FOSSIL ENERGY:

March 1992

From Laboratory To Marketplace

Part II: The Role of Advanced Research

**U.S. Department of Energy
Office of Fossil Energy**

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U.S. Department of Energy
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Washington DC 20585

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Fossil Energy: From Laboratory to Marketplace

Part II - The Role of Advanced Research

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Executive Summary

The April 1991 Department of Energy (DOE), Office of Fossil Energy (FE) publication *Fossil Energy: From Laboratory to Marketplace* presents examples of the technology development and transfer successes of the FE R&D programs in coal, petroleum, and natural gas over the past decade. This sequel to that report provides a summary of the role of advanced research in the overall FE R&D program successes.

The contribution of advanced research can be readily seen in the science and technology products--analytical tools, techniques, and innovative concepts and processes--that have directly contributed to the development and commercial application of advanced fossil fuel systems. Of the 100 successes cited in the report, advanced research products *directly* contributed to 57 of them as follows:

- 29 represent products transferred directly to commercial practice
- 28 represent products transferred to FE technology development programs and industry for further development

The advanced research products themselves can be grouped into three product types:

- Novel process, process step, or subsystem
- Enabling technology base element
- Tool/technique (including software, models, and databases)

The first two product types are particularly critical, as they form the foundations from which advanced fossil fuels systems are designed and developed. Each of the major systems under development in FE today benefits from these foundations. Of particular importance are the *crosscutting* enabling technology base elements which develop *critical enabling science and technology* (such as new materials and separations technologies) that is broadly applicable to multiple systems.

As noted, over one-half of the successes cited in *Fossil Energy: From Laboratory to Marketplace* represent successes where the *discrete* contributions of advanced research products are readily identified. This in itself is remarkable. It is none-the-less a conservative perspective, as the *general* contributions of enabling technology base elements are embedded in the development of most advanced fossil fuel systems. This is particularly true for technologies for the 21st century, when innovative technology will be crucial to resolving underlying technical barriers to new generations of environmentally acceptable and economically competitive fossil fuel systems.

Fossil Energy: From Laboratory to Marketplace Part II - The Role of Advanced Research

I. INTRODUCTION

The April 1991 FE publication *Fossil Energy--From Laboratory to Marketplace* presents many of the technology development transfer successes of the FE R&D programs in coal, petroleum, and gas. As stated in the report's introduction:

"Fossil Energy-From Laboratory to Marketplace is a compendium of progress--progress achieved by teams of university, industrial, and government researchers working through the Federal program to develop new, cleaner and more effective ways to produce and use the nation's abundant fossil fuel resources."

The report cites 100 examples of technology development and transfer successes, presented in the following categories:

- In the Marketplace--technologies which entered the marketplace and redefined the state-of-the-art
- On the Threshold--technologies that have progressed through R&D and are at the threshold of commercial use
- Spinoffs--technologies which created new products/application beyond the original research targets
- Technical Successes--technologies which achieved their R&D goals but have not entered commercial use due to changes in economic conditions
- Data Bases/Software--information bases, data bases, and software tools that supplement hardware/process successes in commercial applications

The final section of that report, titled *Fossil Energy Technologies for the 21st Century*, describes the R&D challenges the current FE programs face--specifically, a heightened worldwide concern over the environment and the desire for continued economic growth and energy security. To meet these challenges, the report specifically notes the importance of innovation:

"For it always has been, and will continue to be, technological innovation that resolves seemingly conflicting goals of the cleaner environment and secure, efficient energy."

The purpose of this sequel to that report is to provide a summary description of the role of advanced research in the overall FE R&D program successes. It presents the specific FE advanced research products that have been adopted commercially or fed into other R&D programs as part of the crosscutting enabling technology base upon which advanced systems are based.

The sources of the material for this report include: the background data and inputs for the original report; Program Summary Description documents from the late 1970s and early 1980s; briefing documents from that same era; discussions with FE program staff; and more recent program documentation. Summary descriptions of the advanced research programs roles are provided only for those situations where specific reference materials could be identified. Suffice to say, this summary report provides a conservative perspective on the important contributions of the advanced research programs.

II. THE ROLE OF ADVANCED RESEARCH

The advanced research programs, which conduct crosscutting fundamental and exploratory research, are an integral part of overall FE and DOE research programs, as shown in Figure 1. In the overall FE R&D program, the advanced research programs focus on innovation and revolutionary technology as opposed to evolutionary development of systems in the process and engineering development programs, and technology demonstration in the Clean Coal program and the Advanced Oil Recovery program.

The programs include the advanced coal research programs, comprising the crosscutting Advanced Research and Technology Development (AR&TD) program and the technology-specific advanced research subprograms in Liquefaction, Surface Gasification, Combustion Systems, Fuel Cells, and Control Technology and Coal Preparation, which are an integral part of the FE coal R&D program; and the Advanced Extraction and Process Technology (AE&PT) program, which is an integral part of the FE petroleum R&D program.

Figure 1
FE Advanced Research in the R&D Spectrum

Over the period from the mid 1970s to the 1990s, the titles of the advanced research programs have changed several times. None-the-less, the thread of continuity exists and is readily apparent from an inspection of program documentation. Several examples highlight this:

- In the Coal program, for ease of presentations in testimony and budget requests, in the mid 1980s, the AR&TD Processes subprogram at the direction of Congress became two separate subprograms, Coal Liquefaction Advanced Research, and Surface Coal Gasification Advanced Research.

- In the late 1980s, again at the direction of Congress, the AR&TD Direct Utilization subprogram was split into four pieces: AR&TD Coal Utilization Science, Combustion Systems Advanced Research, Control Technology and Coal Preparation Advanced Research, and Fuel Cells Advanced Research subprograms.
- In the Petroleum program, the Drilling and Offshore Program and the Advanced Process Technology Program were combined and eventually, in the late 1980s became the Advanced Extraction and Process Technology Program. Subsequent to this, all advanced research on C₁ chemistry, formerly conducted in a fragmented manner in several programs, was consolidated into the AE&PT Program along with the rest of the petroleum chemistry research.

The mission of advanced research within FE is to stimulate and nurture the identification and establishment of the U.S. fossil fuel science and technology base in *critical enabling science and technologies*. These are the core sciences and technologies required to achieve the near-, mid-, and long-term goals of the FE R&D program and thus enhance U.S. economic growth and efficiency, energy security, and environmental quality. The advanced research mission is accomplished by the following:

- Conducting a balanced program of fundamental and exploratory research through *collaboration* with industry, universities, and national laboratories that can leverage the resources of all the participants.
- Promoting *interdisciplinary* research with *crosscutting or multiple application* potential.
- Pursuing innovative institutional arrangements for conducting generic, precompetitive research in fossil fuel science and technology which can increase R&D productivity and speed up the translation of results of this research into commercial practice.
- *Integrating* activities across budget category and program lines to 1) achieve synergies among activities in scientific and engineering disciplines and 2) avoid overlap, duplication, or gaps in program activities.

Priority emphasis is given to focusing Federal involvement on aspects where substantial societal benefits would result, and where the results would not otherwise be developed by sole reliance on private markets.

The advanced research programs focus on critical enabling science and technologies which can significantly contribute to achieving "no regrets" energy options--options characterized by fossil energy systems with simultaneous improvements in cost, technical performance, and environmental acceptability. The fossil fuel science and technology base that is needed for the development of new fossil fuel extraction, processing, and utilization systems includes several critical components. These are fundamental scientific data and information; new and novel tools, techniques and process concepts; and the human resources infrastructure of trained scientists and engineers necessary to apply the data and information.

The advanced research programs conduct two types of research:

- Fundamental, crosscutting applied research to develop an **improved scientific understanding** of underlying phenomena, and to develop associated products--**analytical tools, techniques, and processes**--to apply this understanding to fossil energy systems.
- Exploratory research--of both a crosscutting and technology-specific nature--to pursue **innovative concepts and processes and enhance and pace of technology innovation** for fossil energy systems.

To ensure the critical crosscutting needs are identified and addressed, the research strategy of the advanced research programs has five major elements:

-
- Using a systems perspective to identify and target high-priority research
 - Focusing on critical enabling science and technologies
 - Adapting advances from outside the fossil energy field
 - Sustaining a strong domestic capabilities base in fundamental applied research
 - Using innovative, collaborative mechanisms in planning and conducting research

Underlying these elements is the recognition that innovation in *how* things are done is as important as *what* is being done. The advanced research programs thus focus on the development of the science and technology base necessary for both the development of innovative technology *and* the timely availability of such technology. These are both key factors in the development of new generations of fossil energy systems. An extensive description of this strategy and its application in the individual advanced research programs in the Budget and Reporting (B&R) structure is presented in the FY 1992 *Advanced Research Program Plan: Crosscutting Fossil Fuels Science and Technology* (National Technical Information Service publication # DOE/FE-0250T).

III. ADVANCED RESEARCH PRODUCTS

The success of advanced research mission can be readily seen in the science and technology products--analytical tools, techniques, and innovative concepts and processes--that have directly contributed to the development and commercial application of advanced fossil fuel systems. The advanced research products are applied to these systems through three primary technology transfer paths:

- Direct transfer to commercial applications by the private sector
- Transfer to the private sector for further development prior to commercial application
- Transfer to FE technology development programs for further development

The advanced research products themselves can be grouped into three general product types:

- Novel process, process step, or subsystem
- Enabling technology base element
- Tool/technique (including software, models, and databases)

The first two product types are particularly critical, as they form the technology base from which advanced fossil fuels systems are designed and developed. Each of the major systems under development in FE today benefit from this technology base. These include those for advanced power systems such as Fluidized Bed Combustion, Integrated Gasification Combined Cycle, Advanced Pulverized Coal, Indirectly-Fired Cycles and Fuel Cell systems; Coal-Based Fuel Systems such as Direct and Indirect Coal Liquefaction and Coal Gasification; and Petroleum and Gas Systems such as Oil Recovery, Oil Shale Retorting, Upgrading of heavy crude/residuum, and Liquids from Gases. Both novel process concepts, which are adaptable to multiple systems applications, and the fundamental data/information products of the enabling technology base elements are *crosscutting*. Their developments in *critical enabling science and technology* are broadly applicable to multiple systems. Table 1 presents examples of these critical enabling areas and their application to some of the major FE systems identified above.

Table 1
Application of Critical Enabling Science and Technology

Examples of Critical Enabling Science and Technologies	EXAMPLES OF FE SYSTEMS UNDER DEVELOPMENT									
	Coal					Petroleum			Gas	
	FBC	IGCC	APC/IFC	Fuel Cells	Liquefaction	Gasification	Oil Recovery	Oil Shale Retorting	Heavy Crude/Residuum Upgrading	Gas-to-Liquids
• Reaction Process Analysis and Control	●	●	●		●	●	●	●	●	●
• Materials	●	●	●	●	●	●	●		●	
• Biotechnology			●		●	●	●		●	●
• Measurement & Control Systems	●	●	●	●	●	●	●	●	●	●
• Multiphase Flow/Solids Transport	●	●			●	●	●	●	●	
• Separations	●	●	●	●	●	●		●	●	●

An example of the impacts of enabling technology base elements on a particular system type is for Atmospheric Fluidized Bed Coal Combustion; the combustors represent one of the most significant recent advances in utility coal combustion systems. The technology base contribution includes:

- Evaluation and performance testing of alternative sorbent materials;
- Investigation of inbed tube corrosion and erosion phenomena;
- Evaluation of advanced materials and development of materials performance databases;
- Fluid dynamics modeling of fluid bed behavior and performance;
- Investigation of novel advanced concepts, including two-stage fluid beds; and
- Investigation of heat transfer in fluid beds.

Note that these same elements are also applicable to other combustion systems, and in materials for example, to other fossil energy systems as well. Similar crosscutting technology base applications are seen in Pressurized Fluidized Bed Coal Combustors, in Coal Liquefaction including Coal-Oil Coprocessing, and in Second Generation Pressurized Fluid Bed Gasification.

For a more extensive discussion of the relationship between crosscutting critical enabling science and technology and the various coal, petroleum, and natural gas systems that are addressed in the overall FE R&D program, refer to the FY 1992 Advanced Research Program Plan.

IV. OVERVIEW OF ADVANCED RESEARCH CONTRIBUTIONS

Of the 100 successes cited in *Fossil Energy: From Laboratory to Marketplace*, over one-half represent areas where the discrete contributions of advanced research products are readily identifiable. This contribution is demonstrated by Table 2, which shows the success story citations to which advanced research has directly contributed. Of the 57 specific citations denoted in Table 2, the advanced research products contributed as follows:

- 29 represent products transferred directly to commercial practice
- 28 represent products transferred to the FE technology development programs and industry for further development

This represents a conservative perspective of advanced research contributions as the *general* contribution of enabling technology base elements is embedded in the development of almost all advanced systems.

Table 2
Advanced Research Contributions to Individual Success Citations

Category	Total Citations	Advanced Research Contributions	
		Citations	%
In the Marketplace	34	17	50
On the Threshold	38	26	68
Spinoffs	8	2	25
Technical Successes	8	6	75
Databases/Software	12	6	50
TOTAL	100	57	57

Some examples of these contributions are presented as follows, organized according to the report's major categories:

- **In the Marketplace**
 - "Super 9 Chrome" Alloy, which was transferred directly from the AR&TD Materials subprogram to commercial practice and is now used in over 65 coal-fired plants world-wide. This won a R&D 100 award in 1982.
 - More Durable Refractories for Coal Gasifiers, which are now used in commercial scale gasifiers, resulted from a collaborative AR&TD Materials/industry effort.
 - Project Calcium, a collaborative effort of several advanced research programs and industry, resulted in enabling technology base information that is being used in both commercial and FE technology development efforts.

-
- Polycrystalline Diamond Compact (PDC) drill bits, which resulted from enabling research in the AE&PT program. The PDC bit is now the industry standard in oil and gas exploration and production.
 - Mudpulse Telemetry for Measurement while Drilling, which was developed by the AE&PT program and transferred directly to commercial applications by the oil services industry.
 - **On the Threshold**
 - "Once Through" Liquid Phase Methanol Synthesis, which originated as an advanced research novel concept and is now being demonstrated in the FE Clean Coal Technology Development program.
 - Converting Methanol to Gasoline, which originated as a novel concept for indirect coal liquefaction in the AR&TD program. The process was subsequently developed by Mobil to the point of a full-scale commercial plant.
 - Alumina Membranes for Hot Gas Separation, which are being developed in the AR&TD Materials subprogram and are expected to be lower cost and have higher selectivity and throughput than currently available ceramic membranes.
 - Corrosionless Alloys, which through improvements in the ductility of iron aluminide alloys in the AR&TD Materials subprogram, are poised for commercial introduction. This effort won a R&D 100 award in 1990.
 - Crosswell Seismic Surveying of Oil and Gas Reservoirs, a collaborative AE&PT/industry effort, has developed advanced systems that are now being tested for commercial application.
 - **Technical Successes**
 - Coal Slurry Fuels, which resulted from a novel concept in the advanced research programs, have established an alternative coal-based fuel option and thus helped to establish a price cap above which fuel oil prices cannot be sustained over an extended period.
 - Oil Shale Retorting, in which enabling technology in solids transport and computational fluid dynamics from the advanced research programs has contributed to the technology base for the potential use of a very large domestic resource.
 - **Databases/Software**
 - Intelligent Software for Designing Refractory Systems, in which an AR&TD Materials subprogram/industry consortium collaboratively developed user-friendly software for the design and selection of refractories for commercial applications.
 - Performance and Properties of Coal Conversion Materials, databases which resulted from the AR&TD Materials subprogram and allow users to select appropriate materials for process development and commercial applications.
 - Crude Oil Analysis Data Bank, which was developed by AE&PT and its predecessor program and is widely used by industry in the analysis of crude feeds and process streams in refinery design and operation.

Moreover, this success is demonstrated not just in research *products*, but also in research *mechanisms* to increase R&D productivity, including collaborative team arrangements that bring together unique combinations of research capabilities. Three examples highlight this:

- In fundamental coal science research, an innovative arrangement of collaborative teams--consisting of industry, university, national laboratory, and FE Energy Technology Center participants--was established to address critical enabling science and technology needs in three key topical areas. "Project Calcium" is one of these topical research teams. Not only did this produce significant, widely applied research results, but the team members, both individually and jointly, have become core participants in subsequent process and engineering development work that builds upon these results.
- A highly successful consortium--the Thermomechanical Model Software Development Consortium of DOE, 12 industrial firms, and the State of Tennessee--was formed to develop and transfer software for the design and selection of refractory systems.
- A Crosswell Seismic Forum has been established under the Oil Technology Partnership (a joint DOE/industry collaborative for research) to review potential R&D efforts and jointly fund/conduct selected efforts in seismic receiver, source, and telemetry technology.

The success of these research products and mechanisms success is clearly demonstrated in *Fossil Energy : From Laboratory to Marketplace*. Table 3 shows the individual successes from that report to which advanced research directly contributed, organized according to the major categories in the report. The specific advanced research contributions are described in the Appendix to this report. To facilitate referencing the individual citations in the Appendix, the individual citations are numbered and presented in the Appendix in the order they appear in Table 3.

Table 3
Advanced Research Success Contributions

IN THE MARKETPLACE	
1.	Atmospheric Fluidized Bed Coal Combustors
2.	Microbubble Coal Cleaning
3.	Phosphoric Acid Fuel Cell Power Plants
4.	"Super 9 Chrome"
5.	Component Valves for Entrained Flow Gasifiers
6.	More Durable Refractories for Coal Gasifiers
7.	X-Ray Image Digitization System
8.	Project Calcium
9.	Fiber Optic Sealed Pressure Transducers
10.	Centrifugal Slurry Pump
11.	"Nuclear Meter" for Coal Analysis
12.	Diffusion Method for Bonding Protective Coatings to Alloys
13.	Iron Aluminide Powders
14.	High Compression Oxygen Compressor
15.	Polycrystalline Diamond Drill Bits
16.	Mudpulse Telemetry for Measurement While Drilling
17.	Pressure Core Barrel for Measuring Reservoir Resources
ON THE THRESHOLD	
18.	Pressurized Fluidized Bed Coal Combustors
19.	Metal Oxide Hot Gas Desulfurization

Table 3
Advanced Research Successes Contributions (Continued)

ON THE THRESHOLD (Continued)	
20.	The Coal Refinery Concept
21.	"Once Through" Liquid Phase Methanol Synthesis
22.	Converting Methanol to Gasoline
23.	A New Generation of Catalysts
24.	Second Generation Pressurized Fluid Bed Gasifiers
25.	The Coal-Fueled Diesel Engine
26.	Reburning for NO _x Control
27.	Molten Carbonate Fuel Cells
28.	The RQL Combustion System for Gas Turbines
29.	Single Crystal Silicon Carbide Whiskers
30.	New Nickel-Iron Aluminide Alloys
31.	Glycine Nitrate Process for High Quality Ceramic Powders
32.	Ceramic Filters for Filtering High Temperature Particles
33.	Producing Ceramic Composite Candle Filters
34.	Alumina Membranes for Hot Gas Separation
35.	Advanced Austenitic Alloys
36.	Electrospark Deposition
37.	Microwave Sintering of Ceramics
38.	Corrosionless Alloys
39.	3-D X-Ray Computed Tomography for Ceramics
40.	Advanced Solid State Electrolyte System Materials
41.	Microbial Enhanced Oil Recovery
42.	Producing Liquids from Methane Gas
43.	Crosswell Seismic Surveying of Oil and Gas Reservoirs
SPINOFFS	
44.	Multiphase Flow Measurements In Artificial Heart Devices
45.	Microbially Produced, Coal-Based Fertilizer
TECHNICAL SUCCESSES	
46.	Single Stage Coal Liquefaction
47.	Coal Slurry Pump
48.	Coal Slurry Fuels
49.	Pipeline Gas from Coal
50.	Kinetic Coal Feeder
51.	Oil Shale Retorting
DATA BASES/SOFTWARE	
52.	Coal Technology Data Base
53.	Intelligent Software for Designing Refractory Systems
54.	Performance and Properties of Coal Conversion Materials
55.	Crude Oil Analysis Data Bank
56.	Arctic and Offshore Research Information System
57.	ASPEN Process Simulator

V. OTHER SUCCESSES

The SBIR Program

The emphasis throughout this document has been to identify and characterize the various roles which the advanced research programs have contributed to the successes noted in *Fossil Energy: From Laboratory to Marketplace*. All of the examples cited here to this point involve line-item funded programs found in the B&R structure. Another innovation research program which is funded as a percentage of all extramural research is the SBIR program. Although not technically an "advanced research program," the program is managed in a fashion directly analogous to elements of the advanced research programs, and is also managed by the Office of Technical Coordination, which manages the advanced research programs. In a manner similar to the AR&TD University Coal Research subprogram, research topic descriptions for an annual research solicitation are developed to cover a broad set of high-priority research topics that crosscut the total FE R&D Program.

It is notable that three of the successes cited in the report are direct outgrowths from the SBIR Program. These are:

- The Vortec Coal-Fired Process Heater
- Steam-CO₂ Injection for Heavy Oil Recovery
- Suppressing Voltage Spikes with MHD Technology

Since the April 1991 publication of that report, there have been two additional SBIR successes of note:

- Process for Thin-Film Deposition for Fuel Cell Materials--this process, which received a R&D 100 award, is now being commercialized subsequent to a 1991 FE SBIR Phase I award.
- 3-D Reservoir Mapping and Modeling--an advanced software package for improved oil recovery is now commercially available as the result of a 1990 FE SBIR Phase II award.

Technologies for the 21st Century

As described in *Fossil Energy: From Laboratory to Marketplace*, the overall FE R&D continues to meet new challenges and to create new opportunities for achieving the goals of the National Energy Strategy. As has been true in the past, advanced research will play an important role in achieving these goals.

The key to new knowledge and innovation in energy is basic science and research. Of course, there must also be focused R&D--both to advance new technologies and to better understand existing technologies. A major part of the NES is to expose and expand the role that science and technology can play in achieving U.S. objectives for energy security, economic growth, and enhanced environmental quality. History is full of instances where technology revolutionized both our energy sources and our effectiveness in putting them to human service.

For example, new insights about geology, new extraction techniques, and the exploration of new geographical frontiers more than once have "restocked" domestic petroleum reserves, despite earlier projections that those reserves were about to be exhausted. During the 1980s, new technology helped to break the one-to-one relationship that had long existed between total primary energy consumption and economic growth.

The private sector is primarily responsible for developing and commercializing technology, but the Federal government has a critical role in basic and applied scientific research. The extensive system of national research laboratories and Federal support of academic and private research can profoundly influence the focus, scope, and pace of energy technology development. Accordingly, the NES seeks to maintain U.S. preeminence in fundamental science and engineering research, sharpen the focus of strategy-related research

in energy science and technology, and promote excellence and productivity throughout the U.S. research establishment.

The Office of Fossil Energy supports the NES through a program directed at identifying R&D opportunities and conducting R&D in extracting, processing, and utilizing domestic fossil fuel resources, and in developing fossil energy technologies which can enhance U.S. competitiveness in the energy marketplace. As shown in Figure 2, these overall objectives are supported by specific technology performance targets. In turn, specific advanced research objectives have been established to address these performance targets.

Figure 2
FE Strategic Objectives

A series of program strategies have been established in order to link the activities of the individual programs to the advanced research strategic objectives. These strategies, and their respective advanced research strategic objectives, are presented in Figure 3.

Figure 3
Advanced Research Strategies

Strategic Objectives	Strategies
Strengthen U.S. fossil fuels science and technology base and associated infrastructure	<ul style="list-style-type: none"> • Maintain a balanced portfolio of Federal investments in fundamental fossil fuel science and engineering research supportive of key NES goals and related technical objectives. • In cooperation with industry, conduct cost-shared, university-based applied research to provide opportunities for improved education and training of faculty and students in the scientific and engineering disciplines associated with fossil fuel extraction, conversion, and utilization, and to increase both the flow of useful fundamental research results from universities to industry and the rate of industrial innovation.
Demonstrate new models for increasing productivity of U.S. fossil fuels R&D	<ul style="list-style-type: none"> • By 1994, in cooperation with industry, universities, and national laboratories, implement a portfolio of innovative institutional approaches to 1) conduct collaborative applied research in generic, precompetitive areas of the critical enabling fossil fuel sciences and technologies, and of accelerated technology transfer to private industry and consumers and 2) encourage the adaption and leveraging of scientific and technologic developments from rapidly evolving fields to the fossil fuels field.
Achieve adoption of advanced coal-based power and heat generation systems	<ul style="list-style-type: none"> • In cooperation with industry, conduct a cost-shared collaborative applied research program to establish by 1997, 2002, and 2010, respectively, the necessary enabling science and technology knowledge base, and infrastructure including trained scientists and engineers, for the development and demonstration of advanced coal-based heat and electric power generation systems with conversion efficiencies which exceed 47% (by 2003), 50-55% (by 2008), and 55-60% (by 2015).
Achieve adoption of high-efficiency conversion processes for upgrading heavy hydrocarbons to transportation fuels	<ul style="list-style-type: none"> • In cooperation with industry and universities, conduct a fundamental research program in petroleum and other heavy hydrocarbon chemistry to develop the scientific knowledge base about feedstock properties and performance required to facilitate the design of efficient conversion processes. • In cooperation with industry, conduct a cost-shared collaborative research and development program to obtain by 1997, the necessary technology base for industry to construct and operate advanced processes with high hydrogen and carbon utilization efficiency for upgrading heavy crude, residuum, and coal-derived liquids to transportation fuel feedstocks. • In cooperation with industry, conduct a cost-shared collaborative applied research program to establish by 1997, the necessary enabling science and technology knowledge base and infrastructure, including trained scientists and engineers, for the development and demonstration of coal liquefaction and coal/oil coprocessing processes competitive with \$25/barrel conventional crude oil.
Achieve adoption of advanced geoscience and petroleum engineering tools and techniques	<ul style="list-style-type: none"> • In collaboration with industry and universities, conduct a cost-shared collaborative, interdisciplinary R&D program to establish the critical enabling science and technology base and infrastructure, including trained scientists and engineers, necessary for the private sector to develop and apply new generations of economically competitive geoscientific and petroleum engineering tools and techniques for significantly increasing the recovery of those petroleum resources which are currently unrecoverable due to scientific and technologic constraints.
Achieve adoption of processes for direct conversion of light hydrocarbon gases to transportation fuel feedstocks	<ul style="list-style-type: none"> • In cooperation with GRI and industry, conduct a cost-shared collaborative research, development, and demonstration program to achieve by 2000 prototype demonstration of one or more direct conversion processes for the production of hydrocarbon transportation fuels which will be competitive with \$25/barrel crude oil.

An underlying theme in all program strategies is the development of core capabilities in critical enabling science and technologies which can be applied to multiple systems and across coal, oil, and gas resources. In these core capabilities, science and technology developed primarily for one resource can be readily applied to the requirements of other resources. Examples of this crosscutting applicability are:

- Materials--advanced corrosion-resistant alloys developed in the coal AR&TD program are expected to have oil-field applications where high temperatures and sulfidating conditions exist.
- Separation processes--developments in several advanced research coal programs in gas/liquid and gas/gas separations will have generic applicability to related problems in petroleum and gas processing.
- Fundamental hydrocarbon properties--determination of thermodynamic properties of heavy hydrocarbon compound classes in the AE&PT program will have crosscutting applicability to coal processing in both direct liquefaction and coal-oil coprocessing.

This crosscutting perspective pervades the advanced research programs, integrating fundamental applied research needs across the coal, petroleum, and gas components of the overall FE R&D program. The advanced research programs in coal conduct work that is coal-specific, as well as work with crosscutting applicability to petroleum-related and gas-related research needs. In petroleum, the AE&PT program includes advanced research activities with cross-cutting applicability to all petroleum and reservoir types. It additionally includes gas-related research in gas-to-liquids conversion, as well as other research with crosscutting applicability to both coal-related and gas-related research needs.

The advanced research strategic objectives and strategies integrate the individual program activities by targeting specific performance objectives--in advanced tools, techniques, and processes, and in the research management approaches used in attaining them. The program strategies thus integrate research activities across budget and program lines to 1) achieve synergies among activities in scientific and engineering disciplines and 2) avoid overlap, duplication, or gaps in program activities. Figure 4 presents the relationship of the individual advanced research programs/subprograms, and their funding sources, to the six crosscutting advanced research strategic objectives.

As shown in this figure, two objectives--for a strengthened U.S. fossil fuels science and technology base and for increased productivity of U.S. fossil fuels R&D--crosscut *all* advanced programs and are a key to successfully obtaining the other four objectives, which target advanced technology options for power generation and liquid fuels. The advanced research strategic objectives and program strategies thus directly link the individual advanced research programs to the NES goals and the FE strategic objectives.

Details of this research strategy as it applies to major fossil fuel systems and the individual advanced research B&R programs may be found in the FY 1992 *Advanced Research Program Plan: Crosscutting Fossil Fuels Science and Technology* (National Technical Information Service publication # DOE/FE 0250T).

Figure 4
Crosscut of Advanced Research Strategic Objectives
to Program Funding Sources

Advanced Research Programs Subprograms		Advanced Research Strategic Objectives					
		Strengthen U.S. fossil fuels science and technology base and associated infrastructure	Demonstrate new models for increasing productivity of U.S. fossil fuels R&D	Achieve adoption of advanced coal-based power and heat generation systems	Achieve adoption of high-efficiency conversion processes for upgrading heavy hydrocarbons to transportation fuels	Achieve adoption of advanced geoscience and petroleum engineering tools and techniques	Achieve adoption of processes for direct conversion of light hydrocarbon gases to transportation fuel feedstocks
Coal B&R	Advanced Research & Technology Development						
	• Coal Utilization Science	◆	◆	◆			
	• Materials	◆	◆	◆	◆	◆	◆
	• Components (including Solids Transport)	◆	◆	◆			
	• Instrumentation & Diagnostics	◆	◆	◆			
	• Bioprocessing of Coal	◆	◆	◆	◆		◆
	• University Coal Research	◆	◆	◆	◆		
	Advanced Research - Coal Technologies						
	• Control Technology & Coal Preparation	◆	◆	◆	◆		
	• Coal Liquefaction	◆	◆		◆		
	• Combustion Systems	◆	◆	◆			
	• Fuel Cells	◆	◆	◆			
	• Surface Coal Gasification	◆	◆	◆	◆		◆
Petroleum B&R	Advanced Extraction & Process Technology						
	• Geoscience & Extraction Research	◆	◆			◆	
	• Supporting Tech. & Environmental Research	◆	◆		◆		◆
	• University Geoscience Research	◆	◆			◆	
Crosscut*	Small Business Innovation Research	◆	◆	◆	◆	◆	◆

* Non-B&R program; funded by law as a percentage of extramural research

Appendix

Descriptions of the Role of Advanced Research Products in Individual FE Successes

IN THE MARKETPLACE

1. Atmospheric Fluidized Bed Coal Combustors

Program: Various Advanced Research & Technology Development (AR&TD) subprograms, Including Coal Utilization Science, Materials, and Components; and the Combustion Systems Advanced Research subprogram

Product Type: Enabling Technology Base Element

Status: These systems are now in wide-spread commercial use.

These combustors represent probably the most significant recent advance in utility coal combustion systems. The advanced research programs contributed many technology base products which were crucial to the ability of the DOE/industry program to achieve the commercial success of this technology. Specific research topics which were extensively researched in the AR&TD Materials and Components subprogram, AR&TD Coal Utilization Science subprogram, and Combustion Systems Advanced Research subprogram in the late 1970s and early- to mid-1980s include:

- Evaluation and performance testing of alternative sorbent materials;
- Investigation of inbed tube corrosion and erosion phenomena;
- Evaluation of advanced materials and development of materials performance databases;
- Fluid dynamics modeling of fluid bed behavior and performance;
- Investigation of novel advanced concepts, including two-stage fluid beds; and
- Investigation of heat transfer in fluid beds.

Results of this advanced research became part of the overall technology base which enabled the joint government/industry development and subsequent commercialization of atmospheric fluidized bed to proceed.

2. Microbubble Coal Cleaning

Program: AR&TD University Coal Research subprogram

Product Type: Novel Process

Status: In commercial use in coal cleaning and spinoff applications in non-fossil energy industries

Researchers at Virginia Polytechnic Institute received a University Coal Research grant in 1980 to investigate the use of microbubbles for separating impurities from the ultra-fine coals that are characteristic of finer crushing and grinding processes necessary to clean coal of impurities. Their initial results showed promise and in 1983 the researchers were awarded a second grant to pursue the development of a froth flotation cell using the microbubble technique. Additional FE support, through the process and engineering development activities of the Control Technology and Coal Preparation program, led to a successful demonstration in 1988 of a continuous, 14-inch-diameter column capable of separating 90 percent of the impurities from ultra-fine coal, while recovering 90 percent of the coal heating value. This achievement led to the commercial introduction of the Microcel (TM) technology currently under licensing agreement with ICF Kaiser Engineers. The technology is now in use at the Shell Mining Co. Marrowbone coal preparation plant at Naugatuck, West Virginia. This process has also resulted in several spin-off applications in other industries.

3. Phosphoric Acid Fuel Cell Power Plants

Program: AR&TD Direct Utilization and Fuel Cells Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: Initial commercial power plants are being built for electric utilities in the U.S. and overseas

Research carried out in the AR&TD Direct Utilization subprogram and one of its successor subprograms, Fuel Cells Advanced Research, made important contributions to the successful development. Key contributions included:

- Evaluation of advanced electrochemical catalysts;
- Development of improved electrode materials, and
- Identification and evaluation of improved electrolytes.

4. "Super 9 Chrome"

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: Product transferred to industry for general systems application; the alloy is now used in over 65 coal-fired plants world-wide

In 1980, DOE's Fossil Energy program began studying a new 9 percent chromium-1 percent molybdenum alloy which had been largely developed by Oak Ridge National Laboratory (ORNL) and Combustion Engineering for the Breeder Reactor Program. This new material offered the potential for substantially improved performance in fossil applications. As the result of a joint FE/utility effort, the material was included in the ASME Boiler and Pressure code for use in fossil applications, and was transferred directly to industry from the AR&TD Materials subprogram. The alloy offers many advantages including lower costs, higher allowable design stress and immunity from stress, and corrosion cracking. This was the winner of a prestigious R&D 100 Award in 1982. This alloy is now commercialized and is used world-wide in fossil fuel power plants.

5. Component Valves for Entrained Flow Gasifiers

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: Slag lockhopper valves that are now offered commercially for coal gasification applications embody many of the improvements and modifications from this research

In the late 1970s and early 1980s, the AR&TD Materials and Components subprogram sponsored research at, and through, the Morgantown Energy Technology Center (METC) which established the foundations for subsequent development and testing activities which were conducted later as part of the process and engineering development activities of the Surface Coal Gasification program. Research on these topics transitioned from the advanced research program in the early 1980s. Texaco has stated that the DOE valve and refractory research programs were critical to the successful development of their coal gasifiers which are being used in development and commercial reactors today.

6. More Durable Refractories for Coal Gasifiers

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: Refractories of this type are currently used in commercial scale coal gasifiers

A major research activity in the AR&TD Materials and Components subprogram in the late 1970s and early 1980s was the evaluation and development of advanced materials for use in coal conversion process plants. One of the major topics was the development of refractory materials for use in slagging gasifiers. The results of this collaborative research program with industry led to the successful development and demonstration of acceptable refractory lifetimes in entrained flow coal gasifier applications. It is generally recognized that development of durable slagging refractories was critical to enabling the development and commercialization of partial oxidation reactors which are being used worldwide today.

The success was a direct outgrowth of this advanced research program, and is also closely related to another success described elsewhere in this document (See example No. 53, Intelligent Software for Designing Refractory Systems).

7. X-Ray Image Digitalization System

Program: AR&TD Materials & Components subprogram

Product Type: Tool/Technique

Status: Currently in commercial use by a major ceramic manufacturer

This novel technique, for non-destructive evaluation of ceramics, was developed through the AR&TD program and transferred directly to industry. The advanced research program recognized the need for non-destructive evaluation techniques to pinpoint any potential ceramic flaws prior to the expensive sintering process, thus significantly reducing process costs of materials and manufacturing losses incurred by defective parts. A related tool for control of ceramics quality is 3-D X-Ray Computed Tomography for Ceramics (See example No. 38).

8. Project Calcium

Program: AR&TD Coal Utilization Science, Combustion Systems Advanced Research, and Control Technology and Coal Preparation Advanced Research subprograms

Product Type: Enabling Technology Base Element, Tool/Technique

Status: Results are being used commercially and in FE technology development programs

This success results from a coordinated team research project conducted within the Advanced Research programs and implemented through the Pittsburgh Energy Technology Center (PETC). One direct result is a service that is currently being offered commercially to utilities to assist them in predicting behavior of alternative coal feedstocks on boiler performance. Another is the enabling technology base that allowed the identification and selection of advanced, indirectly-fired combined cycle concepts for the development program currently underway as part of the process and engineering development activities in the FE Combustion program.

This effort has additional significance as the work was conducted through an innovative collaborative team, consisting of industry, university, national laboratory, and FE Energy Technology Center participants. In addition to the research results, team members, both individually and jointly, have become core participants in subsequent process and engineering development activities that build upon those results.

9. Fiber Optic Sealed Pressure Transducers

Program: AR&TD Instrumentation and Diagnostics subprogram

Product Type: Tool/Technique

Status: Some products derived from this technology base are being offered commercially and additional new products are under test and evaluation

Research supported in the inhouse program at METC through the AR&TD Instrumentation and Diagnostics subprogram on the generic topic of fiber optic transducers for pressure and temperature measurement was critical to the development of the family of pressure probes described. It also has led directly to the development of a high temperature fiber optic temperature probe. This new instrumentation technique is under test and evaluation for use in partial oxidation reactors.

10. Centrifugal Slurry Pump

Program: AR&TD Direct Utilization, AR&TD Coal Utilization Science, and Combustion Systems
Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: Product is now offered commercially

Fundamental research in the in-house research activities at PETC, sponsored through several parts of the advanced research program over an extended period of time, made important contributions to the database necessary to design this new generation of slurry pumps. This research included construction of a test loop at PETC which was used to measure rheological parameters of coal-liquid slurries.

11. "Nuclear Meter" for Coal Analysis

Program: AR&TD Direct Utilization subprogram

Product Type: Tool/Technique

Status: In commercial use

Development of the novel instrumentation systems described in this success was conducted at METC and funded by the AR&TD Direct Utilization subprogram during the late 1970s.

12. Diffusion Method for Bonding Protective Coatings to Alloys

Program: AR&TD Materials subprogram
Product Type: Enabling Technology Base Element
Status: An industry/EPRI project is testing the coatings

Basic pack cementation processes have been commercial for some time. However, the existing commercial processes could not consistently produce quality coatings suitable for some fossil applications. In the late 1980s, the AR&TD Materials subprogram initiated a fundamental study of the process chemistry and thermodynamics; as a result, the principles and procedures were established to consistently produce high quality coatings through a new pack cementation diffusion coating process.

Commercialization of this new process is now proceeding. Ohio State, collaborating with the Babcock and Wilcox Company, the Electric Power Research Institute, and the Cincinnati Gas & Electric (CG&E) Company, is producing a coated water wall panel that will be installed and tested in a CG&E power plant. Broad commercial applications of this coating process are expected.

13. Iron Aluminide Powders

Program: AR&TD Materials subprogram
Product Type: Enabling Technology Base Element
Status: Iron Aluminide Powders are commercially available

This development was part of a larger effort to develop iron aluminide alloys for fossil energy applications (primarily coal gasification) that require good high temperature strength coupled with excellent resistance to corrosion. Because these alloys, developed at ORNL, have outstanding sulfidation resistance (second to no other known alloy) their potential for use as sintered metal hot gas cleanup filters was recognized. This led ORNL to initiate a collaborative (cost shared) effort with Ametek Specialty Metals to produce powders for Pall Corporation to in turn produce sintered metal filters. Ametek has produced the powders and taken a license for commercial production. Pall is currently developing the process for fabricating the filters. Significant commercial markets are anticipated for both the powders and the filters. Ametek recently began their commercial marketing campaign for the powders.

14. High Compression Oxygen Compressor

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: The compressor is now commercially available

Coal gasifiers which produce synthesis gas or high to medium Btu syngas require a pure oxygen feed at medium to high pressure. Compressors suitable for full size, high pressure, synfuel plants did not exist when pilot and demonstration plants were being pursued during the 1970s. To meet this need, FE initiated, in the late 1970s, development of a 1,200 tons per day, 2,000 psi pressure, centrifugal oxygen compressor. The resulting program was a collaborative (task shared) effort with Mannesmann Demag of Germany. Demag designed and fabricated the compressor unit which was an extension of their existing commercial, medium pressure compressor. The testing was done under a DOE funded effort at a DOE Energy Technology Engineering Center modified Rocketdyne rocket test facility, in Santa Susana, California.

This effort is an excellent example of a highly successful collaborative teaming of efforts which used the complementary technology and assets of two parties--an industrial compressor designer and manufacturer and the facilities and know how of a program sponsored test facility. This program/approach also obviated the need for technology transfer and was accomplished at a fraction of the time and cost required if a standard full scope development program approach had been used.

15. Polycrystalline Diamond Drill Bits

Program: Advanced Extraction & Process Technology (AE&PT) program

Product Type: Tool/Technique

Status: The advanced research product is incorporated in the technology currently in commercial use as the industry standard for drilling bits

Previous industry attempts to develop diamond cutting bits for oil and gas drillings applications failed because of failure of the bond between the diamond bit and the bit substrate. Research under the AE&PT program by Sandia National Laboratory developed a novel technique to bond the diamond cutter to the body of the drill bit, thus enabling the use of the diamond cutting face.

16. Mudpulse Telemetry for Measurement While Drilling

Program: AE&PT program

Product Type: Tool/Technique

Status: In commercial use by the drilling industry

In the 1970s, the AE&PT program helped pioneer a wireless system that could transmit the location of a drill bit by sending pressure pulses through the drilling mud that circulated from the bit face to the surface. Today, mudpulse telemetry has gained wide acceptance in the drilling industry, allowing continuous monitoring of drilling progress and thus both lowering the cost of drilling and improving drilling accuracy.

17. Pressure Core Barrel for Measuring Reservoir Resources

Program: AE&PT program

Product Type: Tool/Technique

Status: In commercial use

One of the key devices needed to make accurate measurements of underground reservoir conditions is a "pressure core barrel"--a device for retrieving a core sample of reservoir rock while maintaining the ambient pressure of the reservoir. In 1979 and 1980, the AE&PT program funded the development of a prototype core barrel that could maintain the original conditions of the reservoir.

In this effort, Sandia National Laboratories cooperated with several supply and service companies to conduct and test a prototype tool. Many aspects of this technology are now included in the range of tools and services provided by the oil services industry.

ON THE THRESHOLD

18. Pressurized Fluidized Bed Coal Combustors

Program: AR&TD Direct Utilization, AR&TD Materials and Components, and Combustion Systems Advanced Research subprograms

Product Type: Enabling Technology Base Element, Novel Concept

Status: Currently in commercial demonstration stage

As in the case of atmospheric fluidized bed (AFB) combustors, (See example No. 1) substantial research was conducted in several advanced research subprograms during the 1980s on the same research topics as described in the AFB success. This research has contributed significantly to the enabling technology base for the technology development and demonstration programs currently underway in other parts of the overall FE coal R&D program.

The initial exploratory research on the incorporation of a high temperature topping combustor into fluidized bed systems as a means to increase hot gas temperature and system efficiency was conducted in the advanced research programs. It is the evolution of this concept which is a key element of second generation pressurized fluidized bed systems currently under development.

19. Metal Oxide Hot Gas Desulfurization

Program: AR&TD Coal Utilization Science, Combustion Systems Advanced Research, and Control Technology and Coal Preparation Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: Technology is being demonstrated in several projects in the Clean Coal Technology Demonstration program

The technology base for this hot gas cleanup was established in large part by efforts in the advanced research programs. Several advanced research projects have been central to this effort; in particular in-house research on contaminant release and the chemistry and kinetics of hot gas sulfur/sorbent reactions at METC and development of a means to treat the tail gas produced and regenerate the sorbent at Research Triangle Institute.

20. The Coal Refinery Concept

Program: AR&TD Processes, AR&TD Bioprocessing of Coal, Coal Liquefaction Advanced Research, and Surface Coal Gasification Advanced Research subprograms

Product Type: Enabling Technology Base Element, Novel Concept

Status: Demonstration of the concept is underway as part of the Clean Coal Technology Demonstration program

The specific type of "Coal Refinery" concept described is but one of many coal refinery concepts which are currently the subject of interest and research. The pyrolysis-based coal refinery concept or "mild gasification" processes are a subset of a broader class of processes which include hydrolypyrolysis, flash hydrolypyrolysis, and catalytic hydrolypyrolysis. While portions of the technology base which underlies this whole broad set of pyrolysis-based systems dates back to the 19th century, other aspects were researched much more recently.

In the 1970s the AR&TD Processes subprogram conducted extensive research on pyrolysis-based systems including hydrolypyrolysis and flash hydrolypyrolysis, which contributed substantially to the overall knowledge base on this class of processes. More recently, in the late 1980s and early 1990s, the Coal Liquefaction Advanced Research subprogram has conducted research on catalytic hydrolypyrolysis. The Surface Coal Gasification Advanced Research subprogram in the late 1980s and early 1990s conducted research on the reaction mechanisms of mild gasification and characterization of the resulting liquid products and chars.

Beyond the specific class of concepts which are pyrolysis-based, the advanced research programs have also conducted important research on other novel concepts which are candidate approaches for coal refining. Most notable among these are coal-oil coprocessing, and hybrid systems concepts, including bioprocessing and biomimetic steps or combinations of partial oxidation, indirect liquefaction, and direct liquefaction. As discussed in "Once-Through" Liquid Phase Methanol Synthesis (see example No. 21), the research in the advanced research programs also contributed significantly to the feasibility of the coal refinery concept based upon coal gasification with the coproduct production of electric power and liquid fuel.

21. "Once Through" Liquid Phase Methanol Synthesis

Program: AR&TD Processes and Coal Liquefaction Advanced Research subprograms

Product Type: Novel Process

Status: The technology is now being used in a demonstration-scale plant (in the Clean Coal Technology Demonstration Program) for the production of methanol

This novel process concept, for employing a liquid phase to control the large heats of reaction from synthesis gas conversion to methanol, was first researched in the advanced research program as a concept for converting synthesis gas to methane. Previous technology for the conversion of synthesis gas lacked a method for controlling the heat generated in the process. These results were then adapted to "once through" synthesis of methanol, which was demonstrated at laboratory and pilot plant scale and subsequently selected for demonstration in the Clean Coal Technology Demonstration program.

22. Converting Methanol to Gasoline

Program: AR&TD Processes and Coal Liquefaction Advanced Research subprograms

Product Type: Novel Process

Status: The technology has been demonstrated in a 14,500 barrels per day plant in New Zealand

This process resulted from development work in the advanced research programs in collaboration with Mobil Oil. Building on their discovery of new "zeolite" catalysts in the 1960s and early 1970s, scientists from Mobil Oil Company discovered that one of these zeolites successfully reacted methane to form a hydrocarbon mixture resembling gasoline. In 1975 the FE advanced research program joined with Mobil in research and development of the process, resulting in a successful proof of concept of the process. The process was subsequently further developed by the FE process engineering and development program and industry.

23. A New Generation of Catalysts

Program: Coal Liquefaction Advanced Research and AR&TD Materials subprograms

Product Type: Novel Process

Status: This family of catalysts is currently undergoing process and engineering development by the FE Coal Liquefaction program

This new generation of catalysts, the result of a novel process concept sponsored by the Coal Liquefaction Advanced Research subprogram, is based on a unique catalyst support that provides for improved dispersion of catalytic components. The improved dispersion leads to greater hydrogenation activity, and to a lower requirement for active metal in order to provide the same coal liquefaction activity as commercial catalysts. Understanding of the materials properties of the catalyst support--a critical element for these new families of catalysts--was a result of complementary work in the AR&TD Materials subprogram. In this work, Sandia National Laboratories has developed unique hydrous metal oxide catalyst support materials with superior reactivity and selectivity in coal liquefaction.

24. Second Generation Pressurized Fluid Bed Gasifiers

Program: AR&TD Processes, Direct Utilization, and Materials and Components subprograms, and Combustion Systems Advanced Research, Control Technology and Coal Preparation Advanced Research, and Surface Coal Gasification Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: Technology is ready for demonstration-scale testing

In general, much of the enabling technology base research described for the Atmospheric and Pressurized Fluidized Bed Combustors and Metal Oxide Hot Gas Desulfurization successes also directly relates to this technology development.

In addition, fundamental and exploratory research in the AR&TD Processes and Surface Coal Gasification Advanced Research subprograms make significant contributions through topics such as:

- Novel fluid bed gasifier concepts
- Heat transfer in fluid bed gasifiers
- Methods for dealing with gas cleanup peculiar to fluid bed gasifiers

25. The Coal-Fueled Diesel Engine

Program: AR&TD Coal Utilization Science and Control Technology and Coal Separation Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: Prototype coal-fueled diesel engines are undergoing full-scale test and evaluation

Many of the breakthroughs that have enabled coal-fueled diesels resulted from advanced research projects. These include, in particular, diesel wear studies undertaken at Adiabatics, Inc., Southwest Research Institute, MTI, and Tecogen.

26. Reburning for NO_x Control

Program: AR&TD Direct Utilization, AR&TD Coal Utilization Science, Combustion Systems Advanced Research, and Control Technology and Coal Preparation Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: The technology is being demonstrated in three projects in the Clean Coal Technology Demonstration program

Several advanced research programs contributed significantly to the understanding and development of this technology. Included is a major team research effort, with wide-ranging results from research at several university and private industry laboratories. In its work, the University of Arizona has determined the mechanisms governing the destruction of the nitrogen pollutants in the reburning zone; Louisiana State University has found that reburning with lignite results in a high nitrous oxide reduction due to reactions catalyzed by the lignite char; and Energy and Environmental Research Corp. (EER) has found that more than 85 percent of the nitrogen oxide can be removed by injecting ammonium sulfate into the burnout zone.

27. Molten Carbonate Fuel Cells

Program: Fuel Cells Advanced Research and AR&TD Materials and Components subprograms

Product Type: Enabling Technology Base Element

Status: These systems are now being developed for commercial use

The advanced research programs have focused upon removing specific major barriers facing molten carbonate fuel cell (MCFC) development and have made significant contributions in areas such as:

- New materials for anodes and cathodes
- New fabrication techniques
- Corrosion resistance
- Internally-manifolded systems

The results of the advanced research are now being applied by the major MCFC developers

In addition to these important contributions to MCFC development, the research on new fabrication techniques for ceramic electrodes has found important application for use by the private sector in non-fuel cell applications and has been licensed to a startup company to exploit the spinoff benefits of the breakthrough.

28. The RQL Combustion System for Gas Turbines

Program: AR&TD Coal Utilization Science Combustion Systems Advanced Research subprogram

Product Type: Enabling Technology Base Element

Status: The process is under development in the FE process and engineering development program

The advanced research programs funded fundamental and exploratory research as part of the overall development of this technology.

29. Single Crystal Silicon Carbide Whiskers

Program: AR&TD Materials subprogram

Product Type: Novel Process

Status: Development has been completed and technology transfer is underway

Los Alamos National laboratory, working under the AR&TD Materials subprogram, developed a process for producing premium quality, pure, single-crystal silicon carbide whiskers. These whiskers are far superior to whiskers produced by conventional processes for high temperature, high strength applications. Commercial viability of this process is currently being determined through a cost-shared effort with the Carborundum Company. It is expected that these whiskers will ultimately be used in continuous fiber ceramic composites for very demanding high-temperature applications.

30. New Nickel-Iron Aluminide Alloys

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: The alloys have been licensed to five companies; commercialization is expected in 1992

For the unique requirements of fossil energy systems, alloys are needed that couple high strength and low cost with high corrosion and erosion resistance. Research was initiated under the AR&TD Materials subprogram in the mid-1980s on nickel iron aluminides and iron aluminides for meeting these requirements. The research at ORNL on nickel iron aluminides has been completed, with the development of alloys that have outstanding strength properties at high temperature for applications such as turbines. The alloys have recently been licensed to five companies and commercialization initiation during 1992 is anticipated.

31. Glycine Nitrate Process for High Quality Ceramic Powders

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: The process has been patented and licensed

In the late 1980s, Pacific Northwest Laboratories (PNL) initiated research under the AR&TD Materials subprogram on solid state electrolyte systems materials. As part of this research, PNL developed a low cost method of synthesizing a wide range of very high purity and uniform, nanometer size ceramic oxide powders for ionic and electronic applications. This technique was originally discovered by PNL, a few years ago, under a DOE Basic Energy Sciences project on superconducting materials.

The process has been patented and the first commercial license granted. The process is currently being used by government and industrial laboratories in their materials research activities. A DOE Office of Energy Research supported Cooperative Research and Development Agreement (CRADA) is in process to scale-up the process for commercial production. Subsequent broad utilization is anticipated which may give the U.S. a competitive edge in this significant solid state technology area.

32. Ceramic Filters for Filtering High Temperature Particles

Program: Control Technology and Coal Preparation subprogram

Product Type: Enabling Technology Base Element

Status: The filters are being demonstrated as part of the Clean Coal Technology Demonstration program

The advanced research activity has been central to the development of these filters. Westinghouse Science and Technology has been investigating failure mechanisms of high-temperature ceramic barrier filters used in coal fueled advanced power generating systems. The alkali released during coal utilization can react with the binder phase that holds the silicon carbide grains together. This can cause a four fold loss in hot strength within 400 hours. Westinghouse discovered that the material alumina/mullite actually gains strength under these conditions. They have worked with Coors Ceramic Company to develop a high-temperature candle filter from this material. Currently, Coors has made 20 prototype candles from this material which Westinghouse is currently testing. These candles will be eventually tested in the pressurized fluid bed combustion plant at Karhula, Finland.

33. Producing Ceramic Composite Candle Filters

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: Technology transfer activities are underway with initial commercialization expected by 199

In the mid to late 1980s, ORNL demonstrated, under the AR&TD Materials subprogram, the capability of producing controlled porosity ceramic composites suitable for particulate filtering. This was accomplished with the ORNL chemical vapor infiltration and deposition (CVID) process. Based on this technology, ORNL and the 3M Company then initiated a cost-sharing effort to demonstrate the commercial viability of producing full-size ceramic candle filters that are many times more resistant to thermal and mechanical shock.

The ORNL CVID process is continuing to be developed to produce high density structural ceramic composites. Principal advantages over commercial CVI processes are lower costs and the ability to produce parts in hours instead of weeks and parts with much thicker cross sections. Substantial industrial structure applications are expected to result from this companion development. ORNL won the prestigious R&D 100 Award for the development of the CVID process in 1987.

34. Alumina Membranes for Hot Gas Separation

Program: AR&TD Material subprogram

Product Type: Enabling Technology Base Element

Status: High-performance gas separation is expected to be demonstrated in 1993

In the late 1980s, the AR&TD Materials subprogram initiated an effort to demonstrate the viability of the concept of hot-gas cleanup using ceramic membranes. This advanced inorganic membrane technology is expected to be significantly more commercially viable than ongoing industrial ceramic membrane developments due to lower costs and higher selectivity and throughput.

Broad commercial applications of this technology are anticipated for separating liquids or gases involving high temperatures or harsh corrosive, abrasive or chemically reactive environments. This technology could significantly contribute to the U.S. regaining its lead in the hotly competitive international membrane technology markets.

35. Advanced Austenitic Alloys

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: Development of the alloys is expected to be completed in 1993 and limited technology transfer activities are currently underway

In the mid-1980s the AR&TD Materials subprogram initiated an effort to develop advanced austenitic alloys which are modifications of existing commercial alloys. These alloys are being primarily developed for superheater and reheater applications in advanced pulverized coal steam power plants to operate at 1200°F and 5,000 psi pressure as opposed to current operating conditions of about 1000°F and 3,500 psi pressure. This will increase efficiency, lower costs, and reduce environmental emissions.

36. Electrospark Deposition

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: Process refinements and fossil coatings are under development. ESP process/coatings are being commercialized.

The Electrospark Deposition (ESD) process was initially developed in the early 1980s for hard surfacing nuclear reactor components. The AR&TD Materials subprogram initiated an effort in the late 1980s to develop ESD coatings (including ESD process improvements) for fossil applications. The ESD process contributes a new dimension to materials for fossil energy applications by allowing the investigation of surface compositions that are difficult or impractical to achieve by other processes.

The ESD coatings are expected to have wide-spread applications to equipment in fossil energy systems such as atmospheric and pressurized fluidized bed combustion, gasification, liquefaction, and heat engines. Fossil application coatings are expected to be available for commercial use by 1995.

Limited process technology transfer efforts have been highly successful. Commercial ESD coatings are now being used on turbine blades, helicopter components, automotive engine parts, recycle shredders, knife sharpeners, sports equipment, and aircraft cutting tools and drilling bits.

37. Microwave Sintering of Ceramics

Program: AR&TD Materials subprogram
Product Type: Enabling Technology Base Element
Status: Process development is continuing, with commercialization expected by 1995

The AR&TD Materials subprogram initiated a program in the 1980s to explore the feasibility of using microwave heating as a means of fabricating solid state electrolyte parts having improved electrical properties for the solid oxide fuel cells. The application of microwave processing to ceramic materials is an exciting new method for sintering, joining, melting, and heat treating. Initial applications to the sintering of electrolyte materials is expected by 1995.

This project is being conducted at ORNL and is a companion project to ORNL microwave projects sponsored by DOE-Conservation on structural ceramics applications.

38. 3-D X-Ray Computed Tomography for Ceramics

Program: AR&TD Materials subprogram
Product Type: Tool/Technique
Status: Technology transfer activities are underway, with commercialization expected by 1993

It is very important throughout a ceramics manufacturing process to be able to locate defects and characterize the ceramics for density distribution, compositional changes, fiber orientation, etc.

In an AR&TD Materials subprogram project at Argonne National Laboratory, a new three-dimensional X-ray computed tomography system was developed that allows all data from an entire object to be obtained in approximately the same time as only one section using existing two-dimensional technology. A manufacturer of commercial X-ray computed tomography equipment plans to duplicate the Argonne system and offer units for commercial sale. NASA has visited Argonne and will also duplicate the system for use in their development programs.

39. Corrosionless Alloys

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Elements

Status: Technology development is continuing, with commercialization expected by 1995

Coal gasification atmospheres are often highly corrosive to many alloys because of the presence of hydrogen sulfide in the product gases. A tremendous need exists for alloys that can withstand these hostile environments over extended periods of time. Such alloys would dramatically reduce maintenance problems and plant outages resulting from materials failures, and would dramatically reduce costs. Iron aluminide alloys, which are types of intermetallic compounds, have outstanding potential in these applications. Laboratory and plant tests have verified that these alloys resist sulfidation far better than any currently available alloy. They are also expected to be relatively low in cost, and they have excellent high temperature strength and oxidation corrosion resistance. The principal barrier to their use had been their lack of ductility at moderate temperatures.

Under an AR&TD Materials subprogram effort to improve the ductility of iron aluminides at room temperatures, researchers at ORNL have made alloy modifications and special heat treatments that have achieved a 15 to 20 percent level of ductility--a level acceptable for structural applications. This work resulted in a prestigious R&D 100 Award in 1990.

40. Advanced Solid State Electrolyte System Materials

Program: AR&TD Materials subprogram

Product Type: Enabling Technology Base Element

Status: Technology development is continuing, with initial technology transfer to industry expected in 1994

Several years ago, Pacific Northwest Laboratories initiated, under the AR&TD Materials subprogram, research of advanced solid state electrolyte systems materials. Expected applications are solid oxide fuel cells (SOFC), air separation, hydrogen production, electrochemical systems, electrocatalysts, electrochemical synthesis, fluid clean up, and sensors.

Advanced SOFC materials are expected to be developed with initial transfer to industry by 1994 for subsequent development of more efficient, higher performance, and lower cost SOFCs. These results should significantly enhance commercialization of these highly flexible and efficient, non-polluting fuel cell power systems.

41. Microbial Enhanced Oil Recovery

Program: AE&PT
Product Type: Novel Process
Status: Initial commercial applications are underway

In the early 1980s, efforts were initiated through the AE&PT program to identify and assess the potential for enhancing oil recovery through microbially mediated processes. The early advanced research work showed the feasibility of such approaches. The program was transferred to the Enhanced Oil Recovery portion of the FE petroleum R&D program, and FE and industry efforts are now underway to test and evaluate them under various field conditions.

42. Producing Liquids from Methane Gas

Program: Coal Liquefaction Advanced Research subprogram and the AE&PT program
Product Type: Novel Process
Status: The process is undergoing development in a collaborative effort with industry

This novel process concept is the product of advanced research work at the Pittsburgh Energy Technology Center (PETC). PETC has developed and patented a processing two-stage process for converting methane to liquid fuel such as gasoline or methanol. The development of such a process could allow less expensive and more selective production of liquid fuel products from methane and other light hydrocarbons.

43. Crosswell Seismic Surveying of Oil and Gas Reservoirs

Program: AE&PT

Product Type: Tool/Technique

Status: Undergoing collaborative development and testing with industry

Under the Oil Technology Partnership (OTP), a jointly funded DOE/industry activity, advanced crosswell seismic systems (including seismic sources, receiver, fiber optic telemetry, and data handling subsystems) are being developed and tested. These systems will provide a manyfold increase in seismic data resolution to allow improved means of evaluating reservoir characteristics and monitoring extraction processes--both crucial to the economic production of the nation's petroleum resources. The development of the crosswell seismic systems builds upon technology developed in the DOE defense programs. The collaborative work with OTP involves approximately 24 industrial participants in the petroleum production and petroleum services industries.

SPINOFFS

44. Multiphase Flow Measurements in Artificial Heart Devices

Program: AR&TD Direct Utilization, AR&TD Coal Utilization Science, AR&TD Materials and Components and Combustion Systems Advanced Research

Product Type: Enabling Technology Base

Status: Currently being utilized

In-house research at PETC focused on understanding the flow behavior of coal slurries and of multiphase solids transport in several advanced research subprograms led to the development and use of this advanced testing facility for studying complex flow-related phenomena. These facilities and capabilities are now being utilized under a CRADA for advanced flow research.

45. Microbially Produced, Coal-Based Fertilizer

Program: Coal Liquefaction Advanced Research subprogram

Product Type: Novel Process

Status: Commercially available product

The spinoff product is based on research on the biological conversion of coal to liquid products in the Coal Liquefaction advanced research subprogram. The objective of this research, by Arctech, Inc., was to explore ways of dissolving oxidized coals to form liquids. Although the liquid products were not economical as a source of transportation fuels, they have found a different use--as soil supplements that can increase organic matter in depleted soils. While Arctech's research on bioconversion of coal to liquid and gaseous fuels is continuing, this spinoff has provided a near-term, new high-value product. Arctech now processes a naturally oxidized form of coal called "leonardite coal" into a slurry of humic acids. The liquid is then sold as an organic, environmentally safe fertilizer under the tradename Actosol™.

TECHNICAL SUCCESSES

46. Single Stage Coal Liquefaction

Program: AR&TD Processes, AR&TD Materials and Components, and Coal Liquefaction Advanced Research subprograms

Product Type: Enabling Technology Base Element

Status: The technical feasibility of direct liquefaction of coal is now established

During the late 1970s and early 1980s several advanced research programs made significant contributions to the enabling technology base for single stage coal liquefaction. The AR&TD Processes subprogram and a successor program, the Coal Liquefaction Advanced Research subprogram, produced important contributions in critical topics including:

- Fundamental understanding of the mechanisms of liquefaction
- Catalysts for hydrol liquefaction
- Novel concepts for separation of unconverted mineral matter from primary liquefaction product (deashing)
- Elucidation of hydrogen donor solvent behavior and mechanisms
- Preheater design and performance improvement

The AR&TD Processes subprogram also initiated the research project which ultimately confirmed the refinability of coal-derived liquids, using modified petroleum processing technology. This was an extremely important contribution which overturned the then-prevalent conventional wisdom that coal-derived liquids were suitable only for use as boiler fuels.

The AR&TD Materials and Components subprogram made important contributions through research results that provided new materials and fabrication processes suitable for use in coal liquefaction processes. These materials had the necessary corrosion, erosion, and strength under the harsh operating conditions of coal liquefaction processes. This AR&TD effort also provided critical components such as letdown valves and slurry pumps. Advanced materials and unique seals and hydraulic design features were used to attain long life. The successes of this effort were a critical step in establishing the operability and maintainability of liquefaction process plants.

As a result of this research, it is now widely accepted that materials of construction for coal liquefaction plants have been developed and tested under realistic operating conditions, and that long-term operability and maintainability can be achieved.

This research was originally initiated under the FE AR&TD program and subsequently completed under the FE Coal Gasification program.

47. Coal Slurry Pump

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: Initial development completed, with further industry development pending a commercial liquefaction industry

Coal liquefaction plants require pumps capable of feeding hot coal oil slurries at high pressure. This is a very aggressive environment equivalent to pumping a hot sand slurry. The pumps are normally subjected to rapid erosive wear. In the late 1970s, FE initiated a program to develop a full size slurry pump module suitable for full size liquefaction plants. Advanced materials and unique seals and hydraulic design features were used to attain long life. The feasibility of utilizing high pressure centrifugal slurry pumps for coal liquefaction was successfully demonstrated by approximately 250 hours of testing. The development of this unique pump was concluded in early 1984 due to the discontinuation of the FE synfuels demonstration plant program. The initial development of the pump was accomplished and a design drawing package exists. Development completion awaits initiation of a coal liquefaction industry. This research was originally initiated under the FE AR&TD program and subsequently completed under the FE Coal Gasification program.

48. Coal Slurry Fuels

Program: AR&TD Direct Utilization, AR&TD Coal Utilization Science, and Combustion Systems Advanced Research subprograms

Product Type: Novel Process, Enabling Technology Base Element

Status: Coal-water slurry fuels are now a proven technology and are being commercialized outside the U.S. The enabling science and technology base to manufacture and utilize them in the U.S. exists and if oil prices warrant, can be utilized by industry.

While coal-oil mixture fuels have a long history of use, the concept of a coal-water mixture fuel was first explored in the AR&TD Direct Utilization subprogram in the late-1970s. As a result of the successful early research conducted in this program, the novel concept moved rapidly into advanced development and subsequently to demonstration in other parts of the FE program, as a retrofitable fuel for converting oil-fired stationary combustors.

As oil prices receded from their high levels in the early 1980s, interest in these fuels has been limited within the U.S. None-the-less, the successful discovery and subsequent development of the coal-water slurry fuel has made a significant contribution to the World energy economy. By establishing an alternative coal-based fuel which could be substituted for oil in stationary applications, it has helped to establish a price cap above which fuel oil prices cannot be sustained over an extended period of time.

49. Pipeline Gas from Coal

Program: AR&TD Processes, AR&TD Materials and Components, and Surface Coal Gasification Advanced Research subprograms

Product Type: Enabling Technology Base Element, Novel Process

Status: The enabling technology base has been adapted to other gasification applications (synthesis gas, power generation). Novel process steps (liquid phase methanation, catalytic gasification) have been adapted and evolved into other applications

In the mid- to late-1970s and early 1980s the coal advanced research subprograms conducted fundamental and exploratory research which not only helped establish the feasibility of producing pipeline quality gas from coal, but opened up important new science and technology paths with generic applicability to gasification-based systems and to reaction process concepts. As noted elsewhere in the success stories, "Once-Through" Liquid-Phase Methanol Synthesis (see example No. 21)--first researched in the AR&TD Processes subprogram--established an important part of the technology base for development of the once-through liquid-phase methanol process and to other applications of liquid-phase reactions which are currently being explored in other parts of the FE program.

Other adaptations which have roots in this research have also occurred or are occurring, including:

- Catalytic approaches to optimize selectivity of gas-make to desired CO/H₂ ratio for synthesis gas, or preferentially to produce H₂
- Catalytic approaches to convert C₁ and other light alkanes in gas streams to higher hydrocarbons

Finally, the research on solutions to materials problems in the AR&TD Materials and Components program has been adapted and applied to gasification systems in general as described in the success stories for More Durable Refractories for Coal Gasifiers (see example No. 6), Intelligent Software for Designing Refractory Systems (see example No. 53), and Performance and Properties of Coal Conversion Materials (see example No. 54).

50. Kinetic Coal Feeder

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: Proof-of-concept was established with further development pending a substantial coal gasification industry

In the mid 1970s, the AR&TD program initiated a program to develop a better dry coal feed system. This resulted in the exploratory development of totally new and truly unique dry coal feed concept, known as the Kinetic Coal Feeder, which uses centrifugal force to move a plug of pulverized coal at high pressure.

The kinetic feeder's high continuous throughput rate, simple rotary motion, absence of high wear valves and seals in the coal feed area, and very low contact velocity inherently provide: low installed cost; reliable and very durable operation; and low power, maintenance, and operating costs. The proof of concept was established by 250 hours of endurance test on the final configuration which verified good performance and very reliable, durable operation.

This research was originally initiated under the FE AR&TD program and subsequently concluded under the FE Coal Gasification program.

51. Oil Shale Retorting

Program: AR&TD Materials and Components subprogram

Product Type: Enabling Technology Base Element

Status: Generic research is continuing on solids transport and computational fluid dynamics with applications to coal-based systems and oil retorting

Simultaneous with research on oil shale retorting processes conducted through the FE Oil Shale R&D program, research underway in the solids transport activity of the coal AR&TD Materials and Components subprogram during the 1980s and currently has contributed to the enabling science and technology base for the new, "cascading bed process" which was conceptualized by the Lawrence Livermore National Laboratory (LLNL). Research is continuing on solids transport and computational fluid dynamics which is applicable to both coal-based systems *and* the LLNL "cascading bed process," including research at LLNL.

DATA BASES/SOFTWARE

52. Coal Technology Data Base

Program: All coal advanced research subprograms

Product Type: Enabling Technology Base Element

Status: Data from the advanced research subprograms are integrated into the various databases

Research conducted throughout the coal advanced research programs has produced important data for these databases. The fundamental data and information that results from the advanced research programs form the foundation (the "technology base") upon which much other information is ultimately derived.

53. Intelligent Software for Designing Refractory Systems

Program: AR&TD Materials subprogram

Product Type: Tool/Technique

Status: Technology was transferred to industry in 1991

A Thermomechanical Model Software Development Center (TMSDC) consortium was formed in the late 1980s to develop a user-friendly and intelligent computer-based software for the design of monolithic and brick refractory systems. The purpose of the consortium was to transfer information gained earlier in the AR&TD Materials subprogram on the thermomechanical analysis of refractory linings for coal gasification systems to the industrial sector in a form that would be most useful to refractory manufacturers and users.

The resulting software has broad application to a wide variety of industrial processes using high-temperature refractories under high-stress conditions.

54. Performance and Properties of Coal Conversion Materials

Program: AR&TD Materials and Components subprogram

Product Type: Tool/Techniques

Status: Materials data base was completed in the mid-1980s and hard copies are available from the Institute of Standards and Technology (NIST)

During the late 1970s and early 1980s an extensive amount of research and large-scale pilot plant operation of coal gasifications and liquefaction processes was underway. Construction and operation of these plants entailed a wide variety of materials problems peculiar to the harsh operating conditions; during this period the AR&TD Materials program was primarily directed to investigating and resolving these problems, where ever possible, with existing materials. In the instances where available materials would not solve the problems, new materials investigations/developments were initiated; one example, refractory materials for potential oxidation reactors is described in a separate success story (see example No. 6).

A wealth of data relative to materials performance was collected during this period. In anticipation that such data would subsequently be invaluable to a commercial coal conversion industry, FE sponsored a special data collection and compilation effort to preserve the data for future reference. Two data centers were established at the National Bureau of Standards (now NIST). The first data center was the Materials and Components Plant Performance Data Center. NBS was given the responsibility for collecting, abstracting, and disseminating information about operating events and materials and components failure analyses submitted by pilot plant personnel and various laboratories that performed failure analyses of these plants. The second data center, also at NBS, was the Materials Properties Data Center, established to collect, abstract, and disseminate construction materials properties and testing performance data. Data compiled by the two data centers were tabulated and summarized in NBS Special Publication 642.

55. Crude Oil Analysis Data Bank

Program: AE&PT program

Product Type: Tool/Technique

Status: The information service is currently used extensively by FE, private industry, universities, and others

This database, developed through the AE&PT program and predecessor programs, contains analyses of over 9,000 crudes. The available information covers critical chemical and physical parameters which govern how the crudes can be processed and refined. It is thus a critical, widely used information source in the evaluation of process designs and their ability to process various crude stream mixtures.

56. Arctic and Offshore Research Information System

Program: AE&PT program

Product Type: Tool/Technique

Status: The information service is publicly available

This information system was developed by the FE advanced research program to collect and make accessible reliable information related to the Arctic and Offshore characteristics that are of importance to oil and gas resource evaluation and development. It incorporates information from 85 Arctic-related databases and provides information on scientific/engineering related topics such as permafrost and sea ice characteristics.

In a separate, but related AE&PT research activity, a novel instrumentation system for collecting seismic data for use in offshore platform designs was developed and successfully deployed in cooperation with industry. In the late 1970s, DOE/SNL implemented a program to develop and demonstrate on acoustic data systems--the Seafloor Earthquake Measurement System (SEMS)--for undersea measurements of geophysical phenomena. The SEMS is capable of measuring strong motions of the sea-bottom sediments caused by earthquakes to provide inputs to the structural design of offshore platforms. The SEMS is capable of measuring and recording strong sediment motion with a three-axes probe buried in the seafloor. The SEMS has been utilized in earthquake prone offshore California and in various offshore Alaska areas.

57. ASPEN Process Simulator

Program: AR&TD Processes subprogram

Product Type: Tool/Technique

Status: ASPEN is widely used by DOE, industrial, university, and other research and development groups

The concept for the ASPEN simulator originated in the AR&TD program in the mid-1970s. The program subsequently supported development of the original ASPEN code. Support from the process and engineering development programs then expanded the original version to a wide range of related process simulation tools, with expanded applicability in terms of the types of processes and the design/operating conditions that can be simulated. ASPEN is now a key design tool for a wide range of fossil fuel processes.