery, its experience conducting compliance and safety workshops indicates that it may have the

capacity to assist in future cooperative technology transfer efforts.

With field offices located throughout the producing community, the Division is ideally situated to inform California producers of existing and emerging technologies and their potential for boosting production, extending economic reservoir life, and/or cost-effectively meeting environmental and regulatory compliance and reporting requirements. To the extent that physical, budget, and regulatory constraints and positive industry relations permit, the Division could be an effective lead or host organization for future cooperative technology transfer activities.

Research Universities

California is served by at least three high quality universities with graduate research programs in chemical or petroleum engineering, petroleum geology, geophysics, and related disciplines. Most of

CALIFORNIA	Current or Potential Oil and Gas Technology Transfer Functions																							
	Data & Publications							Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance					
	Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering
Organization																								
State Agencies																								
Division of Oil, Gas, and Geothermal Resources	C	C	C		C	C	C						P	C	C									
Division of Mines and Geology					C	C					C													
Research Universities																								
University of California at Berkeley					C	C	C	C	C	C						C	C	C	C	P				
University of Southern California						C	C	C	C	C						C	C							
Stanford University						C	C	C	C	C		P	P			C	C						P	P
Industry Organizations																								
Conservation Committee of California Oil and Gas Producers	C	C	C	C		P		C	P	P		P	P	P	C									
California Independent Petroleum Association								P		P		P	P		C									
Pacific Oil Conference															C									
Western States Petroleum Association				C				P		C	C				C									
Independent Oil Producers' Agency								C			C				C						P			
C = Currently performs																								
P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints																								

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

the graduate research programs receive limited funding support from domestic or foreign petroleum industry grants for specific R&D projects. Most also receive limited Department of Energy support for graduate research in oil and gas and hydrocarbon geoscience disciplines.

The University of California at Berkeley is a state institution located east of San Francisco in Northern California, away from the primary oil producing areas located to the south. Berkeley offers Bachelors, Masters and Doctoral degrees in petroleum engineering. Expected 1991 enrollments included 24 B.S. degree candidates, 9 M.S. degree candidates, and 16 Doctoral candidates. The B.S. degree program in Petroleum Engineering is not yet accredited.

Research programs pursued by the petroleum engineering program faculty and graduate students concentrate in drilling and production engineering, reservoir engineering, and thermal and surfactant enhanced oil recovery. Dr. George Cooper coordinates the program. His research interests lie in areas of drilling, with particular emphasis on drilling mechanics and in horizontal and long reach drilling. Under Dr. Cooper are various faculty members who conduct research in rock mechanics and micromechanics of flow in porous and fractured rocks, electrical logging methods and cross-well techniques, reservoir engineering and ground water flow, reservoir modeling, seismology, and steam flooding. Dr. Clayton Radke has research projects in EOR, especially those involving surfactant-enhanced foams.

Berkeley faculty and graduate students present the results of their research through a variety of mechanisms, including direct research reports to private and federal research sponsoring organizations, technical papers, and journal articles presented to and/or published by professional societies such as the Society of Petroleum Engineers. Faculty also participate periodically in local, regional, and national meetings and seminars sponsored by industry associations, professional societies, and other organizations related to oil and gas research. These are conventional technology transfer methods that traditionally have been employed throughout the academic community.

Regardless of its location away from the more intensive oil and gas exploration and development regions of coastal and south central California, Berkeley could play a stronger role in technology transfer to California's producing community. Given Berkeley's limited focus on thermal EOR techniques, which are critical to producing the California heavy oil resource base, it could participate effectively in conducting workshops and short courses to communicate improved recovery methods to California producers. Due to its location, however, Berkeley would probably not be an optimal location for a technology outreach or field assistance facility.

The University of Southern California (USC) is a private institution located in Los Angeles, California. USC offers Bachelors, Masters, and Doctoral programs in Petroleum Engineering and performs an extensive program of basic and applied industry and government sponsored research in improved oil and gas recovery and related geosciences. Enrollments in 1991 were estimated at 12 B.S. degree candidates and 22 M.S. degree candidates, and 16 Doctoral candidates. The Petroleum Engineering faculty, directed by Dr. Iraj Ershaghi, consists of five professors and associate professors and seven lecturers. Faculty research interests include well testing, formation evaluation, fracture diagnostics, reservoir simulation, thermal recovery, fluid dynamics, chemical problems, and improved recovery techniques.

Only a portion of USC's petroleum research is focused directly on the problems encountered in the California resource base. USC's Petroleum Engineering Program is currently engaged in five distinct research activities. Two are directly related to oil recovery:

- **Through the USC Center for Study of Fractured Reservoirs**, the Fractured Reservoir Study examines fracture properties in Monterey Formations and the Austin Chalk. Sponsored by several oil companies, the project receives \$90,000/year in funding and involves three faculty members and seven graduate assistants.

- USC is modeling the processes and mechanics of flow in thermal oil recovery. DOE provides \$150,000/year in funding for one faculty member and four research assistants.

Two studies, funded by Gas Research Institute, address issues related to gas transportation and storage:

- The Pressure Transient Study of Gas Storage Fields is modeling transient effects in gas storage fields. It is sponsored by the GRI which provides \$60,000/year and supports one faculty member and two research assistants.
- In the area of gas distribution, USC is developing an approach to optimal modeling of distribution networks. Sponsored by GRI at \$150,000 per year, the work is conducted by one faculty member and two research assistants.

USC is also continuing its R&D work in the area of Geothermal Energy Resources of DOE.

- A \$75,000 per year effort in fractal modeling of geothermal systems is being performed by three faculty and three research assistants.

Like many research universities, USC conveys the results of its research primarily in papers presented at national meetings of professional societies and in journal publications. USC has significant interaction with local R&D centers and producing companies.

USC is conveniently located in Los Angeles, in close proximity to southern California's coastal and offshore oil fields. USC is also relatively close to the major oil producing fields near Bakersfield and Kern County in the south-central parts of the state. Provided adequate financial and faculty resources are available, USC could perform a significantly expanded role in assisting the transfer of existing and emerging improved recovery and related production technology to California oil and gas producers. USC personnel could also work with other academic, state, and industry personnel to develop effective workshops, short courses, and training programs.

Stanford University is also a highly regarded private educational institution. Located south of San Francisco, near Palo Alto, Stanford offers Bachelors, Masters, and Doctoral programs in Petroleum Engineering. 1991 enrollments included three B.S. candidates, 15 M.S., and 32 Doctoral candidates. The petroleum engineering faculty consists of 11 full and six consulting professors.

Stanford's faculty and students are actively engaged in significant research projects directed toward improved oil recovery and related topics. Research is not necessarily directed specifically toward problems of the California petroleum resource base, although the technologies and knowledge advances emerging from its R&D projects are likely to be relevant.

As a private university, Stanford is prohibited by law from receiving any state funding for its research or operations. Beyond tuition and endowments, significant funding comes from private industry sources and the U.S. Department of Energy. New programs must also demonstrate direct educational benefits to the students.

Stanford has developed six industry affiliate programs to perform cooperative R&D with U.S. and foreign oil companies:

- The **Stanford Center for Reservoir Forecasting**, directed by Dr. Andre Journel, is an interdisciplinary attempt to develop and integrate geological, geophysical, and petroleum engineering techniques for forecasting reservoir flow performance. This work is highly relevant to developing improved understanding of reservoir heterogeneities and process performance in highly heterogeneous reservoirs. Twenty companies participate in this effort, each contributing \$20,000 per year.
- The **Geothermal Affiliates Program**, directed by Dr. Henry J. Ramey and Dr. Roland Horne, conducts interdisciplinary research in engineering and earth sciences aimed at developing engineering techniques useful to the geothermal industry. The results of the research are transferred through papers as well as an annual international Workshop on Geothermal Reservoir

Engineering held at Stanford. The effort is funded by DOE (\$200,000 per year) and industry (\$75,000 per year).

Four additional research programs are incorporated under the mantle of a single institute known as the Stanford University Petroleum Recovery Institute (SUPRI).

- **Thermal Oil Recovery (SUPRI-A)** is directed by Dr. William Brigham and focuses on recovery of heavy oils by steam injection and in-situ combustion. Ten industry affiliates provide a total of \$100,000 annually, supplementing annual DOE funding of \$600,000.
- **Reservoir Simulation (SUPRI-B)** is directed by Dr. Khalid Aziz and is designed to explore and develop numerical techniques used to predict the performance of oil recovery processes with an emphasis on enhanced oil recovery methods. The activity concentrates on the development of simulators for reservoir performance prediction. It is funded by eighteen industry affiliates each of whom contributes \$15,000 per year.
- **Miscible Flooding (SUPRI-C)** is directed by Dr. Franklin M. Orr. The program investigates interactions of fundamental mechanisms that affect the performance of miscible flood processes with an emphasis on CO₂ flooding. The effort is funded with \$250,000 from DOE and \$130,000 from ten industrial affiliates annually.
- **Well Test Interpretation (SUPRI-D)** is directed by Dr. Roland Horne. This project focuses on development of computer algorithms for high speed well test interpretation. Seven industrial affiliates fund the \$70,000 program annually.

The industrial affiliates approach to research funding applies quite well to technology transfer. Stanford presents its research results in annual workshops and advance copies of research reports, papers, and other publications distributed to its sponsors and industrial affiliates membership. These mechanisms are considered highly effective.

Stanford has also successfully begun a series of personnel exchanges with major oil and gas producing companies in which company research personnel study in residence at Stanford on a specific cooperative research topic funded by the company. Recently, Stanford has hosted a senior researcher in residence from BP. The University is currently discussing a similar relationship with Mobil Oil.

Faculty members teach short courses at the University and affiliate member offices. Stanford also offers workshops and training programs to producing companies throughout the world. In addition, results are provided and communicated more broadly through participation in annual conferences and seminars hosted by trade association and professional societies, including SPE and others.

The Stanford/SUPRI environment, attitude, and approach is ideal for interaction with the producing community in California and elsewhere. The opportunity is constrained, however, by location and other factors. Like other universities, Stanford is highly constrained by limited funding and declining enrollments in petroleum engineering and related geosciences. Damage from the Loma Prieta earthquake has also left the University constrained for teaching, laboratory and office space. The Stanford program has expressed an interest and willingness in assisting the development and performance of focused workshops, problem identification functions, and other technology transfer functions if resources are available without conflicting with current or future work.

Industry Organizations

The Conservation Committee of California Oil and Gas Producers (CCCOGP) is a unique, industry-supported and tax exempt organization which has administered a voluntary hydrocarbon resource conservation program for the Division of Oil, Gas and Geothermal Resources since 1929. CCCOGP represents the oil and gas industry before the Division on matters related to oil and gas conservation. Comprised of both majors and independents, membership accounts for about 99% of California production. It is funded by a millage on production of large producers and by a fixed membership fee of \$60 per year for very small producers.

CCCOGP Executive Director Dick Crippen likens the Committee to the Texas Railroad Commission with the significant exception that it is operated by the industry rather than the state. The organization works through a technically qualified, industry-appointed Engineering Board supplemented by a small paid staff. Its charter is to monitor operations, calculate maximum efficient recovery (MER) rates, and assemble and evaluate production and reservoir data from onshore, state tidelands, and OCS areas. The Committee prints and distributes five statistical publications annually which describe the resource, production trends, and the producing industry.

While the Committee does not engage in R&D functions, it sponsors monthly luncheon-business meetings and periodic seminars throughout the state which are open to committee members as well as industry and government guests. Past topics have included:

- Secondary and tertiary recovery technology
- Improvements in horizontal drilling technology
- Impacts of environmental regulation
- Improved drilling and completion techniques
- Oil and gas pricing forecasts and scenarios
- Related regulatory and operational topics

The Committee also works closely with Western States Petroleum Association, the California Independent Petroleum Association, and the U.S. Minerals Management Service.

This Committee could be a highly effective host organization for focused technology transfer workshops and problem identification functions, training programs, field trips, and other technology transfer functions all aimed at conserving the California resource base. Working with industry associations, university programs, industry research labs, and professional societies, this group could provide significant technology transfer leadership.

The **Pacific Oil Conference (POC)** is a regional management institute and trade show that focuses on

regulatory and legislative issues that will affect the membership. The annual meetings and occasional workshops are held to address these regulatory issues. Workshops are held to educate members on impacting legislation and its effects on their operations. With its legislative and regulatory agenda, POC may be an effective supporter of state funding assistance for technology transfer but is probably not the ideal host organization to assemble and conduct a technically focused program.

The **California Independent Petroleum Association (CIPA)** is a 750-member trade association, headquartered in Sacramento, that represents California independent crude oil and natural gas producers. In addition to legislative representation and public relations activities, CIPA also offers educational seminars and assists its members in procedures for effective environmental and regulatory compliance.

Until 1992, CIPA was located near Los Angeles, in proximity to the state's oil and gas producing regions. In 1992, CIPA moved its offices to Sacramento for closer interaction with the state legislature and the regulatory functions of the Division of Oil, gas and Geothermal Resources.

CIPA is also a regional cooperating association of the Independent Petroleum Association of America (IPAA). Through this relationship, CIPA members are participants in IPAA's on-going efforts to build a national technology transfer organization to help coordinate and capitalize on potential synergies of the activities of numerous R&D and technology transfer organizations.

Through its access to independent producers, CIPA can help make operators aware of the need to become knowledgeable about improved recovery technologies and opportunities and attract their more active participation in focused problem identification and technology transfer activities. CIPA can also apply its experience in performing educational seminar for its membership to hosting more technology-intensive workshops.

The **Western States Petroleum Association (WSPA)**, founded in 1906 and currently directed by Douglas F. Henderson, is America's oldest trade association. It represents all companies which develop, produce, transport, and market petroleum

products in the six western states of Arizona, California, Hawaii, Nevada, Oregon and Washington. WSPA's chief objective is "to foster a business and political climate that will allow industry to provide abundant and affordable petroleum products." It accomplishes this goal primarily by monitoring and acting upon the regulatory and legislative proposals considered by government entities and policymakers in the six western states.

WSPA emphasizes communication not only with its members, but with the general public it serves. WSPA participates regularly in conferences held by local government organizations by displaying a booth, distributing information, and hosting events. WSPA has also hosted educational tours of petroleum company operations. WSPA recently co-sponsored both the 5th Annual Energy Information Night with the Society of Petroleum Engineers and the West Coast Chapter of American Petroleum Institute. In addition, WSPA communicates with members and the public through briefing kits, brochures, fact sheets, annual reports, quarterly newsletters, videos, and other materials.

The **Independent Oil Producers' Agency (IOPA)**, directed by Les Clark, Jr., is a marketing association that serves independent oil producers, at the government, business and industry levels to secure equitable prices for its members' crude oil. IOPA monitors the prices its members receive for oil by purchasing the heavy crude oil from its members under five-year "evergreen" contracts, then reselling the product to major oil companies.

The Agency is involved with a number of special studies on crude oil price differences. IOPA has also supported the San Joaquin Valley Air Quality Study and has worked closely with DOE and Caufield Enterprises in developing the report, "Regulatory Economic Impact on Independent Oil Producers in Kern County, California."

IOPA works closely with all levels of government — federal, state, county and municipal — to communicate the interests and needs of independent oil producers. IOPA also works closely with CIPA and WSPA and is involved with the IOGCC, the IPAA, and the Ground Water Protection Council (GWPC). In addition to these services, IOPA both represents its members and keeps them informed on environmental issues. IOPA has offices

in both Sacramento and Taft to cover the oil industry.

IOPA sponsors quarterly meetings for discussion of environmental issues among its members. It also co-sponsors oil industry related meetings, workshops, and field trips with various governmental agencies.

III. OBSERVATIONS

California's expansiveness and its diversity is reflected in the breadth of government, industry, and academic organizations that exist to serve the petroleum industry. These same factors, however, contribute to the lack of any central focal point for disseminating technology information in coordination with the state's oil and natural gas producers.

Critical issues related to resource abandonments, improved recovery technologies, and environmental protection are evidently essential to the future of the state's future onshore, offshore, heavy and light oil production. These issues, in addition to the expanding national interest in natural gas as a replacement fuel for oil, necessitate improved coordination within the state and with other regional and national organizations.

- Effective problem identification efforts can identify and prioritize the most pervasive technological problems faced by the state's producers in specific operating environments. Such activities could be hosted by industry organizations such as CIPA and/or the CCCOGP with the participation, as appropriate, of university or industry research organizations.
- Once problems have been identified, classified, and prioritized, the results should be disseminated to the service and consulting community, as well as to the industry and academic research and development community. Existing technology solutions can then be identified and transferred through focused workshops and other mechanisms to address problems of near-term urgency. These solutions can help defer abandonments and sustain or increase production.

- Applied and basic research can be focused to address technology and knowledge essential to addressing longer-range needs. University research, particularly that funded by the state, can then focus on prevalent, high-priority problems encountered in the state with high payoff opportunities. An energized industry will also result in increased applications for and enrollment in petroleum related academic programs.
- Regulatory agencies are seldom the best organization to initiate problem identification and technology transfer activities for producers, especially independents. However, California clearly needs a strong technology information and data resource presence in the producing areas. Given the Division's field offices in the producing areas and its positive relations with the producers and the CCCOGP, the Division may be an effective host or co-host in particular producing areas of the state. Clearly it is in the Division's and the State's interests to encourage sustained or increased production and the application of safer, more effective technology to protect the environment and to conserve the resource.
- Greater coordination is needed among the industry organizations and between these organizations, the university research community, industry professional societies, and appropriate state agencies.
- Industry associations can significantly expand their focus to include operator education in improved recovery and reservoir management techniques as a primary activity of the organization in addition to legislative and regulatory advocacy roles. This is consistent with similar roles played by trade associations in other industries.
- State, industry, research, and professional organizations can significantly leverage their resources, capabilities, and effectiveness by cooperatively participating in national organizations committed to oil and gas technology transfer and resource conservation.
- Industry associations and professional societies should also encourage producer cooperation with and participation in federally-funded programs intended to stimulate application of improved recovery and related technologies in specific, high-priority reservoir classes while leveraging operations limited resources.

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- Tertiary Oil Recovery Information System

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**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
ILLINOIS**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR ILLINOIS

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil was first discovered in Illinois in 1889. Through 1987, Illinois had produced 3.9 billion barrels of oil, with about 5.3 BB of Illinois's 9.2 billion barrel (BB) original-oil-in-place (OOIP), or 57.2%, still in the ground. With 0.2 BB in proved reserves, almost 5.7 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

The largest portion of Illinois's ROIP can be found in Delta/Fluvial-Dominated reservoirs, although there are large amounts of oil in the Strandplain/Barrier Cores and Shorefaces, Delta/Tide-Dominated, and Peritidal reservoirs as well (Figure 2). The remainder is distributed among five other geologic classes.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Production

Fifty-one of Illinois's 102 counties have some oil and/or gas production (Figure 3). There were 32,255 producing oil wells in the state in 1991. Nearly all were classified as stripper wells, producing less than 10 barrels per day, and most were on artificial lift. Consequently, Illinois's crude oil production is attributable to stripper wells almost in its entirety.

Crude oil production in Illinois peaked in 1940 at 148 million barrels (MMB). By 1980, production had declined to 23 MMB. During the first half of the 1980's, production increased steadily with the oil boom, rising to 30.3 MMB in 1985. After the 1986 oil price collapse, production fell sharply back to a level of 19 MMB by the end of 1991 (Figure 4). Wellhead prices for crude oil in Illinois dropped by over 50%, in 1991 dollars, between 1985 and 1986. Since 1986, prices have remained unstable and generally low.

Figure 3. Counties with Production

Figure 4. Crude Oil Production

Most natural gas production in Illinois is associated with oil production. As with oil, in the early 1980's, natural gas production in Illinois was generally on the rise in response to relatively high gas prices. Between 1986 and 1991, however, production fell by over 63% (Figure 5). Natural gas production peaked in 1944 at 18 Bcf. As with crude oil production, the early peak and maturity of the resource led to much lower production rates over time. Natural gas wellhead prices appear to be leading the production trends as they increased

Figure 5. Natural Gas Production

during the early part of the decade before falling by nearly 60% between 1983 and 1991.

Improved Oil Recovery

While there has not been a significant amount of historical enhanced recovery activity, Illinois's reservoirs may be prime targets for enhanced oil recovery (EOR) methods. Since 1977, four micellar polymer flood and two polymer flood EOR projects have been implemented in Illinois oil fields. Less than 1% of Illinois's crude oil production was attributable to the use of EOR methods in 1991. year.

The maturity of the resource, the large number of stripper wells, and the predominance of artificial lift suggest that the remaining oil resources is at risk of abandonment before oil prices make EOR processes economic. Other improved recovery techniques offer significant potential. Many Illinois reservoirs have been waterflooded, but waterflood response has not always been positive because of fractured reservoirs, lack of reservoir communication, and other reservoir heterogeneities. Ongoing efforts by the Illinois State Geological Survey to use new technologies to characterize the reservoirs and simulate process responses provides the basis for the strategic application of advanced secondary techniques such as targeted in-fill drilling and polymer assisted waterflooding for injection profile modification. Some infill drilling projects will require relaxation of state well spacing regulations.

Exploration

The steady drop in wellhead prices in Illinois during the 1980's led to a decrease in drilling activity. Between 1982 and 1985, the number of operating rotary rigs fell by nearly 62%. In the next year, the number fell by over 79% and has not since recovered. The drilling of exploratory wells in proven areas, and new-field wildcats in previously unexplored areas, both declined. Exploratory well drilling dropped over 84% between 1983 and 1991, and wildcat well drilling fell by almost 89% during the same time span. Even development well drilling fell by over 80% from 1982 to 1991. New field discoveries and extensions have not replaced produced reserves.

Crude Oil Reserves

Illinois proved oil reserves fluctuated significantly during the 1980's but generally reflected a downward trend. From a level of about 110 million barrels in 1980, reserves increased to a decade high of 155 million barrels in 1987 before falling to 120 million barrels by 1991 (Figure 6). While new field discoveries have been minimal, adjustments and extensions in existing fields have been responsible for reserve increases which have offset or reduced the impacts of production. Some of these extensions are attributable to the use of improved reservoir description technologies and reservoir development strategies. Illinois ranks eighth among the lower-48 states in known remaining oil in place as shown in Figure 1. That resource serves as the target for improved recovery technologies.

Figure 6. Crude Oil Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques, or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. Given that all of the state's producing wells operate on costly artificial lift, and practically all are classified as stripper wells, the threat of abandonment of a significant resource is particularly large. While the annual rate abandonments has been erratic, annual stripper well abandonments increased by almost 450% from 353 to 1,004 between 1989 and 1991 (Figure 7). As in other states, increasingly stringent environmental regulations and the threat of potential future liability for environmental impacts of improperly plugged and abandoned wells have amplified the effects of price instability and resource maturity on well abandonments.

Figure 7. Stripper Well Abandonments

Economic Impacts

Reductions in exploration, drilling and production have had significant impacts on economic activity and state and local revenues as well. Between 1980 and 1986, overall employment in Illinois's oil and gas industry, including extraction, refining and marketing, fell by over 19%. Employment in the oil and gas extraction sector of the industry declined by 57% between 1982 and 1989 (Figure 8). The industry has made a slight recovery in recent years but not enough to recoup the more than 4,200 extraction jobs that were lost.

Figure 8. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and persistent low prices have also resulted in a decrease in the wellhead value of production. The real wellhead value of crude oil and natural gas was over 70% lower in 1991, as compared to the beginning of the 1980's. There are no severance taxes on the wellhead value of oil and gas production; however, related income and other taxes from oil and gas activities have declined by more than two-thirds. Clearly, the state has a stake in maintaining a viable petroleum producing industry.

Other Industry Concerns

Unlike many of the other states with large remaining oil resources, Illinois' oil and gas producing industry is comprised almost entirely of independent producers, due to the maturity of the resource base and low rates of production. The presence of the major integrated producing companies is extremely small. Small and medium-sized producers account for a significantly higher percentage of total production than in other states. This increases the challenge of accelerating the acceptance of improved reservoir management and production technologies and has significant implications for the nature of technology transfer functions to be offered.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

The need for broader and more effective technology transfer in Illinois is clear. If operators are to maximize production of the Illinois oil resource, state-of-the-art operations are essential. As the responsibility for producing the resource increasingly shifts to the independents, their awareness of and access to improved recovery technology and related information and resources must be enhanced.

In the near-term, technology transfer has the opportunity to deploy existing technologies to defer reservoir abandonments and preserve access to the reservoirs and the resource base for application of even more efficient emerging technologies and improvements in geoscientific understanding. This is especially important in Illinois. In the mid-term, technology transfer functions can ensure the broad deployment of emerging technologies and advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic research and development communities and the producing community as new technologies and processes are developed over the long-term.

Petroleum R&D and Technology Transfer Organizations

A handful of public and private entities in Illinois are currently engaged in performing petroleum extraction research, disseminating results and information, and offering technology assistance and related services to oil and gas producers. Increasingly, and effectively, these entities are working together to address the needs of the industry and to conserve the resource. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1), with suggestions on how their functions might be expanded, modified, or improved to expedite near- and mid-term technology transfer to Illinois producers.

State Agencies

The **Illinois Department of Energy and Natural Resources** is responsible for all non-regulatory state-funded activities related to oil and gas exploration, development, and production. The **Department of Mines and Minerals** enforces regulations by the Illinois Oil & Gas Act and is responsible for the regulation of the Illinois oil and gas industry including well spacing and regulations of all aspects of production, storage, transportation, and oil and gas waste issues. The Department of Mines and Minerals does not conduct research or technology transfer functions related to oil and gas recovery but does encourage use of state-of-the-art technologies as part of its duty to conserve the oil and gas resource base.

The **Illinois Oil and Gas Advisory Board**, created by the Illinois Oil and Gas Act, serves as an Advisory Board to the Illinois Department of Mines and Minerals. The Board, composed of six members

representing all aspects of oil and gas exploration and production, advises the Department on the formulation of regulations affecting the oil and gas industry. Members of the Oil and Gas Board meet at least quarterly to review all Federal and State rules and laws affecting the Illinois oil and gas industry and various technical information. The Board then advises and consults with the Director of Mines and Minerals on these and other oil and gas related issues.

Also under the auspices of this Department is the **Illinois State Geological Survey (ISGS)** which is headed by State Geologist Morris "Brud" Leighton. The ISGS has responsibility for applied research and development and analyses to promote the economic development of the state's mineral resources. The Oil and Gas Section of the ISGS is directed by Donald F. Oltz. One of the missions of the Oil and Gas Section is "to aid Illinois's independent producers in the recovery of higher percentages of oil from already discovered fields, develop new

ILLINOIS		Current or Potential Oil and Gas Technology Transfer Functions																							
		Data & Publications						Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance						
		Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering
Organization																									
State Agencies																									
Department of Mines and Minerals															C										
Illinois State Geological Survey	C	C	C	C	C	C	C	C	P	P	C	P	P	P	P	C	C	P	C	P	C	C	C	P	
Industry Organizations																									
Illinois Oil and Gas Association	C	C	C	P				C	P	P	P	P	P		C							P	P	P	
C = Currently performs												P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints													

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

incentives to encourage exploration, promote wise development of Illinois's oil and gas resources, and provide complete and timely information to the oil industry."

ISGS performs this function, in part, by offering the traditional services and functions of a geological survey. ISGS technical support services include a geological records library, a geological samples library, a reference and map library, custom computerized mapping services, computer facilities, and an Earth Science information unit. Through its equipment and lab facilities, the survey also offers services and research capabilities in the area of core retrieval, cutting and storage, evaluation and prediction of formation damage, log analysis, determination of porosity and absolute and relative permeability, petrographic analysis, and PVT analysis.

The ISGS has digital records on over 159,944 oil and gas wells. ISGS logs, cores, cuttings, and samples provide an exceptional resource for interdisciplinary reservoir modeling and simulation research. One of the most useful and highly visible new services of the ISGS is the development of the Questor system. Questor is a user friendly data management and retrieval system that allows users to select and map well data including locations, logs, and drilling information, at a variety of levels. The combined data query, retrieval, and mapping capabilities expedite exploration and production research functions. The ISGS recently installed a loan copy of the Questor system at the offices of the Illinois Oil and Gas Association in Mt. Vernon Illinois for use by producers.

ISGS services promote extensive interaction with oil and gas producers in the state which facilitate understanding and awareness by ISGS of problems encountered by producers and identifies areas for future R&D activities. Inputs to problem identification, R&D prioritization, and technology transfer activities are actively solicited through semi-annual meetings of ISGS staff and directors with its Petroleum Advisory Committee/Technical Advisory Committee which includes key representatives of the Illinois producing industry.

To fulfill its mission, the oil and gas section conducts an extensive program of inter-disciplinary applied geoscience research and development

activities that is aimed at maximizing production of the state's oil and gas resources. This teamed approach bridges the traditional separation of geology and engineering. It is a significant factor in the R&D program's effectiveness and its credibility with the producing community to whom the results are transferred.

With base funding of \$500,000 per year from the state plus additional matched state and federal grants totaling \$1.2 million, the ISGS has formed an integrated ENR/DOE Improved and Enhanced Oil Recovery Program. The research staff includes 24 highly qualified geologists, engineers, and geochemists. R&D focuses primarily on two of the most prolific reservoir formations encountered in the state, the Cypress and the Aux Vases sandstones. ISGS is conducting increasingly detailed examinations of the structure and improved recovery potential of 14 Illinois oil fields producing from these formations.

Given the maturity of the Illinois resource, ISGS research focuses on improved reservoir characterization to identify opportunities for reserves growth in known reservoirs as well as supporting exploration for new discoveries. By improving the ability to map reservoir architecture and define heterogeneities in three dimensions, ISGS's research enables producers to apply more precise reservoir management strategies including targeted infill drilling. Further, by linking the 3-D geological model with a numerical simulator, the 3-D reservoir model can be tested through history matching and future performance of waterflooding, or improved recovery project designs can be predicted in terms of incremental oil and water production and project economics.

The results of ISGS's disciplinary and integrated geoscience and petroleum engineering research are disseminated through a variety of traditional mechanisms including:

- Production, well, and reservoir data dissemination;
- Publication of geology, petroleum engineering and geophysics research reports, case studies, regional reports, field and pool studies, and geochemical and source rock studies;

- Technical articles in industry and research journals; and
- Papers and presentations at local, regional, and national meetings of professional societies such as AAPG, SEG and others.

Technology transfer to oil and gas producers, however, is conducted in a far more direct hands-on manner, tailored to specific audiences. ISGS personnel regularly participate in industry association meetings. Twice annually, ISGS conducts a seminar in the heart of the state's oil producing regions to inform operators of the applied research being performed at ISGS and how the results can be applied to improve reservoir management and sustain or increase oil production in Illinois reservoirs. The subject matter is carefully assembled to provide an integrated program.

For example, the topics of a recent seminar held in Mount Vernon presented the capabilities of the 3-D subsurface reservoir modeling approach, followed by a demonstration of the approach in analyzing cross sections from a Cypress formation outcrop. This was followed by a presentation of the results of two advanced secondary recovery process simulations using 3-D reservoir models. An additional presentation demonstrated the use of seismic techniques as a supplemental or alternative approach to define reservoir heterogeneities. In the afternoon, the session was opened to discuss the presentations with ISGS personnel and to receive hands-on demonstrations of the Questor system and a reservoir simulator.

ISGS coordinates its activities closely with the Illinois Oil and Gas Association and other industry organizations and professional societies to ensure effective two-way communication of information to the producing community and feedback to the R&D program. ISGS is also a member of the Petroleum Technology Transfer Council and contributes to the formulation of the national technology transfer effort. ISGS has played a significant role in informing producers of opportunities to participate in the federal oil research program's cost-shared field demonstration projects. ISGS has offered assistance in defining appropriate projects and has participated in the preparation of proposals and performance of the work.

Industry Organizations

The **Illinois Oil and Gas Association**, under the direction of Marshall Daniel and Lelan Russell, provides essential trade association functions and represents the interests of Illinois oil and gas producers before the legislature and state regulatory bodies. IOGA helps keep producers aware of regulatory requirements and strategies for effective compliance.

In addition to these functions, IOGA serves an important role as a coordinator of activities related to oil and gas technology transfer to independent operators in the producing areas of the state. IOGA has served as a host organization for ISGS meetings and conferences in the producing region as well as a sponsor of several technology related meetings of its own. In 1989, IOGA hosted an important meeting sponsored by the IOGCC to learn of technology transfer channels used by Illinois independents. By serving as a focal point, IOGA has also stimulated discussions among producers as to problems encountered and effective solutions.

For decades, IOGA has collected and served as a repository and library for well logs, production and development data, project histories, and other archives of the Illinois producing industry. Recently, as discussed above, IOGA has arranged with ISGS to have a Questor data system located in IOGA's offices in Mount Vernon Illinois for use by operators. Between this data retrieval system and the data already in IOGA's collection, IOGA now has the largest collection of oil and gas reservoir, well, and production data in the state.

With the 1986 downturn and the surge in stripper well abandonments, IOGA recognized a potential threat of premature abandonment of reservoirs, reductions in ultimate production of the oil resource, and severe impacts on the producing industry, service sectors, and related activities. In response, IOGA significantly expanded its activities, within the constraints of its budget. IOGA aims to discourage premature stripper well abandonments and make its membership aware of and interested in technical solutions to sustain economic production until improved recovery technologies and advanced reservoir description approaches could result in reserve additions, increased production, or reduced operating costs. IOGA actively informs its

membership of opportunities to participate with ISGS, the U.S. Department of Energy, Gas Research Institute, and other organizations to demonstrate improved recovery and reservoir description technology in their reservoirs. IOGA has encouraged Illinois producers to participate in DOE's Class 1 (Fluvial Dominated) and Class 2 (Shallow Shelf/Open Carbonate) PON solicitations.

IOGA works with the Liaison Committee of Cooperating Oil and Gas Associations to keep abreast of other approaches to assist Illinois operators. The organization is also working closely with the Independent Petroleum Association of America in its effort to provide leadership to the development of a national industry-driven, industry-focused technology transfer organization to help coordinate the transfer of technology information from the research and service communities to producers.

III. OBSERVATIONS

One of the most important strengths of Illinois's technology transfer activity is the enthusiasm surrounding it. The two key participants, ISGS and IOGA, are making effective technology transfer a commitment and a primary goal, and they are willing to work with each other and other private, state or federal institutions.

Both ISGS and IOGA have built a strong foundation for effective technology transfer. Both could continue and expand their roles. Although ISGS conducts problem identification on a one-to-one basis, a more systematic problem identification workshop may be illuminating. Unless current funding is extended, however, even ongoing activities could be curtailed. IOGA is well situated to provide and coordinate technology transfer because of its location in Mount Vernon, and its existing data repository. Located in Champaign, ISGS is geographically distant to serve field activities. As mentioned previously, it is less accessible to operators, especially as a data source.

However, ISGS can still effectively conduct seminars, workshops, short courses, and other activities that can be taken to the operators in the producing regions.

By virtue of IOGA's interest, current functions and location, several future roles can be envisioned for the organization. First, IOGA should take a lead role in coordinating problem identification workshops with ISGS and other appropriate technology resources. To follow-up, IOGA should host technology workshops (problem-solving workshops) focused on the highest priority reservoir problems identified in the problem identification workshops and by ISGS. In addition, IOGA has the potential to coordinate the implementation of a complete resource center or similar outreach center with ISGS, in the heart of the producing region. IOGA can also attract other private and federal sources of technology information to contribute to the effort and broaden its scope to address surface, equipment, and other problems that are not specifically part of the ISGS focus.

The primary constraints facing Illinois is the lack of staff and funding available. An increase in funding will enable ISGS and IOGA to improve their facilities and efforts to produce a highly effective technology transfer operation which is already well on its way.

Source List

- American Petroleum Institute, *Basic Petroleum Databook*
- Department of Commerce, *Bureau of Economic Analysis*
- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price*
- Energy Information Administration, *Petroleum Supply Annuals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

TECHNOLOGY TRANSFER CONTACT LIST FOR ILLINOIS

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Illinois Department of Mines and Minerals Oil and Gas Division	Lawrence Bengal Supervisor	Springfield	Phone: 217-782-7756 FAX: 217-524-4819
Illinois State Geological Survey	Morris Leighton Chief	Champaign	Phone: 217-333-5111 FAX: 217-244-7004
Illinois State Geological Survey	Donald Oltz Oil and Gas Division	Champaign	Phone: 217-244-1156 FAX: 217-244-7004
Illinois Oil and Gas Association	Lelan Russell Executive Vice President	Mt. Vernon	Phone: 618-242-2857 FAX: 618-242-3418

**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
KANSAS**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR KANSAS

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil was first discovered in Kansas in 1861. Through 1987, Kansas had produced 5.1 billion barrels of oil (BB), with 12.5 BB of Kansas's 17.5 BB original-oil-in-place (OOIP), or 70.9%, still in the ground. With 0.4 BB in proved reserves, over 12 BB of remaining-oil-in-place (ROIP) is the target for current and emerging improved recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

Most of Kansas's remaining oil resource is found in Peritidal, DeltaFluvial-Dominated, and Shallow Shelf/Restricted reservoirs (Figure 2), with the remainder in three other geologic classes. The resource is mature and reservoirs tend to be highly fractured, thus requiring wells to be drilled on relatively close spacing where permitted, and produced using costly artificial lift methods.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas

In Kansas, 57% of the 56.4 trillion cubic feet (Tcf) of natural gas resource has already been produced. Of the remaining 24.2 Tcf, less than 40% is proved reserves. These proved reserves are recoverable under existing economic and operating conditions. The remaining 14.9 Tcf of undiscovered resource is comprised of probable, possible, and speculative reserves and includes the portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Production

Ninety of Kansas's 105 counties have some oil and/or gas production (Figure 4). Producing oil wells totalled 48,628 in 1991. Because of the state's producing conditions, however, almost all were on artificial lift. Over 93% of the producing wells are

Figure 3. Natural Gas Resource

stripper wells, producing less than 10 barrels per well per day (versus the national average of about 75%). Stripper wells account for 73% of the state's annual oil production. Many of these wells, operating at or near the economic limit, will be candidates for abandonment in the near future unless currently available remediation and improved recovery techniques are applied or operating costs decrease.

Crude oil production in Kansas peaked in 1956 at 124 million barrels (MMB) and declined steadily thereafter, making a temporary recovery during the exploration and production boom of the early 1980's.

Figure 5. Crude Oil Production

From 1984 to 1991, however, oil production declined another 25% to just below 57 MMB (Figure 5). The recent production trend closely mirrors the trend of crude oil wellhead prices as measured in dollars. Even in decline, however, Kansas still ranks eighth among the lower-48 states in terms of crude oil production.

Conversely, after a sharp decline in the early 1980's, natural gas production in Kansas rebounded, even with depressed gas prices, increasing by almost 41% after 1982 to a level of 605 Bcf in 1991 (Figure 6). This level was still far below the state's peak

Figure 4. Counties with Active Production

production level of 900 BCF, which occurred in 1970. While crude oil production followed price trends closely, natural gas production apparently moved in the direction opposite of price trends, increasing significantly even as prices (in 1991 dollars) dropped by over 35% between 1982 and 1991.

Figure 6. Natural Gas Production

Improved Oil Recovery

There has not been a significant amount of enhanced oil recovery (EOR) activity in Kansas. Since 1982, two polymer flood EOR projects have been conducted in Kansas's oil fields. An alkali-surfactant-polymer flood is planned for the near future, to be performed by the National Institute for Petroleum and Energy Research. Only 22,630 barrels were produced in the past year using EOR methods. With high oil priced, reduction in process costs, and improved characterization of target reservoirs, significant EOR reserves could be produced in the future.

Many of Kansas's reservoirs, however, are prime targets for a variety of advanced secondary processes such as permeability profile modification and polymer assisted waterflooding. These projects appear to be quite conducive to the state's fractured reservoirs. Numerous field projects implemented by the University of Kansas' Tertiary Oil Recovery Project (TORP) have demonstrated the effectiveness of such projects in increasing oil production and deferring reservoir abandonments.

Reserves

Kansas currently ranks fifth among the lower-48 states in remaining oil-in-place. However, the state's proved crude oil reserves are in decline. After reaching a decade peak of 324 million barrels in 1985 during the oil boom, reserves fell sharply and have since declined further to a 1991 level of 300 million barrels. This trend may continue and accelerate as exploratory activity remains weak and abandonments increase (Figure 7).

Figure 7. Crude Oil Reserves

Natural gas reserves, on the other hand, followed a far different path. Even as the real wellhead price of natural gas fell, reserves increased as a result of new discoveries, by almost 13% from 1985 to 1986. Since that spike, however, reserves have fallen back to their pre-1986 levels (Figure 8).

Figure 8. Natural Gas Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques, or plug and abandon the well. Premature well abandonments threaten the future option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. This issue is particularly critical in Kansas given the maturity of the resource base. Annual well abandonments rose by over 350%, from about 480 to about 1,700, between 1981 and 1986, and has since been sustained (Figure 9).

Figure 9. Stripper Wells Abandonments

Exploration

Between 1981 and 1986, the number of operating rotary rigs in Kansas fell by 76%. The drilling of exploratory wells in proven areas, and new-field wildcats in previously unexplored areas both declined. Exploratory well drilling dropped over 63% between 1984 and 1991, and wildcats fell by almost 40% between 1987 and 1991. As a result of diminished activity and reduced finding rates, new field discoveries and extensions have not replaced produced reserves. Even development well drilling fell by more than 72% between 1981 and 1991. Most of these declines occurred in the period from 1985 to 1991.

Economic Impacts

Employment in Kansas's oil and gas production, refining, and marketing industry fell by 30% overall between 1981 and 1990. The oil and gas extraction

sector of the industry was particularly hard hit, contracting by 51% during the same time span, representing a loss of more than 8,860 jobs in Kansas's petroleum extraction sector (Figure 10).

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced oil production rates and persistent low prices also resulted in a decrease in the wellhead value of crude oil production. The value dropped over two-thirds between 1981 and 1991, from almost \$3.5 billion to \$1.1 billion. Despite significantly higher levels of production, the wellhead value of natural gas in Kansas dropped by nearly 10% after 1983 because of depressed gas prices. Because severance taxes are levied as a percentage of the wellhead value of production, these reductions in the value of production have severely impacted state tax revenues. Reductions in employment, production value, and other relative economic activity have had significant impacts on state tax revenues. Clearly the state has a significant interest in maintaining a viable petroleum industry.

Kansas has attempted to respond to declining production, increasing well abandonments, and the impacts of reduced economic activity related to petroleum production by providing tax incentives for investments in new tertiary enhanced oil recovery projects. By an act of the Kansas legislature in 1989, the five percent severance tax was lifted from all production resulting from a tertiary recovery process. However, this incentive has not applied to production resulting from investments in advanced secondary recovery processes in the state. In 1990, the federal government offered tax relief to stimulate

enhanced oil recovery in the form of a fifteen percent investment tax credit for tangible and intangible expenses incurred in implementing new EOR projects or significant expansions of existing projects. Still, continued price uncertainty and other technical issues, including access to capital and potential environmental liabilities, have kept interest in EOR projects low.

Other Industry Concerns

Major producing companies are accelerating their departure from the lower-48 resource base because of increased costs, lower finding rates, more stringent regulation, higher costs of compliance, and more promising opportunities overseas. Many major producers have already essentially pulled out of Kansas due to the maturity of the resource base. As they continue to divest themselves of their holdings, independent producers in Kansas face both an opportunity for good investments and the challenge of acquiring properties that require significantly higher levels of technological sophistication to efficiently produce the resource. With increasingly stringent environmental regulation, the challenge to large, mid-size, and small independents is even greater.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

The need for broader deployment of existing and emerging improved recovery technology and information in Kansas is clear. If companies are to maximize production of the Kansas oil resource, state-of-the-art operations are essential. As the responsibility for producing the resource continues to shift to independents, their access to and understanding of improved recovery technology and related information and resources requires expansion.

In the near-term, technology transfer has the opportunity to deploy *existing* technologies to defer reservoir abandonments and preserve access to the reservoirs and the resource base. In turn, even more efficient emerging technologies and improvements in geoscientific understanding can be applied. In the mid-term, technology transfer functions can ensure the broad deployment of *emerging* technologies and

advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic research and development communities and the producing community as new technologies and processes are developed over the *long-term*.

Both the nature of the Kansas oil resource and the maturity of the reservoirs require that a smooth transition in the industry structure be predicated on a foundation of effective R&D and technology transfer. The major producers, service companies, and state and private research organizations must help transfer knowledge and technologies to independent oil and gas producers if the oil resource is to be efficiently produced.

Petroleum R&D and Technology Transfer Organizations

Kansas is well ahead of many states in its awareness of the importance of effective technology transfer and its progress in instituting technology transfer mechanisms. Numerous public and private entities in Kansas are already engaged in performing oil and gas R&D, disseminating results, data, and information, and offering technology assistance and related services to oil and gas producers. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1), and suggestions how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to Kansas producers.

State Agencies

The Kansas Corporation Commission (KCC) Oil and Gas Division, directed by William R. Bryson, is located in Topeka. The KCC is the principal agency responsible for regulating the oil and natural gas producing industry in Kansas and for conserving the state's oil and gas resources. KCC's regulatory functions include well permitting, injection permits, and improved recovery project permitting. The KCC also administers exploration, development, drilling, production, reserves, injection, and disposal data collection and reporting and performs related statistical analyses. The KCC encourages the application of advanced technologies to ensure that the resource is efficiently produced through its project review function.

The KCC has periodically offered workshops and seminars for operators on methods or strategies for compliance with state and federal regulations and reporting requirements. It has not, typically, conducted workshops to inform operators of improved recovery and reservoir management techniques or to teach them how they might be applied in the reservoir. However, in a departure from a purely regulatory role, the KCC has recently funded a joint interdisciplinary project by the University of Kansas Tertiary Oil Recovery Project (TORP) and the Kansas Geological Survey (KGS) to perform improved reservoir and geologic characterization and determine the potential applications of improved recovery technology and reservoir management techniques in the Zenith Field in southcentral Kansas.

KCC *could*, with sufficient resources, assist in conducting workshops and related technology transfer functions. However, this function may prove superfluous for KCC given the existence of a highly

effective, state-assisted technology transfer program that is continuing to evolve from the state's research university and geological survey (see below).

Research Universities

The University of Kansas (KU) is a state funded university with its central campus in Lawrence. KU serves as an "umbrella" organization for state-funded or -assisted petroleum engineering education and research, improved oil recovery outreach to the producing community, geology education and research, and the research and public service functions of the state geologic survey, each of which is discussed below. In 1991, these cooperating but disparate elements of the university joined forces to create a coordinating organization known as the Kansas University Energy Research Center.

The Kansas University Energy Research Center (KUERC), co-directed by Lee C. Gerhard

KANSAS Organization	Current or Potential Oil and Gas Technology Transfer Functions																							
	Data & Publications							Meetings/Seminars				Workshops				R&D/Analysis				Project Assistance				
	Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering
State Agencies																								
Kansas Corporation Commission	C	C	C	C				C	P	P		P	P		C						P	C		
Research Universities																								
KU Energy Research Center	C	C	C	P	C	C	C	C	C	P	P	C		P	P	P	C		P	C	C	C	C	C
KU Tertiary Oil Recovery Project				C		C	C	C	C	C	P	C	C	C		C	C	P	C	C	C	C	C	C
Kansas Geological Survey	C	C	C	C	C	C	C	C	C	P	C	P	P	C		C			C	C	C			
Industry Organizations																								
Kansas Independent Oil & Gas Assoc.				C				C	P	P	P	P	P		C						P			
Professional Societies																								
Kansas Geological Society	C	C	C	P	C	C		C	P	P	C	P												
C = Currently performs												P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints												

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

and Don W. Green, with W. Lynn Watney, executive director, facilitates interdisciplinary research and technology transfer functions on the KU campus. Its primary objective is to advance near-term and long-term activities in petroleum research and technology transfer. This advancement, in turn, will improve oil and gas extraction efficiency and competitiveness and increase ultimate recovery of the Kansas resource base. KUERC's goals are to:

- Increase industry and federal participation in petroleum related programs at KU.
- Elevate technology that has demonstrated significant potential for improved oil and/or gas recovery.
- Facilitate and accelerate technology transfer by focusing on solutions to real problems .
- Establish an energy research and technology transfer center building for joint studies and centralized research and meeting facilities.

Three groups currently comprise the major participation in the Energy Research Center: the Department of Geology, the Geological Survey, and the KU Tertiary Oil Recovery Project (TORP). Other academic units, including the Department of Chemical and Petroleum Engineering and Microbiology, also participate. Individually or collectively they have planned and/or performed numerous activities over the past year under the mantle of the KU Energy Research Center, including:

- Problem identification workshops for producers.
- Technology workshops on advanced water flooding, reservoir description, and application of underutilized technologies.
- Technical/informational seminars.
- Industry surveys on computer usage.
- Resource center requirements: electronic bibliographies and software for integrated data management and analysis.
- Collaboration with producers on DOE cost-shared field demonstration projects.

- Development of technology transfer manuals to convey information from workshops.
- A planned newsletter to integrate activities of KUERC participants.
- Regional atlas of oil and gas fields in the northern mid-continent.
- Development of a Fossil Energy Strategy (FES) for the Governor of Kansas.

According to the plan, KUERC would expand the current roles of its three component organizations to focus on efforts to develop Kansas's natural gas resources, work on environmental problems related to energy development, and utilize and develop alternative energy sources. KU is seeking federal assistance for the KUERC. KU/TORP has recently bid and received \$2 million of a \$4 million project bid in response to the DOE Class I Program Opportunity Notice (PON) for fluvial-dominated deltaic reservoir research.

The Department of Energy also recently awarded the KUERC \$500,000 in funding to expand the technology transfer concept developed by TORP (see below) into a cross-disciplinary model that could be applied in other oil and gas producing states. In the past year, TORP and KUERC have worked together to broaden TORP's liaison approach to include a series of well focused and targeted problem identification workshops for Kansas producers. Based on the conclusions, KUERC is seeking to match problems with current technologies and identify research priorities for problems without effective current solutions. The plan also includes KUERC's continuing involvement in TORP demonstration projects and new federally cost-shared technology demonstration projects in Kansas reservoirs. KUERC is in the process of documenting this enhanced model for dissemination through DOE to other producing states.

Once the goals, missions, and responsibilities of the participating organizations that comprise the KU Energy Center are defined and implemented, the KUERC could comprise a highly qualified, broad-based, and interdisciplinary technology and information resource center to serve the oil and natural gas producing community in Kansas.

The University of Kansas has one of the nation's most highly regarded petroleum engineering and R&D departments as well as strong Geology and Chemical Engineering departments. These departments offer undergraduate and graduate degree programs leading to bachelor's, master's, and doctoral degrees. The Petroleum Engineering department, chaired by G. Paul Willhite, is chartered to perform highly focused research concentrated on the state's indigenous oil and natural gas resources.

Faculty and students of the Department of Geology conduct research into reservoir characterization, sequence stratigraphic analysis of reservoir horizons, high-resolution seismology, and diagenesis of reservoir rocks. Several research projects have emphasized describing the stratigraphy and depositional environments of important reservoir successions, including the Mississippian, Atokan, and Cherokee of western Kansas and the Cherokee of Eastern Kansas. While some of this research is funded by the KGS or by TORP, it is undertaken or overseen by faculty in the Department of Geology and may involve funds from other sources.

The **KU Tertiary Oil Recovery Project (TORP)**, co-directed by Don W. Green and G. Paul Willhite, was initiated by direction of the State legislature in 1974 to provide a base of research and development in new technology for petroleum recovery in Kansas and to distribute results to operators in the state. The focus has since expanded to include conventional technology applications and improved reservoir management techniques.

TORP has several objectives:

- To evaluate the potential of oil recovery processes in Kansas;
- To conduct R&D on tertiary oil recovery processes applicable to Kansas and to investigate reservoir engineering applications and geology;
- To disseminate the gathered information;
- To conduct technology transfer activities and provide technical assistance; and
- To educate students in tertiary oil recovery technology and in efficient reservoir management.

Initially, communication of the R&D results and new technologies was performed through the traditional channels of publishing R&D reports and project results and lecturing on these topics. Technology transfer methods changed, however, as EOR processes became uneconomic with lower oil prices, and the needs of smaller independent producers for conventional as well as improved recovery technologies became more urgent. TORP began an aggressive technology outreach program to transfer conventional and improved recovery technologies to Kansas producers. TORP accomplished this by providing hands-on assistance to operators and by designing, implementing, and assessing the performance of effective and cost-efficient solutions in the reservoir.

The TORP research and development programs are currently examining the application of gelled polymer systems for flow control in reservoirs. The focus is on reaction kinetics and prediction of gel time, gelation behavior of the systems in porous media, and mathematical modeling of the gelation process in porous media. The intent of this work is to develop polymers that will plug high-permeability zones previously swept by waterflooding and allow new injection fluids to penetrate previously unswept zones.

An evaluation of the potential of several improved oil recovery processes was conducted jointly with the Kansas Geological Survey (KGS) in the Zenith field, in south central Kansas. The goal of the program was improved reservoir and geologic characterization, more efficient reservoir management, and increased understanding of new oil recovery technologies.

A major portion of TORP work is the dissemination of technical information. Information is passed to industry through a variety of means. TORP field engineers have much direct contact with operators and engineers. The TORP technology transfer/liaison program has several key features which combine to make it highly effective:

- An industry advisory board reviews and approves nominated projects to demonstrate innovative solutions to real problems in specific operating environments.

- TORP staff work one-to-one with operators to troubleshoot problems at their level.
- Unbiased referrals direct operators to service companies or consultants to help operators implement solutions where TORP cannot participate or does not participate to avoid competition with the private sector.
- Solutions combine results of TORP R&D and other conventional technology.
- TORP pays TORP staff and expenses; Operators pay all project expenses and agree to release all project information for publication.
- Project results provide essential input to defining elements of TORP research program.
- Project progress and results, positive or negative, are disseminated in a hands-on manner, through field trips, seminars, and focused technology workshops as well as more conventional articles and publications.

Since 1983, TORP has been highly successful in demonstrating the effectiveness of technical solutions to reservoir problems, encouraging independents to invest in technologies and deferring well abandonments. A key element to this success has been gaining operator trust and confidence through the positive interaction of TORP personnel with operators at the operator's level. TORP has benefitted from gaining an understanding of the real reservoir problems from the perspective of the operator as well as a real world laboratory for testing and demonstrated improved recovery processes. An advisory board, representing a cross-section of the industry, has helped guide the program.

In addition to TORP's direct interaction and liaison engineering efforts with Kansas producers through its field pilot projects, TORP conducts effective technology transfer through a series of seminars and short courses focused to address the immediate needs of Kansas producers. These activities have focused on waterflooding techniques, the use of personal computers, and reservoir characterization. Every two years, TORP conducts a two-day improved oil recovery symposium for

Kansas producers and interested researchers, industry personnel, and observers from outside the state. Papers in these conferences present results of field studies, applied research, and cost-effective technologies. The papers are directed at operators, engineers and geologists who deal with production problems.

The value and success of this R&D and technology transfer model has been recognized throughout the oil producing states. Operators have become more comfortable with TORP with time, and the number of requests for assistance by Kansas producers is increasing. This confidence comes at a time when the TORP program is significantly constrained by limited levels of funding from the State of Kansas for personnel and facilities. Recently, TORP has sought to leverage its funds through the KUERC by teaming with several independent producers in Kansas to compete for DOE cost-shared awards to conduct near-term and mid-term demonstration projects in Kansas Class I (fluvial deltas) and Class II (open-shelf carbonate) reservoirs. TORP, KUERC, and operator funds are combined to provide the required cost-share. With TORP's financial and personnel resources committed to these projects, there is concern that TORP's ability to continue existing services, to respond to other Kansas operators, or take on worthy non-PON projects will be curtailed. With adequate funding and personnel, TORP can continue to be a highly effective R&D and technology transfer organization in Kansas.

The Kansas Geological Survey (KGS), directed by Lee C. Gerhard, is a state agency operated by the University of Kansas and located on its Lawrence campus. As a R&D organization, its mission is "to conduct geological studies and research and to collect, correlate, preserve and disseminate information on the geology of Kansas with special emphasis on geological resources of economic value, including oil and gas." The Survey undertakes "supportive applied research and development ... for other state agencies, individuals, and industry and provides new tools and techniques to stimulate activity." The Survey employs more than 50 full time professionals.

The Petroleum Research Section performs the bulk of petroleum related activities with assistance from the Survey's Mathematical Geology (automated

log analysis and statistical correlation of hydrocarbon resources) and Geologic Investigations (digital geologic mapping) sections. The Survey is currently focusing on developing and applying new concepts and methods for improved characterization of petroleum reservoirs including:

- Sequence stratigraphy for more precise geologic interpretation.
- Geologic simulation models for reconstructing observed geology and improving prediction.
- Expert systems for geologic interpretation.
- High resolution seismic for improved description of carbonate and sandstone reservoirs.
- Integrated structural interpretation.
- Evaluations of source, timing, and location of petroleum distribution and migration.
- Spatial and stratigraphic distributions of oil and gas statistics.

KGS is also creating and distributing a state oil and gas atlas and production database. Log analysis, contouring, and log correlation software programs have been developed for industry use.

Industry helps focus the activities of the KGS through participation in the KGS Advisory Board. KGS communicates the results and applications of its research back to the public through a variety of methods. About 25 percent of the lead petroleum professional's time is occupied in person-to-person technology transfer.

KGS staff also present papers, technical talks, short courses, and field demonstration trips often in conjunction with the Kansas Geological Society, the Kansas Independent Oil and Gas Association, and other organizations and professional societies.

KGS emphasizes interaction with the public and the industry. KGS has two major public facilities:

- A Core Library (about 150,000 ft. of cores) and Examination Laboratory with a public access log and well data library (Lawrence).

- A Sample Cut and Samples Library in Wichita with samples from about 135,000 wells (Wichita).

These facilities provide on-site use and check-out capabilities. They serve as centers for information, advice and conferrals and for publication distribution.

Industry Organizations

The **Kansas Geological Society**, a private organization, also serves as a conduit of information. The Society possesses the most comprehensive geological library in the state. Although no research and development is conducted, many operators look to the Society and its library for historical data and information they need with regards to their reservoirs. A library of this nature could be a valuable liaison between operators and researchers in the transfer of R&D results. The Society works closely with the Kansas Geological Survey to coordinate projects, seminars, and other technical services to the producing community. This relationship could be nurtured and sustained with the integration of the KU energy elements into an integrated energy center.

The **Kansas Independent Oil and Gas Association** (KIOGA), a 750 member trade association headquartered in Wichita, represents the interests of Kansas independent crude oil and natural gas producers before the Kansas legislature, the KCC, and national deliberative bodies. In addition to legislative representation and public relations activities, KIOGA also offers educational seminars and assists its members in procedures for effective environmental and regulatory compliance.

KIOGA is also a regional cooperating association of the Independent Petroleum Association of America (IPAA). Through this relationship, KIOGA members can participate in a national, industry-wide effort led by IPAA to build a national technology transfer organization to help coordinate and capitalize on potential synergies of the activities of numerous R&D and technology transfer organizations.

Through its access to Kansas independent producers, KIOGA can expand its efforts to make producers aware of the need to become knowledgeable about improved recovery technologies and opportunities and attract their more active

participation in focused problem identification and technology transfer activities. Barring financial constraints, KIOGA could also broaden its functions to encourage continued technical education of its membership and to publicize technology transfer events sponsored by more technology oriented organizations, including the KUERC.

III. OBSERVATIONS

Kansas is making excellent progress in developing and implementing an integrated approach to oil and gas technology transfer statewide. TORP's technology outreach program is effective and the joint efforts of KUERC to develop and offer prototype problem identification workshops have evolved a format that promises to yield an objective unbiased picture of the needs and priorities of the producing industry.

In a nutshell, the integrated KUERC program performs all of the functions essential to effective focused technology transfer to Kansas oil and gas producers, specifically:

- Objective problem identification and prioritization in specific operating environments
- Problem-focused needs analysis and technology assessment
- Demonstration and transfer of existing technologies to address priority problems in a manner that is effective for the specific target audience(s)
- Focused geoscientific and petroleum engineering R&D to develop solutions to high priority problems
- Feedback to others in the R&D community as to research priorities and technology advances
- Cooperation with other state, regional and national public and private research and technology organizations

TORP has done an excellent job in promoting and publicizing its research and technology outreach work in the areas of polymer applications for water control and injection profile modification. There was some initial concern that in problem identification workshops, especially with TORP staff as facilitators, operators might be disposed to address only problems related to research being performed by KU and minimize discussion of other key problem areas or technologies. Observed evidence from the workshops and the independent evaluation that follows, suggests that this is probably not a problem. Workshop facilitators should be aware of the possibility, however, and continue to design workshops with an eye to discouraging this possible response.

State and private organizations are also beginning to work together well. If the various geology, engineering and biology departments and agencies operated by the University of Kansas can develop a smooth, interdisciplinary working relationship under the mantle of the KU Energy Research Center, significant synergistic benefits can accrue to R&D and technology transfer and to the producing industry and the State of Kansas.

The KUERC seeks to advance the coordination by constructing a building to house the integrated petroleum R&D functions of TORP, KGS, and related departments and functions. A more integrated working environment could help the disparate units of the KUERC program to work more cohesively. To the extent that building funds can be raised without detracting from funding for the actual work of the R&D and technology transfer programs in Kansas and other states, the KUERC building appears to be a good idea. Prevailing attitudes in Congress and the federal government currently appear to favor funding R&D and technology transfer functions over so called "bricks and mortar" projects.

Budget and staffing levels for TORP are too low if TORP is to continue to adequately provide the full range of services it has initiated and participate with Kansas producers in the cost-shared federal oil technology demonstration projects. Therefore, additional funding support should be sought from university, state, industry, and federal sources.

The Kansas producing industry, comprised now largely of independent producers, has demonstrated through its expenditures and participation its confidence in the Kansas approach. Of significant note, the state legislature firmly supports the activities of TORP and KGS, and the concept of the energy center. The efforts of KIOGA, EKOGA, and others have contributed significantly to support from Governor Joan Finney and Kansas' key U.S. Representatives and Senators. Ways in which the independent producer associations could assist more would include encouraging their members to support the integrated KUERC effort financially and by participation in its activities.

Source List

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- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price*
- Energy Information Administration, *Petroleum Supply Annuals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

TECHNOLOGY TRANSFER CONTACT LIST FOR KANSAS

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	W. Lynn Watney Executive Director		
University of Kansas Tertiary Oil Recovery Project	Don W. Green G. Paul Willhite Co-Directors	Lawrence	Phone: 913-864-3001 FAX: 913-864-4967
University of Kansas Kansas Geological Survey	Lee Gerhard Director	Lawrence	Phone: 913-864-3965 FAX: 913-864-5317
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Kansas Independent Oil and Gas Association	Donald Schnacke Executive Vice President	Wichita	Phone: 316-263-7297 FAX: 316-263-3021

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**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
LOUISIANA**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR LOUISIANA

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil was first produced in Louisiana in 1902. As of 1987, 27.2 billion barrels (BB) of original-oil-in-place (OOIP) had been discovered in onshore reservoirs and 14.1 billion barrels had been produced, leaving about 13.1 BB of known oil, or 48.1%, still in the ground. With 0.7 BB in proved reserves, over 12.4 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1). An additional 10 billion barrels have been produced from Louisiana state and federal offshore areas.

Figure 1. Discovered Oil Resource

Louisiana's remaining onshore oil resource is concentrated almost entirely in Delta/Fluvial-Dominated reservoirs with the remainder distributed across eight other geologic classes (Figure 2). Only a small portion (less than 1%) of the state's ROIP is heavy oil.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas

In Louisiana, more than 73% of the 293 trillion cubic feet (Tcf) estimated natural gas resource (including offshore) has been produced. Of the remaining 79 Tcf, about 12%, or 9.5 Tcf, are proved reserves, recoverable under existing economic and operating conditions. The remaining 69.6 Tcf of estimated undiscovered reserves is comprised of probable, possible, and speculative reserves and includes a portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Production

All of Louisiana's 64 parishes have some oil and/or gas production (Figure 4). There were 23,612 producing oil wells in the state in 1991, over 91% of which were operated on artificial lift. Seventy-five percent of Louisiana's producing wells are stripper

Figure 3. Natural Gas Resource

wells. In 1991, stripper wells accounted for less than 2% of the total crude oil produced in the state. A significant portion, almost 70%, of Louisiana's oil production comes from coastal and offshore platforms in the state and federal waters of the Gulf of Mexico.

Louisiana is currently the second largest producer among the lower-48 states. Crude oil production in Louisiana (including state and federal offshore) peaked in 1971 at 945 million barrels (MMB) and fell by 450 MMB by 1981 (Figure 5).

Figure 5. Crude Oil Production

Figure 4. Parishes with Active Production

During the early 1980's oil boom, crude oil production in the state increased, rising about 15% by 1984, and then resumed its decline. New offshore development increased production to 419.1 MMB by 1991. Production trends have generally been preceded by changes in the crude oil wellhead price.

Louisiana is the nation's fourth largest producer of natural gas. Gas production peaked at 8.2 Tcf in 1972 and declined almost one-fourth between 1981 and 1991, largely because of depressed gas prices (Figure 6).

Figure 6. Natural Gas Production

Improved Oil Recovery

Enhanced oil recovery (EOR) efforts have been tested and applied in Louisiana reservoirs since 1963. Nineteen EOR projects have been conducted or are currently on-going in Louisiana's reservoirs. Ten of these have been conducted using CO₂ methods, primarily CO₂ miscible and immiscible floods. The remainder of the projects are split between thermal and chemical EOR techniques. Additional projects using CO₂ miscible processes have been planned. Crude oil production by EOR processes represents a relatively small portion of the Louisiana total production, less than 1%. However, the large remaining resource and declining conventional production indicate that Louisiana may be a good target for future improved recovery efforts.

Recovery efficiency in Louisiana is greater than in many other states (as shown in figure 1) because of the relatively high permeability and continuity of the reservoirs. However, as many of the reservoir

structures near the state's numerous salt dome formations are steeply dipping, improved reservoir characterization and primary and secondary recovery technologies offer significant promise for reserve additions and increased production in known onshore and offshore fields. Of particular interest are advanced seismic techniques for reservoir description and strategic infill drilling and applications of horizontal or directional drilling technologies.

Oil and Gas Reserves

Louisiana currently ranks third among the lower-48 states in proved oil reserves. Like most other states, Louisiana saw its oil reserves (including federal offshore) decline in the 1980's. Unlike many states, the decline has been less severe. Between 1981 and 1987, crude oil reserves fell by over 22% from almost 3 billion barrels to 2.3 billion. With extensions and new discoveries, reserves recovered by almost 6% to 2.5 BB by 1991 (Figure 7).

Figure 7. Crude Oil Reserves

Conversely, natural gas reserves have declined steadily, falling by 32% from 1981 to 1991. During the 1980's and into 1991, production fell steadily. Louisiana was producing more than 31% less natural gas in 1991 than in 1981 (Figure 8). Still, Louisiana's gas reserves, at almost 33 Tcf including federal offshore, are greater than any other lower-48 state.

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques or plug and abandon

the well. Premature well abandonments threaten the option to apply current or emerging improved recovery technologies to produce remaining oil-in-place. Between 1981 and 1987, declining oil prices stimulated a massive increase in annual stripper well abandonments, while abandonments rose from 59 to 1,326. By 1990, however, abandonments had decreased to just over 400 and leveled off. Nonetheless, the current rate of abandonments remains more than 8 times that of 1981 (Figure 9).

Figure 8. Natural Gas Reserves

Figure 9. Stripper Well Abandonment

Exploration

The steady drop in Louisiana oil and natural gas prices led to a significant across the board decrease in drilling activity in Louisiana between 1981 and 1991. Exploratory drilling, including new field wildcats, and development drilling all declined by 75

to 80 percent during the period. Depressed exploration and development drilling activity contributed significantly to the industry's inability to fully replace produced oil and gas reserves.

Economic Impacts

Because of reduced exploration activity and contraction in refining and marketing between 1981 and 1987, overall employment in Louisiana's oil and gas industry fell by almost 38%. A loss of more than 51,000 jobs. Almost 85% of these losses were in the oil and gas extraction sector of the industry (Figure 10). Since 1987, employment in oil and gas extraction in Louisiana has increased slightly, not enough to return to previous levels.

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and persistent low prices have also resulted in a decrease in the wellhead value of production. The wellhead value of crude oil, in 1991 dollars, decreased by 64% in real terms between 1981 and 1991. The value of natural gas production fell by over 64% between 1982 and 1991. The decline in oil and gas production and prices and the subsequent decline in the value of production led to a decrease in Louisiana state revenue from severance and production taxes between 1982 and 1991, of more than 58% to a level of \$565 million. Reductions in overall state revenues from oil and gas extraction have been amplified by the effects of reduced employment, equipment and supplies manufacturing and sales, and related economic activity on sales and income tax revenues. With sustained higher oil and gas prices and increased

production, these revenues may increase in the foreseeable future. The state has a clear stake in maintaining a viable petroleum producing industry.

Other Industry Concerns

Louisiana's oil and gas operators face unique concerns related to the producing environment. Much of the state's oil and gas resources lay beneath state or federal offshore waters, in tidal wetlands, or other sensitive environmental areas. Increasingly stringent environmental regulations related to platform sitting, drilling operations, disposal of produced waters and drilling fluids, and containment of naturally occurring radioactive material pose new technical challenges as well as economic costs. In addition, the costs of exploration and production in state and federal offshore waters are increasing, especially as activity expands to deeper water with new technological developments. The effects of 1992's Hurricane Andrew which caused an extensive shut-in of Louisiana offshore oil and gas production will severely impact 1992 production rates and 1993 abandonments. The federal and state governments and the producing industry face significant challenges in sustaining an economically viable oil and gas extraction industry while protecting this unique environment.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

Even with higher recovery efficiency rates and unique coastal and offshore producing environments, the need for broad and effective technology transfer in Louisiana is clear. If companies are to maximize production of the Louisiana oil resource, state-of-the-art exploration, production and environmental control operations are essential. Until recently, onshore oil and gas operations have been the province of independent producers and offshore and coastal activities have largely been conducted by major companies. As the responsibility for producing the known remaining resource increasingly shifts to the independents, their access to and understanding of improved recovery technology and related information and resources needs to be expanded.

In the *near-term*, technology transfer has the opportunity to accelerate market penetration to deploy new and *existing* technologies to defer

reservoir abandonments and preserve access to the reservoirs and the resource base for application of even more efficient emerging technologies and improvements in geoscientific understanding. In the *mid-term* technology transfer functions can ensure the broad deployment of *emerging* technologies and advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic research and development communities and the producing community as *new* technologies and processes are developed over the *long-term*.

Petroleum R&D and Technology Transfer Organizations

Numerous public and private entities in Louisiana are currently engaged in performing oil and gas research, disseminating R&D results and technology information, and offering technology assistance and related services to oil and gas producers. The current activities and capabilities of the most prominent of these organizations are described below (Table 1) with observations as to how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to Louisiana producers.

State Agencies

The **Louisiana Department of Natural Resources, Office of Conservation**, managed by Herbert Thompson, is the lead agency responsible for regulation and oversight of onshore and state offshore oil and gas exploration production in Louisiana. This agency is responsible for conservation of the state's oil and gas resources. The Department of Conservation also collects, analyzes, and reports reserves and production data, drilling statistics, well completion data, well abandonments, reservoir data, and other information required to perform its overall mission of conserving the state's oil and gas resources.

The **Louisiana Geological Survey**, directed by William Marsalis, is located on the campus of Louisiana State University in Baton Rouge and operated by the Department of Natural Resources. LGS performs most of the traditional functions of a state survey. It is responsible for analyzing and mapping the surface and subsurface geological

structures of the state, analyzing its mineral resources, and assisting the public in efficiently producing these resources, including oil and natural gas. The survey also maintains well core and cuttings samples to assist in research. LGS works with oil and producers to interpret the data and analyses generated by the Survey in order for them to make investment and development decisions. LGS provides public access to its log library, core samples, and cuttings collections. LGS staff also work directly with the public to assist in analysis and interpretation of geological information.

Research Universities

Research and development and technology transfer activities in Louisiana are largely the province of university programs. Several large and small universities have academic and research programs focused on Louisiana oil and gas exploration and production.

Louisiana State University, (LSU) located in Baton Rouge, is among the nation's most highly regarded academic and research universities. In addition to strong academic departments in Petroleum Engineering and Geology, the University performs extensive research and development activities for government, industry, and other sponsors. Much of the oil and gas extraction and related environmental R&D elements are conducted through specialized research institutes and coordinated with the academic departments in large part through the University's Center for Coastal, Energy, and Environmental Resources (CCEER), directed by Dr. Charles G. Groat. Of particular note among these units are the LSU Basin Research Institute and the Petroleum Engineering Research and Technology Transfer Laboratory.

The **LSU Center for Coastal, Energy, and Environmental Resources (CCEER)**, special programs in energy and environmental research, under the direction of Research Director Chacko J.

LOUISIANA	Current or Potential Oil and Gas Technology Transfer Functions																							
	Data & Publications						Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance						
	Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering
Organization																								
State Agencies																								
Louisiana Dept. of Natural Resources	C	C	C	P											C									
Louisiana Geological Survey	C	C	C		C						C	P	P		P	C				C	P	C	P	
Research Universities																								
Louisiana State University							C	P	C	P		P	P	C	C	C	C	C	P	P	P	P	P	P
Louisiana Tech University							C	P	C	P		P	P	P		C	C	C	C	P	P	P	P	P
Industry Organizations																								
Louisiana Mid-Continent Oil and Gas Association				C				C	P	P	P	P	P		C						P			
Louisiana Independent Oil and Gas Association				C				C	P	P	P	P	P		C						P			
C = Currently performs																								
P = Has potential to perform, barring legislative, regulatory, fiscal, or other constraints																								

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

John, is presently engaged in several research projects that address the oil and gas resource base and problems currently encountered or likely to be encountered in the foreseeable future:

- CCEER recently completed a project with the Texas Bureau of Economic Geology to develop an atlas of the major gas reservoirs (>10 Bcf) on the Central Gulf Coast. The effort was funded through a subcontract on a BEG grant from the Gas Research Institute (GRI). The *Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs* has been published.
- CCEER is currently conducting an analysis funded by DOE, of the environmental constraints on expanding reserves in current and future reservoirs in wetland areas. The analysis, which is based on experience in the development in 10 wetland fields, seeks to identify means by which exploration and production activities can be performed while reducing E&P impacts on wetland resources. The study also seeks to identify the potential for future activity in these areas, list potential problems related to future resource development, qualify and quantify the environmental constraints placed on operators to avoid minimize or mitigate environmental problems, and find new ways to reduce environmental damage without sacrificing the state's potential for increased reserves.
- LSU/CCEER has also been involved in DOE's geopressure-geothermal research program since its inception in 1975. Currently, microseismic and subsidence monitoring at geo-pressured geothermal test sites in Texas and Louisiana and a study of prospect geology at Louisiana test sites are being conducted.
- LSU/CCEER will be working with the Texas Bureau of Economic Geology on an offshore Northern Gulf of Mexico Atlas for major oil and gas reservoirs which will present information similar to that found in the already published atlases by BEG.

CCEER staff publish numerous technical and analytical articles and reports in scientific and professional journals each year. They also participate in and present papers at national, regional, and local meetings of professional societies and industry trade and professional associations. They also work directly with producers and engage in symposia and other more direct technology transfer functions through their interaction with the LSU Center for Energy Studies, the LSU Basin Research Institute, and numerous other related research institutes that conduct the University's extensive petroleum engineering, geosciences, and related environmental research programs.

CCEER and its component institutes have the potential to play a much larger technology transfer role. They could potentially serve as an information resource for operators on reservoir geology and producing conditions in an integrated technology transfer with the university and the producing industry. Additionally, LSU/CCEER could be a valuable information source on the regulatory and environmental compliance requirements faced by operators.

LSU's Petroleum Engineering Department, headed by Dr. Zaki A. Bassiouni, conducts extensive research and technology transfer activities. There are nine full-time faculty conducting research, often in conjunction with and/or in addition to the work of the Petroleum Engineering Research and Technology Transfer Lab and CCEER. Their work is leveraged by an additional 9 full-time research technical staff. LSU has extensive EOR and well control and blowout prevention facilities, an MWD loop, a well logging unit, a gas measurement setup, and a full-scale production setup for offshore platform safety training.

Several studies are being conducted or have recently been completed by the Department.

- Two of the largest projects involve assessing the bypassed oil resource in the state. LSU is carrying out DOE-funded research in conjunction with LGS, the Basin Research Institute, and two private consulting firms on the recovery of bypassed oil from reservoirs in the Gulf of Mexico. The Department has completed a project performed jointly with the LSU Geology and Geophysics

Department, Computer Sciences Department, and TSarien Research Institute. It used improved reservoir characterizations to locate large areas of bypassed oil in Louisiana. The work was funded by DOE and the Louisiana Education Quality Support Fund (LEQSF).

- GRI sponsored LSU in its characterization of the wetability and producibility of low-permeability tight gas sands. (Completed July 1992)
- As a supplement to its work assessing the resource and producing conditions in the state, LSU completed extensive research in enhanced oil recovery using CO₂ "Huff-n-Puff" methods in November 1992. This work is currently being conducted in sectors affecting organic deposition during CO₂ flooding.

The Department also has evaluated new processes of gas/oil separation during a blowout for Lawrence Livermore National Laboratory and saltwater intrusion in the Weeks Island SPR Oil Storage Facility for Sandia National Laboratory.

LSU has close contact with industry and an extensive technology transfer function. In addition to the traditional university transfer functions of writing papers and reports and giving lectures, LSU staff train drilling personnel in well control and blowout prevention and tests new rig fire suppression methods and agents invented by industry. LSU research staff and faculty also sponsor or participate in public conferences and workshops to describe advances in technology; a recent example is LSU's 1991 Workshop and Short Course on Horizontal Drilling.

Future technology transfer efforts involve the establishment of a technology transfer office to assist independent operators. LSU plans to offer training to operators in workover and drilling safety for MMS certification.

In addition to these future efforts, LSU could play an even larger role in the technology transfer process in Louisiana. With the work being done in assessing the producibility and location of the remaining resource and LSU's experience in training

and EOR R&D, LSU would be an ideal host organization for problem identification, focused technology, and technology training workshops and seminars. With increased coordination with industry associations, the University's contact with independent producers can be further expanded to the benefit of the industry and the state.

Establishing a technology transfer office to assist independents will be an important step to an effective technology transfer program in Louisiana. The information gained through research and the expertise of its staff make LSU/CCEER a strong resource to assist operators (both large and small) in project development. Its cooperative association with LGS will further enhance this role. In addition, the synergies of the cooperation with LGS should be further exploited in order to provide operators with as much assistance as possible.

In addition to a strong petroleum engineering department, LSU also has a unit entirely devoted to the transfer of research technology — the Petroleum Engineering Research and Technology Transfer Laboratory.

Louisiana Tech University is located in Ruston in north central Louisiana. Louisiana Tech's Department of Petroleum Engineering and Geosciences, directed by Dr. John Lohrenz, includes six full time professional staff who perform interdisciplinary research in several areas involving oil and gas and mineral extraction.

- Analysis of the economics and future potential of horizontal drilling (completed)
- Studies in decision economics regarding production shut-in and abandonments relate directly to DOE research initiatives in future EOR technologies (Ongoing, 2 manuscripts completed)
- An R&D proposal to assess environmental hazards at abandoned oil and gas production sites.
- Analysis of microbial applications for sulphur removal from lignite and other "clean fuels" applications

- Development of a logging tool to calculate magnetic permeability of reservoirs

The Department possesses a networked workstation within its facilities that allows researchers to do 3-D reservoir simulation, online log analysis, cross-section correlation, and production analysis. The workstation has several geoscience software packages including the Department of Energy's (DOE) BOAST and enhanced oil recovery (EOR) programs.

Louisiana Tech could play a significant role in the technology transfer process in the state. Given the focus of its research work, and its location near independent producer activities, the university would be a good host organization for seminars and symposia. Louisiana Tech could also sponsor problem identification and focused technology workshops. While the university could expand its role in these areas, the university is particularly suited to becoming a resource center for operators and producers. Louisiana Tech's history suggests the potential for collaborative technology transfer programs with LSU/CCEER.

Given adequate facility, personnel, and funding, Louisiana Tech could expand the size and research focus of its workstation to include assisting operators in assessing production options. The foundation for a successful resource center already exists in the research workstation. The resource center would require state-of-the-art software and current reservoir and technology information as well as the ability to offer producers expert assistance to operators.

Industry Organizations and Professional Societies

The oil and gas producers in the state are represented by two industry associations — the Louisiana Mid-Continent Oil and Gas Association and the Louisiana Independent Oil and Gas Association. The **Louisiana Mid-Continent Oil and Gas Association** (LMOGA) represents its members (including majors and independents) before regulatory entities, the legislature, and the public. Located in Baton Rouge, its primary focus is on government and public relations. LMOGA has expressed its support for improved technology transfer to independents and could perhaps serve as a host to encourage producer participation in technology and regulator workshops. LMOGA will

also be a key intermediary between its membership and the technology transfer process.

The Louisiana Independent Oil and Gas Association (LIOGA) is a relatively recent organization that replaced the now-defunct Louisiana Association of Independent Producers and Royalty Owners (LAIPRO) as the principal representative of the independent producing community in Louisiana. In addition to representing its membership in the legislative area, LIOGA takes on a variety of other roles for its membership. Currently, LIOGA's directors are planning a series of seminars, the publication of an Environmental Reference Manual, and the distribution of a regular newsletter to its membership. LIOGA has also been a supporter of the Independent Petroleum Association of America's efforts to develop a national technology transfer "umbrella" organization.

LIOGA has expressed a strong interest in being involved in a technology transfer effort in the state. Given adequate resources, the association could take a more proactive role in the process by co-sponsoring workshops and symposia on areas of concern to its membership. By actively involving its members in the technology transfer process, LIOGA will provide a crucial element to an effective technology transfer effort.

In addition to industry trade associations, additional research and technology transfer functions are performed through local chapters of the Society of Petroleum Engineers, the American Association of Petroleum Geologists, the Society of Exploration Geophysicists, and local geological and/or geophysical societies.

III. OBSERVATIONS

All the important pieces for effective technology transfer are present in Louisiana. There is a recognized need for technology transfer in the state. But, as with many other states, there is very little coordination. In particular, the potential additional synergies of expanded cooperation between the Louisiana Geologic Survey and Louisiana State University/CCEER need to be exploited. Additionally, Louisiana Tech needs to be introduced to this cooperative effort. As a new organization

with fresh ideas, LIOGA is an ideal organization to provide leadership in a coordinated state, university, industry technology awareness and transfer project or task force.

Once such a cooperative effort is established, several other steps can be taken to promote improved oil and gas recovery in Louisiana.

- A workshop program (both problem identification and focused technology) can be developed to determine technology needs and priorities of operators, and inform and assist them in using currently available advanced technologies. Much of the research has already been performed and is ready to be related to the producing community.
- Increased research needs to focus on new and improved technologies which can address the opportunities presented by Louisiana's mature reservoirs. Expanding the research focus can assist operators and increase ultimate production.
- Industry associations can recognize and expanded role to include more proactive technology transfer in addition to public relations roles. These organizations have the best potential to encourage their membership's involvement in technology transfer processes. An initial role can include sponsorship and endorsement to their membership of seminars and workshops to conduct problem identification, and communicate current technology options.

- A technology outreach/field assistance effort could be established in a LGS/LSU/ Louisiana Tech cooperative effort. Project assistance in troubleshooting, analysis, technical approaches, and engineering reviews will greatly aid operators in conducting effective EOR efforts.
- Ultimately, a resource center where operators would have access to analytical tools and referrals to assist them in their operations is would be helpful, especially to independents. Private, state, or federal funding would be required to establish staff, a center and perhaps an adjunct field location.

Source List

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- Department of Commerce, *Bureau of Economic Analysis*
- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price Annuals, Natural Gas Annual*
- Energy Information Administration, *Petroleum Supply Annuals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

TECHNOLOGY TRANSFER CONTACT LIST FOR LOUISIANA

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Louisiana Geological Survey	W. Marsalis	Baton Rouge	Phone: 506-388-5320 FAX: 506-388-5328
Louisiana State University Department of Petroleum Engineering	Zaki Bassiouni Chairman	Baton Rouge	Phone: 504-388-6040 FAX: 504-388-5990
Louisiana State University Center for Coastal, Energy, and Environmental Resources	Charles G. Groat Executive Director	Baton Rouge	Phone: 504-388-6316 FAX: 504-338-5328
Louisiana Tech University Department of Petroleum Engineering and Geosciences	John Lohrenz Coordinator of Research	Ruston	Phone: 318-257-3972 FAX: 318-257-2562
Louisiana Mid-Continent Oil and Gas Association	B. Jim Porter	Baton Rouge	Phone: 504-387-3205 FAX: 504-344-5502
Louisiana Independent Oil and Gas Association	Rutledge Deas Chairman	Baton Rouge	Phone: 504-388-9525 FAX: 504-388-9561

**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
NEW MEXICO**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR NEW MEXICO

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

New Mexico began producing gas in 1921 and oil in 1922. By 1987, 15.6 billion barrels had been discovered. Of this, New Mexico had produced a total of 4.7 billion barrels (BB) of oil through 1987. About 10.9 BB of New Mexico's 15.6 BB original-oil-in-place (OOIP), or 69.8%, is still in the ground. Excluding 720 million barrels of proved reserves, 10.2 BB of remaining-oil-in-place (ROIP) is the target for current and emerging improved oil recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

Most of this known remaining oil is found in the Shallow Shelf/ Open (carbonate) reservoirs (Figure 2) with the remainder in seven other geologic classes. Virtually all of New Mexico's oil is light oil.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas

Almost 58% of New Mexico's estimated 73.1 trillion cubic feet (Tcf) of natural gas resource has already been produced. Of the remaining 31 Tcf, 18.5 Tcf, or almost 60% is proved reserves. These proved reserves are recoverable under existing economic and operating conditions. The remaining 12.5 Tcf of undiscovered reserves is comprised of probable, possible, and speculative reserves. This includes the portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Production

Eleven of New Mexico's 39 counties have some oil or gas production (Figure 4). Oil production is concentrated in four counties in southeastern New Mexico. Producing oil wells totalled more than 17,600 in 1991, of which 83% were on artificial lift.

Figure 3. Natural Gas Resource

Although almost 87% of the producing wells are stripper wells, stripper wells produced only 20% of the state's annual production in 1991.

New Mexico ranks seventh in U.S. oil output. Crude oil production in New Mexico peaked in 1969 at about 130 million barrels (MMB), and then declined steadily, falling almost half to 71 MMB in 1982. Production rose to 79.3 MMB in 1984 responding to earlier investments during the oil boom of the 1980's. With the 1986 price decline, oil

production levels resumed their steep decline. In 1991 there was a slight increase in production, from 67.2 to 70.4 MMB, but the overall production levels decreased more than 11% from 1984 to 1991 (Figure 5). Oil production mirrored the price trend, with a lag time of approximately three years.

Figure 5. Crude Oil Production

New Mexico currently ranks fourth in natural gas production. Natural gas production plummeted in the early and mid-1980's, falling from 1,150 billion cubic feet (Bcf) in 1980 to 703 Bcf in 1986. With

Figure 4. Counties with Active Production

incentives for unconventional gas production and new discoveries, production increased sharply in 1987 and has continued a sharp upward trend rising to a 1991 level of 1,015 Bcf (Figure 6), even as gas prices continued to fall. About 22% of the gas produced in 1991 was coal seam gas from the San Juan Basin.

Figure 6. Natural Gas Production

Improved Oil Recovery

Although New Mexico began utilizing enhanced oil recovery (EOR) methods in 1981, EOR has since played a relatively minor role in production. Five EOR projects have been implemented in New Mexico's reservoirs, four of which are currently active. All projects involved CO₂ miscible gas flooding. In 1991, EOR projects accounted for less than .1% of New Mexico's crude oil production. No projects planned have been announced. However, with a new EOR tax credit and increased CO₂ pipeline capacity, new EOR projects could be announced in the near future.

Although most tertiary EOR processes are at best marginally economic at today's oil prices, more than 36% of New Mexico's oil production, about 25.4 MMB, was attributed to conventional secondary recovery processes in 1991. These processes included pressure maintenance and waterflooding. Advanced secondary recovery processes such as targeted infill drilling, horizontal drilling, and polymer augmented waterflooding techniques all have significant potential in New Mexico reservoirs. These and other advanced secondary technologies can help sustain production in marginal fields as new technology is being developed.

Reserves

New Mexico ranks seventh among the lower-48 states in proved oil reserves. Unlike most other states, New Mexico saw its oil and gas reserves increase through the 1980's. Even as production fell in response to declining prices, booked reserves increased because of new discoveries and extensions. The price of oil dropped almost 63% from 1981 to 1991. Oil reserves rose from 555 MMB to 721 MMB (Figure 7).

Figure 7. Crude Oil Reserves

Similarly, while the wellhead price of natural gas fell from \$3.60/Mcf (1991 dollars) in 1983 to the 1991 price of \$1.42/Mcf, proved gas reserves increased almost 60 percent, from 11.6 Tcf to 18.5 Tcf in 1991 (Figure 8). Most of the increase was due to new discoveries and the booking of coalbed methane reserves.

Figure 8. Natural Gas Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques, or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. New Mexico well abandonments reflect the trend of the nation in general. The annual rate of stripper well abandonments rose steadily, increasing from about 450 to almost 700 wells between 1981 and 1986. The 1986 oil price decline and increasingly stringent regulations stimulated a major increase in abandonments to a level of 1,760 wells in 1987. Although the abandonments have since slowed, the 1991 number of abandonments, at 861, was still more than double the rate of 10 years prior (Figure 9).

Figure 9. Stripper Well Abandonments

Exploration

The number of active rotary rigs and the number of new wells drilled also dropped sharply with lower oil prices. The total number of active rigs was down by 70% in 1991 from its peak in 1981, consistent with the national trend. The drilling of exploratory wells in proven areas and new-field wildcats in previously unexplored areas both fell sharply. Exploratory well drilling dropped 76% between 1981 and 1991, and wildcats fell almost 90% during the 1980's. Even development well drilling fell by 50% between 1981 and 1991.

Economic Impacts

Declining production and exploratory activity had a severely negative impact on employment in New Mexico's oil and gas extraction industry. Although extraction sector employment increased 12% between 1980 and 1981, depressed prices and exploration and development activity caused it to decrease by almost 30% between 1981 and 1989. Since then, extraction sector employment has increased slightly, but overall, the industry has suffered a loss of almost 4,000 jobs from 1980 to 1991. The extraction sector was the hardest hit, accounting for almost 3,500 of those jobs (Figure 10).

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and low prices have also resulted in a decrease in the wellhead value of both oil and natural gas production. The sales value of crude oil in 1991 was \$1.36 billion, down \$159.4 million (10.5%) from 1990. Similarly, the value of natural gas decreased \$162 million, or 10.3%, from 1990 to the 1991 value of \$1.4 billion. As severance tax is calculated as a percentage of wellhead value, reductions in the value of production have severely impacted state revenues. Between 1981 and 1991, the revenues collected by the state through severance taxes on oil and natural gas production fell by more than half, in 1991 dollars, from \$468 million to \$230 million. Even with this decrease, the petroleum industry continues to be one of the greatest single sources of revenue. Clearly, the state has a stake in maintaining a viable petroleum producing industry.

Production Incentives and Relief -- Both the state and federal governments have tried to encourage sustained stripper well production and defer premature resource abandonments by modifying plugging and abandonment regulations. In addition, the federal government has granted significant royalty relief to operators of stripper wells on federal lands. In 1991, the federal government also implemented a new 15 percent tax credit for new investment in new or expanded EOR projects.

The State of New Mexico has carefully analyzed and debated the most appropriate approach to stimulating improved oil recovery through severance tax relief and other incentives. In 1992, the state granted partial relief from the severance tax on incremental production resulting from EOR projects.

Industry Demographics

Major producing companies are accelerating their departure from the lower-48 resource base because of increased costs, lower finding rates, more stringent regulation, higher costs of compliance, and more promising opportunities overseas. As they divest some of their marginal holdings, independent producers in New Mexico face both the opportunity for good investments and also the challenge of acquiring properties that require higher levels of technology to efficiently produce the remaining resource.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

To maximize production of the New Mexico oil resource, state-of-the-art operations are essential. Major companies still account for a large percentage of New Mexico's oil production. As the responsibility for producing the resource increasingly shifts to the independents, their access to and use of analytical tools, data, improved recovery technology, and related information and resources must be expanded.

In the near-term, effective technology transfer has the opportunity to deploy *existing* technologies to defer reservoir abandonments and preserve access to the reservoirs for future application of even more efficient emerging technologies. In the mid-term,

technology transfer functions can ensure the broad deployment of *emerging* technologies and advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic research and development communities and the producing community as new *future* technologies and processes are developed over the long-term.

Petroleum R&D and Technology Transfer Organizations

Numerous public and private entities in New Mexico are already engaged in performing oil and gas research, disseminating results and information, and offering technology assistance and related services to major and independent oil and gas producers. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1) and suggestions on how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to New Mexico oil and gas producers.

State Agencies

The **Energy, Minerals & Natural Resources Department, Oil Conservation Division (OCD)**, directed by William J. LeMay, is the lead regulatory agency for oil and natural gas production in the state. Established in 1935 as the Oil and Gas Conservation Commission, its mission is to increase ultimate recovery of the resource base, and benefit the state and its citizens by maximizing tax revenues, royalties, and employment.

The OCD was created by a 1977 reorganization. It regulates the drilling and production of oil and gas and injection operations related to crude oil, natural gas (including CO₂), and geothermal resources in the state. The OCD's mandate is to prevent waste, protect the correlative rights of owners in any pool, prevent loss or contamination of fresh water, and collect and disseminate records and statistics on regulated operations in the state.

In addition to a central administrative office in Santa Fe, OCD has four field offices in the producing regions of the state, located in Hobbs, Artesia, Aztec, and Santa Fe. These offices perform application, permitting, inspection, enforcement, and

records maintenance functions. They are not engaged in research or technology transfer with the exception, perhaps, of informal suggestions, advice, or referrals to local producers.

The OCD is responsible for Underground Injection Control regulation of about 5,000 Class II injection wells. Over a third of New Mexico oil is produced by water flooding.

The OCD also maintains an Environmental Bureau, a Reclamation Fund that pays to plug orphaned abandoned wells, and a Gas Marketing Bureau to promote the state's gas resources and natural gas use. The Gas Bureau holds three or four conferences per year, publishes a monthly newsletter, and maintains and coordinates contact between various elements of the gas producing, marketing, consumer sectors.

Research Universities

Most of the non-industry oil and gas R&D and technology transfer work in New Mexico is performed either by its state funded universities and colleges or in association with them:

- New Mexico Institute of Mining and Technology (New Mexico Tech)
- Eastern New Mexico University (ENMU), and
- New Mexico Junior College (NMJC)

All have teaching programs and/or facilities conducting research and development related to oil and gas exploration, drilling, or extraction.

The bulk of state funded oil-related scientific and technical research and technology transfer functions are performed through the **New Mexico Institute of**

NEW MEXICO		Current or Potential Oil and Gas Technology Transfer Functions																							
		Data & Publications						Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance						
		Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering
Organization																									
State Agencies																									
Energy, Minerals & Natural Resources Department, Oil Conservation Division	C	C	C		P			C	C						P							C			
Research Universities																									
East New Mexico University							C	C	P	P				C		P		P		P	P	P			
NM Institute of Mining & Technology Petroleum Engineering Department							C	P	C	P						C	C	P	C						
Petroleum Recovery Research Center				C		C	C	C	C	C	C	P	P	C	P	C	C	C	C	C	C	C	C	C	
Bureau of Mines and Mineral Resources	C	C	C		C		C	C	C	C	C	P	P									C	C		
Industry Organizations																									
New Mexico Oil & Gas Association				C				C	C				P	P		C						P			
C = Currently performs												P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints													

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

Mining and Technology (NMIMT). The organization conducts academic programs in petroleum engineering and geology, and it houses the New Mexico Bureau of Mines and Mineral Resources and the New Mexico Petroleum Recovery Research Center. Both of these organizations and facilities are located on the NMIMT campus in Socorro, in south central New Mexico.

The NMIMT Petroleum Engineering Department, chaired by Dr. Robert Bretz, offers Bachelors, Masters, and Doctoral Programs in Petroleum Engineering. 1991 enrollments included 41 BS candidates, 9 MS candidates, and 14 PhD candidates. The faculty consists of six full time teaching faculty and ten adjunct faculty. The research interests of the faculty include: petroleum fluids, the environmental aspects of drilling and production operations, drilling modeling, natural gas engineering, reservoir characterization and simulations, and well testing and logging. Many of the adjunct faculty are also engaged in research in the Petroleum Recovery Research Center. Excluding the PRRC work, the Department is engaged in approximately \$510,000 in research projects addressing:

- Coal seam gas simulation and type curves;
- Pipeline leak detection for oil spill prevention;
- NORM problems;
- Numerical simulation of neutron decay tool response in complex lithologies;
- Stress distribution in subsurface formations;
- Bioremediation of oilfield production pit sludges;
- Environmentally benign drilling fluids rod pumping simulator;
- Reservoir fluid properties;
- Well testing while drilling, and
- Gas hydrates decomposition.

Ten additional research projects are currently planned. These projects include studies of:

- Optimization of air drilling technology to minimize the detrimental effects associated with conventional drilling fluids;
- Application of centrifuge technology for minimizing tank bottom wastes (technology transfer);
- Casing-perforating in horizontal wells;
- Effect of oil and gas drilling and production operation on the radioactive Contamination of the Environment;
- Application of electromagnetic waves in oil waste treatment;
- Stability of oil/gas tubulars under torque and axial force loading conditions;
- Insitu stress predictions and evaluations;
- Expert system for waste-management;
- Shallow horizontal drilling system; and
- Coal bed methane.

The department transfers the results of its research to the industry through conventional mechanisms including the training of engineers, research reports, presentations, lectures, and technical articles. It also collaborates in or supports technology transfer functions of the PRRC on request.

The New Mexico Petroleum Recovery Research Center (PRRC), directed by F. David Martin, is one of the leading petroleum research centers in the nation. Formed in 1975 by an act of the New Mexico Legislature, the PRRC has served as a focal point for improved oil and gas recovery and technology transfer activities for sixteen years. It has a staff of approximately 30 full-time engineers, scientists, and support personnel. The center's mission is to:

- Engage in theoretical and practical research in the recovery of petroleum;
- Disseminate the information to the public;
- Assist others in their efforts to recover petroleum;

- Perform any petroleum or other energy research as directed by New Mexico Tech's Board of Regents; and
- Cooperate with state and federal agencies in carrying out the work of the PRRC.

The PRRC's research efforts must be relevant to the needs of the producing industry in New Mexico and the nation. This mandate is due to federal and industry cost sharing requirements imposed by the legislature. Funding for FY92 was about \$2.1 million including about \$650,000 in base funds from the state, \$450,000 in industry cost-shares, and \$800,000 in U.S. Department of Energy support. The PRRC also works closely with the Oil Conservation Division in Santa Fe and elsewhere in the state and with the Bureau of Mines and Mineral Resources which is located adjacent to the Kelly Petroleum Building on the New Mexico Tech Campus.

PRRC is taking the lead in New Mexico in planning and preparing major field tests. Research is also coordinated or jointly performed with national laboratories, other universities, and industry and other private sector research organizations. The PRRC's research is focused in several key areas, including petrophysics and surface chemistry, low permeability gas formations, improved water flooding and chemical flooding methods, gas flooding processes and reservoir simulation, CO₂ mobility control and flow heterogeneities, and field applications.

Several current and planned research projects include:

- Field verification of CO₂ foam in the East Vacuum Grayburg-San Andres Unit;
- Direct thickeners for CO₂;
- Wetting properties of crude oil;
- Fluid diversion and sweep improvement with chemical gels in oil recovery processes;
- Comparative study of techniques for fluid diversion in oil recovery;
- Field laboratory for improved recovery description;

- Candidate selection and placement techniques in water shutoff processes; and
- Hobbs Oil Well Experimental Facilities (HOWE) for environmental control of oilfield waste water.

Following up on an initial study of *The Potential of Enhanced Oil Recovery by Carbon Dioxide Flooding in New Mexico* conducted by the Interstate Oil Compact Commission in 1986, the PRRC recently completed its participation in a DOE sponsored new look at the potential of advanced secondary and enhanced oil recovery processes in New Mexico. This is part of a "multi-state" study sponsored by DOE and the Interstate Oil and Gas Compact Commission.

Technology transfer is a key element of the PRRC research and development function. In fact, the dissemination of information is part of the original mission as given in the State Charter. Technology transfer is conducted through both traditional and innovated mechanisms.

More traditional methods of transferring technology include written reports, technical papers and other documents, and the presentation of results at various conferences, meetings and seminars. The PRRC also distributes a semiannual newsletter to more than 1,000 interested individuals and companies, and offers technical support in personal computer software applications technology.

The PRRC offers two highly effective short courses. One course is on Reservoir Characterization which is taught in the heart of the producing community in Roswell. The other course on Wastewater Management approaches and techniques was developed through a multi-university effort in the state. It is presented simultaneously at numerous university, community college, and industry sites throughout the state by interactive closed-circuit video. The PRRC is currently investigating additional opportunities to expand this inter-university research and development and technology transfer function.

The PRRC is committed to maintaining and increasing contact with the state's operators. Many New Mexico independent producing companies are managed by professional geologists and others who from time to time require engineering support. The

PRRC retains on staff a full time field petroleum engineer, William Weiss. Mr. Weiss provides New Mexico operators with advice and "troubleshooting" assistance to address production problems.

The PRRC also interacts with producers through an exchange of personnel. Scientists, geologists, engineers, and oil production personnel visit the center, sometimes for a year or more, to see the problem-solving techniques first hand.

In addition, the PRRC receives input from members of independent and major oil companies operating in New Mexico and members of oil and gas associations who make up an Industry Advisory Board. The Board meets in Socorro to discuss current PRRC projects and oil and gas research activities throughout the state and country.

Interaction between the PRRC and producers is important not only for identifying problems, but for solving them as well. A number of field trials representing joint efforts between the PRRC and oil operators, designed to improved oil and gas production, have been conducted for this purpose.

In the New Mexico Improved Oil Recovery Project, the PRRC has teamed up with members of the national laboratories, oil and gas associations, other universities, and representatives of major and independent oil companies to develop reservoir description technology. An oilfield property has been donated to New Mexico Tech for this project and tests at this site are being performed and planned. PRRC is working with industry operators in the Field Verification of CO₂-Foam project. The project involves the characterization of a reservoir with an ongoing CO₂-flood and the subsequent planning, implementation, and monitoring of a field test of CO₂-foam. It is being coordinated at the East Vacuum Grayburg/San-Andres unit, operated by Phillips Petroleum Company. Several of the unit working interest owners participate in a Joint Project Advisory Team, which serves as the first line for technology transfer from the project.

Through these processes a very important exchange function is performed. The producers learn on a one-to-one basis about currently available technologies to help remedy specific field and production problems. At the same time, the PRRC

learns from the perspective of the producer what the most prevalent production problems are. This interaction provides important input to the direction of the future research and technology transfer functions performed by the PRRC and its sponsoring organizations.

Key issues affecting the PRRC's plans for future R&D and technology transfer efforts center largely around continuity of funding. The PRRC's overall budget has continued to grow, even as the industry has contracted and reduced both staffing levels and R&D budgets. In highly focused technology areas, the PRRC has demonstrated that its cost-shared problem-solving efforts can be more cost effective than an in-house industry lab. The PRRC's base funding, however, has not grown in nominal dollars since 1985, thus requiring the center to operate with less resources at a time when it could be expanding its functions.

The PRRC's services have been well received by the New Mexico industry. Limited levels of funding and field personnel staffing, however, restrict the ability of the PRRC to more fully serve the technology transfer needs of the industry and the interests of the state in efficiently producing the resource.

Previous research has demonstrated that significant quantities of New Mexico's remaining oil resource could be produced at current prices with existing improved recovery processes. With additional funding and personnel, the PRRC could expand its problem identification, technology assessment, and R&D and technology transfer roles to more fully address the growing need for improved recovery technology in the state.

The New Mexico Bureau of Mines and Mineral Resources (Bureau) is also located on the NMIMT campus and operated by the school. Whereas the PRRC is the outlet for petroleum engineering research and technology, the Bureau, directed by State Geologist and Director Charles E. Chapin, conducts geological research and provides services to the community related to the geological and geophysical aspects of the State of New Mexico and its oil and gas resource base. The Bureau conducts an expanded version of the functions of a state geological survey.

Of the Bureau's full-time staff of approximately 50, the oil and gas section has a staff of four, including two petroleum geologists. Under the direction of oil and gas section head Ronald Broadhead, the Bureau also collects and serves as a central repository for geological data related to the oil and gas resource base. The Bureau's collection includes completion tickets, electro-magnetic, geophysical, and strip logs, drilling data, cuttings, and core samples on tens of thousands of wells drilled in the state. The Bureau also offers a wealth of reports, articles, publications, and open file reports.

From this research resource, the oil and gas section is developing an extensive interactive database and query system, at the well level, to provide data services for industry, academic, and public use. There are data on 90,000 wells. The system plans to include terminals located in the Oil Conservation Division's field offices in Artesia, Hobbs, and Aztec. The section also provides a full suite of surface and subsurface geologic mapping services. It is presently developing comprehensive oil and gas atlases of the state.

In addition to its collection and analytical functions, the Bureau is engaged in several technical outreach functions. As a service organization, the oil and gas section provides advisory services to New Mexico producers and offers producers technology referrals to the petroleum engineers at the PRRC. In addition, the section works closely with the New Mexico Geological Society in development of joint publications and the organization of an annual field trips to sites, outcrops, and other geologic features relevant to oil and gas production. The Bureau and the oil and gas section also contribute to the society's annual meeting and periodic workshops.

The Bureau of Mines and Mineral Resources and its oil and gas section appear to be highly interested in expanding their roles to assist further the producing industry in New Mexico through workshops, publications, and broadened application of the bureau's existing interactive data management and retrieval system. To expand its role as a resource center, the oil and gas section would need sufficient funding to expand its staff while drawing on the additional resources of the approximately 20 staff and graduate student assistants of the petroleum geology academic program at NMIMT.

With adequate resources, it is apparent that the PRRC, the petroleum engineering department, the Bureau, and the NMIMT geology department could effectively integrate their resources and functions to develop an integrated data information and technology resource center for the industry. While these individual components of the NMIMT already offer focused services to producers, an *integrated* function could achieve significant synergies of benefit to the producers, the NMIMT, and the state.

Other State Schools

The **New Mexico Junior College** offers an Associates Degree in Environmental and Petroleum Technology, but does not perform extensive R&D. However, the Hobbs Oil and Water Experimental (HOWE) Facility of the New Mexico Waste Management Educations and Research Consortium (WERC) is located on its campus. The HOWE facility is administered jointly with both the Petroleum Engineering Department and the PRRC at NMIMT. The WERC is a DOE pilot program involving state universities and national laboratories and directed by New Mexico State University. The purpose of the HOWE facility is to provide support for projects that study the minimization or management of oilfield wastes or other oilfield environmental concerns through the application of new technology and to provide technology transfer in those areas. There is extensive analytical capability at the HOWE facility, including: GC/MS, GC, Ion Chromatograph, and Atomic Absorption.

The **Oilfield Training Center (OTC) at Eastern NM University (ENMU)** is designed to prepare individuals for the oilpatch in the areas of drilling, well servicing, and production. OTC finds most of its interaction with industry coming from its advisory committee which keeps it up-to-date on oilpatch happenings, needs, and expectations. OTC staff assist the Bureau of Land Management (BLM) and industry seminars, Minerals Management Service (MMS) well control, H₂S and safety training, and other activities for industry. Facilities include an outdoor laboratory with a functional drilling rig, a production yard, pulling units, and pipeyards. There are five training holes under the rig (four of around 1,400 feet and one of around 870 feet). OTC has been involved in some experimental work on a bit as well as other limited research. Both NMJC and

ENMU have the potential to participate in oil and gas technology transfer.

Industry Organizations

Oil and gas production in the state is performed by a combination of major and independent producers. Most of the large and giant oil fields in southern New Mexico are primarily operated by the majors and very large independents with the participation of smaller and medium sized producers. According to the PRRC, there is a trend toward major companies contracting independent firms to produce certain reservoirs. With the exception of work performed under contract by the PRRC and NMIMT, virtually all of the research related to New Mexico reservoirs that is performed by the major operating companies is conducted at industry labs outside the state.

The New Mexico Oil and Gas Association (NMOGA), headquartered in Santa Fe, is a private organization that represents the interests of approximately 350 major and independent oil and gas producers in the state. The principal role of the association is to represent oil and gas interests before the state legislature and the Oil and Gas Conservation Division on legislative and regulatory matters. In addition, the association helps to ensure that its membership is aware of and able to comply with state and federal operating, environmental and regulatory requirements. NMOGA holds several meetings and conferences annually to address these matters and approaches to effective and economical compliance. NMOGA's experience in conducting workshops and seminars in these areas suggests that it might be an effective organization to assist or host performance of problem identification workshops or technology workshops in the state. NMOGA has expressed interest and willingness to expand its role in the area of technology transfer to New Mexico producers.

With gas production primarily in the northwestern part of the state and oil production primarily in the southeast, producers in the state share common interests and concerns with California regarding the gas resource and Texas regarding the oil resource. Many producers also belong to other associations such as Western Oil and Gas Association, the Rocky Mountain Oil and Gas Association, and the Independent Petroleum

Association of the Mountain States (IPAMS) which address regulatory concerns on a regional basis.

The Independent Petroleum Association of New Mexico (IPA), directed by Alvin Baca, is located in Santa Fe and represents the interests of independent oil and gas producers in the northern and southern regions of the state. IPA works with the legislature and the Oil Conservation Division on specific issues of concern to independent producers. IPA is a strong advocate of expanded application of advanced technology to increase oil and gas production and conserve the New Mexico resource.

The association has endorsed the concept of a national technology transfer umbrella organization and has pledged to cost share with such an organization. IPA holds periodic membership meetings and publishes a newsletter to keep its membership apprised of its actions before the legislature, to hear their views and concerns, and to inform them of new R&D and technology transfer opportunities in which New Mexico producers can participate.

Working in coordination with other organizations in the state and national R&D and technology organizations, IPA has the potential to play a broader significant role in introducing independents to technology solutions targeted at prevalent problems encountered in New Mexico reservoirs.

III. OBSERVATIONS

New Mexico's oil and gas technology transfer mechanisms are progressing well as indicated by positive cooperative relationships with the producing industry, other academic institutions, the Bureau of Mines and Minerals, the Oil Conservation Division and the legislature. In order to be fully effective, however, additional field engineering staff could be deployed to allow NMIMT and PRRC to be more proactive by expanding troubleshooting, problem-solving, and field assistance functions.

Recognizing increasing concerns of operators regarding environmental compliance, the PRRC is contemplating expansion in the direction of research and technology transfer in bioremediation of oilfield

wastes and broader aspects of petroleum E&P waste management. To achieve these goals and continue its research and development activities, additional funding will be required.

As with the PRRC, the Bureau of Mines and Minerals Oil and Gas Section has the potential to perform significantly expanded functions in support of oil and gas production in the state. These capabilities are constrained primarily by staffing levels and operating budget.

In combination, the PRRC, the Bureau of Mines and Minerals, and NMIMT's petroleum engineering and geology faculties and research staffs already in effect provide a centrally located resource center and data repository for New Mexico oil and gas operators. Although the "center" is not located directly in the producing region, extension offices could be located in producing areas. State-of-the-art communication and data transfer technologies could also avail producers of these resources and expertise.

The New Mexico Oil and Gas Association and the Independent Petroleum Association of New Mexico, in coordination with IPAMS, NMOGA and other organizations, can expand their roles in encouraging New Mexico producers to avail themselves of existing and emerging improved recovery technologies, data and information services, and troubleshooting assistance.

Ideally, problem identification seminars and technology transfer workshops focused on specific high priority problems encountered by producers should be conducted on a regular basis to sustain lines of communication and facilitate and expedite the transfer of technologies and information from the research community to producers and from the producers back to the R&D community.

The elements of effective technology transfer are in place. They need to be expanded and coordinated.

Source List

- American Petroleum Institute, *Basic Petroleum Databook*
- Department of Commerce, *Bureau of Economic Analysis*
- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price*
- Energy Information Administration, *Petroleum Supply Annals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

TECHNOLOGY TRANSFER CONTACT LIST FOR NEW MEXICO

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Eastern New Mexico University Oilfield Training Center	Bob Cates Associate Dean	Roswell	Phone: 505-624-7337 FAX: 505-624-7188
New Mexico Junior College	Steve McCleery Dean of Arts & Sciences	Hobbs	Phone: 505-392-5603 FAX: 505-392-2527
Petroleum Recovery Research Center	F. David Martin Director	Socorro	Phone: 505-835-5142 FAX: 505-835-6031
New Mexico Bureau of Mines and Mineral Resources	Ronald Broadhead Senior Petroleum Geologist	Socorro	Phone: 505-835-5402 FAX: 505-835-6333
New Mexico Oil and Gas Association	D. Van de Graaff Executive Vice President	Sante Fe	Phone: 505-982-2568 FAX: 505-986-1094
Independent Petroleum Association of New Mexico	Alvin Baca Director	Santa Fe	Phone: 505-982-2500

**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
OKLAHOMA**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR OKLAHOMA

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil Resources

Oil was first produced in Oklahoma in 1891. Through 1987, Oklahoma had produced 11.7 billion barrels (BB) of oil with about 29.8 BB of Oklahoma's 41.5 BB original-oil-in-place (OOIP), or 71.7%, still in the ground. With 0.8 BB in proved reserves, 29 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1). Virtually all of the Oklahoma oil resource is light oil.

Figure 1. Disccovered Oil Resource

Oklahoma's ROIP is concentrated primarily in three reservoir classes: Delta/Fluvial-Dominated, Strandplain/Barrier Cores and Shorefaces, and Shallow Shelf/Open reservoirs. The remaining portion of the resource is distributed across eight other geologic classes (Figure 2).

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas Resources

In Oklahoma, about 54% of the estimated 135.9 trillion cubic feet (Tcf) of natural gas resources has been produced. Of the remaining 62.6 Tcf, about 14.6 Tcf, less than 24%, is proved reserves. These proved reserves are recoverable under existing economic and operating conditions. The remaining 47.9 Tcf of undiscovered reserves is comprised of probable, possible, and speculative reserves and includes the portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Production

Seventy of Oklahoma's 77 counties have some oil and/or gas production (Figure 4). In 1991, there were 101,438 producing oil wells in the state, almost 89% of which were operated on artificial lift. Seventy-two percent of Oklahoma's producing wells are stripper wells, just below the national average.

Category	Tcf	%
Produced to Date	73.3	54.0%
Proved Reserves	14.7	10.8%
Probable	16.2	11.9%
Possible	16.2	11.9%
Undiscovered Reserves	15.3	11.3%
Total	135.9	100%

Natural Gas-in-Place 135.9 Tcf

Source: Potential Gas Agency
 Geological Survey of Mines
 & A. F.A.A.

Crude oil production in Oklahoma reached its peak in 1927 at 277.8 million barrels (MMB). Between 1980 and 1984, during the oil boom, crude oil production in the state increased by over 12% from 150.1 MMB to 168.4 MMB. Since 1985, however, production levels have declined steadily, falling almost 36% to 108.1 MMB in 1991 (Figure 5). These swings in production trends have

Year	Crude Oil Production (MBBLs)	Northward Price (1961\$)
1980	150	10.5
1981	155	10.8
1982	158	10.2
1983	158	9.8
1984	168	9.5
1985	162	9.2
1986	150	7.5
1987	135	8.0
1988	130	7.5
1989	115	8.0
1990	110	8.5
1991	108	8.0

Conversely, natural gas production in Oklahoma declined in the early 1980's, falling by 15% between 1982 and 1983. Since then, however, natural gas production has generally increased, reaching more than 2.3 Bcf in 1991 (Figure 6), which represents the peak natural gas production in the state's history. Due to new discoveries, the increase in production

Oklahoma State Profile

has come despite a concurrent steep decline in the wellhead price of natural gas. Between 1982 and 1991, natural gas wellhead prices, in 1991 dollars, fell by over 61% from \$3.83/Mcf to \$1.48/Mcf.

Figure 6. Natural Gas Production

Improved Oil Recovery

Oklahoma currently ranks third among the lower-48 states in known remaining oil-in-place. This remaining resource is the target for new and emerging improved recovery technologies. Enhanced oil recovery (EOR) efforts have been applied in Oklahoma since 1977. Thirteen EOR projects have been conducted or are currently on-going in Oklahoma reservoirs. Almost half of these have been conducted using chemical EOR methods (three polymer floods, one microbial, and one micellar-polymer project). The remainder of the projects involve gas EOR methods (CO₂ miscible, hydrocarbon miscible, nitrogen immiscible) and one steam flood. Additional projects have been planned or recently initiated using innovative microbial oil recovery processes.

While crude oil production by EOR methods still represents a relatively small portion of the Oklahoma total, just over 2%, the combination of the large remaining resource and declining conventional production rates suggest that Oklahoma may be a prime target for future EOR efforts at higher oil prices.

Although many tertiary EOR processes are at best marginally economic at today's oil prices, advanced secondary recovery processes such as targeted infill drilling using advanced reservoir

characterization techniques, horizontal drilling, and improved waterflooding techniques all have significant potential in Oklahoma reservoirs. These and other advanced secondary technologies can help sustain production in marginal fields as new technology is being developed.

Oil and Gas Reserves

Even with oil production and reserves in decline, Oklahoma still ranks fourth in production and fifth in proved oil reserves among the lower-48 producing states. Between 1982 and 1991, Oklahoma's crude oil reserve levels fell by almost 28% (Figure 7). Even as prices have stabilized, reserves have continued to plummet.

Figure 7. Crude Oil Reserves

Natural gas reserves, on the other hand, increased during the early 1980's due to new discoveries. These levels were sustained, despite falling prices, through 1990 and have since begun to fall (Figure 8). From 1980 to 1983, reserves increased by over 23% and grew to 16.7 Tcf in 1987 before declining to 14.7 in 1991.

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques, or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. Since 1982, annual well abandonments in Oklahoma have risen steadily. Between 1981 and

1990, stripper well abandonments more than tripled, rising from about 675 to almost 2,100, before decreasing slightly in 1991. These abandonments have been spurred not only by depressed prices, but also by concern about future environmental regulations and uncertainty as to the potential of technology to produce more oil economically (Figure 9).

Figure 8. Natural Gas Reserves

Figure 9. Stripper Well Abandonments

Exploration

The steady drop in wellhead prices in Oklahoma during the 1980's led to a decrease in drilling activity. After 1981, the number of operating rotary rigs fell by nearly 85% from 698 to 105 rigs in operation in 1991. Consistent with the national trend, oil and gas exploratory activity is also in decline in Oklahoma. The drilling of exploratory wells in proven areas and new-field wildcats in

previously unexplored areas experienced a decline similar to that of active rotary rigs. Between 1981 and 1986, exploratory well drilling dropped 70%. Between 1986 and 1991, activity levels fluctuated but remained below those of the early part of the decade. Between 1981 and 1989, wildcat well drilling fell by almost 62%. Although activity then increased slightly in 1991, it still remains far below the levels of the early 1980's. New field discoveries and extensions have not replace produced reserves. Development well drilling, conducted in areas of proven production, fell by 82% between 1981 and 1991.

Economic Impacts

Between 1982 and 1989, overall employment in Oklahoma's oil and gas producing, marketing, and refining industry fell by over 51%. During that same time span, employment in the oil and gas extraction sector of the industry dropped by over 60% (Figure 10). Of the more than 68,000 industry jobs lost during the downturn, over 61,000 of them were in extraction sector. Since 1987, extraction industry employment has leveled out, but has not returned to previous employment levels.

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and persistent low prices for crude oil have also resulted in a decrease in the wellhead value of crude oil and natural gas production. The wellhead value of crude oil decreased in real terms by over 74% from its 1981 level of \$8 billion to its 1991 level of \$2 billion, with the largest portion of the decrease coming between 1985 and 1986 when the value more than halved. The influence of rapidly

decreasing prices outweighed that of modestly increasing production rates to lead to a decline in the value of natural gas production. Much like crude oil, the value of natural gas production fell 53% from 1982 to 1987 with the largest drop coming between 1985 and 1986. A slight increase in value was made before falling to \$3.4 billion in 1991.

The continuing decline in crude oil production and low wellhead prices for both oil and natural gas resulted in depressed overall levels of wellhead value of production from 1986 through 1991. As state severance taxes are calculated as a millage on the value of production, direct state revenues from oil and gas production correspondingly fell. While severance tax revenues, on a constant dollar basis, have fluctuated since 1983, the \$419 million dollars collected in 1991 is fully 60 percent less than the amount collected in 1983, in real terms (1991 dollars).

Oil and natural gas production remain the largest single element of Oklahoma's economic base. In addition to the direct effects of reduced wellhead value of production and extraction sector employment, corresponding reductions in petroleum related economic activity and employment are having a significant impact on employment tax revenues and the overall health of the State's economy. Increasing natural gas prices and production during 1992 promise some relief from current conditions, but it is clear that the state has a vital stake in preserving a viable oil and natural gas producing industry.

Oklahoma has recognized the threat of resource abandonments and the promise of improved recovery technologies for many years. It was among the first states to encourage broad use of waterflooding techniques. In 1987, the Oklahoma Legislature passed a bill offering producers an exemption from the 7% production tax on all incremental oil produced from secondary and tertiary projects until payback or for three years, whichever is less. The bill excludes standard waterfloods.

Other Industry Concerns

Several states, including Oklahoma, Texas, and Louisiana have sought in recent years to enact regulations to allow the state to prorate natural gas production, much as Texas and Oklahoma have prorationed oil production, in order to avoid the

physical waste of the resource through overproduction or premature abandonments. The U.S. Congress expressed its sense that prorationing for the sake of conservation is acceptable so long as the sole purpose is not to artificially support higher prices. To the extent that gas prorationing continues to be allowed, higher prices for gas should stimulate further exploration and production in Oklahoma.

The impacts of increasingly stringent environmental regulations on Oklahoma producers has contributed to the accelerating rate of well abandonments and consequent resource abandonments. Of particular concern is the issue of continuing future liability for environmental hazards even after a well has been transferred to a new owner. This plugging and abandonment liability issue also extends to increasing costs to the state to plug and abandon so called idle orphaned wells that have been abandoned by insolvent operators. The state has recommended a reclamation fund based on a tax on production to cover these costs. The effect of the tax, however, is to further increase costs of production. The industry, through a Stripper Well Commission, is examining ways to address these problems without placing further onerous costs on producers or encouraging even more premature reservoir abandonment.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

The need for broad and effective technology transfer in Oklahoma is clear. If companies are to maximize production of the Oklahoma oil resource before premature abandonment makes it uneconomic to produce, state-of-the-art operations are essential. As the responsibility and opportunity for producing the resource increasingly shifts to the independents, they will require broad access to and understanding of improved oil and gas recovery technology and related information and resources.

In the *near-term*, technology transfer has the opportunity to deploy *existing* technologies to defer reservoir abandonments and preserve access to the reservoirs and the resource base for application of even more efficient emerging technologies and improvements in geoscientific understanding. In the *mid-term*, technology transfer functions can ensure the broad deployment of *emerging* technologies and

advances in the knowledge base. These activities will provide the structure for continuing interactive technology transfer and communication between the private, state, federal, and academic R&D communities and the producing community as *new* technologies and processes are developed over the *long-term*.

Petroleum R&D and Technology Transfer Organizations

There are numerous public and private entities in Oklahoma currently engaged in performing oil and gas research targeted at the Oklahoma resource base, disseminating results and information, and offering technology assistance and related services to Oklahoma oil and gas producers. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1) and observations as to how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to Oklahoma producers.

State Agency

The **Oklahoma Corporation Commission Oil and Gas Division** located in Oklahoma City, is the principal regulator of oil and natural gas exploration and production activities in the state. It is responsible for oil and gas prorationing activities in the state. The Division issues well permits, monitors regulatory compliance, oversees underground injection practices, and reviews proposed improved oil recovery projects in the state. In addition, the Division collects, analyzes and disseminates a broad range of statistical data on oil and gas extraction activity and production and injection volumes. With increasing environmental concerns, the Commission has an increased role in the monitoring and enforcement of compliance with environmental protection requirements. Numerous organizations have recently recommended that funding for the operations of the oil and gas division of the Commission be expanded significantly to enable the Commission to carry on this role fully.

OKLAHOMA	Current or Potential Oil and Gas Technology Transfer Functions																										
	Data & Publications						Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance									
	Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering			
Organization																											
State Agencies																											
Oklahoma Corporation Commission Oil and Gas Division	C	C	C		C			C							P												
Oklahoma Geological Survey	C	C	C		C	C		C	C	P	C	P	P	P	P					C	P	P					
Research Universities																											
University of Oklahoma Energy Center				C		C	C	P	P	P	C		P	P		C	C	C	C	P		C	C	P			
University of Tulsa				P		P	C	P	C	P	P		P	P		C	C	C	P	C		P	P	P			
Oklahoma State University							C									C	C										
Center for Reservoir Characterization	C			P		C	C			P	C	P	P			C	C		P	P	P	P	P	P			
Industry Organizations																											
Oklahoma Independent Petroleum Association				C				P	P	P		P	P		P						P						
C = Currently performs																								P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints			

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

The Commission from time to time sponsors seminars to teach operators how to comply with state and federal reporting requirements. However, the Commission does not conduct or sponsor research related to improved oil and gas recovery technologies or engage in any other direct technology transfer functions.

Geological Survey

The **Oklahoma Geological Survey (OGS)** is a state agency operated by the University of Oklahoma. The expressed mission of OGS is "to decipher the state's geological history, assess its mineral and energy resources, identify hazards that may exist with regard to these resources, and to disseminate the results" of multidisciplinary studies and research to the public and to industry for the common good.

Under the direction of State Geologist Charles J. Mankin, OGS conducts extensive geological, geophysical and statistical research and analyses directly related to the state's extensive oil and gas resources and exploration and production activities. OGS studies and analyses frequently predict or highlight areas of concern that must be addressed by researchers and/or policymakers. Recent studies have addressed regional subsurface structures, features and trends, identification and description of natural gas plays, geologic assessments of specific structures, and preliminary evaluations of coalbed methane potential in the state. OGS is also a key participant in the OU Energy Center and its Gypsy Reservoir Characterization Laboratory.

OGS' extensive lab, samples, and data facilities enhance its abilities to conduct detailed studies and to respond quickly to requests for information and assistance from the producing community, regulators, state and national legislative bodies, and the Governor of Oklahoma. OGS' data and information services and technical assistance functions are a key element in effective technology transfer to Oklahoma producers.

The centerpiece of the OGS oil and gas data and information function is its Natural Resources Information System (NRIS) which was developed with support from the U.S. Department of Energy. NRIS is an integrated data management and retrieval system that contains extensive data on the state's

mineral and energy resources. The oil and gas component consists of two major data sets: Monthly oil and gas production by lease and a historical well data set containing current and historical data on more than 400,000 wells drilled in Oklahoma.

A user lab is currently being developed in association with NRIS to allow public use of and access to NRIS data and analytical capabilities. The lab will be staffed with qualified oil and gas geoscientists and other personnel to provide high quality technical and analytical assistance to NRIS users, including producers and other researchers.

The OGS Well Log Library is a repository for suites of logs from over 200,000 wells and completion reports for 400,000 wells. The Core and Sample Library contains cores from over 2,500 wells and samples from about 40,000 wells drilled in the state. Information on the location, depth, formations penetrated, and general conditions of each core is recorded and catalogued for easy reference. Both facilities are open to the public and staffed to assist visitors. Data from the Core and Sample Library is also available on-line.

OGS addresses inquiries from the general citizenry regarding the oil and gas potential of properties, oil and gas environmental matters, and general information about the state's oil and gas industry. It also performs analytical functions to respond to requests from the Governor, the Oklahoma Legislature, the U.S. Congress and numerous regional and federal agencies, commissions, and task forces.

In addition to its research, libraries, and public access information services, OGS actively seeks to provide technical information and direct technical assistance to major and independent oil and gas operators in the state. This occurs through several specific functions:

- Briefings and training are provided to individual companies on a small company consultation basis to address needs and concerns with regard to geological interpretation, reservoir characterization, exploration prospects, surveys, and regional trends, and technology requirements.

- An OGS/OU annual regional technical workshop is held each spring with DOE's Bartlesville Research Facility to address a specific priority concern of mid-continent oil and gas producers. In 1993 the workshop will address operations and problems in Fluvial Dominated reservoirs. These workshops are held in the facilities of the OU Center for Continuing Education in Norman which houses a computer laboratory
- As part of the University of Oklahoma Energy Center, OGS personnel work with the faculty of the OU Geology and Geophysics and OU Petroleum Engineering Departments to offer petroleum education and training courses through the OU Center for Continuing Education.

At request of the Governor and the industry, OGS has also developed a new Stripper Well Commission which intends to recognize and suggest solutions to address problems posed by increasingly large numbers of stripper wells and well abandonments. The purpose of the Commission is to find ways to keep stripper wells producing until currently available and emerging improved oil recovery processes can be economically deployed. This Commission is presently wrestling alternative approaches to self-insurance for plugging and abandonment and environmental liability.

As with other geological surveys, OGS personnel also participate actively in a broad variety of functions sponsored by geological and geophysical professional societies (such as AAPG and SEG) and industry trade associations and publish technical articles and research results in their technical and scientific journals.

Research Universities

The majority of the petroleum-related engineering and geoscience-related research performed in Oklahoma is conducted by two prominent universities, the public University of Oklahoma and the private University of Tulsa. Additional research is also performed by Oklahoma State University.

The University of Oklahoma Sarkey's Energy Center serves as a coordinator of research and

development and technology transfer programs performed by the University related to oil and natural gas exploration and production and associated geosciences. The Oklahoma Geological Survey, discussed above, the School of Petroleum and Geologic Engineering, the School of Geology and Geophysics, and the Geological Information Systems department are part of the Energy Center organization. These academic and research departments are all housed in the Sarkey's Energy Center building, a fifteen story structure with 340 offices, 55 teaching laboratories, and 135 research laboratories. The annual combined petroleum research related budget of the Energy Center exceeds \$20 million. The center is committed to performing multi-disciplinary research and aggressive technology transfer to major and independent producers.

The University of Oklahoma's School of Petroleum and Geologic Engineering (PGE) has a research staff of approximately 13 people. Work is done in several areas, including microbial enhanced oil recovery (EOR), rock mechanics and well completions, production technology and reservoir engineering, and natural gas exploitation. Under each general category, there are several specific topic areas in which research is conducted. Currently, projects are funded from four different sources: the Department of Energy (DOE), the Oklahoma Center for the Advancement of Science and Technology (OCAST), the Gas Research Institute (GRI), and industry support.

DOE is funding several projects related to microbial EOR. The projects include a study of the effects on carbonate reservoirs, field pilot studies, and quantification of microbial products and their effectiveness. There are also studies being done on predictability of formation damage, characterization of non-Darcy flow in petroleum bearing formations, and assessment of dispersion measurement as a method of quantifying geologic characterization and defining reservoir heterogeneity. The total funding being provided by DOE is just below \$2.0 million.

OCAST is providing approximately \$1.2 million in funding for several projects. Research is being conducted on technology for exploiting naturally fractured reservoirs and horizontal drilling to improve oil and gas recovery. An expert system is being developed for reservoir completion and stimulation. In addition to general rock mechanics

research, studies are being done on pore collapse problems in oil reservoirs.

GRI is presently funding three projects at a total level of approximately \$16.6 million. A feasibility study on fracturing fluid characterization is being conducted as a fracturing fluid characterization facility is being developed. In addition, a solvent treatment is being developed for enhanced recovery of coaled methane.

Industry provides support for general PGE research and for other oil- and gas-related projects. There is a rock mechanics research consortium with 13 major and international petroleum companies and service companies. Also, Exxon is funding the development of digital data acquisition and processing system drilling simulator. Total industry support falls just below \$2.2 million.

The **OU Center for Reservoir Characterization (CRC)**, directed by Dr. Daniel J. O'Meara, conducts an intensive program of applied interdisciplinary geoscience and engineering that stresses implementation of current and emerging technologies. CRC's mission is to assist and support its clients in improving recovery of oil and gas through better reservoir characterization. CRC believes the key to accomplishing this goal is communication with field operators, encouraging a two-way information flow.

CRC's principal R&D work is the Gypsy Field Project, a field-scale laboratory for reservoir characterization which was contributed to the University by British Petroleum (BP) Exploration. The Gypsy Field Project is still funded by BP through an annual \$250,000 grant. This is in addition to the \$4.3 million that BP spent on the project before it was donated. The University of Oklahoma matches the \$250,000, and DOE contributes \$350,000 annually.

The Gypsy project involves the testing of an outcrop of a reservoir that has been exposed where a road was cut through the ground. Researchers can observe the reservoir containing six fluvial channels, both at the surface, and 20,000 feet underground where it lies 20 miles away.

The field site is designed to bring together researchers from all relevant geoscience and

engineering disciplines. Many projects have been conducted to learn about the reservoir itself and recovery processes. OGS transfers this information and technology through a database constructed for demonstration and training. CRC is in the process of developing a consortium to fund an integrated R&D program in the Gypsy formation. Besides communication with operators and the Gypsy Field Project database, CRC transfers technology through a quarterly newsletter and by encouraging personnel exchanges with its corporate partners.

Technology transfer from the research programs of the OU Energy Center and its component research organizations occurs through a variety of approaches. Industry funded work is transferred through personnel exchanges with the sponsoring organizations, seminars and workshops with company-sponsor personnel, and advance copies of research reports, technical reports, and publications before general release. Each industry research agreement includes explicit provisions governing the ownership of intellectual property and permitting university researchers to publish their results either immediately or after a prescribed period of time. Efforts that include federal funding also require publication and release of the research methodology, approach, activities, and results.

The Gypsy project is an exceptional example of the potential for cooperative, interactive, multi-disciplinary technology transfer. In return for funding partners receive:

- Exclusive access to the Gypsy data set;
- A seat on the external advisory board that governs projects in the outcrop laboratory;
- The right to designate one graduate student each year;
- Preferential access to Gypsy field sites;
- Royalty-free license to technologies developed by the CRC during their sponsorship;
- Technical reports on all projects supported by the Center for Reservoir Characterization;

- Participation in personnel transfers and other technology transfer functions;
- A quarterly newsletter; and
- Participation in the CRC annual technical meeting.

Technology transfer is also facilitated through the participation of other research organizations in the Gypsy research projects and outcrop laboratory. Additional research participants have included:

- DOE Lawrence Berkeley Lab for crosswell seismic measurements and fractal well tests;
- Western Research to develop and test geostatistical software;
- GRI/New England Research for seismic/sonic detection of heterogeneities;
- University of Leeds and Manchester University for Ground Penetrating Radar.

The OU Center for Reservoir Characterization, the Oklahoma Center for Advanced Science and Technology, and the engineering and geological academic and research departments that comprise the OU Energy Center have an exceptional opportunity to coordinate their R&D and technology transfer efforts into a highly beneficial interdisciplinary resource center to benefit all producers in the State of Oklahoma and to provide significant additional benefits to producers throughout the nation.

The **University of Tulsa** is also actively engaged in oil and gas R&D. The university's Petroleum Engineering Department, chaired by Dr. Stefan Miska, conducts a wide range of oil and gas related research, most of which is closely coordinated with the oil and gas industry. The funding levels have stayed around \$2 million for each of the last three fiscal years, and it is anticipated that it will remain at this level for the foreseeable future. The majority of this funding comes from private businesses. The bulk of the R&D work done at the University involves four cooperative research projects conducted with industry:

- University of Tulsa Drilling Research Projects (TUDRP) -- TUDRP conducts

applied drilling research, including fundamental studies in rock mechanics and drilling fluids. Twenty-two national and international production and service companies contribute support to the programs which have funding of approximately \$400,000. Sixty individual projects have already been completed since the formation of TUDRP. There are six currently being conducted.

- University of Tulsa Fluid Flow Projects (TUFFP) -- The program seeks to identify and solve problems involved in the production, transportation, and separation of oil, water, and natural gas. Twenty-nine national and international firms contribute support to TUFFP which has funding of approximately \$600,000. Seventy-five projects have been completed since its formation and there are four currently being conducted.
- University of Tulsa Artificial Lift Projects (TUALP) -- TUALP conducts research in artificial lift systems in order to understand their performance and maximize their efficiency. Eighteen production and service companies support the work through membership fees which total around \$380,000. The program has approximately \$4 million in equipment and is currently conducting seven projects.
- University of Tulsa Petroleum Reservoir Exploitation Projects (TUPREP) -- The program conducts basic and applied research in well testing, reservoir characterization, and simulation. The focus of TUPREP projects is generally theoretical. There are eight projects currently being conducted.

The University of Tulsa's technology transfer function is effected largely through industry's involvement in the cooperative research projects. Through membership on the advisory boards for each project, the sponsors have direct input into the specific types of projects that will be carried out. In addition, University faculty, graduate students, and research staff write an extensive number of papers and conduct many lectures and presentations. These traditional types of activities bring the research

results to those in industry who are not directly involved in the cooperative research efforts. Largely, these recipients are intermediate transferrers of new technology information such as researchers, other service companies, or large independents.

Industry Organizations

The **Oklahoma Independent Petroleum Association (OIPA)** is an industry trade association representing the interests and concerns of Oklahoma independent oil and gas producers. Headquartered in Oklahoma City, OIPA is run by Executive Vice President Mickey Thompson. Most of the current functions of OIPA relate to informing members of changes in operating and environmental protection regulations, informing them of strategies for compliance, and communicating concerns and interests back to the regulatory agency and to the state legislature and the national independent industry association (IPAA). OIPA also informs its members of opportunities for participation in public and private research and demonstration projects. OIPA coordinates with other independent producers through its participation in the Liaison Committee of Cooperating Oil and Gas Associations and through the Independent Petroleum Association of America.

With a small staff and limited budget, OIPA communicates to its members through a newsletter and periodic membership meetings. Nonetheless, by virtue of its direct access to and relationship with Oklahoma's independent producers, OIPA will perform a significant role in encouraging independents to participate in technology transfer functions.

Recently, OIPA has been selected to coordinate with the Gas Research Institute (GRI) to transfer the results of GRI's Supply R&D Program to the independent producers of natural gas, and to help GRI identify and prioritize its R&D initiatives. OIPA will work with regional GRI technology transfer agents to accomplish this. OIPA has expressed interest in participating actively in a nationally and regionally coordinated technology transfer process.

Industry Research Labs

Several large petroleum industry production engineering and geoscience research labs, operated

by major producers and service companies, are located in the state. Many of the producing company labs maintain close and expanding working relationships with the university research organizations, particularly as internal R&D functions are pared back and R&D tasks are refocused to other resource targets.

Technology developments are transferred directly and indirectly to producers. In the case of the producing company's labs, cooperative R&D performed with the universities is released at a relatively fast track as consortia members share results and academic researchers publish in trade and scholarly journals. Broad dissemination of results through field demonstrations and other activities is not typical. Nor are public access workshops and other technology dispersion techniques.

In the case of service companies, research is designed to develop technologies for broader application. Technology is transferred on a commercial basis directly to producers including owners, engineers and geologists, and field personnel through training courses, briefings, trade show exhibitions, advertising, and a variety of other means. Technology is also transferred through direct marketing of services to apply the technology to resolve a specific problem in a particular well or field.

III. OBSERVATIONS

Virtually all of the elements required for effective technology transfer to the entire producing community in Oklahoma are present:

- Majors and service companies sponsor university/cooperative R&D at OU and UT
- Both universities perform R&D with applications for majors and independents
- Industry and service company labs produce research results and technology advances
- OGS provides essential geoscience and improved recovery data, analysis, and insight to major and independent industry users and state and federal government entities

- OIPA provides a potential focal point for communicating technology opportunities to independent producers.
- Changing economics, demographics, and industry structure are removing competitive and regulatory constraints to inter-company cooperation

What is missing from the Oklahoma profile is a structural framework and systematic approach for putting all of these pieces together on a cooperative basis. There is significant potential to achieve synergies in Oklahoma through cooperation of the major and independent producing industry, public and private universities, and government funded research organizations in defining and prioritizing R&D and conducting focused and systematic technology transfer.

Broader technology transfer effectiveness will only occur through concerted efforts to address the needs of the independent producing community in the R&D program design. This requires a concerted effort by performers of research as well as by the independent producing community itself. Independent producer associations must recognize and accept the potential of technology and continued training and convince their membership of the same.

A strong industry association that accepts the challenge and the potential of advanced technology and continuing education can provide essential leadership to insure independent producers have input to the direction of government and university research programs and to the structure and content of technology transfer programs.

OIPA, with support from its national organization, can motivate independent producers to examine and apply improved E&P technologies. OIPA can begin by providing a framework for problem identification and needs assessment by

independents and by serving as a host organization for coordination and presentation of technological solutions to independent producers by the state's numerous R&D and technology transfer organizations. The OU Energy Center, the Geological Survey, UT, major and service company R&D labs, and DOE's research lab can and should participate in this process.

Besides coordinating with each other, Oklahoma's organizations have a significant opportunity to coordinate with federal agencies. The Oklahoma oil and gas industry could benefit through a stronger relationship with the federal research laboratory in Bartlesville. This opportunity will be enhanced as a new Federal Oil Research and Development Program is implemented and a new mission and structure of management is introduced at Bartlesville. The importance of natural gas in Oklahoma also suggests that significant benefits can be achieved through coordination with DOE's gas research programs.

Oklahoma has each piece of the puzzle, but they must be put into place to form the picture of successful technology transfer.

Source List

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- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price*
- Energy Information Administration, *Petroleum Supply Annuals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

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**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
TEXAS**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR TEXAS

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil was first discovered in Texas in 1866. Since then, more than 161 billion barrels of original-oil-in-place (OOIP) have been discovered. Through 1987, Texas had produced 51 billion barrels (BB) of oil, leaving 110 BB, or 68.4% still in the ground. With 7 BB in proved reserves (including offshore), 103 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

Texas' ROIP is widely distributed across several reservoir classes with the Shallow Shelf/Open and Shallow Shelf/Restricted reservoirs containing the largest portions. The remaining portions of the resource are dispersed across 15 other geologic classes (Figure 2). With such a wide distribution of oil resources, Texas operators face a range of producing problems not experienced in other states.

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

Natural Gas

In Texas, a full 66.4% of the estimated 447 trillion cubic feet (Tcf) natural gas resource (including offshore) has been produced. Of the remaining 150 Tcf, almost 30% is proved reserves, that are recoverable under existing economic and operating conditions. The remaining 107 Tcf of undiscovered reserves is comprised of probable, possible, and speculative reserves and includes a portion of the discovered but unconfirmed gas resource that is not included in proved reserves (Figure 3).

Production

Two hundred and sixteen of Texas' 254 counties have some oil and/or gas production (Figure 4). There were close to 192,500 producing oil wells in the state in 1991, 92% of which were operated on artificial lift. Over 66% of Texas' producing wells

Figure 3. Natural Gas Resource

are stripper wells (versus the national average of 79%). Stripper wells account for almost 20% of the crude oil produced in the state. Texas also has production in the western portion of the Gulf of Mexico. Over 4% of Texas' oil production is attributable to offshore platforms.

Crude oil production in Texas reached its peak in 1972 at 1.3 BB and declined to 977 million barrels (MMB) by 1980. Since 1980, crude oil production

in the state has been in a steady and consistent decline. During the span of 1980 to 1991, annual production has fallen by over 28% to 702.4 MMB (Figure 5). Between 1981 and 1986, wellhead prices (in 1991 dollars) for crude oil in Texas fell by nearly 66 percent. After 1986, the price made a modest recovery, but it was unstable and generally low. Despite the production decline, Texas is currently the largest oil producing state in the nation and by far the largest producer in the lower-48.

Figure 5. Crude Oil Production

Figure 4. Counties with Active Production

Texas natural gas production peaked in 1972 at 8.7 Tcf. By the early 1980's, natural gas production in Texas was also in steep decline. Between 1980 and 1983, production fell by almost 17%. After that time, natural gas production made a recovery to the 1991 production level of 6.3 Tcf (Figure 6). Natural gas wellhead prices appear to be going in the direction opposite from production. From 1980 to 1983, natural gas prices (in 1991 dollars) rose by almost 24% before falling by nearly 54% to the 1991 price of \$1.47/Mcf.

Figure 6. Natural Gas Production

Tertiary Enhanced Oil Recovery

Tertiary enhanced oil recovery (EOR) efforts have been undertaken in Texas since 1966. Given the diversity of geologic settings and associated producing problems, a wide variety of EOR methods have been applied. Sixty-three EOR projects have been conducted or are currently on-going in Texas reservoirs. The majority of these, 36, have been conducted using CO₂ methods, primarily CO₂ miscible floods. The remainder of the projects are split between thermal (mostly steam) and chemical (mostly polymer) EOR techniques. Additional projects have been planned using steam flooding and CO₂ miscible processes. While crude oil production by EOR processes represents a relatively small portion of the Texas total, 7%, the large remaining resource and declining conventional production make Texas a prime target for continued EOR efforts.

Reserves

Texas currently ranks first in the nation, by a wide margin, in terms of known remaining oil in place. Proved oil reserves dropped by almost 13% between 1985 and 1991. However, Texas still led the nation in total reserves with 6.9 BB in 1991 (including offshore). During the course of the 1980's, reserves trends followed those of prices fairly closely (Figure 7).

Figure 7. Crude Oil Reserves

Texas natural gas reserves also declined steadily throughout the 1980's with the steepest drop coming between 1984 and 1985 when reserves fell by almost 20%. Like crude oil, natural gas reserves fell with the price, but reserves fell more slowly (Figure 8).

Figure 8. Natural Gas Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. Preventing the premature abandonment of the resource is particularly important in Texas due to its large share of the nation's ROIP. During the better part of the 1980's, well abandonments in Texas increased dramatically. Between 1981 and 1987, abandonments increased by over 290%. While the total has since fallen by nearly 35% to 4,959 wells in 1991, it is still far above the 1981 level and poses a significant threat to remaining oil reserves (Figure 9).

Figure 9. Stripper Wells Abandonments

Exploration

The steady drop in wellhead prices in Texas during the 1980's led to a decrease in rotary rig activity and well drilling. Between 1981 and 1989, the number of operating rotary rigs fell by 80%. The total has since made a modest recovery but is still far below the level of the early 1980's, consistent with the national trend. The drilling of exploratory wells in proven areas and new-field wildcats in previously unexplored areas have both declined dramatically. Exploratory well drilling dropped nearly 74% between 1984 and 1991 as reflected in reserves and production data. Since 1981, new-field wildcat drilling has fallen by almost 86%. New field discoveries and extensions have not replaced produced reserves. Even development well drilling,

conducted in areas of proven production, fell by over 70% between 1984 and 1989. Developmental wells have since made a slight recovery but totals are still far below those of the early 1980's.

Economic Impacts

Between 1982 and 1989, overall employment in Texas's oil and gas industry fell by over 35%. During that time span, employment in the oil and gas extraction sector of the industry dropped by over 45% (Figure 10). The extraction sector and the industry as a whole have made a slight recovery in recent years but not enough of one to recoup the more than 153,000 jobs that were lost during the downturn.

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and persistent low prices have also resulted in a decrease in the wellhead value of production. The wellhead value of crude oil decreased in real terms by nearly 70% between 1981 and 1986, before falling to \$13 billion in 1991 (a decrease of 73% from 1981). The value of natural gas production likewise fell sharply during the 1980's. After 1982, the value of the produced natural gas fell by almost 53% by 1991. The decline in production totals and the subsequent decline in the value of production led to a decrease in state revenue from severance and production taxes. Between 1982 and 1990, the amount of severance and production taxes collected by the state of Texas fell by over 66%. Yet even with declining production, activity, and prices, Texas still collected \$1.35 billion from the industry. Given the number of jobs involved and

the income and other taxes received from producers, the state has a clear stake in maintaining a viable petroleum producing industry.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

Effective, interactive problem identification, needs analysis, research and development, and technology transfer and bi-directional communications are the keys to unlocking the potential of Texas's remaining hydrocarbon resource. Accelerated rates of abandonment make implementation of these functions urgent.

In the *near-term*, focused technology transfer has the potential to stimulate operators' awareness and deployment of effective, *already proven* technologies to increase production or reduce operating costs to defer premature abandonments. These deferrals preserve future economic access to the reservoir for application of even more effective *emerging* technologies. In the *mid-term*, e.g. five to ten years, technology transfer can ensure the broad deployment of newly *emerging* technologies and improvements in the technological knowledge base. These activities, if performed soon, will provide the structure and systematic approach for continuing interactive technology transfer and communications between the private, state, federal, and academic performers of petroleum R&D and the producing community as new technologies, processes, and knowledge are developed over the *long-term*.

R&D and Technology Transfer Organizations and Current Functions

Numerous national, state, academic, and industry entities in Texas *already* perform oil and gas exploration and extraction-related research, disseminate results, and offer technology assistance and/or training to oil and gas producers. Discussed below are the current activities and capabilities of the most prominent of these organizations in terms of their structure, mission, resources, and approaches to technology outreach and transfer. Finally, the profile offers suggestions as to how these organizations and functions might be expanded, modified, or otherwise improved to expedite effective near-term, mid-term,

and long-term technology transfer to Texas oil and gas producers.

State/Regional Agencies

The **Office of Governor Ann Richards**, has taken an active interest in the expansion of oil and gas technology transfer efforts to better address the priority problems and current and future needs of the independent producing community in Texas. The Governor's Office, through the State Energy Representative, has made significant funds available from the state's oil overcharge funds. The funds are used to support a state-industry cost-shared technology transfer program of technology forums, workshops, and information and data resource centers. This program is discussed in greater detail in the Industry Organizations section of this profile.

Under the direction of Chairman James E. (Jim) Nugent, Commissioner Mary Scott Nahers, and Commissioner Barry Williamson, the **Railroad Commission of Texas (RRC)**, headquartered in Austin, is the principal regulator of the oil and gas drilling, producing, and transportation industry in the state and the conservator of the oil and gas resource base. The RRC is highly regarded among the producing states and by other producing nations as a model for regulation of oil and gas exploration, production, and conservation.

The RRC's Oil and Gas Division, directed by David M. Garlick and Assistant Directors Rex King and Jerry Mullican, receives, analyzes, and makes available a variety of reports, maps, test results, well logs, and exploration, drilling, production, abandonments, and other data at the field, pool, and well level. The RRC also maintains for public use thousands of surface maps and plats on drilling and production activities.

The RRC's best known role, as conservator of the resource, is to prorate oil and gas production to prevent over-production. This process sets aggregate production levels for the state and allocates allowable production to operators on a pro rata basis. The RRC also approves new projects, certifies advanced secondary and enhanced oil recovery, certifies tight gas and other unconventional gas resources, and enforces compliance with plugging, abandonment, environmental protection and other regulations. Thus the RRC has the capacity and authority to take

actions to ensure that reservoirs are produced efficiently from a technological and resource standpoint.

The RRC does not directly perform research. It does sponsor workshops and seminars to educate producers and the public on state and federal regulations and methods for compliance with operating, safety, and reporting requirements. Recent workshops have addressed groundwater protection, hydrogen sulfide safety, natural gas policy, oil forms and procedures, and gas prorationing. These seminars are offered on a continuing basis. The RRC has the potential to expand its workshop focus to address more problem- and technology-specific issues. However, as these functions are already performed by other institutions in Texas they are perhaps best performed by others.

Geological Survey

The Bureau of Economic Geology (BEG), a division of The University of Texas at Austin, has been the state's geologic survey since 1909. Directed by State Geologist William L. Fisher, BEG is one of the nation's largest public geoscience and energy resource research entities. BEG is responsible for researching, analyzing, and disseminating information about all of the state's geological attributes and mineral resources. About two-thirds of BEG's functions are related to energy, the bulk of which addresses the geoscientific aspects of production and development, and to a lesser extent exploration, of oil and natural gas. BEG has a research staff of more than seventy.

Great emphasis is placed by BEG on producing the known remaining resource more efficiently while new discoveries are sought. This focus on "reserves growth" is a key element of BEG's R&D program in oil and gas geosciences. Advances in geoscientific

TEXAS		Current or Potential Oil and Gas Technology Transfer Functions																										
		Data & Publications						Meetings/Seminars				Workshops			R&D/Analysis				Project Assistance									
		Reservoir Data	Field Data	Well Data	Bulletin	Maps	Case Studies	Topical Reports	Seminars	Lectures	Symposia	Field Trips	Problem ID	Focused Tech	Training	Regulatory	R&D Reports	Processes	Equipment	Software	Trouble Shooting	Referrals	Project Assistance	Project Design	Engineering			
Organization																												
State Agencies																												
Texas Railroad Commission	C	C	C		C		C	C	P	P			P		C													
Bureau of Economic Geology	C	C	C		C	P	C	C	C	C	C	C	C	P		C	C	P	P	P	P	C	C					
Research Universities																												
University of Texas Department of Petroleum Engineering						C	C	P	C	P	P	C	C	P		C	C	C	C			C	C	C				
Texas A&M University						C	C		C		P	P	P	P		C	C	P	C			P	P	P				
Texas Tech					C	C						C				C	C											
Industry Organizations																												
Houston Advance Research Center Geotechnology Research Institute								P	P				P	P		C	C	C	C			P						
Energy Research Clearing House								P	P				P	P								C	C					
Texas Independent Petroleum and Royalty Owners Association				C				C	C	P	P	C	C	P	C					P	P	P	P					
C = Currently performs																								P = Has potential to perform barring legislative, regulatory, fiscal, or other constraints				

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

understanding and reservoir description technologies will facilitate strategic infill drilling approaches, reservoir extensions, and improved design of advanced secondary and enhanced oil recovery processes.

BEG conducts much of its research on an interdisciplinary basis, coordinating expertise in geology, geophysics, geostatistics, and petroleum engineering. Cooperative relationships are maintained with the petroleum engineering and geological science departments of the University of Texas and other R&D institutions in Texas and elsewhere. BEG also receives significant funding from Gas Research Institute (GRI) to apply its skills and knowledge to studies of the U.S. conventional and unconventional gas resources, supply potential, and improved reservoir description technologies. Work performed for Gas Research Institute (GRI) is communicated and transferred to the producing industry through a series of GRI publications, including quarterly reports, and numerous workshops addressing gas supply issues.

A major function of BEG is the dissemination of analytical results and information about the Texas and U.S. oil and gas resource base, new insights to recovery potential, and new approaches to describing, characterizing, and developing reservoirs. BEG conducts technology transfer through a variety of conventional and innovative approaches: publications; outside lecturing; company-sponsored short courses and lectures; industry visitation; workshops sponsored by producer associations, and an industry associates program which provide direct financial support and advice for the conduct of research.

BEG annually publishes approximately 12 new energy monographs and distributes some 30,000 copies of these and other publications throughout Texas, the U.S. and foreign nations. The bulk of these publications are purchased by independents working with the Texas resource base. In addition, an average of 50 papers and articles relevant to oil are published annually in professional journals and trade publications. A BEG annual report is distributed to approximately 10,000 readers. BEG staff also deliver more than 100 energy-related lectures annually to academic organizations, professional societies, and other public groups. Privately contracted short courses on oil and gas

geosciences and technologies were presented to some 35 major U.S. and foreign petroleum companies and large independents in 1991. More than 2,000 representatives of major and independent producers consult annually with the research staff and use the Bureau's resources and facilities, including its Core Research Center. BEG staff estimate total contacts, exclusive of publications, at about 50,000 per year.

Through BEG's industry funded Industrial Associates program, exploration and producing companies subscribe to participate in specific studies and research projects of interest to their firms. Sponsor company employees receive the results of R&D as well as training, field seminars as appropriate, and access to the BEG research staff. Five such programs are currently underway, including:

- An Applied Geodepression Lab to model complex hydrocarbon traps, sponsored by 14 major U.S. and foreign producers;
- An Abandoned Well Study, sponsored by American Petroleum Institute under direction of a committee of nine U.S. majors and very large independent producing companies;
- Outcrop and reservoir research on complex carbonate reservoirs in the San Andres-Greyburg formation, sponsored by 16 U.S. and foreign major producing companies;
- Geologic Evaluation of Frontier Exploration Areas in the Gulf of Mexico, sponsored by 14 U.S. and foreign companies including one major service company.
- Outcrop and subsurface characterization of deltaic reservoir architecture and permeability structure, sponsored by 12 major U.S. and foreign producing companies.

These programs are highly effective for performing cooperative research and direct technology transfer from BEG to the sponsoring organizations. Transfer of the research results beyond the research sponsors takes place through publication in Bureau and Society journals, field seminars sponsored by local and national societies, and at regional and annual society meetings.

A promising new technology transfer program is underway at BEG. BEG is working with the Texas Independent Producers and Royalty Owners Association (TIPRO), other Texas oil and gas associations, the UT Petroleum Engineering faculty, other Texas universities, the Department of Energy, and GRI to provide geoscientific substance to a program of needs analyses, focused workshops, and technology resource centers. The program intends to inform independents of existing technologies, assist in defining applications and their potential, encourage independent producers to use technologies to more efficiently explore and produce the resource base, and encourage feedback from independents as to their needs for the development of new technology. A series of one-day, integrated technology transfer workshops presented early in 1993 at major producing centers throughout the state was well attended and received by the independent producing community. The joint BEG-TIPRO program is discussed in greater detail in the Industry Organizations section of this profile.

Through BEG's resource studies, its reservoir description, quantification, and modeling R&D, and its Industry Associates programs, BEG serves Texas's major exploration and producing sectors of the Texas industry well. In these programs, BEG's technology transfer functions appear to be well received. Through association with TIPRO and local independent associations, BEG is expanding its role in industry-focused technology transfer to the independent exploration and producing sectors of the industry.

Research Universities

Texas is home to several high-quality colleges and universities with oil field training programs, academic study, or research programs in petroleum engineering, petroleum geology, geophysics, and related disciplines. Many of the graduate research programs receive significant levels of R&D funding from petroleum industry grants for specific R&D projects. Many also receive Department of Energy and/or other federal agency support for research in oil and gas and hydrocarbon geoscience disciplines. Those with the most notable research and active technology transfer functions are described below.

The University of Texas (UT) is a state-funded public university with extensive undergraduate and

graduate education programs and research functions related to petroleum geology and engineering and related disciplines. Headquartered in Austin, the University has additional campuses throughout the state.

The **UT Department of Petroleum Engineering (PEN)**, chaired by Dr. Larry W. Lake, has a research and development unit, the **Center for Petroleum and Geosystems Engineering (CPGE)**, which is directed by Dr. Gary A. Pope. The Petroleum Engineering department is the teaching unit of the program and offers undergraduate and graduate level degrees in petroleum engineering. PEN has a current enrollment of approximately 125 undergraduates and 140 graduate students.

CPGE is the interdisciplinary research arm of the program. Established in 1987, CPGE serves as an interface between industry, government, and the University in specific areas of research, provides a structure for funding new research, disseminates results to industry, and conducts meetings that provide research results to funding entities. CPGE's research activities address oil, gas, and geopressured/geothermal energy production; energy and mineral resources analysis, groundwater remediation and other areas. These projects are frequently interdisciplinary in nature and performed in conjunction with BEG, the Geological Sciences Department, and the Institute for Geophysics. CPGE has also collaborated with Brookhaven, Los Alamos, and Sandia National Laboratories and other universities in performing its R&D programs.

A unit of the College of Engineering, CPGE serves as an umbrella organization for the coordination of 11 separate R&D programs:

- Enhanced Oil and Gas Recovery
- Geosystems Engineering
- Energy & Mineral Resources Analysis
- Computing & Database Research
- Geopressured/Geothermal Energy Research
- Imaging Laboratory
- Petrophysics & Logging
- Production Research & Offshore Technology
- Rock Mechanics
- Stimulation, Logging and Formation Damage
- Wellbore Stability and Drilling Fluids

Together, these programs involve 30 faculty members from the Petroleum and Chemical Engineering, Chemistry, Engineering Mechanics, and Geological Sciences departments and an additional 12 research professionals from the PE program and the Bureau of Economic Geology. In each program, students seeking graduate degrees assist the research. Examples of specific project areas include reservoir characterization and stimulation, process chemistry and physics, process performance and design, and formation evaluation and simulation. Annual funding is over \$4.2 million, about \$2.6 million from private sources, \$1 million from federal (DOE/NSF) funds, and \$0.6 million in state funds. Private funds come from 43 major U.S. and foreign petroleum companies, service companies, and equipment manufacturers from 7 countries.

The industry partners for whom CPGE performs its research facilitate effective transfer of research results, information, and new technologies from the CPGE to the sponsoring organizations. The Center's broad contact with other research entities and universities also contributes to technology transfer. CPGE staff interact with producers and producing associations through conventional methods: academics publish extensive articles and reports, and lecture. Above all, classroom instruction serves as the University's most effective form of technology transfer. During the past eighteen months, CPGE staff have also participated with BEG and TIPRO in instituting a new technology transfer program to encourage use of available technologies and improved recovery processes for reservoir description and improved oil and gas recovery.

Many of the other campuses of the University of Texas System are located in communities in or adjacent to the oil and gas producing regions of the state. Many offer adjunct programs in petroleum engineering and related geosciences. These institutions, by virtue of location and their connections to the local industry associations, producers, and professional society chapters, have the potential to host expanded technology transfer functions, including data and information repositories, resource centers, and problem identification and intensive, highly focused technology workshops. Of particular note in this regard is the University of Texas at the Permian Basin's Center (UTPB) for Energy and Economic Diversification in Odessa.

CPGE also offers a Remote M.S. program whereby M.S. degrees in petroleum engineering are offered via a televised link between Austin and UTPB. The program is in its third year and will have five M.S. graduates this spring. The link could serve as a channel between Austin and Midland for communications such as short courses, seminars, and consulting meetings, as well as M.S. courses.

Texas A&M University's Department of Petroleum Engineering, located in College Station, offers four graduate level degrees and supports a research faculty and staff totalling sixteen. A&M is recognized as one of the nation's best teaching institutions in petroleum engineering. Research areas include: fractured reservoir studies, economic optimization, acid fracturing, formation paraffin removal, petroleum environmental engineering, improved oil and gas recovery, and international petroleum studies. Active research programs currently include:

- Expert Systems Lab for Petroleum Reservoir Management;
- Center for Economic Optimization of Oil and Gas Field Operations;
- Development of Two-Phase Flow Model for Reservoir Performance Prediction;
- Miscible Flooding Strategies for Stratified Reservoirs;
- Use of Transient Pressure Analysis to Develop Methods to Estimate Reserves in Gas Reservoirs;
- MI and CT Imaging Techniques to Develop and Test a New EOR Process;
- Reservoir Characterization Techniques; and
- Low Permeability Gas Reservoirs.

Texas A&M's technology transfer functions follow the form of most university research programs. Results and activities are reported through published papers, offering lectures to industry associations and professional societies, and publishing journal articles. Technology transfer is also facilitated by hiring professionals from the

major producing and service companies as researchers and adjunct faculty. Texas A&M is increasing its technology transfer role by participating in the recent technology transfer program being developed by TIPRO and BEG.

Texas Tech's Department of Petroleum Engineering, located in Lubbock, is relatively small compared to programs in the state. With six full time faculty and 19 active M.S. and Ph.D. students, the department conducts research in several areas. Much of this research is coordinated with the University's Department of Geology through its interaction in the Center for Applied Geophysical Studies. Current research topics include:

- Capillary Pressure and Saturation -- By identifying variables that introduce error and cause discrepancies between well logs and core analyses, success will provide more precise water saturation values and estimates of oil-in-place. The project is partially funded by the Governor's Office for use on state lands;
- Carbon Dioxide Cyclic Well Stimulation -- This research examines use of a CO₂ soak approach in a single well to stimulate production by swelling the oil and reducing viscosity. It is partially funded by the Governor's Office.
- Environmental Research -- The project currently addresses use of drilling fluids to reduce tailings in mining operations (partial industry funding). It will be expanded to address Naturally Occurring Radioactive Material (NORM) in produced fluids and scale;
- Porosity -- This program uses microscopic studies of thin sections to determine total porosity and micro-porosity in reservoir rock. Partially funded by state funds, it is performed by the Geology Department with the Center for Applied Petrophysical Studies; and
- Clay Content -- This program uses scanning electron microscopy and x-ray diffraction methods to determine the amount and type of clay in reservoir rocks. The research is

funded in part by the state and performed with the Center for Applied Petrophysical Studies.

In addition to the traditional academic university activities, Texas Tech also conducts a Southwest Petroleum Short Course each April. Courses such as this could be important vehicles in the technology transfer process in Texas. Texas Tech is also an active participant in the emerging TIPRO/BEG effort.

Several smaller colleges and universities in Texas also conduct research and development related to oil and natural gas exploration and production. Rice University, the University of Houston, and Lamar University also have respected programs in petroleum engineering and/or geosciences that could participate actively in a coordinated technology transfer program. Many of these programs provide essential training for field personnel including drilling and completion technologies, maintenance and remediation operations, and environmental protection and safety procedures and requirements.

The **Houston Advanced Research Center (HARC)**, located in The Woodlands, is a research organization which focuses on performance of development of advanced technologies to diversify the Texas industrial and economic base. While R&D functions at HARC range from advanced materials research to supercomputing, it includes two specific components that focus on oil and natural gas exploration and production. HARC's **Geotechnology Research Institute (GTRI)** was created by the Texas legislature in 1985 to conduct basic and applied research to help improve oil and gas exploration and production. Funded by several large independents and major E&P companies, GTRI is making advancements in petroleum geophysics, including advanced seismic processing, seismic "bright spot" investigations to detect hydrocarbons, 3-D visualization, and ground penetrating radar for shallow subsurface environmental investigations.

Industry Organizations

In response to recommendations from the National Petroleum Council (NPC), HARC formed the **Energy Research Clearing House (ERCH)**. The ERCH is an industry sponsored organization which provides an organizational structure for the funding and performance cooperative upstream

petroleum exploration and production research by major and independent petroleum companies. Organizations wanting to perform research on a specific topic may propose the project to the clearing house. Clearing house members will then determine their level of interest in the R&D and decide whether and how to fund the research and share the results. The actual research may be performed by one or more of the participating companies. Rather than broad ranging technology transfer, this function offers companies a mechanism to leverage their research funds. This is particularly important with shrinking private R&D budgets for upstream research on the U.S. lower-48 resource base. However, research results are not disseminated beyond the participating companies.

Producer Associations

Some producing states have no state-level producer association to represent their interests or coordinate workshops and related technology transfer functions. Texas has no less than six. The **Texas Independent Petroleum and Royalty Owners Association (TIPRO)**, directed by Julian G. Martin, is joined by five unaffiliated regional producer associations in the state, including:

- East Texas Producers and Royalty Owners Association;
- North Texas Oil and Gas Association;
- Panhandle Producers and Royalty Owners Association;
- Permian Basin Petroleum Association; and
- West Central Texas Oil and Gas Association;

Working together with the state's university research organizations, GRI, DOE, and the Independent Petroleum Association of America, these organizations, led by TIPRO, are beginning to play a pivotal role in an ambitious new technology transfer process. This program attempts to pull together all of the key producer associations, local organizations and technology sources, organize them on a regional basis, and apply a uniform approach to identifying problems, transferring technologies to address the specific high-priority problems in each region, and identifying R&D priorities to be

addressed by industry, government, and university R&D.

Beginning in 1991, with TIPRO's leadership and substantive technical support from the Bureau of Economic Geology, eight technology "forums" were held across the producing regions of Texas to identify the needs of independent producers in the area of improved oil and gas recovery technology. TIPRO and BEG staff were supplemented in each region by local association officers and technical experts from the industry and academic organizations in the respective region. The results of these forums, attended by some 400 Texas producers, were used to establish a baseline for near-term technology transfer efforts to offer technology information. Regional oil and gas associations hosted the initial workshops, got their membership involved, and disseminated results. Their contact with their membership will also facilitate future interaction between producers and R&D entities to ensure that research addresses the needs and concerns of producers.

The initial results of these forums were reported in March 1992. Through this interaction, the project hopes to provide feedback from each region to the research organizations and to the federal research program as to the research priorities on which they should focus.

In an accelerated second phase, which was recently concluded, TIPRO and BEG devised a series of seminars designed to offer information about currently available technologies that can address the needs identified in the first phase. The first of these seminars, held September 28, 1992, in Austin, addressed Oil Reserve Growth, Gas Reserve Growth, and Exploration Strategies, and included a small exhibition of relevant products, technologies and analytical tools. Each of three segments was further divided into three or four lectures presented by professors from University research programs at BEG, UT, Texas A&M, University of Houston, and Texas Tech. A follow-on series of workshops offered in Dallas, Houston, Midland, Abilene, Wichita Falls, and Amarillo was attended by over 600 independents in January through March 1993. These seminars, addressing 3-D seismic applications, improved oil recovery strategies, and improved gas recovery from complex reservoirs and tight gas sands, are essentially the same as were presented in Austin.

TIPRO, through its Applied Research and Technology (ART) Committee, directed by Dr. William L. Fisher, is also proceeding with BEG to develop an information service that could be used by operators in a resource center for the petroleum industry. The Improved Recovery Information Service (IRIS) is expected to provide a data, information, and referral center where operators can bring problems, receive advice, access technology information, review research results and use various analytical tools and software. IRIS will then obtain feedback from those who use its services so that operator's problems can be better understood and addressed. IRIS is intended to provide access so that operators can make informed decisions about reservoir management and improved recovery projects in specific formations and reservoirs. Questions as to content, location, staffing, funding, and structure are still being addressed. TIPRO hopes to phase the service in over three years beginning in October 1993.

The speed with which the TIPRO/BEG program has progressed is notable, demonstrating a commitment from producers, academia, the state, and professional societies to work together to effect technology transfer. The TIPRO/BEG project has held itself out as a prototype for the nation as well as for the other regions of Texas. It joins other prototypes from New Mexico, Kansas, and Illinois as contributors to the development of a hybrid technology transfer program for the other producing states.

III. OBSERVATIONS

The TIPRO/BEG effort has succeeded in incorporating participation of the state's universities, its regional producer associations, service companies, and professional societies into the fabric of a technology transfer program to serve all Texas producers. It has been effective in bringing research results to the producers, in particular, those supported by GRI and DOE. This breadth of coverage and participation is essential if the program is to effectively address specific problems encountered in specific formations and operating environments encountered in Texas's numerous oil and gas producing basins.

The coordination of technology transfer functions of the universities, producer associations, industry R&D groups, service companies, and professional societies in Texas, offers significant potential for achieving synergistic benefits for the entire state, as well as for the nation. By taking an interdisciplinary approach and working together, improved understanding of the reservoirs and innovative solutions to reservoir and production problems will be stimulated.

Texas has made the most important, and often the most difficult, step in the technology transfer process -- recognition of the need for a centralized structure to facilitate technology transfer. The TIPRO/BEG technology transfer program should provide that essential framework. While it is a positive step forward, however, it is only the first step.

BEG continues to develop new approaches to maximize dissemination of recovery-research information. Planning for a second series of workshops to present results of recovery-optimization studies of state lands fields funded through the Office of the Governor is underway. University programs and other R&D entities can also become more actively involved in the seminars and workshops in order to ensure the most effective application of research to needs.

The technology transfer framework needs to be extended to allow and encourage the participation of major producers as well as independents. While independents have the most dire need for technology solutions, majors may have some of the answers. Majors must recognize the overall benefit to the state and the nation that can come from increased interaction with and help to independents.

Finally, the state and federal government can be more actively involved, particularly the state government. Be it through tax incentives or direct financial support, funding must be provided for the technology transfer program. Texas regulation of oil overcharge funds is an appropriate means to assist R&D and technology transfer. The state will reap the rewards in increased tax revenue and jobs for its citizens.

Texas is making a positive step forward. The results of the work being done there, once defined should serve as a model for other states in establishing enhanced technology transfer programs.

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**STATE
TECHNOLOGY TRANSFER
PROFILE FOR
WYOMING**

Interstate Oil and Gas Compact Commission

STATE TECHNOLOGY TRANSFER PROFILE FOR WYOMING

I. CONTEXT FOR UNDERSTANDING TECHNOLOGY TRANSFER

Oil was first produced in Wyoming in 1884. Through 1991, Wyoming had produced 6.1 billion barrels (BB) of oil, with about 12.9 BB of Wyoming's 18.7 BB original-oil-in-place (OOIP), or 68.9%, still in the ground. With 0.9 BB in proved reserves, 12 BB of remaining-oil-in-place (ROIP) is the target for current and emerging advanced recovery technologies (Figure 1).

Figure 1. Discovered Oil Resource

Most of Wyoming's ROIP is found in eolian reservoirs (Figure 2) with the remainder in twelve other geologic classes. More than 95% of the remaining oil is light oil.

Natural Gas

Only about 15.9 trillion cubic feet (Tcf) of Wyoming's estimated 101.7 Tcf natural gas resource had been produced through 1991. Of the remaining

Figure 2. Distribution of Known Remaining Oil by Reservoir Classification

86.6 Tcf, less than 12% are proved reserves, which are recoverable under existing economic and operating conditions. The remaining 77 Tcf is undiscovered resource that is comprised of probable, possible, and speculative reserves. This includes a portion of the discovered, but unconfirmed, gas resource that is not included in proved reserves (Figure 3). With extensive proved reserves and a promising resource base, Wyoming is in a highly favorable position for sustained future gas production.

Production

Twenty-one of Wyoming's 23 counties have some oil or gas production (Figure 4). In 1991, there were 11,234 producing oil wells and 2,831 gas wells. While almost 93% were operated by artificial lift, only 25% of the producing wells are stripper

Figure 3. Natural Gas Resource

wells. This is far below the national average of 79 percent. In 1991, stripper well production accounted for only 5% of the state's production.

Wyoming crude oil production peaked at 160.3 million barrels (MMB) in 1970. In the early 1980's, crude production was sporadic, reflecting both the drilling boom and softening oil prices. After reaching its 1985 level of 128.5 (MMB), production levels responded negatively to the 1986 price decline, falling more than 22% to a level of 100 MMB by

1991 (Figure 5). Wyoming ranks sixth among the states in crude oil production, accounting for almost 4% of lower-48 production.

Figure 5. Crude Oil Production

Crude oil prices and natural gas prices have followed the same general trend, increasing initially before falling off in the mid-1980's. Natural gas prices, however, fell more drastically -- declining from the high of almost \$4.50/Mcf in real terms in 1982 to a low of about \$1.20/Mcf by 1991. Natural gas production, however, did not respond as sharply

Figure 4. Counties with Active Production

to falling prices. After an initial fall off due to depressed prices, gas production showed a general increase, primarily after 1988 as more wells were drilled, and continued to climb, reaching its peak in 1991 at 747.2 billion cubic feet (Bcf) (Figure 6). The 1991 production level incorporating CO₂ production was 960.4 Bcf.

Figure 6. Natural Gas Production

Improved Oil Recovery

Wyoming's reservoirs first became a target for enhanced oil recovery (EOR) methods in the 1940's. Since that time, EOR projects have become more prominent in Wyoming oil fields. Fifty-eight EOR projects are currently active. EOR projects currently account for almost 15% of Wyoming's crude oil production. A variety of EOR processes are employed in Wyoming. Forty-five of the current projects apply polymer flooding. The others consist of thermal (steam injection), nitrogen, surfactant, and gas miscible (CO₂) processes in about equal proportions.

Secondary recovery processes have been employed in Wyoming since as early as 1959. These processes have primarily been waterfloods. According to Wyoming statistics, waterflood projects have been performed or are still active in more than 385 fields in the state and in multiple pools and formations in many of the fields. Many of these projects have been followed by polymer augmented waterfloods or profile injection projects to plug already swept higher permeability zones to allow for improved sweep efficiency and production. Other improved recovery processes being employed or

considered in the state include strategically targeted infill drilling using advanced reservoir description techniques and horizontal drilling.

Oil and Gas Reserves

Wyoming accounts for 3% of current U.S. proved oil reserves. The state's oil reserves were severely affected by the price decline. The state's natural gas reserves, however, were not. Crude oil reserves fell 22% against a price decline of 70% from 1983 to 1991 (Figure 7). Gas reserves fluctuated, however, rising and falling at 15% intervals twice before stabilizing at about the 1983 level in 1990 and 1991 (Figure 8).

Figure 7. Crude Oil Reserves

Figure 8. Natural Gas Reserves

Abandonments

As wells reach their economic limits, operators must decide whether to invest in workovers or improved recovery techniques or plug and abandon the well. Premature well abandonments threaten the option to apply current and emerging improved recovery technologies to produce remaining oil-in-place. Well abandonments increased sharply from 1982 through 1987, almost entirely because of price weakness and the sudden 1986 price decline. Almost 4,700 stripper wells were abandoned during this period. Over 400 of these abandonments were a result of underground injection control regulations. By 1988, the abandonment rate fell back to about 450 and proceeded to return to the former rate of almost 100 abandonments per year by 1991 (Figure 9).

Figure 9. Stripper Well Abandonments

Exploration

Drilling activity also dropped sharply with lower oil prices. The total number of active rigs was down by almost 84% in 1991 from its peak in 1981, consistent with the national trend. The drilling of exploratory wells and new-field wildcats dropped almost 77% between 1981 and 1991. New field discoveries and extensions have not replaced produced oil reserves. Even development well drilling, conducted in areas of proven production, fell by almost 71% in these years.

Economic Impacts

Reduced oil and gas exploration due to low prices has had a significant impact on employment in

Wyoming's oil and gas extraction industry, with a 63% decline in the oil and gas extraction sector. This drop was part of loss of more than 14,700 in the industry as a whole (Figure 10).

Figure 10. Oil and Gas Extraction Employment

Besides affecting employment, reduced production rates and continued price instability have also resulted in a decrease in the wellhead value of both oil and natural gas production. Reductions in the value of production have severely impacted state revenues. Between 1981 and 1991, the revenues collected by the state through severance taxes on oil and natural gas production have fallen, in 1991 dollars, from \$388.2 million to \$236.7 million. Clearly, the state has a stake in maintaining a viable petroleum producing industry.

II. R&D AND TECHNOLOGY TRANSFER TRENDS AND ACTIVITIES

The need for broader and more effective technology transfer in Wyoming is clear. If companies are to maximize production of the Wyoming oil resource, state-of-the-art operations are essential. The responsibility for producing the resource is shifting to the independents. While many independents have experience and expertise from their work with the majors, it is essential to expand all independents' access to improved recovery technology and related information and resources.

In the near-term, technology transfer has the opportunity to deploy existing technologies to defer

Both the nature of the Wyoming oil resource and the maturity of the reservoirs require that a smooth transition in the industry structure be predicated on a foundation of effective R&D and technology transfer. The major producers, service companies, and state and private research organizations must transfer knowledge and technologies to independent oil and gas producers if the oil resource is to be efficiently produced.

Several public and private entities in Wyoming are currently engaged in performing oil and gas research, disseminating results and information, and offering technology assistance and related services to oil and gas producers. Described below are the current activities and capabilities of the most prominent of these organizations (Table 1) and suggestions on how their functions might be expanded, modified, or improved to expedite near-term and mid-term technology transfer to Wyoming producers.

The Wyoming Oil and Gas Conservation Commission, managed by State Oil and Gas Supervisor Donald B. Basko, is Wyoming's oil and gas regulatory agency. It is also a major distributor of information on the state's producing industry and

Table 1. Current and Potential Functions of Principal R&D and Technology Organizations

resource base. The Commission publishes an annual oil and gas statistics report that details exploration and production activity and reports the status of water, gas, air and thermal injection tertiary recovery projects, and makes available other publications. The Commission also prepares and distributes statistics on production by county, formation, and operator and other specific maps, charts and data. In addition, the Commission has the computer capability to generate production summaries from 1978 to the present, and to perform production decline curve analyses. The Commission does not conduct any specific research or technology transfer functions, but encourages the use of improved recovery processes where appropriate to maximize production and conserve the resource.

The **Geological Survey of Wyoming**, directed by State Geologist Gary B. Glass, is a valuable source of data and information for oil and gas producers. The Survey's mission is to "study and interpret the geologic, mineral, and energy resources of the State," including serving the needs of the exploration and producing community. To accomplish this mission:

- The survey performs applied research and field and laboratory investigations and information dissemination related to understanding the state's geologic framework; assessing mineral and energy resources; and modeling mineral and energy resource processes.
- The survey disseminates information by publishing geological maps; preparing and distributing scientific and technical reports on geologic structures and mineral and energy resources; providing an "open file" library for public use; and operating a public information service to provide data to the community and help answer specific geology-related problems.
- It publishes and distributes a state oil and gas map; maps and reports for the exploration and producing community; and it contains a public records area with oil and gas well logs (in paper, microfiche, and microfilm formats).

In addition, the Survey has data bases containing data on reservoir parameters of oil and gas composition for more than 100 of the largest gas reservoirs in the state. The Survey publishes a quarterly newsletter updating the oil and gas and mineral activity.

Research Universities

Petroleum engineering and geoscientific research and development efforts in Wyoming are conducted primarily by the universities. There are two university programs addressing petroleum engineering in the state.

The **Casper College Petroleum Program** is essentially an academic program designed to provide the basic knowledge and skills for technicians entering the exploration and production areas of oil and gas operations.

The limited research work conducted by the program focuses on hydrocarbon sensor research for rig safety and a study of existing and new government regulations that impact the oil and gas industry. The Petroleum Technology Program is funded in its entirety by Casper College. It is a small program with only one staff member, the coordinator, Edward C. Boyer. The program conducts little technology transfer, other than its direct training function, but it does maintain relationships with companies engaged in the industry and other petroleum R&D programs in the West.

The exploration and production curriculum at the associated degree level is designed to integrate with the training programs of companies involved in transportation, refining, marketing, and research. Through this process, the skills and knowledge acquired from the College are applied in the industry. The program receives information and input from the industry through a program advisory board composed of executives from major companies. The petroleum technology program also coordinates within the college's Department of Geology to provide assistance to the oil and gas producing community. Although its facilities are limited, Casper College could be an effective host and participate in expanded technology transfer functions in the Casper area.

The **University of Wyoming**, located in Laramie, conducts more extensive research and development programs and is well positioned to transfer technology applicable to Wyoming's producing conditions. The Department of Petroleum Engineering, consists of six full-time and two part-time tenure-track faculty members who are all involved in research. The academic program provides formal training for future petroleum engineers, at the bachelors, masters and PhD levels, but it is the R&D work that sets the University of Wyoming apart. Included among the research projects currently being conducted are the following:

- A study of the Mesaverde Tight Gas Sands in the Green River Basin in Wyoming. The project evaluates the gas resource, the localization of highly productive regions, methods of formation evaluation, and drilling and completion techniques. The study is being funded by the Gas Research Institute.
- Analysis of the pressure compartments in the Powder River Basin in Wyoming. Variations in subsurface reservoir pressure are being mapped with extensive analysis of drill stem tests. The study is also being funded by GRI.
- Modeling of cyclic ("Huff-n-Puff") thermal and CO₂ injection for EOR projects. Cyclic injection is a potentially important enhanced oil recovery technique. In order to better apply it to Wyoming reservoirs, the predictive ability of models assessing the process must be improved. There are two separate projects being funded in this area - one by the Enhanced Oil Recovery Institute (EORI) and the other by the American Chemical Society.
- Oil recovery in fractured reservoirs using steam/hot water injection. There are two projects being conducted in this area. The first, funded by EORI, delineates the main physical mechanisms responsible for oil recovery from fractured porous systems during steam and hot water injection. The second project, funded by the Wyoming Mining and Mineral Institute, will incorporate the results of the first project as well as numerical schemes and algorithms

into a model for the oil recovery in these reservoirs.

- Study of CO₂ supply and demand in the Powder River Basin. The oil found in the Powder River Basin seems amenable to CO₂ processes for increasing recovery of the oil. There is a problem in that there is not enough supply of CO₂ to the region to support the projects that may be undertaken. This study, jointly funded by the department and AMOCO, seeks to give estimates of the supply and demand for CO₂ in the region and of the amount of additional oil that may be recovered by increased application of these processes.

Technology Transfer from R&D performed in the academic department is of the traditional variety, consisting of publishing papers in academic and trade journals and presenting research results at meetings of trade associations and professional societies.

The University of Wyoming offers more than just the Department of Petroleum Engineering for R&D and technology transfer work. Two petroleum research institutes are situated on its campus - the **Enhanced Oil Recovery Institute (EORI)** and the Western Research Institute (WRI). EORI is tailored to Wyoming's specific producing conditions and focuses on enhanced oil recovery (EOR) research. EORI disseminates the results of its research through various channels. The Institute uses the traditional methods of publishing reports and journal papers, and it also conducts an annual symposium, held in May in Casper, Wyoming. The Symposium is two days long, and speakers are invited to talk about recent progress in EOR. EORI also maintains contact with individual operators on a person-to-person basis.

EORI is made up of a multidisciplinary research group that works for the majors, but primarily for Wyoming's independent operators. It receives its funding from many sources including both the state and federal government and various operators and companies. EORI works on a variety of research projects, such as the CO₂ "Huff-n-Puff" project and research involving Nuclear Magnetic Resonance. EORI has just recently concluded a working agreement with Texaco and Cherokee, forming a partnership which is applying for a Department of

Energy grant to advance technology transfer in Wyoming and the Northern Rocky Mountain states.

Western Research Institute (WRI) is a non-profit R&D organization that resulted from the defederalization of the Department of Energy's former Laramie Energy Technology Center. The mission of WRI is "to provide industry and government with scientific and technological solutions to problems related to energy and the environment." WRI's primary area of focus is the production, transportation, use, upgrading, and environmental considerations associated with oil and gas and coal production in the Rocky Mountains; elsewhere in the U.S., and worldwide.

Areas of petroleum related research performed at WRI include:

- **CO₂ Huff'n Puff EOR** . WRI works with the University, EORI, and private companies in a consortium to develop this technology. WRI is assisting field tests and numerical simulation in 32 wells in 19 fields.
- **Horizontal Drilling**. WRI is engaged in simulation, evaluation, and field testing of horizontal wells in combination with steamflooding for thermal applications in shallow formations.
- **Gravity Drainage**. WRI is using test data to develop numerical simulation models for gravity drainage
- **In-Situ process modeling and numerical simulation of steamfloods in fractured reservoirs**.
- **Tank bottoms treatment using the WRI TaBoR process**.
- **Surface processing of petroleum**
- **Crude oil and asphalt characterization**

In addition, WRI has requested funding from DOE or other organizations for R&D projects in production of heavy crude oil through hydrovisbreaking; quaternary EOR (combination of oil mining, horizontal drilling, primary, and EOR techniques); and design and implementation of

waterflood and polymer augmented EOR. In addition to the tank bottoms research, WRI has also developed processes for in-situ remediation of oil-waste-contaminated soils.

Technology transfer from WRI occurs in a variety of mostly traditional approaches including:

- Direct sale or licensing of technologies to generate financial rewards to inventors and revenues for the institute, including invention disclosure, intellectual property, and related procedures;
- Publications of research results in papers and technical journals;
- Presentations at professional societies and technical meetings; and
- Sponsorship of annual conferences at WRI (two of which relate to oil and gas R&D) for WRI and other researchers to provide results.

There is little direct contact, troubleshooting, or extension engineering type of contact with the producing community, excluding WRI's annual 2-day technical conference for oil and gas.

Most WRI research projects have a duration of eighteen to twenty-four months and a budget of \$250,000 to \$500,000. With a staff of approximately 110, WRI's annual budget of approximately \$10 million is funded by federal, state, and private funds, including a multi-million dollar annual cooperative agreement from the Department of Energy that includes the possibility of cost-sharing for approved projects.

Industry Organizations

Several industry associations represent the oil and gas producing industry in Wyoming and the Rocky Mountain Region. Most of these organizations exist to monitor regulatory activity in the state legislature and regulatory agencies and communicate concerns and changes in the regulated environment between producers and regulators. These include, primarily, the Petroleum Association of Wyoming (PAW), the Wyoming Independent Petroleum Association (WIPA), the Rocky Mountain Oil and Gas Association (RMOGA) and the

Independent Petroleum Association of the Mountain States (IPAMS).

The **Petroleum Association of Wyoming (PAW)** is Wyoming's oil and gas industry is a potentially important link in the technology transfer process. The association accumulates and disseminates information on all facets of the petroleum industry to foster the best interests of the public and the industry. Most of the current work involves legislative and regulatory issues including environmental, public lands, taxation, marketing, and exploration and production related legislation. As the Wyoming division of the Rocky Mountain Oil and Gas Association, PAW represents 90 percent of the oil and gas producers in the state. Thus, the association could serve as a facilitator of information placing its membership in contact with the research and development community. PAW has expressed an interest in maintaining and updating a bibliography of research and development topics. PAW's resources are constrained by funding and size. PAW's three professionals (an executive director and two associate directors) have the potential to coordinate, motivate and assist Wyoming producers in participating in expanded public and private technology transfer activities.

Although located in Denver, IPAMS serves the independent petroleum community throughout the Rockies. Under the direction of Executive Vice President Karyn Plank, IPAMS is also actively participating in a national effort by independent producers to coordinate technology transfer functions with state, regional, and national industry, academic, and government research and development and technology transfer organizations. IPAMS has recently volunteered to coordinate independents activities throughout the Rockies region should such an "umbrella" organization be formed.

III. OBSERVATIONS

Wyoming has the basic ingredients for an effective technology transfer mechanism. It now needs to build on the foundation. While the research and development community within the universities is fairly strong, and focuses on some of the critical problems encountered in the state, the input and feedback from the industry, particularly small

operators, is somewhat limited. While informed one-to-one contacts with independents and other producers can be highly effective and beneficial, a more structure problem identification process can provide further insight as to relative magnitude of problems and suggest priorities for focused research and technology transfer activities. These activities could be integrated into the structure of the annual symposium, or they could be held on their own.

PAW, WIPA, and IPAMS can also be highly effective participants. PAW already has the infrastructure and contacts with the industry necessary to gain operators input on research and development needs. More frequent bidirectional communication between the industry organizations and the R&D entities will help to match R&D and technology transfer functions with priority needs. An obvious concern is funding and personnel for the Association. Additional funding from industry, state, and/or other sources will be required to staff and conduct problem identification and technology transfer to bring R&D and the industry together.

Lack of effective coordination between the state agencies, industry, associations, the R&D community, and producers is, perhaps, the greatest stumbling block to more effective technology transfer. Wyoming's operators could benefit greatly from a centralized resource center which contained and made accessible all of the information. Casper is more centralized than Laramie, but both are in the producing region and could house this resource.

Most of the essential pieces are in place for Wyoming to begin to build more effective technology transfer mechanisms. At this point, strong leadership and coordination of the various efforts will make the process more complete.

Source List

- American Petroleum Institute, *Basic Petroleum Databook*
- Department of Commerce, *Bureau of Economic Analysis*
- Energy Information Administration, *Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*
- Energy Information Administration, *Current Dollar Price*
- Energy Information Administration, *Petroleum Supply Annuals, Natural Gas Annual*
- Independent Petroleum Association of American, *The Oil and Natural Gas Producing Industry in Your State*
- Interstate Oil and Gas Company Commission and Natural Stripper Well Association, *National Stripper Well Survey*
- Minerals Management Service, *Federal Offshore Statistics*
- *Oil and Gas Journal*, Annual Production Report 4/20/92
- Potential Gas Agency, Colorado School of Mines
- Tertiary Oil Recovery Information System

TECHNOLOGY TRANSFER CONTACT LIST FOR WYOMING

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