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Fossil Energy Program

Summary Document

May 1980

MASTER

U.S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Budget and Administration

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U.S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Budget and Administration
Washington, D.C. 20545

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PREFACE

We are pleased to present this description of the Department of Energy's Fossil Energy program. Described in this report are our major efforts to develop new and improved ways of producing and using this Nation's abundant fossil energy resources: coal, oil shale, tar sands, unrecovered oil and unconventional natural gas.

Significant advances have been made since we published last year's edition of this report, both in our technical programs and in the Fossil Energy organization itself. Following a restructuring of the Department in the fall of 1979, the Fossil Energy program was elevated to an Assistant Secretary level. This reflects the growing recognition that fossil resources like coal, oil and gas -- which today supply almost 94 percent of our Nation's energy -- will continue to be energy mainstays well into the next century and that new sources of fossil energy, such as oil shale and tar sands, will be increasingly important contributors.

The importance placed on the role of fossil energy is further reflected in the growth of the research and development budget. The Fiscal Year 1981 budget described in the following pages totals over $1 billion for the first time. This represents a substantial growth from the FY 1980 appropriated level of $850 million and is a twentyfold increase since FY 1973.

The primary thrust of our program is on coal, both to improve the environmental acceptability and efficiency of burning it directly and on the development of advanced methods of converting it to clean-burning synthetic liquids, gases and solids. In FY 1981, working with several industrial partners, we will move into the major construction phase of large-scale projects to demonstrate advanced synthetic fuel technologies. This effort, coupled with our continuing research and development program, will complement the initiatives proposed by the President in 1979 to begin a national synthetic fuels industry.

We are also engaged in a coal mining research and technology program focusing on increased productivity and worker safety through the development of improved technologies.

Other fossil energy activities are intended to complement and supplement efforts underway by the private sector in the petroleum and gas areas. These programs will continue the shift begun last year toward high technology development projects which promise significant improvements in production.

Incentives to stimulate the commercial production of shale oil, unconventional gas, and previously unrecoverable oil are an integral part of the President's energy initiatives. Our research and development efforts will ensure that present and new techniques in these areas continue to be brought to the commercial threshold.

In short, we are working to ensure that this Nation is fully prepared for the future, and that a full range of demonstrated, environmentally acceptable fossil energy technologies described in this report is available to help meet the Nation's future energy needs.

George Fumich, Jr.
Assistant Secretary
for Fossil Energy

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ABSTRACT

This Program Summary Document presents a comprehensive overview of the research, development, and demonstration (RD&D) activities that will be performed in FY 1981 by the Assistant Secretary for Fossil Energy (ASFE), U.S. Department of Energy (DOE). The ASFE technology programs for the fossil resources of coal, petroleum (including oil shale) and gas have been established with the goal of making substantive contributions to the Nation's future supply and efficient use of energy.

On April 29, 1977, the Administration submitted to Congress the National Energy Plan (NEP) and accompanying legislative proposals designed to establish a coherent energy policy structure for the United States. Congress passed the National Energy Act (NEA) on October 15, 1978, which allows implementation of the vital parts of the NEP. The NEP was supplemented by additional energy policy statements culminating in the President's Address on July 15, 1979, presenting a program to further reduce dependence on imported petroleum. The passage of the NEA-related energy programs represent specific steps by the Administration and Congress to reorganize, redirect, and clarify the role of the Federal Government in the formulation and execution of national energy policy and programs. The energy technology RD&D programs carried out by ASFE are an important part of the Federal Government's effort to provide the combination and amounts of energy resources needed to ensure national security and continued economic growth.

This document reflects the DOE budget request as presented to the Congress during January 1980. Subsequent budget decisions concerning FY 1981 funding levels for Fossil Energy have not been incorporated.

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I. U.S. ENERGY POLICY

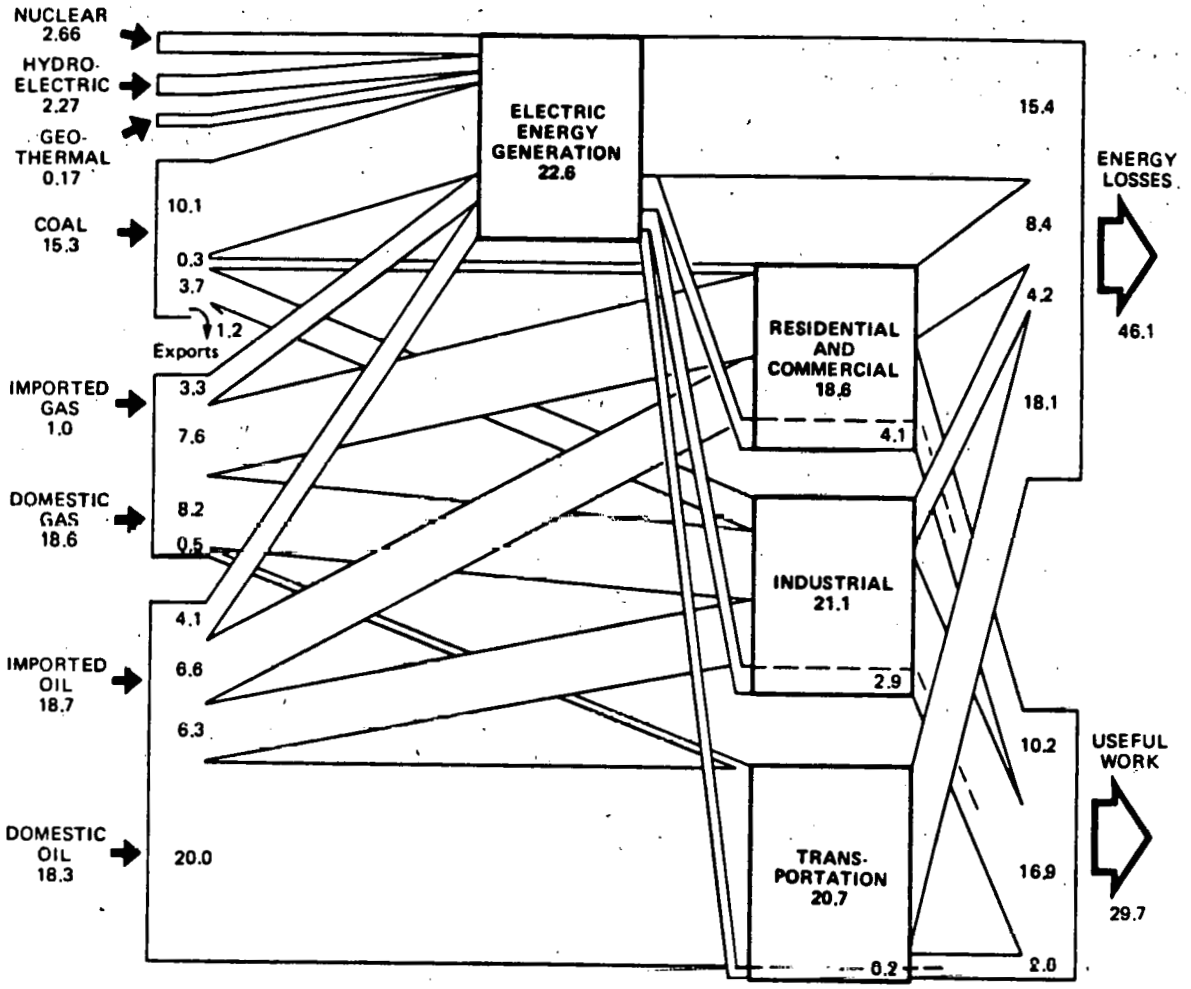
A. CURRENT U.S. ENERGY POSTURE

The United States is at a pivotal point in its energy/economic history. In the past, economic growth has been fueled by abundant supplies of inexpensive, readily available domestic fossil energy; currently, the United States competes in an international marketplace to purchase the supplies of oil and gas on which the domestic economy has become dependent. In the past, economic planners could assume an uninterrupted supply of energy from a variety of sources; currently, the United States must search for new supplies of energy needed for economic expansion. In short, the high cost and uncertain availability of once inexpensive and plentiful energy have become major obstacles to the orderly growth of the U.S. economy.

In 1977, the United States consumed approximately 79 Quads (including coal exports) of energy in the residential/commercial, industrial, and transportation end-use sectors. Almost 50 percent (37.9 Quads) of 1977 energy demand was supplied by petroleum, while natural gas supplied 26 percent (19.5 Quads), coal supplied 19 percent (15.4 Quads), and nuclear/hydropower supplied over 6 percent (5.2 Quads). This U.S. energy consumption and use pattern is shown in the following figure.

At current world oil prices, domestic oil and natural gas resources are not capable of supplying the growing U.S. demand for oil, gas, and their products. In fact, U.S. imports of foreign oil and gas that are needed to augment domestic energy supplies have been increasing steadily in recent years. For example, in 1960 imported oil supplied 28 percent of the U.S. oil demand, and imported gas supplied 2 percent of the U.S. gas demand. By 1977, these percentages had increased to 45 percent and 5 percent, respectively, generating the urgent requirement for the rapid implementation of a program to reduce this foreign oil dependence which has contributed significantly to this country's present high rate of inflation and increased vulnerability of our national security.

Among the estimated domestic fossil fuel resources, coal, unconventional gas, oil shale, and petroleum from enhanced recovery methods account for 90 percent of the resource base, of which 56 percent is coal. The accompanying table shows the estimated resource of each fossil fuel in equivalent billions of barrels of oil.



SOURCE: Reference Energy System, Year 1977, National Center for Analysis of Energy Systems, BNL
Energy Flows are indicated in Quads.

U.S. Energy Conversion Factors in Quads

Fossil Energy Source	Estimated Resource (Billions of Barrels Crude Oil Equivalent)
Coal	1,600
Oil Shale (25 gal/ton or greater)	600
Enhanced Oil Recovery	334
Unconventional Gas (Excluding Geopressured Methane)	105
Conventional Oil	139
Conventional Gas	130

The amount of each resource that can be recovered is dictated by economics, the successful implementation of new technologies and the solution of environmental and related problems.

However, this resource base with successful RD&D of required technologies does provide the potential to reduce the reliance on foreign oil.

B. ENERGY PROGRAM GOALS

The April 1977 Administration submission to Congress of the National Energy Plan (NEP) and accompanying legislative proposals were designed to produce a coherent energy policy for the United States. The National Energy Act, passed by Congress in mid-October 1978, provides for implementation of vital parts of the NEP. Actions taken by the Administration since 1977, including the President's address on July 15, 1979, have cut the Nation's projected 1990 needs for imported oil by 8.5 million barrels per day, a reduction of approximately one-half.

The key elements of the President's program announced on July 15, 1979 are:

- Create an Energy Security Corporation to direct the development of 2.5 MMbbl/d of oil substitutes from coal liquids and gases, oil shale, biomass, and unconventional gas by 1990.
- Establish an Energy Mobilization Board empowered to expedite permitting and construction of critical energy facilities.
- Provide new incentives for development of heavy oil resources, unconventional gas, and oil shale.
- Require utilities to cut current oil consumption by 50 percent, saving 750,000 barrels of oil per day by 1990.
- Establish a major new residential and commercial conservation program designed to save 500,000 barrels of oil per day by 1990.
- Provide $2.4 billion annually in assistance to low-income families in the United States.
- Provide a total of $16.5 billion over the coming decade for improvements in the Nation's mass transportation system and in automobile fuel efficiency.

An overall strategy for reducing imports is essential to secure the continuing economic strength and security of the United States. In developing this program, the Administration has examined all tools available to cut foreign oil dependence, including production of synthetic fuels, conservation, production of unconventional sources of oil and natural gas, direct use of coal, and solar energy. The program presented by the President draws on each of these resources to achieve the import reduction targets.

The National Energy Plan also recognized that petroleum and natural gas are resources which cannot continue indefinitely to support the present high rates of growth in energy consumption. To meet the demand for oil, the United States has turned increasingly to imports. This has resulted in a

progressively larger dependence on an uncertain future world oil market and, therefore, a growing vulnerability to supply interruptions.

With this serious situation confronting us, the NEP establishes three overriding energy objectives:

- As an immediate objective that will become even more important in the future, to reduce dependence on foreign oil and vulnerability to supply interruptions
- In the mid-term, to keep U.S. imports sufficiently low to weather the period when world oil production approaches its capacity limitation
- In the long-term, to have renewable, essentially inexhaustible sources of energy for sustained economic growth.

The strategy of the NEP contains three major components to achieve these objectives:

- First, by carrying out an effective conservation program in all sectors of energy use, through reform of utility rate structures and by ensuring that energy prices reflect true replacement costs, the Nation should reduce the annual rate of growth of demand to less than 2 percent. That reduction would help achieve both the near-term and the mid-term goals. It would reduce vulnerability and prepare the Nation's stock of capital goods for the time when world oil production will approach capacity.
- Second, industries and utilities using oil and natural gas should convert to coal and other abundant fuels. Such a substitution would reduce imports and make gas more widely available for household use. An effective conversion program would thus contribute to meeting both the immediate- and medium-term goals.
- Third, the Nation should pursue a vigorous research and development program to provide renewable and other resources to meet U.S. energy needs in the next century. The Federal Government should support a variety of energy alternatives in their early stages, and continue support through the development and demonstration stage for technologies that are technically, economically, and environmentally most promising.

To meet the President's goal for reducing oil imports, early implementation of a number of fossil energy technologies is essential. These technologies include coal liquefaction and gasification, shale oil extraction, improved direct combustion of coal, and coal-oil mixtures. Implementation of improved environmental controls will also be needed to insure acceptability of the new technologies for use of fossil fuels.

C. ENERGY LEGISLATION

The original enabling legislation that established energy as a national priority was contained in the Energy Reorganization Act of 1974, the Federal Nonnuclear Energy Research and Development Act of 1974, and other legislation that related specifically to components of the energy issue such as solar heating and cooling, geothermal energy, solar energy RD&D, electric and hybrid vehicle RD&D, and surface mining control and reclamation. In addition, there is a considerable body of related legislation regarding environmental impact and controls, and conservation measures.

On October 15, 1978, the National Energy Act was passed by Congress. The purpose of the act is to establish a policy framework for decreasing oil imports by:

- Replacing oil and gas with abundant domestic fuels in industry and electric utilities
- Reducing energy demand through improved efficiency
- Increasing production of conventional sources of domestic energy through more rational pricing policies
- Building a base for the development of solar and renewable energy sources.

The NEA is composed of eight public laws as follows:

- The National Energy Conservation Policy Act of 1978

  This act emphasizes both energy conservation and solar energy measures, taking into consideration that a major component of the Nation's effort to sustain economic growth over the long run depends upon initiatives for conserving energy as well as developing renewable energy sources.

- The Power Plant and Industrial Fuel Use Act of 1978

  This act is related to the coal conversion program. The effect is to streamline the regulatory process and to dramatically improve the program's effectiveness in reducing consumption of oil and gas in industrial and utility boilers as a result of the increased use of alternative fuels such as coal.

  New facilities (above 10 MW) are now legally constrained from burning oil or gas until the owners have demonstrated to DOE that an exemption is justified.

The major change under the new law for existing facilities is a streamlining of the procedures for ordering units with the capability for burning coal to return to coal use.

- The Public Utilities Regulatory Policy Act

  This act provides for voluntary standards on rate design and other utility practices and requires that rate standards be evaluated for appropriateness relative to conservation, efficiency, and equity. The act also establishes FERC rules favoring industrial cogeneration and authority to require interconnections of electric power transmission facilities. Other significant provisions include natural gas retard policies and expediting legislation related to permits for crude oil transportation.

- The Natural Gas Policy Act of 1978

  The act is designed to redress these fundamental market distortions by establishing prices that are certain and applicable to both interstate and intrastate systems as well as removing outmoded regulatory burdens on sales in the interstate market. The price ceiling system is designed to provide the highest incentives for more risky exploratory drilling, while restraining price increases on previously discovered gas to prevent significant inflationary impacts.

- The Energy Tax Act of 1978

  This act provides for various taxes or tax credits for energy saving investments. The eligible investments for tax credits include residential insulation and conservation, residential solar, gasohol, geothermal and geopressured natural gas, business energy and denial of credit for new oil- and gas-fired boilers.

- FY 1980 Interior Appropriation (P.L. 96-126)

  P.L. 96-126 provided $2.2 billion to the Department of Energy "to expedite the domestic development and production of alternative fuels ... at maximum levels at the earliest time practicable." For the purposes of this appropriation, alternative fuels include: "gaseous, liquid or solid fuels and chemical feedstocks derived from coal, shale, tar sands, lignite, peat, biomass, solid waste, unconventional natural gas and other minerals or organic materials other than crude oil or any derivatives thereof." This new Congressional appropriation includes:

  - $100 million for project development feasibility studies; a maximum of $4 million per project

  - $100 million for cooperative agreements; a maximum of $25 million per project

- $500 million as a reserve for loan guarantees; not to exceed $1.5 billion in total guarantees

- $1.5 billion for purchase commitments or price guarantees.

- Priority Energy Project Act of 1979

  In response to the President's emphasis on domestic development of a synthetic fuels production capability, the Senate passed S-1308 and the House passed HR-4985. The major differences were the Energy Mobilization Board composition and the waiving of Federal law to achieve a "fast track" for priority energy projects. At press time (ca. January 15, 1980) the conferees have agreed on the board composition and are close to finalizing an agreement on waiving of existing law.

- Extension of Defense Production Act of 1950

  The House and Senate, in responding to President Carter's request for an Energy Security Corporation, passed differing versions of S-932. The House would have used the Defense Production Act under authority of the President to stimulate synthetic fuels production. The Senate version established a Synthetic Fuels Corporation to stimulate industry with incentive packages. The House-Senate conferees are presently at a temporary impasse over the number of financing mechanisms available to the President under the Defense Production Act and the language regarding government authority to build government-owned, contractor- operated (GOCO) plants.

D. DOE POLICY FOR FOSSIL ENERGY

1.0 THE FOSSIL ENERGY PROGRAM

The United States relies upon fossil energy for more than 90 percent of its energy requirements. Three-fourths of this is supplied by petroleum and natural gas, which constitute only 11 percent of proven U.S. reserves. Coal provides another 20 percent, yet accounts for about 77 percent of proven U.S. fossil energy reserves (about 56 percent of the potential resource). Oil shale, which constitutes an enormous potential resource (approximately 21 percent of proven reserves), is untapped. To support the goals of the U.S. Energy Policy, Fossil Energy is developing technology that will:

- Provide a capability to convert coal to clean liquid and gaseous fuels.
- Assure that current and new facilities burn coal in an economically viable and environmentally acceptable manner.
- Increase domestic production and utilization of coal, oil, gas and oil from shale.
- Allow more efficient and economically attractive utilization of fossil energy resources.

2.0 FOSSIL ENERGY RESOURCE STRATEGIES

The Fossil Energy Program is concerned with fossil fuel resources including solids, liquids, and gases. The strategies for each resource are complementary in that each is designed to help achieve the Fossil Energy goals mentioned above. Within each resource strategy are programs which, while placing major emphasis on that resource, also are applicable to others.

Coal Resource Strategy

The DOE coal strategy is to develop technology to allow expanded use of coal and peat in an environmentally acceptable manner and to demonstrate production techniques for processes to convert coal to clean synthetic liquids and gas. In addition a significant effort will be conducted in support of the near-term deployment of alternative fuels by providing technical expertise and judgment on technologies to be funded, supported or guaranteed by the U.S. This strategy is implemented through the following specific objectives.

Objective I: Assure that stationary facilities now burning coal can continue to do so under applicable environmental standards and that coal combustion can become an increasingly viable option for new facilities in the industrial and utility sectors during the next decade.

This objective will be supported by Fossil Energy RD&D programs to:

- Support coal preparation and physical coal cleaning processes to increase the amount of coal that can be burned directly in existing facilities or used with flue gas desulfurization systems (FGD) in new and existing facilities.

- Develop chemical coal cleaning technology to assist in meeting strict environmental standards and to provide additional options for new facilities.

- Develop both regenerative and nonregenerative FGD systems, emphasizing improvements in operating performance and reliability.

- Develop atmospheric fluidized-bed (AFB) technologies, emphasizing commercialization of small industrial AFBs in the near term with development of utility-scale systems drawing from experience with industrial AFBs.

Objective II: Demonstrate the capability for producing synthetic liquids and gas from coal by the mid- to late-1980s so that significant capacity could be built in the 1990s if oil prices rise, and to hold open the option for legislative initiatives that can accelerate introduction of these processes into the private sector.

This objective will be supported by:

- Demonstration of methods of producing liquids such as gasoline and distillate fuels from coal as an option for the transportation and the residential/commercial sectors

- Demonstration of the capability to produce heavy liquids from coal to displace residual fuel oil and other products

- Demonstration of the viability of coal-oil mixtures in utility and industrial applications

- Demonstration of an advanced gasification process in a full-scale module to enable use of a broader range of coals, particularly eastern, high-sulfur caking coals

- Demonstration of technology for medium-Btu gas in an industrial application

- Acceleration of R&D on highly advanced process concepts which offer potential for significant cost reductions

- Characterization of the environmental issues associated with the production and utilization of coal-derived liquids and gas.

Objective III: Develop systems that will use coal in a more economic, efficient, and environmentally acceptable manner for the 1990s and beyond.

This objective will be supported by:

- Magnetohydrodynamics (MHD) electric generation
- Fuel cells based on coal-derived fuels for either urban central station or dispersed electric generation
- High-temperature turbines for improved efficiency as well as turbines that allow combustion of heavier and dirtier fuels
- Other advanced thermodynamic cycles (i.e., pressurized fluidized-bed and combined-cycle gasifier with high-temperature turbine) and heat recovery systems.

Objective IV: Provide fundamental improvements in the technology base for economic, efficient, and environmentally acceptable use of coal and its products.

This objective will be achieved by a broad range of basic and applied research activities to provide the basis for a technically diverse coal program. Development of a strong technology base to keep new concepts flowing will be combined with rigorous selection procedures for choosing candidates for further development. Since process scaleup is costly and demands continuing resource commitments, an analytical selection process will be applied to key transition points in the technology development process.

Priority

Prime emphasis will be placed on direct coal utilization and coal-derived liquids. Major efforts will also be directed toward coal gasification. Other work will include improved efficiency of coal utilization technologies.

Petroleum Resource Strategy

The DOE petroleum strategy is to find means of providing more domestic petroleum and synthetic fuels to reduce the shortage of liquid fossil fuels. The Administration's alternative fuels efforts to deploy technology leading to increased liquids supply in the near term will also be significantly supported. Some of the specific objectives of this strategy are:

- Improve existing and develop new exploration, development, and enhanced recovery technologies.
- Develop improved technology to recover liquid fuels from oil shale that can be processed into petroleum substitutes.
- Develop equipment and processes capable of using a wide variety of synthetic fuels in an environmentally acceptable manner.
- Provide a significant and current technical data base to stimulate technology transfer.

Gas Resource Strategy

The general objective of the natural gas recovery program is to obtain significant production of natural gas from unconventional sources to reduce the national dependence on foreign sources of gas or oil.

The strategy is to identify and assess new sources of natural gas that have significant production potential and to develop technologies to extract this resource at acceptable costs and in an environmentally and socially acceptable manner. These sources include Devonian shales, tight sands, methane from coal seams, and geopressured aquifers (geopressured methane). (Geopressured methane is covered under the Geothermal Program.)

This strategy involves:

- Determining characteristics and production potential of the different resources
- Developing reliable exploratory techniques for the significant resources
- Developing, demonstrating, and transferring effective extraction technologies
- Developing end-use alternatives for unconventional gas.

The strategy includes cost sharing projects with the private sector to enhance timely transfer and commercialization of the technology. It is designed to assure that economical and environmentally acceptable sources of supplementary gas will be available.

II. FY 1981 FOSSIL ENERGY PROGRAM OVERVIEW

A. PROGRAM SUMMARY

1.0 ACTIVITY STRUCTURE AND BUDGET

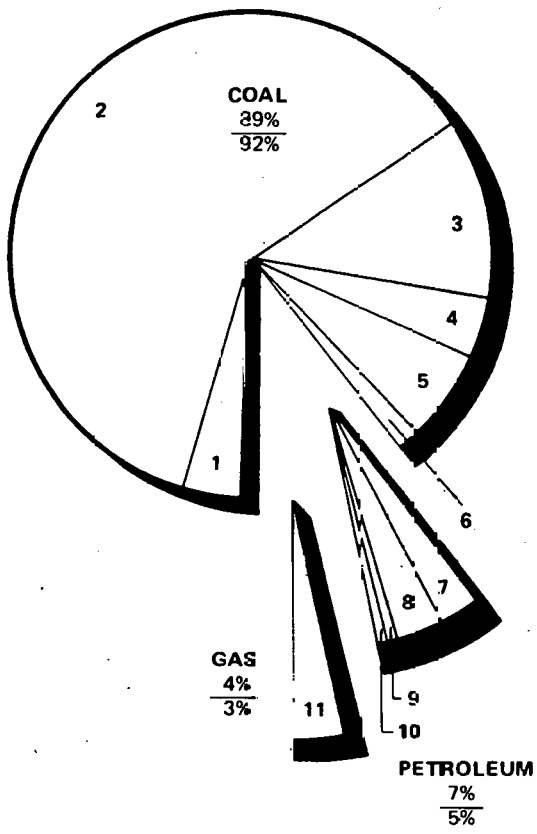
Fossil Energy activities are associated with three main resources: coal, petroleum, and gas. DOE and its predecessor organizations have assessed requirements in keeping with stated objectives, analyzed potential payoffs and risks associated with selected technologies and processes, and structured financial requirements accordingly. Total annual funding has increased from $58 million in FY 1973 to $850 million in FY 1980. Of a total FY 1981 request of $1,141 million, $1,047 million is planned for Coal Resources, $63 million for Petroleum, and $31 million for Gas.

The Department of Energy has been restructured and the Office of the Assistant Secretary for Fossil Energy has been established to implement the increased emphasis on the fossil resources and technologies. The new structure is described in Section II-B. The budget structure accommodates this organizational change and ensuing functional redistribution while retaining general similarity to last year's structure. The following figure compares FY 1980 and FY 1981 funding levels.

A summarized history of funding levels comparing budget authorities for FY 1974 through FY 1978 is shown in Table 1. The changes in emphasis in various categories can be observed. More detail on the recent FY 1979, 1980, and 1981 budgets is provided in Table 2. This table summarizes, by functional area, allocation of funds to projects for technical development toward potential commercialization.

2.0 MAJOR TECHNOLOGY ISSUES

The Fossil Energy program is structured to develop appropriate technologies which can help meet future U.S. energy needs. The technology base effort develops basic information and advanced concepts with potential application for providing energy from coal, oil, gas and other fossil resources. The technology base elements are basic research, applied research and exploratory development relative to the extraction, conversion and utilization of fossil energy resources. The technology base focuses on better scientific and engineering data for research and development programs as well as basic improvements related to improving process efficiencies and/or utilizing lower cost technology which can operate in an environmentally acceptable manner. Fossil Energy will also be heavily involved in directly supporting the technical decisions concerning the Federal Government's actions to stimulate deployment of alternative fuels technologies in the near term.



RATIO = $\frac{\%\text{ of FE Budget} - 1980}{\%\text{ of FE Budget} - 1981}$

	(FIGURES IN THOUSANDS OF DOLLARS)			
	FY 80	FY 81	DIFFERENCE	%–1980/%–1981
COAL				
1 Coal Mining	63,850	46,500	−22,350	8/4
2 Coal Processing	376,156	672,400	+296,244	44/59
• Coal Liquefaction	250,306	523,900	+273,594	29/46
• Coal Gasification	115,850	138,500	+22,650	14/12
• In Situ Gasification	10,000	10,000	0	1/1
3 Coal Utilization	127,850	136,900	+9,050	15/12
• Combustion	50,850	68,500	+17,650	6/6
• Fuel Cells	26,500	25,000	−1,500	3/2
• Heat Engines and Heat Recovery	50,500	43,400	−7,100	6/4
4 Advanced Environmental Control Technology	38,250	42,500	+4,250	5/4
5 Advanced Research and Technology Development	56,150	64,461	+8,311	7/6
6 Magnetohydrodynamics (MHD)	75,000	72,000	−3,000	9/6
Program Direction	11,387	12,145	+758	1/1
TOTAL COAL RESOURCE	753,643	1,046,906	+293,263	89/92
PETROLEUM				
7 Enhanced Oil Recovery	23,100	19,400	−3,700	3/2
8 Oil Shale	28,200	36,048	+7,848	3/3
9 Drilling and Offshore Technology	3,000	2,370	−630	.4/.2
10 Advanced Process Technology	6,000	5,000	−1,000	.7/.4
Program Direction	781	940	+159	.1/.1
TOTAL PETROLEUM RESOURCE	61,081	63,758	+2,677	7/5
GAS				
11 Enhanced Gas Recovery	35,310	30,548	−4,762	4/3
Program Direction	276	273	−3	.1/.1
TOTAL GAS RESOURCE	35,586	30,821	−4,765	4/3
TOTAL FOSSIL ENERGY (Direct Appropriations)	850,310	1,141,485	291,175	100/100

Fossil Energy FY 1981 Funding Percentages

Table 1. Fossil Energy Development
FY 1974-FY 1978 Total Funding Levels
Budget Authority
(Dollars in Millions)[1]

RESOURCE/ACTIVITY	FY 1974	FY 1975	FY 1976	FY 1977 AND TQ	FY1978
COAL					
Mining Research and Development[2]	$ —	$ —	$ —	$ 51.9	$ 62.8
Liquefaction	45.5	107.7[3]	164.4[3]	111.4[3]	126.5
Surface Gasification	53.7	109.8	117.6	135.2	195.6
In Situ Gasification	1.7	6.6	7.8	8.2	12.6
Advanced Research and Technology Development	4.8	23.3	44.2	44.1	37.0
Heat Engines and Heat Recovery	0	4.1	13.5	25.9	42.3
Combustion Systems	15.5	35.9	59.6	56.9	66.1
Fuel Cells[4]	—	—	—	19.1	35.4
Magnetohydrodynamics	7.5	14.3	41.3	40.0	71.5
TOTAL COAL RESOURCE	128.7	301.7	448.4	492.7	649.8
PETROLEUM					
Enhanced Oil Recovery	8.7	26.4	30.5	23.8	46.2
Oil Shale	3.2	4.9	17.4	19.3	28.8
Drilling and Offshore Technology	0	0	2.9	2.4	1.6
Advanced Process Technology	[5]	1.8	2.2	1.8	1.4
TOTAL PETROLEUM RESOURCE	11.9	33.1	53.0	47.3	78.0
GAS					
Enhanced Gas Recovery	[5]	[5]	16.9	18.6	27.1
TOTAL GAS RESOURCE	0	0	16.9	18.6	27.1
TOTAL FOSSIL ENERGY	$140.6	$334.8	$518.3	$558.6	$754.9

1. Based on FY 1980 budget structure. Includes both Operating Expenses and Capital Acquisition funds.
2. Funded by Department of the Interior prior to FY 1978.
3. Includes $78.021 million in unobligated funds for the Clean Boiler Fuel project which was used to offset the FY 1979 appropriation for the coal program.
4. Funded under Conservation prior to FY 1978.
5. Funds included under Enhanced Oil Recovery total.

Table 2. Fossil Energy Development
FY 1981 Budget Estimates
Summary Table by Technologies
Budget Authority
(Dollars in Thousands)

COAL RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
I. MINING RESEARCH AND DEVELOPMENT			
a. Underground Coal Mining	$52,860	$43,000	$26,000
b. Surface Mining and Reclamation Act	0	5,000	0
c. Surface Coal Mining	12,615	8,000	8,000
d. Coal Preparation and Analysis	9,871	12,650	11,000
Prior Year Funds	−7,500*	0	0
Capital Equipment	220	200	1,500
Construction – Mining and energy related technologies education center/coal utilization facility	570	0	0
TOTAL MINING RESEARCH AND DEVELOPMENT	68,636	68,850	46,500
II. COAL LIQUEFACTION			
a. Direct Hydrogenation			
1. Ebullated-Bed (H-Coal) Pilot Plant	33,000	64,500	57,000
2. Fixed-Bed Hydrogenation (Synthoil) PDU	2,389	0	0
Total Direct Hydrogenation	35,389	64,500	57,000
b. Solvent Extraction			
1. Donor Solvent Liquefaction (EDS) Pilot Plant	34,600	30,000	32,000
2. Co-Steam Process	540	0	0
Total Solvent Extraction	35,140	30,000	32,000
c. Third Generation Processes			
1. Process Research/Technology Development	8,700	10,000	10,000
2. Zinc Chloride Catalyst PDU	2,100	2,500	0
3. Disposable Catalyst Hydrogenation	1,011	9,500	4,200
4. Flash Liquefaction Process	2,000	3,000	5,000
Total Third Generation Processes	13,811	25,000	19,200
d. Support Studies/Engineering Evaluations			
1. Cresap Liquefaction Test Facility	10,000	0	0
2. Environmental Studies and Other Support	4,286	14,506	12,000
Total Support Studies/Engineering Evaluations	14,286	14,506	12,000
e. Liquefaction Demonstration Plants			
1. Solvent Refined Coal (SRC) I Demo Plant			
Operating Expenses	7,000	7,000	5,000
Construction (78-2-d)	40,000	40,000	175,000
2. Solvent Refined Coal (SRC) II Demo Plant			
Operating Expenses	7,000	14,000	5,000
Construction (79-1-r)	50,000	40,000	190,000
3. Solvent Refined Coal (SRC) Pilot Plant	13,500	15,000	28,000
4. Design and Technical Support	1,600	0	0
Total Liquefaction Demonstration Plants	119,100	116,000	403,000
Capital Equipment	200	300	700
TOTAL COAL LIQUEFACTION	$217,926	$250,306	$523,900

*The FY 1979 Appropriations Act provides for offsetting FY 1979 appropriations with carryover funds from prior years.

Table 2 (Continued)

COAL RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
III. SURFACE COAL GASIFICATION			
a. High-Btu Gasification			
1. Bi-Gas Pilot Plant	$7,900	$13,500	$10,000
2. Synthane Pilot Plant	2,620	0	0
3. Peat Gasification	4,500	3,000	13,000
Total High-Btu Gasification	15,020	16,500	23,000
b. Low-Btu Gasification			
1. Fixed-Bed Gasification	4,190	6,000	7,000
2. Fluidized-Bed Gasification	4,000	8,000	9,000
3. Entrained-Bed Gasification, Atmospheric Process	3,790	3,000	3,000
4. Gasifiers in Industry	1,000	500	0
Total Low-Btu Gasification	12,980	17,500	19,000
c. Third Generation Processes			
1. Hydrogasification	6,147	7,000	11,800
2. Catalytic Gasification Pilot Plant	7,228	9,000	13,200
3. Process Research/Technology Development	9,700	4,000	5,000
Total Third Generation Processes	23,075	20,000	30,000
d. Special Projects and Support Studies			
1. Hot Gas Cleanup	1,000	0	0
2. Gasification Test Facility	3,600	7,000	0
Prior Year Funds	−34,100*	0	0
Total Special Projects and Support Studies	−29,500	7,000	0
e. Technical Support			
1. Engineering Evaluations	2,100	0	0
2. Equipment, Materials and Process Development	2,100	0	0
3. Environmental Studies and Other Support	8,328	0	0
4. Design and Technology Support	2,495	8,350	10,000
Total Technical Support	15,023	8,350	10,000
f. Gasification Demonstration Plants			
1. High-Btu Pipeline Gas Demonstration Plant			
Operating Expenses	2,000	10,000	1,000
Construction (76-1-b)	40,000	27,000	55,000
2. High-Btu Pipeline Gas Demonstration Plant			
Operating Expenses	8,000	14,000	0
Construction (77-1-b)	2,000	0	0
3. Low/Medium-Btu Fuel Gas Demo Plant, Industrial			
Operating Expenses	3,000	0	0
Construction (76-1-c)	14,000	0	0
4. Low-Btu Fuel Gas Demo Plant, Small Industrial			
Operating Expenses	1,300	0	0
Construction (78-2-c)	9,000	0	0
Carryover Funds from Project 78-2-c	0	−12,000	0
5. Low Btu Fuel Gas Demo Plant, Utility			
Operating Expenses	0	7,000	0
Construction (77-1-c)	0	0	0
Total Gasification Demonstration Plants	79,300	46,000	56,000
Capital Equipment	500	500	500
Prior Year Funds	− 4,000*	0	0
TOTAL SURFACE COAL GASIFICATION	$112,398	$115,850	$138,500

*The FY 1979 Appropriations Act provides for offsetting FY 1979 appropriations with carryover funds from prior years.

Table 2 (Continued)

COAL RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
IV. IN SITU COAL GASIFICATION			
a. Western Low-Btu Gasification (Linked Vertical Wells)	$ 4,300	$ 2,700	$ 6,500
b. Western Medium-Btu Gasification (Packed Bed)	2,450	3,200	2,700
c. Steeply Dipping Beds	4,550	3,000	0
d. Environmental Support	900	600	500
e. Supporting Research	2,100	400	200
Capital Equipment	700	100	100
TOTAL IN SITU COAL GASIFICATION	15,000	10,000	10,000
V. ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT			
a. Processes	7,850	14,800	20,400
b. Direct Utilization	9,460	7,100	11,000
c. Materials and Components			
1. Materials	7,350	7,000	7,000
2. Components	1,940	5,900	2,000
Total Materials and Components	9,290	12,900	9,000
d. Program Development and Coordination			
1. Budget and Administration	892	700	561
2. Engineering Analysis	2,975	2,500	2,400
3. Environmental Activities	3,161	2,500	2,400
4. Planning and Policy	6,130	2,000	2,500
Total Program Development and Coordination	13,158	7,700	7,861
e. University Coal Research	0	5,000	5,000
Capital Equipment	375	400	500
Construction	6,350	8,250	10,700
TOTAL ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT	46,473	56,150	64,461
VI. ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY			
a. Flue Gas Cleanup			
1. Lime/Limestone Scrubbers	800	6,050	6,000
2. Advanced Flue Gas Desulfurization	600	8,300	9,000
3. Combined Flue Gas Cleanup	1,300	5,700	6,000
Total Flue Gas Cleanup	2,700	20,050	21,000
b. Gas Stream Cleanup			
1. Turbine Cleanup Systems	1,400	7,000	8,000
2. Fuel Cell Cleanup Systems	0	1,400	3,000
3. Process Modification Technology	1,000	2,000	2,000
Total Gas Stream Cleanup	2,400	10,400	13,000
c. Cleanup Base Technology	1,900	7,000	8,000
Capital Equipment	0	800	500
TOTAL ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY	$ 7,000	$38,250	$42,500

*The FY 1979 Appropriations Act provides for offsetting FY 1979 appropriations with carryover funds from prior years.

Table 2 (Continued)

COAL RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
VII. HEAT ENGINES AND HEAT RECOVERY			
a. Central Power Systems			
1. Closed-Cycle Systems	$ 3,500	$ 2,300	$ 2,400
2. Open-Cycle Systems	17,200	22,500	19,800
Total Central Power Systems	20,700	24,800	22,200
b. Dispersed Power Systems			
1. Directly Fired Heat Cycles	11,920	9,200	10,600
2. Externally Fired Heat Cycles	2,000	3,580	3,200
3. Prototype Systems Assessment	1,000	220	3,100
Total Dispersed Power Systems	14,920	13,000	16,900
c. Heat Recovery Component Technology			
1. Low Grade Heat Recovery	3,435	8,500	4,300
2. High Grade Heat Recovery	9,825	4,000	0
3. Heat Exchanger Technology	2,920	0	0
Total Heat Recovery Component Technology	16,180	12,500	4,300
Capital Equipment	300	200	0
TOTAL HEAT ENGINES AND HEAT RECOVERY	52,100	50,500	43,400
VIII. COMBUSTION SYSTEMS			
a. Atmospheric Fluidized Beds (AFB)			
1. AFB Boiler, 30 MW_e	8,700	7,000	3,100
2. AFB Industrial Applications	0	7,300	5,200
3. AFB Turbine Test Unit (TTU)	914	800	0
4. AFB Component Test and Integration Unit (CTIU)			
Operating Expenses	11,800	9,800	65
Construction (80-FE-10)	0	0	9,935
5. AFB Anthracite Applications	2,186	1,000	3,500
6. AFB Support	0	0	1,000
Total Atmospheric Fluidized Beds	23,600	25,900	22,800
b. Pressurized Fluidized Beds (PFB)			
1. PFB Combined Cycle Pilot Plant (13 MW_e)			
Operating Expenses	2,500	3,500	4,000
Construction (80-FE-11)	0	0	9,200
2. PFB Support/IEA	11,734	6,500	8,200
3. PFB Utility EDS Plant	0	5,000	0
Total Pressurized Fluidized Beds	14,234	15,000	21,400
c. Advanced Combustion Technology			
1. Engine Combustion Technology	2,150	0	2,000
2. Improved Oil and Gas Burners	500	500	0
3. Coal Combustion Support and Engineering Evaluations	4,692	4,450	0
Total Advanced Combustion Technology	7,342	4,950	2,000
d. Alternative Fuel Utilization			
1. Coal-Oil Mixtures	5,450	2,500	22,000
2. Alternative Fuel Combustion	1,950	0	0
3. Coalbed Methane Utilization	2,000	0	0
Total Alternative Fuel Utilization	$ 9,400	$ 2,500	$22,000

Table 2 (Continued)

COAL RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
e. Combustion Systems Demonstration Plants			
1. Design and Technical Support	$ 0	$ 2,500	$ 0
Capital Equipment	573	0	300
Prior Year Funds	−3,000*	0	0
TOTAL COMBUSTION SYSTEMS	52,149	50,850	68,500
IX. FUEL CELLS			
a. 4.8 MW Electric Utility Power Plant Development	5,500	0	0
b. Phosphoric Acid Systems Development	14,000	14,000	11,000
c. Molten Carbonate Systems Development	17,000	12,000	11,000
d. Advanced Concepts	4,000	0	3,000
Capital Equipment	552	500	0
TOTAL FUEL CELLS	41,052	26,500	25,000
X. MAGNETOHYDRODYNAMICS			
a. Open-Cycle Plasma Systems			
1. Component Development and Integration Facility (CDIF)			
Operating Expenses	18,889	20,600	17,200
Construction (77-1-d)	3,000	0	0
2. Engineering Development	32,171	29,900	31,800
3. Engineering Test Facility	400	800	400
4. Systems Engineering	10,486	8,100	8,700
5. Supporting Research	13,554	13,600	11,400
Total Open-Cycle Plasma Systems	78,500	73,000	69,500
b. Closed-Cycle Systems	1,000	2,000	2,000
Capital Equipment	500	0	500
TOTAL MAGNETOHYDRODYNAMICS	80,000	75,000	72,000
XI. PROGRAM DIRECTION	11,207	11,387	12,145
SUBTOTAL COAL RESOURCES	703,941	753,643	1,046,906
PRIOR YEAR FUNDS	−78,021*	0	0
TOTAL COAL RESOURCE	$ 625,920	$ 753,643	$1,046,906

*The FY 1979 Appropriations Act provides for offsetting FY 1979 appropriations with carryover funds from prior years.

Table 2 (Continued)

PETROLEUM RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
I. ENHANCED OIL RECOVERY			
a. Heavy Oil	$20,329	$ 7,250	$ 7,900
b. Light Oil	23,819	10,550	5,000
c. Tar Sands	2,024	4,800	5,900
Capital Equipment	700	500	600
TOTAL ENHANCED OIL RECOVERY	46,872	23,100	19,400
II. OIL SHALE			
a. In Situ Conversion	32,700	27,000	34,298
b. Surface Conversion	15,000	0	750
Capital Equipment	900	1,200	1,000
TOTAL OIL SHALE	48,600	28,200	36,048
III. DRILLING AND OFFSHORE TECHNOLOGY			
a. Drilling	1,509	1,500	500
b. Offshore Technology	585	1,000	1,300
c. Environment and Support	506	500	200
Capital Equipment	0	0	370
TOTAL DRILLING AND OFFSHORE TECHNOLOGY	2,600	3,000	2,370
IV. ADVANCED PROCESS TECHNOLOGY			
a. Advanced Exploratory Research	0	1,700	2,200
b. Shale Oil Refining and Utilization	1,000	2,500	1,000
c. Product Characterization and Utilization	1,200	1,300	1,300
Capital Equipment	0	500	500
TOTAL ADVANCED PROCESS TECHNOLOGY	2,200	5,000	5,000
V. PROGRAM DIRECTION	582	781	940
TOTAL PETROLEUM RESOURCE	$100,854	$61,081	$63,758

Table 2 (Continued)

GAS RESOURCE	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
I. ENHANCED GAS RECOVERY			
a. Eastern Gas Shales	$18,000	$13,000	$12,400
b. Western Tight Gas Sands	7,500	12,800	12,400
c. Methane from Coalbeds	4,000	5,000	5,000
d. Environment and Support	3,902	4,110	248
Capital Equipment	200	400	500
TOTAL ENHANCED GAS RECOVERY	33,602	35,310	30,548
II. PROGRAM DIRECTION	209	276	273
TOTAL GAS RESOURCE	33,811	35,586	30,821
SUBTOTAL FOSSIL ENERGY (DIRECT APPROPRIATIONS)	760,585	850,310	1,141,485
ENERGY SECURITY TRUST FUND[1]			
Indirect Liquefaction	0	0	28,000
Coal Liquids Refining	0	0	5,000
Coal Preparation and Analysis	0	0	7,000
In Situ Coal Gasification	0	0	10,000
SUBTOTAL ENERGY SECURITY TRUST FUND	0	0	50,000
TOTAL FOSSIL ENERGY	$760,585	$850,310	$1,191,485

[1] Energy Security Trust Funds for Coal R&D will be requested in separate legislation.

Specific direction of these technology base efforts is toward the following areas:

- Advanced fossil fuel conversion processes, involving coal gasification, liquefaction and refining of shale and coal-derived syncrudes to distillate fuels and chemical feedstocks
- Advanced, environmentally acceptable direct combustion utilization processes for both coal and synfuels
- Supporting research on materials and components, waste use and disposal, and fossil fuel science and engineering
- Systems studies contributing to development of a logical, integrated strategy and rationale for selection and development of Fossil Energy options.

Additional technology base efforts are discussed under appropriate activity descriptions in Chapters III, IV and V.

3.0 COMMERCIALIZATION ISSUES

Commercialization does not routinely occur at the end of the development cycle (discussed in Chapter VII); requirements for successful commercialization influence efforts in earlier phases. Commercial introduction of a technology requires the following:

- All technical and engineering problems associated with the technology must have been solved.
- The economics of the technology must be such that manufacturers can obtain a fair return on investment at prices that offer users an attractive alternative to conventional technologies.
- Users must accept the technology as effective and reliable.
- The public must be satisfied that the socioeconomic and environmental effects of the new technology have been properly analyzed and that actions are being taken to eliminate adverse effects. (Environmental effects are discussed in Chapter VIII.)

When these conditions are satisfied and commercialization proceeds, an institutional infrastructure (producers, distributors, suppliers of raw materials, and industry associations) will evolve. The development of this infrastructure can be aided by certain Government actions. Examples of such actions could be financial incentives, revised regulations, or sponsorship of the RD&D process. In sponsoring the technology, every attempt is made to develop a situation where the activities are cosponsored by an industrial cost-sharing sponsor, since this insures that industry has a real and participatory interest in the program under development.

The DOE policy is that at a certain point in maturity, the Federal responsibility will shift from ASFE to the Assistant Secretary for Resource Applications (ASRA) and/or the Energy Security Corporation. Fossil Energy

will provide the technical support for commercialization decision-making by maintaining an aggressive RD&D program directly linked to Resource Applications and the Energy Security Corporation.

4.0 ENVIRONMENTAL ISSUES

Implementation of the Fossil Energy program will require that factors affecting the physical and biological environment, worker health and safety, and property management and protection be properly addressed. These include:

- The effect on the human environment of each major Fossil Energy activity
- The impact of emerging laws, standards, and regulations on Fossil Energy programs, technologies, and prospects for commercialization
- The means for and control of waste disposal from plant operations
- Identification of the need for additional monitoring and characterization activities with reference to the impact of FE technologies
- Analysis of water resource utilization and provisions for quality maintenance
- Necessary actions to aid technology development in areas where naturally occurring background emissions exceed Federal pollution standards.

These are only samples of the top level issues. Each technology and/or project causes unique impacts due to the nature of the project, its geographical location, and the existing state of the environment. These aspects are discussed in the resource activity chapters III, IV, and V and the environmental chapter VIII.

5.0 SOCIOECONOMIC ISSUES

The development of major new technologies will have a social and economic impact on the development of the region in which they are established. Every effort will be made to minimize the negative effect of such development and to enhance the positive aspects. Major social and economic factors addressed include:

- The effects of industry size and rate of development on the specific location and surrounding region
- The impact on the regional economies and the national economy of the implementation of various Fossil Energy technologies
- The possible lifestyle changes caused by large-scale energy development, e.g., boom towns

- The Federal Government's role in ameliorating adverse social and economic impacts on the sparsely settled regions where large-scale energy development is likely to occur.

6.0 SMALL AND DISADVANTAGED BUSINESS UTILIZATION

The Fossil Energy program will participate in the Small and Minority Business Program by coordinating and identifying procurements that can be performed by small or minority businesses. This will be done in conjunction with the Office of Small and Disadvantaged Business Utilization, which is being established within the Department of Energy pursuant to HR 11318. Also, Fossil Energy prime contractors will be required to submit subcontracting plans that describe the extent to which small and minority businesses will be used.

B. MANAGEMENT APPROACH

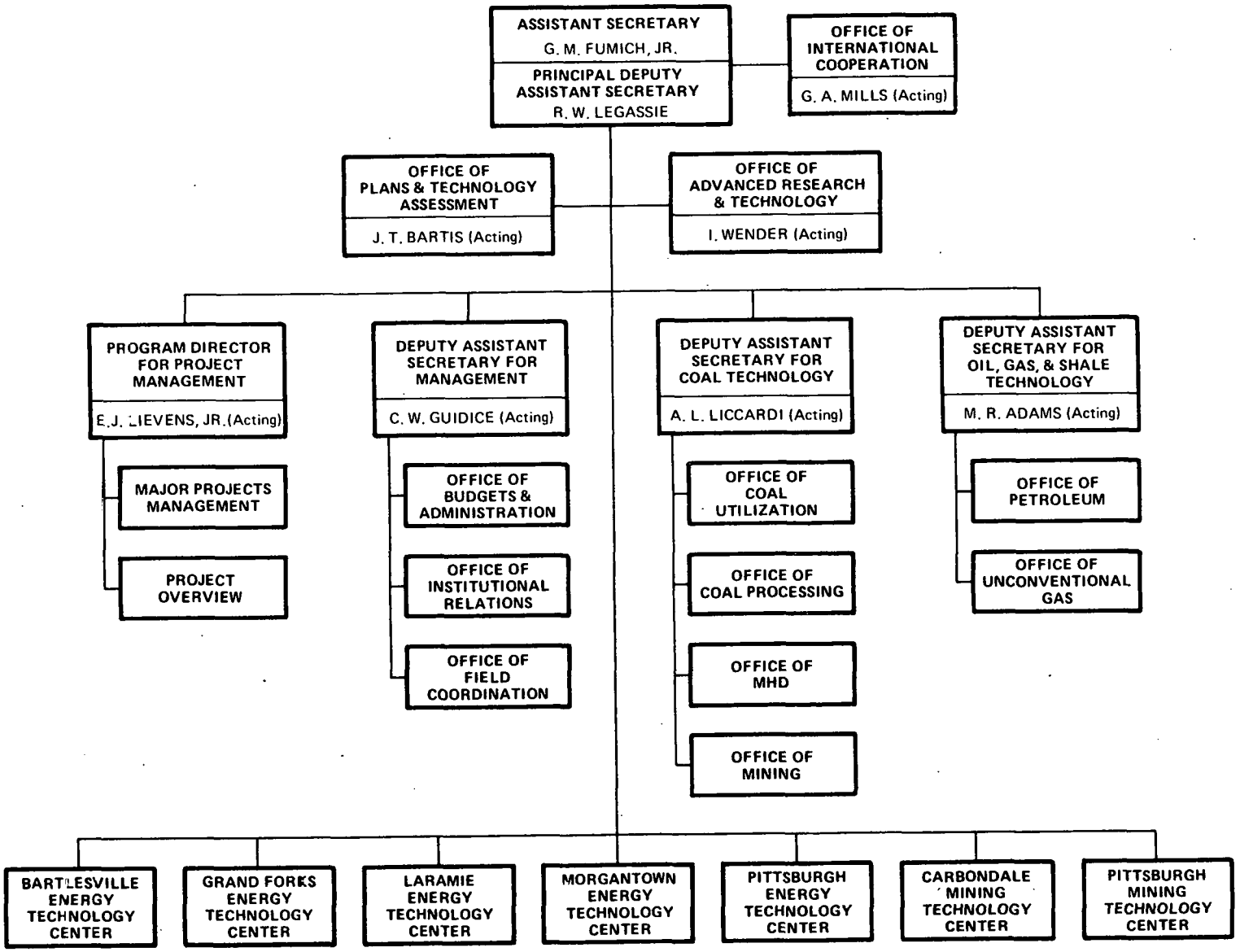
1.0 OVERVIEW

Fossil Energy is employing a management approach that is responsive to the mission of the Department of Energy. Added emphasis and urgency related to the fossil resources and technologies have resulted in elevation of the functions of Fossil Energy to an assistant secretary level. The following figure presents the new organization of the Assistant Secretary for Fossil Energy (ASFE) and describes the program flow and management and control of major research, and development and demonstration projects. The basic ASFE responsibilities are divided into the functional roles of policy and program development, and implementation. The division of responsibility under the new management approach will be for headquarters to handle policy and program development and for the field activities to assume the implementation responsibility.

2.0 POLICY AND PROGRAM DEVELOPMENT — HEADQUARTERS

Program management, policy initiatives, and governmental interface with the Congress, OMB, other agencies and industry, and international programs will be performed by headquarters. Specific responsibilities of headquarters include the following:

- Prescribe policy for the Fossil Energy Program.
- Determine those technologies which will be developed.
- Establish and maintain liaison with other assistant secretaries.
- Develop and maintain program plans for each assigned area.
- Develop and justify budgets.
- Interface with the Office of Management and Budget, the Congress and other groups that influence the program.
- Measure work progress in the various program/project areas and inform DOE management of program results.
- Approve field procurement plans.



Fossil Energy Organization (Interim)

The program organizations of Project Management; Coal Technology; and Oil, Gas, and Shale are complemented by the staff offices of Plans and Technology Assessment; International Cooperation; and Advanced Research and Technology, with the Deputy Assistant Secretary for Management providing administrative and management support to ASFE and its component parts.

Table 3 presents the programmatic responsibility by office.

3.0 PROGRAM IMPLEMENTATION — FIELD ACTIVITIES

The various field activities will assume responsibility for implementation aspects of the FE program, including contracting authority to a certain extent. Lead activities have been assigned for the various activities, and projects as shown on Table 4.

Additional assignments are being made as specific program plans are developed. Current project management and support assignments are discussed under the appropriate activity descriptions in Chapters III, IV and V.

Project management responsibility for the various university projects are assigned to the appropriate field activity.

The field activities will be responsible for the following:

- Development of integrated and individual plans for activities and projects
- Development of procurement plans
- Chairing source evaluation boards and technical advisory committees as appropriate
- Management of projects consistent with milestones and costs
- Maintaining and reporting obligations/costs on project and program bases
- Development and maintenance of adequate technology bases for each program area.

The decentralization process (i.e., technical management of projects to field) is continuing. It has been, and will continue to be, the approach applied to both existing and new projects.

4.0 INDUSTRY, UNIVERSITIES, AND OTHER GOVERNMENT AGENCIES

The vast majority of ASFE RD&D activities are performed by private industry. Industry participation increases as the project or technology matures from basic research toward demonstration phases of the RD&D process. As a process advances to the pilot plant phase or beyond, this participation becomes a partnership between government and industry, including cost-sharing arrangements.

Table 3. Program Responsibility by Fossil Energy Office

FY 1981 PROGRAM STRUCTURE	ASFE ORGANIZATIONS										
	DAS COAL TECHNOLOGY						DAS OIL, GAS & SHALE TECHNOLOGY			DAS MGMT	
	MAJOR PROJECT MANAGEMENT	COAL UTILIZATION	COAL PROCESSING	MINING	MHD	PETROLEUM	UNCONVENTIONAL GAS	OIL SHALE	BUDGETS & ADMINISTRATION	OFFICE OF PLANS AND TECHNOLOGY ASSESSMENT	
Mining Research and Development				X							
Coal Liquefaction	X		X								
Surface Coal Gasification	X		X								
In Situ Coal Gasification							X				
Advanced Research and Technology Development										X	
• Materials										X	
• Components, Conversion Processes, Direct Utilization	X	X	X								
• Program Development & Coordination									X		
• University Coal Research										X	
Advanced Environmental Control Technology		X									
Heat Engines and Heat Recovery		X									
Combustion Systems		X									
Fuel Cells		X									
Magnetohydrodynamics					X						
Enhanced Oil Recovery						X					
Oil Shale								X			
Drilling and Offshore Recovery						X					
Advanced Process Technology						X					
Enhanced Gas Recovery							X				

Note: DAS = Deputy Assistant Secretary

Table 4. Major Field Project Responsibilities and Activities

FY 1981 PROGRAM STRUCTURE	FIELD AGENCIES					
	BETC	GFETC	LETC	METC	PETC	OTHERS
Mining Research & Development						X[1]
Coal Liquefaction					X	
SRC I & II						X[2]
Surface Coal Gasification				X		
Low-Rank Coals (Applic. Center)		X				
Fuel Gas Demonstration						X[3]
Coal Feeding Systems				X		
In Situ Coal Gasification			X			
Advanced Research and Technology Development	X	X	X	X	X	X[5]
Advanced Environmental Control Technology				X		
Gas Stream Cleanup						X[6]
Heat Engines & Heat Recovery	X			X		
Combustion Systems						
Direct Coal Combustion					X	
Coal Mixtures					X	
Fluidized-Bed Combustion				X		
Internal Combustion Systems	X					X[6]
Fuel Cells						
Magnetohydrodynamics						
MHD/CDIF						X[4]
MHD Combustion					X	
Enhanced Oil Recovery	X					
Oil Shale			X			
Drilling & Offshore Recovery	X					
Advanced Process Technology	X					
Enhanced Gas Recovery						
Western Tight Gas Sands	X			X		
Eastern Gas Shales				X		
Coalbed Methane				X		

1 Carbondale MTC/Pittsburgh MTC. Administrative Direction and Support provided by PETC.
2 Oak Ridge Operations
3 Chicago Operations
4 Idaho Operations
5 AL, ANL, BNL, INEL, LASL, LBL, LLL, ORNL, PNL, SL
6 NASA

University participation in ASFE's RD&D is also extensive and involves a large number of projects. The contribution of University Programs is usually in basic and applied research in areas such as materials research, coal structure, environmental effects, kinetics, and mechanisms of conversion processes, interfacial affects in tertiary oil recovery, combustion of emulsified fuels, and modeling of MHD processes. The research may be in direct support of major projects or investigation related to the more advanced concepts.

The ASFE has cooperative arrangements with other Federal agencies to conduct investigations of mutual benefit to the charters and goals of the participants. Such arrangements foster more efficient development of national energy programs of benefit to the country.

5.0 INTERNATIONAL PROGRAMS

Concurrent with its domestic programs, the ASFE pursues an aggressive program of international exchange. The members of the International Energy Agency (IEA) have joined in a common commitment to reduce energy consumption in response to current shortages. Through the IEA and through a series of bilateral agreements, the Department of Energy is working with other consuming countries toward a more satisfactory energy future. For example, IEA countries are seeking to limit their collective oil imports to 26 million barrels per day in 1985. The IEA reviews the adequacy of member country energy policy contribution toward the achievement of this objective. In addition to joint development of fossil energy technologies and design, construction, and operation of pilot and demonstration facilities, agreements for the exchange of scientific information, both in the IEA and bilaterally, can help advance new technologies. The Office of International Cooperation of the Office of Fossil Energy seeks to further national goals by negotiating international agreements for cooperative joint ventures to advance the development of fossil energy technologies. Joint international ventures with industrialized nations promote the development of technologies which draw on the information and experience of participating countries. The Office of International Cooperation also assists in the transfer of technologies to less developed countries, assisting their move toward energy independence.

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III. ACTIVITY DESCRIPTION — COAL

COAL RESOURCE OVERVIEW

Coal is the Nation's most plentiful fuel resource, with enough reserves to last several centuries. It offers the greatest potential in the 1980s for relieving or minimizing the current U.S. energy shortfall. The United States has reserves estimated at 3.2 trillion tons of unmined coal, whereas supplies of oil and natural gas are becoming rapidly depleted. Major efforts of the Coal Research, Development, and Demonstration Program are aimed at tapping this abundant source of energy for direct use as a fuel in an efficient and environmentally acceptable manner, and for processing into clean synthetic fuels to provide a substitute for limited oil and natural gas resources.

Coal constitutes about 77 percent of U.S. conventional energy reserves, but currently supplies less than 20 percent of energy consumption. Coal is capable of supplying all demand sections since it can be burned directly or transformed into liquid, gas, or feedstock. But the full potential of coal cannot be realized until a number of problems are solved. Coal is bulky and therefore is more difficult to transport and burn than liquids and gaseous fuels, the transportation system for increased quantities may be inadequate, and coal burning is a source of pollution. The processes for making liquids and gas from coal have yet to be fully developed to meet increasing rigorous environmental standards and marketplace competition. The DOE Coal Strategy is designed to help surmount these problems and allow the Nation to utilize the potential of its coal resources.

The DOE coal strategy is organized around the extraction, processing, and utilization of coal in an environmentally acceptable manner. The industrial sector is given special attention because it has options for using coal and is presently a major consumer of oil and gas.

The principal objectives of the Coal Resource Program are to:

- Accelerate the development of environmentally acceptable technology for extracting coal, converting coal to liquid and gaseous fuels by both surface and in situ processing.
- Stimulate improved methods for the direct combustion of coal.
- Foster rapid development of advanced power conversion systems, including fuel cells and magnetohydrodynamics, for generating electricity from coal.

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- Validate technical, economic, and environmental acceptability of second-generation coal processes by design, construction, and operation of near-commercial-scale modules.
- Expand the technology base and the supply of technically trained manpower.
- Support the evolving coal conversion and utilization technologies.
- Stimulate technology in the area of greater heat conversion efficiency from fossil fuel products.
- Support the near-term deployment of alternative fuels by providing technical assistance and guidance.

Need for Coal R&D Programs

The needs for coal extraction, processing, and utilization programs are diverse and are dependent on complex issues. The basis for each of these programs is addressed below.

Mining Research and Development: From 1945 to 1968, the mining industry experienced increasing productivity. Beginning in 1969, this trend underwent a significant reversal in both underground and surface mining. Productivity in underground and surface mining dropped by 50 and 30 percent, respectively. This decline coincided with an increasing demand for coal and is attributed mostly to more stringent safety, health, and environmental restrictions.

No simple answers are forthcoming to these complex problems. The Mining R&D program necessarily includes many technological approaches to cover the spectrum of requirements for different equipment, techniques, and applications. Of roughly 6,200 producing mines in the United States, only 11 of the companies involved in mining can be considered large; these 11 each produced in excess of 10 million of the 665 million tons of total U.S. output in 1976. Equipment manufacturers are generally unable to find mine operators who are willing to accept the risk associated with trying new equipment. In addition, 90 percent of the equipment manufacturers are too small to afford extensive R&D. Labor unrest, social change, regulatory (health, safety, and environmental) constraints, and miner skills, attitudes, and motivations add to the complexities of developing mining systems.

Liquids: Petroleum liquids provide almost half of U.S. energy needs but constitute less than 8 percent of domestic energy reserves. The demand for oil is projected to grow at over 4 percent a year.[1] Because domestic production is declining (except for a small jump caused by Alaskan production) oil imports are increasing at over twice that rate. The consequences of these trends for the Nation are serious.

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[1]Conservative estimate representative of range of estimates from various series in EIA, Administrator's 1978 Report to the Congress, Volume 2, Table 64, pp. 133.

Increased dependence on foreign oil jeopardizes national security and weakens the value of the dollar. Reliance on imports also leaves the economy vulnerable to rises in world oil prices.

Supplemental Gas: Natural gas supplied 26 percent (or 19 Quads) of the total domestic energy consumption in 1977. Demand for dependable supplies of natural gas exceeds supplies available from conventional domestic sources. Although natural gas pricing legislation is expected to encourage additional production of conventional natural gas, shortfalls will eventually result. At this time, coal-derived synthetic gas can help fill this gap in the form of high-Btu (pipeline quality) gas or medium- or low-Btu gas for industrial applications. Development of this capability is important as a backstop to high world energy prices in the 1990s and beyond.

Direct Combustion: The demand for coal in 1985 is projected to range from 1.0 billion to 1.2 billion tons.[2] Because close to 90 percent of the coal consumed in this country is and will continue to be burned directly, any program to increase coal utilization must place primary emphasis on promoting direct coal combustion.

Industrial Feedstocks: Industrial consumption of natural gas and oil for chemical feedstocks could be reduced significantly if coal-based synthesis gas were used. Moreover, technology for producing synthesis gas from coal is already well known. Three commercial processes for making synthesis gas have been widely used abroad (Lurgi, Koppers-Totzek, and Winkler) and two improved processes are in active private sector development (Texaco and Shell-Koppers). The petrochemical industry is showing active interest in coal-base synthesis gas because it is nearly economical at today's prices, and the economics will improve as natural gas and oil become more costly. Initial application could be stimulated with modest financial or regulatory incentives.

Increased Efficiency: Typically, heat engines extract approximately 30 percent of the available energy from the fuel. Many technologies are available to extract energy from coal more efficiently, but they are in early stages of development, and the economics are such that the private sector cannot develop these technologies without Federal participation.

Environmental Requirements: Environmental standards pose the greatest constraint on increasing direct coal use. Unless new technologies are available for meeting these standards, many facilities that might use coal will turn to other fuels.

The environmental performance required for both utility and industrial coal-burning facilities depends largely on the age and location of the facility. Most existing facilities meet the emission standards of the Clean Air Act. New facilities on which construction began before proposal of the

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[2]Conservative estimate representative of range of estimates from various series in EIA, Administrator's 1978 Report to the Congress, Volume 2, Table 64, pp. 133.

EPA's revised New Source Performance Standards (NSPS) must meet the current NSPS. However, future coal use will be increasingly affected by the stricter standards in upcoming NSPS revisions.

Development of new environmental control technologies will be closely linked with development of more efficient heat engines.

Coal R&D Program Objectives

The DOE Coal Resource Program has been established to meet the needs discussed above. Program direction has been organized into activity areas, each of which will be covered in appropriate sections of this chapter. Basic objectives of the Coal Resource Program activity areas listed below are briefly discussed in the following paragraphs.

- Mining R&D
- Coal Liquefaction
- Surface Coal Gasification
- In Situ Coal Gasification
- Advanced Research & Technology Development
- Advanced Environmental Control Technology
- Heat Engines and Heat Recovery
- Combustion Systems
- Fuel Cells
- Magnetohydrodynamics.

The Mining Research & Development Activity supports the substitution of abundant energy sources (i.e., coal and oil shale) for less abundant sources (i.e., oil and natural gas) by developing technologies that will improve the economics of production; maximize resource recovery; protect the health and safety of mine workers; and protect the environment. Based upon the National Energy Plan and the major requirements of mining technologies identified above, the functions of the Mining Research & Development Activity are to conduct research in the areas of underground coal mining, surface coal mining, and coal preparation.

Coal conversion activities develop processes to convert coal into products that substitute for those derived from oil and natural gas. These substitutes include crude oil, fuel oil, and distillates; chemical feedstock, pipeline quality (high-Btu) and fuel (low- and intermediate-Btu) gas; and other by-products, such as char, that may be useful in energy production. The Liquefaction and Gasification Activities address the development of these products and their use in the market.

Significant advances have been made in the coal conversion and utilization technology. The current effort in this area is directed towards demonstrating second-generation technology on a near-commercial scale in the early 1980s. Four coal liquefaction processes (SRC-I, SRC-II, H-Coal and EDS) are now in advanced stages of development. Surface coal gasification processes have been commercially available for many years, but are being further developed to improve process efficiencies and to reduce associated costs. In situ coal conversion has been demonstrated by highly successful subpilot-scale field tests. Government and industry are jointly

participating with a near-term goal to develop at least one commercial underground conversion process during 1985-87.

The Advanced Research and Technology Development projects in the DOE energy technology centers, national laboratories, and in conjunction with other government agencies, private industry, and universities will develop the basic and applied technology and data upon which present and future fuel conversion and utilization processes depend. Included under this activity are program planning and development efforts essential to the formulation of Fossil Energy plans and policy.

The Advanced Environmental Control Technology Activity has received new emphasis based on a transfer of several projects from EPA to DOE in FY 1979. The activity is directed toward developing technology to minimize the environmental impacts of new or existing fossil fuel utilization systems. The desired goals will be achieved through research and development of technology in the areas of flue gas cleanup and gas stream cleanup.

The Heat Engines and Heat Recovery Activity will develop technology to maximize energy savings in the utility, industrial, and residential/commercial market sectors. Three major objectives for achieving the goal are to increase the direct utilization of coal in the utilities by developing advanced, highly efficient, integrated coal conversion/utilization systems; to develop advanced cogeneration systems that can supply both electric and thermal needs for the equivalent fuel energy now being used to generate basic electrical requirements; and to develop advanced heat recovery component technology for producing useful work from waste heat and minimizing heat rejection by the utilities, industrial, and residential/commercial sectors.

The objectives of the Combustion Systems Activity are to develop fluidized-bed coal combustion systems capable of directly burning high-sulfur and other coals of all ranks and quality in an environmentally acceptable and economic manner; develop technology to substitute coal for a substantial portion of oil in existing combustors capable of firing coal-oil mixtures; and improve the reliability and efficiency of present boilers and furnaces.

Fuel cells represent a new energy-conversion alternative which is highly efficient, flexible, modular, economically attractive, and environmentally acceptable. These characteristics permit location of power plants in large load centers and even onsite in urban, rural, and residential areas. The near-term (3 to 6 years) objective of the DOE's Fuel Cell Activity is to establish the commercial feasibility of fuel cell power plants for electric utility applications, industrial cogeneration, and for building total energy systems.

The magnetohydrodynamics (MHD) system of power production from coal is considered a potential future source of low-cost, central-station, electric power. Low NO_x emissions, inherent sulfur removal, and high efficiency of the MHD system make it environmentally attractive. Commercialization is expected by the early 1990s.

The following table summarizes the funding levels by Activity for the FY 1979 to 1981 period.

COAL RESOURCE ACTIVITIES	BUDGET AUTHORITY (DOLLARS IN THOUSANDS) ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Mining Research and Development	68,636	68,850	46,500
Coal Liquefaction	217,926	250,306	523,900
Surface Coal Gasification	112,398	115,850	138,500
In Situ Coal Gasification	15,000	10,000	10,000
Advanced Research and Technology Development	46,473	56,150	64,461
Advanced Environmental Control Technology	7,000	38,250	42,500
Heat Engines and Heat Recovery	52,100	50,500	43,400
Combustion Systems	52,149	50,850	68,500
Fuel Cells	41,052	26,500	25,000
Magnetohydrodynamics	80,000	75,000	72,000
Program Direction	11,207	11,387	12,145
Prior Year Funds	−78,021*	0	0
Total Direct Appropriations	625,920	753,643	1,046,906
Energy Security Trust Fund	0	0	50,000
TOTAL	625,920	753,643	1,096,906

*The FY 1979 Appropriations Act provides for offsetting for FY 1979 appropriation with carryover funds from prior years.

A. MINING RESEARCH AND DEVELOPMENT

The objective of the Office of Coal Mining (OCM) R&D program is to develop the technology to meet the Nation's coal demands at reduced economic, environmental, and social cost. This objective is consistent with the National Energy Plan (NEP II) which calls for reduction in the Nation's dependence on unpredictable foreign sources of energy by substituting relatively abundant domestic resources. Further, it is consistent with an essential part of President Carter's latest energy initiative which is aimed at developing a synfuel production capability using coal as the primary feedstock.

Among the factors which have negatively impacted the cost of coal mining are:

- Sharply declining productivity resulting from necessarily strict Federal and State health and safety regulations
- Increasingly difficult mining conditions
- Federal and State regulations concerning the environmental impacts of mining and using coal.

The program endeavors to counter these factors through technology development.

The major thrusts of the coal mining R&D program are as follows:

Underground Mining

- Develop the technology and tools that enable a mine operator to optimize mine design.
- Develop mechanized shaft construction systems for rapid access to coal reserves.
- Develop systems that integrate the coal extraction, roof support, and haulage functions to effect an efficient continuous operation.
- Develop mine monitoring and control technology to optimize logistics.

Surface Mining

- Develop technology to enable surface mining in an economically competitive, environmentally acceptable manner.

- Apply new techniques and technology to improve the efficiency of existing systems.
- Develop new techniques and equipment to extend the depth of economic operation and to substitute continuous for cyclic modes of operation.
- Develop alternative coal mining technologies (Surface Mining R&D Act Sec. 908) to include mining of unusually thick seams and improving health and safety.

Coal Preparation

- Develop techniques and equipment to increase the efficiency of separating waste materials from raw coal, recover the fine coal presently lost, and remove water from the cleaned product.
- Develop cost-effective processes for removal of both organic and inorganic sulfur from coal.

The following table summarizes the program funding levels by subactivity for the FY 1979 to FY 1981 period.

MINING RESEARCH AND DEVELOPMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Underground Coal Mining	52,860	43,000	26,000
Surface Mining & Reclamation Act	0	5,000	0
Surface Coal Mining	12,615	8,000	8,000
Coal Preparation and Analysis	9,871	12,650	11,000
Prior Year Funds	− 7,500	0	0
Capital Equipment	220	200	1,500
Construction — Mining and energy related technologies education central/coal utilization facility	570	0	0
Total Direct Appropriations	68,636	68,850	46,500
Energy Security Trust Fund	0	0	7,000
TOTAL	68,636	68,850	53,500

1.0 UNDERGROUND COAL MINING

Historically, the majority of domestic coal production has been through underground techniques, although in recent years underground mining has decreased to 41 percent of the total coal produced.

The goal of the Underground Coal Mining subactivity is to provide the technology base necessary to sustain a strong growth in underground

production while providing for the protection of today's miners and the environment. In order to meet these needs, the Underground Coal Mining R&D program is structured to address each of the basic elements of the mining cycle:

- Mine Planning and Development
- Production Systems
- Transport and Supporting Activities.

Mine Planning and Development

Mine planning is a key to efficient coal production. An optimal mine design will assure economical production with minimal undesirable consequences, both during mining and long after it ceased. Thus, mine planning has decisive influences on productivity, safety, economics and environmental impacts.

The goal of mine planning research is to provide the mining industry with new tools to allow improved and more effective mine planning. Specific objectives are to improve upon existing geophysical analysis, engineering, computer modeling, and other techniques relevant to the planning and design of underground coal mines.

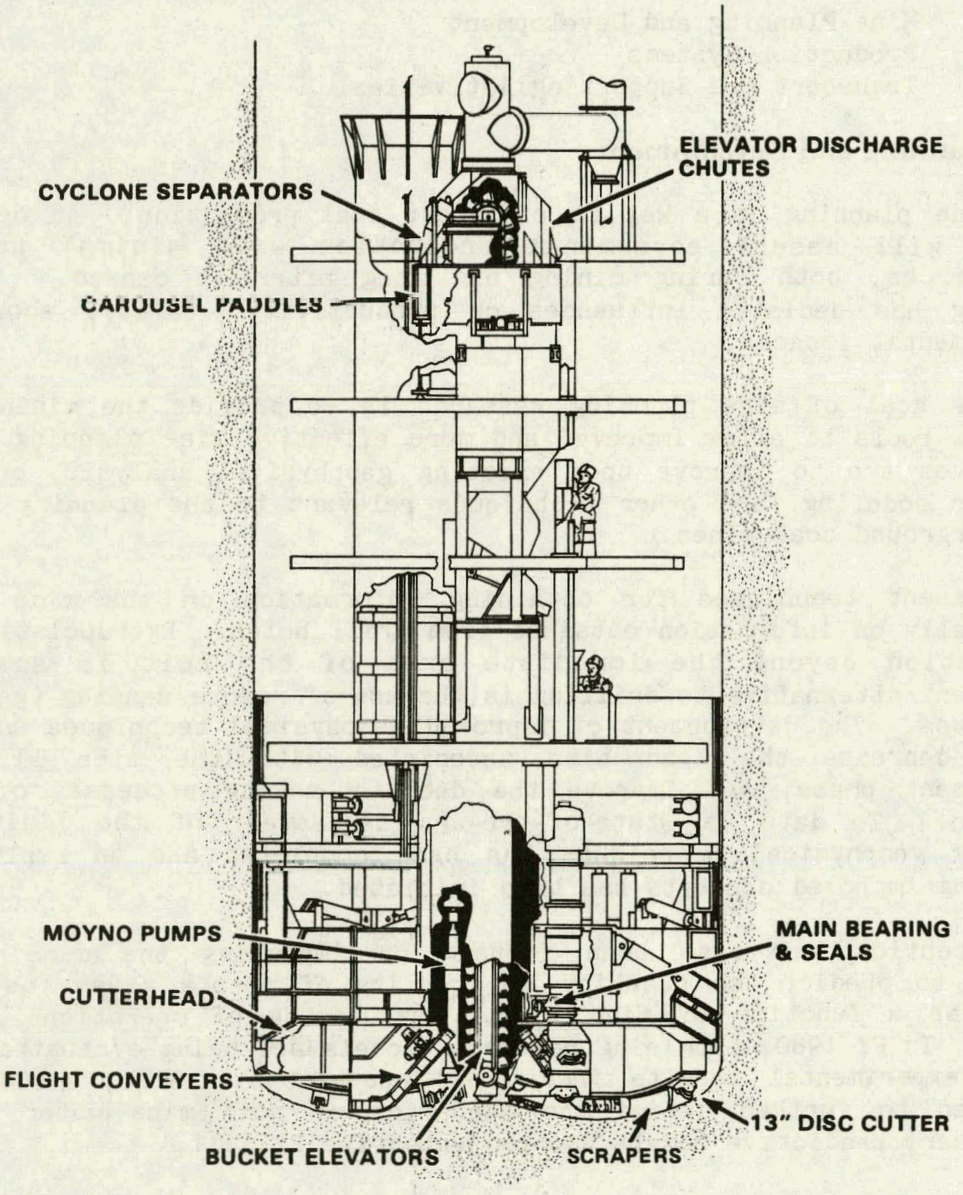
Present techniques for obtaining information on the mine site rely principally on information obtained from drill holes. Extrapolation of this information beyond the immediate area of the hole is suspect. A supplement/alternative to drilling is the use of remote sensing (geophysical) techniques. The development of improved geophysical techniques would reduce costs, decrease the lead time associated with the mine planning and development phase, and improve the decision-making processes of the mine operator. To date, a state-of-the-art assessment of the limitations of existing geophysical techniques has been completed and an exploration of promising improved concepts has been initiated.

Attention has also been focused on improving the mine operators' ability to predict the quantity and quality of strata gases (methane) and fluids as a function of mine layout, sequencing of operations and mining method. In FY 1980, promising reservoir models are being evaluated using the latest experimental results from field operations. Also, field work was conducted to further define the mechanics of acid mine water formation. Preliminary predictive models are projected for FY 1981.

Research is being conducted to interface an existing computer-based mine simulation model with an economic model. This will allow mine operators to vary relevant mining inputs and determine the impacts upon operation and costs. A preliminary working model is scheduled for FY 1981.

Mine development is comprised of two principal areas: (1) coal seam access and (2) in-mine development of entries to establish production centers. A pacing element in underground mining is the preparatory excavation required to construct ventilation shafts, man and material access shafts, and in-mine roadways (entries) required for coal production. Because of the enormous investments required to open a mine (currently $40 or more per annual ton of production) and the high cost of borrowed capital, it is

imperative that accessing coalbeds and their subsequent development for coal production be done quickly in order to reduce coal production costs.



Blind Shaft Borer — Rotating Components

There are basically three size-regimes used for shafts in coal mines. Shafts of less than 10 feet in diameter are used principally for power drops and the supply of bulk materials. Shafts from 10 to 20 feet in diameter are used for ventilation and limited materials handling. Shafts greater than 20 feet in diameter are used for ventilation and coal hoisting. The present method of sinking the larger diameter shafts, which achieves an average rate of only 40 feet per month, uses conventional drilling and blasting. In this

labor-intensive operation, crews are constantly transported in and out of the shaft to accommodate blasting. The crews must remain idle as the shaft is cleared of dust and fumes, and a number of precautionary measures are taken to ensure health and safety. These factors, coupled with the limited pool of skilled labor available for conventional shaft sinking, contribute to this method's high cost.

A program for the development of mechanized shaft-sinking systems to reduce the time and cost associated with current methods was initiated in 1975. This effort has concentrated on the development of (1) a downhole-powered system (i.e., the power supply is located at the cutting head) for construction of shafts exceeding 20 feet in diameter, and (2) a surface-powered system for construction of shafts up to 20 feet in diameter. Both systems have the design capability to sink the shafts blind, (i.e., without having to depend on previous development in the mine itself).

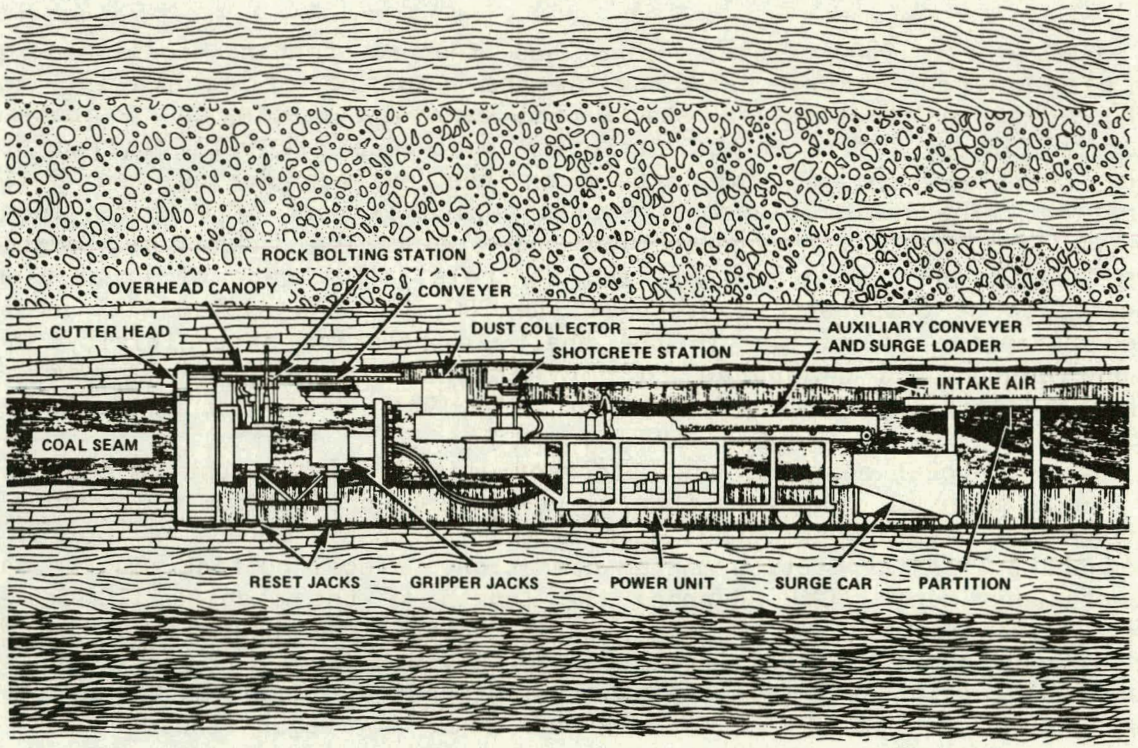
The DOE/Robbins Shaft Boring Machine (SBM) is a system with a design capability of excavating 24-foot-diameter shafts to depths of 2,000 feet. With the aid of a staged work deck atop the SBM, a 12-inch concrete lining is installed as the shaft is excavated. The system advances in 20 foot increments and has a design capability of advancing to 40 feet per day. A prototype system underwent field trials at United States Steel's Oak Grove Mine, where it was employed to construct a 1,160-foot-deep shaft. Subsequent to these trials, the SBM will be modified and retested. A second trial of an improved system is scheduled for FY 1983.

During FY 1980, final design and feature testing continued on a surface-powered rotary drilling system capable of excavating up to 20-foot-diameter ventilation shafts and remotely placing a 12-inch-thick concrete lining. This method employing scaled-up oil well drilling technology enables men to stay safely on the surface during the drilling operation. The lining placement system, which is part of this development, borrows from the civil construction and electronics industries, combining slip-forming and remote sensing and controls. The rate of excavation is expected to be comparable to that of the SBM, but the system will have the added advantage of no men in the shaft, a relative insensitivity to bad ground conditions (compared to conventional or downhole system), and excellent mobility. Trials will begin in FY 1981.

Once the coal seam has been accessed, mine passages must be constructed for men, material and air flow to establish production sections. The conventional development method used is the same basic method as applied in a "room-and-pillar" production mining operation. A coal cutting machine called a continuous miner (CM) advances the length of the machine (20 feet) in several incremental cuts. A pair of rubber-tired haulage units called shuttle cars cycle back and forth transporting coal from the continuous miner to a loading point away from the production section. Once the CM has cut its length, it is trammed to an adjacent area to begin another cut. A roof-bolter is then moved into the vacated entry to install permanent roof supports called roof bolts. This place changing is dictated by mining law which states that a mining machine operator cannot proceed beyond the last permanent roof support. There is also the practical limit of advance dictated by the stability of the roof itself, which is quite variable.

Other laws also affect how a group of entries (heading) is advanced. For example, only one cutting machine is allowed on a single stream (split) of air. This is to ensure that the methane and dust emissions from one machine do not add to that of another with the potential of creating either explosive conditions or unhealthy working conditions. Since 5 to 15 entries may be required on a development heading, the cyclic nature of the work and the limitations in numbers of machines result in very slow progress.

Efforts to date in the in-mine development area have concentrated on the evaluation of machines, which show potential, as new approaches, to relieve the problems of congestion and slow development rates. For example, tunnel boring machines (TBMs), used successfully in the construction industry are capable of rapidly driving large stable openings, often in poor ground conditions. As part of this research, a TBM was adapted to the hazardous coal mine environment and operated in a gassy eastern coal seam. Although, a planned 6,000-foot tunnel was successfully completed, the system was unable to sustain rapid rates of construction because of the complexity of the system which was dictated by the mining regulations applied to this initial effort. The results of these tests are being critically reviewed to establish the machine's performance and economic potential. If the findings look promising for a system designed specifically for coal operations,

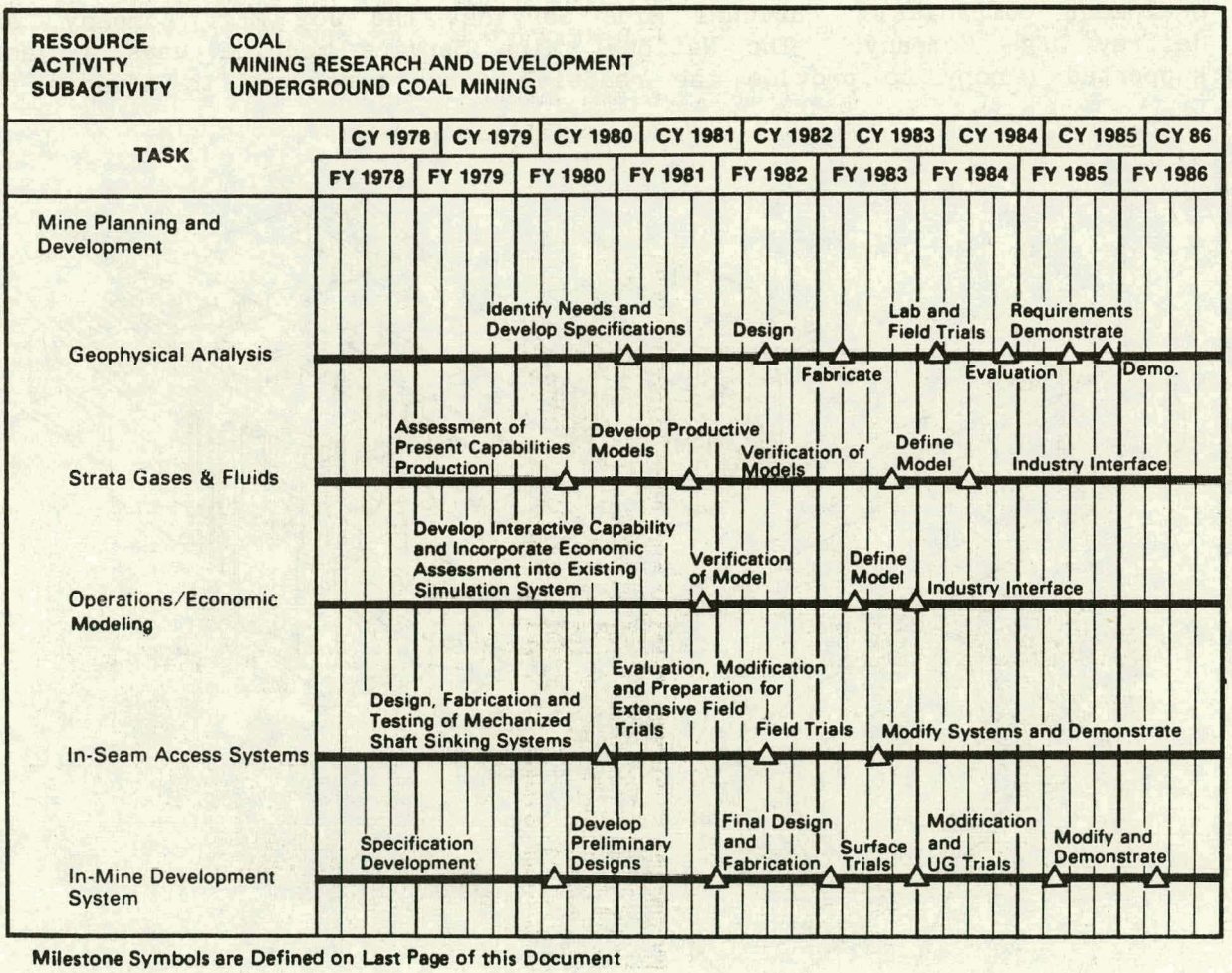


Tunnel Boring Machine

development will be initiated in FY 1981. Other equipment such as the British National Coal Board (NCB)/DOSCO in-seam miner developed for special development operations has also been examined to determine applicability as a U.S. development tool.

Having established the performance potential of a number of pieces of mining equipment, emphasis now is to explore system designs (integrating cutting, roof support, haulage and ventilation, etc.) which will maximize the efficiency of mine development efforts. This effort should be concluded in FY 1981.

Concurrently work is proceeding to increase the efficiency of coal production systems. Much of this equipment will have direct application to the development work and will be considered in the design effort indicated above.



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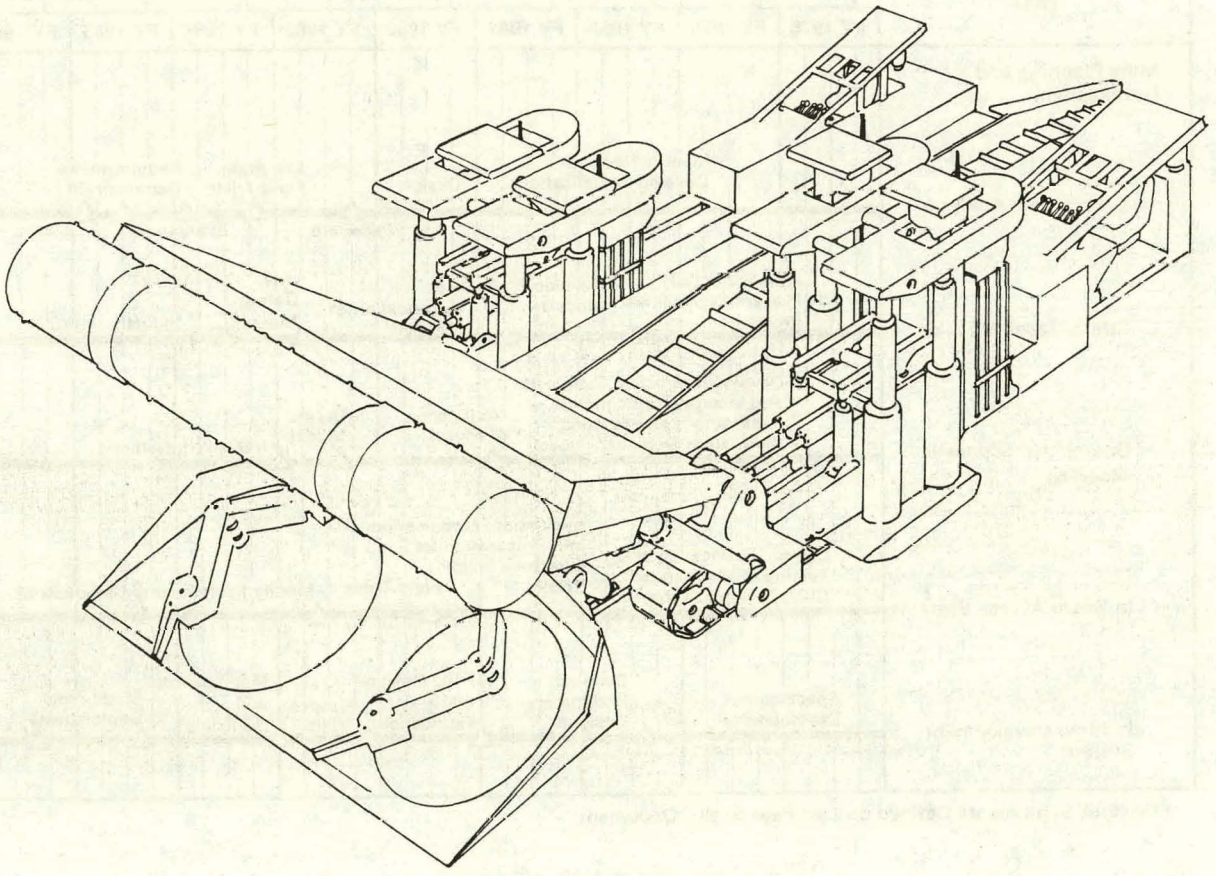
Production Systems

The predominant method for underground coal extraction in the United States is "room-and-pillar" mining. The term "room-and-pillar" is derived from the mining pattern which consists of a series of excavated areas (rooms)

and unexcavated areas (pillars) which are left to support the roof. In many cases the pillars are eventually removed, allowing the roof to cave. Because of the regulations, the CM, though mechanically capable of mining continuously, actually operates intermittently, typically cutting coal only 25 percent of a shift. A major increase in production and efficiency could be achieved by integration of the roof support and extraction functions. With emplacement of permanent roof support concurrent with the cutting of coal, the CM could proceed forward in a more continuous manner. Place changes would be much less frequent. The development of such a miner/bolter has a major priority within the underground activity. In 1975/1976 work began on the integration of bolters with the continuous miner for moderately thick coal seams (2 meters). The goal of this work is to develop a truly integrated system with high production capabilities which have no adverse impact on overall system reliability.

Presently, OCM is developing three different concepts for miner/bolters. These are being built for DOE by three of the major mining equipment companies: National Mine Service, the Joy Mfg. Company, and Jeffrey Mfg. Company. The National Mine Service machine uses a jack-supported canopy to provide the reactive force necessary to advance the

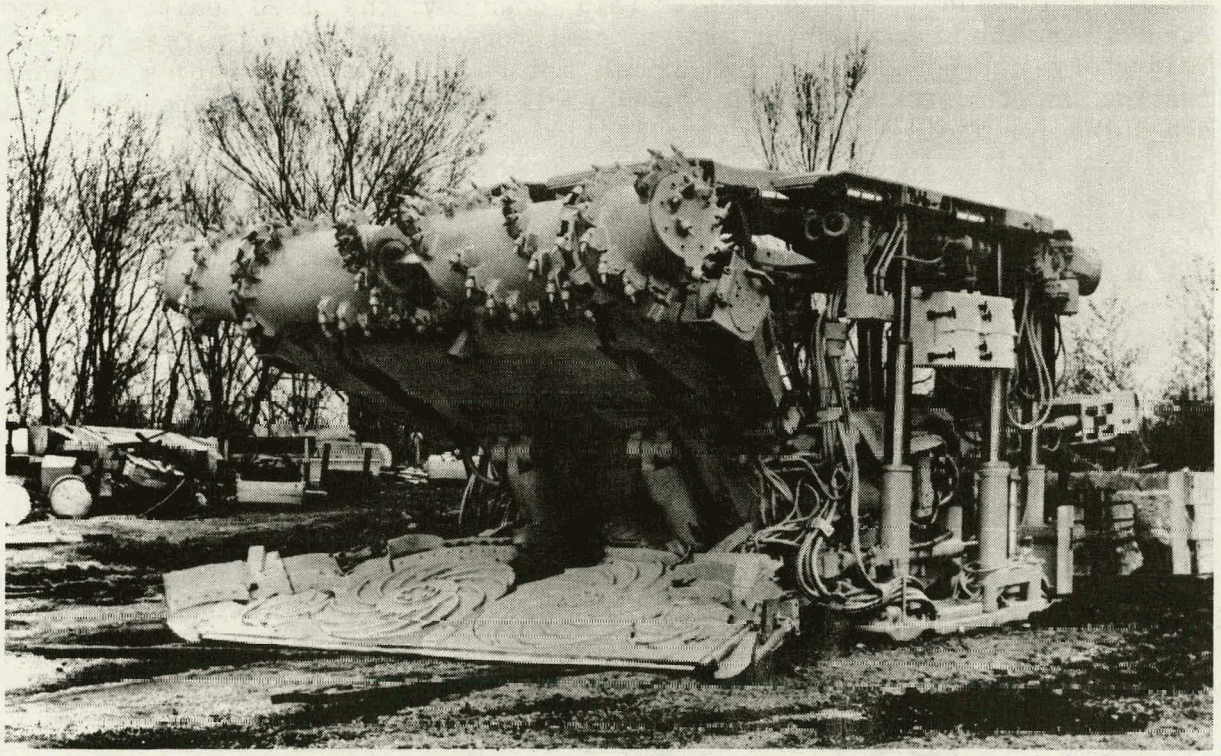


Miner/Bolter

machine and a temporary roof support to protect the miners. The roof bolts are manually installed at the rear end of the canopy concurrent with the cutting operation. The system underwent initial field trials and is in the process of being redesigned to correct the observed problems. Fabrication surface trials of the second prototypes are planned for FY 1981.

Joy Mfg. Company's miner/bolter slides through a set of four bolter modules, which are locked between roof and floor to provide thrust reaction. Bolter modules are automated and remotely operated. A carousel arrangement feeds the resin bolts or drills as needed by the drive unit. This system is undergoing laboratory testing with limited underground trials planned for FY 1980. Modification of the equipment will follow with more extensive laboratory testing in FY 1981.

The third miner/bolter system is being developed by Jeffrey Mfg. The system uses a modified, radio controlled continuous miner which is used in conjunction with a transfer unit which incorporates the roof bolting modules. The bolting modules are automated. A prototype production unit is under laboratory testing. Limited trials for this equipment are scheduled for FY 1980 with extensive underground testing in FY 1981.



Prototype Miner/Bolter

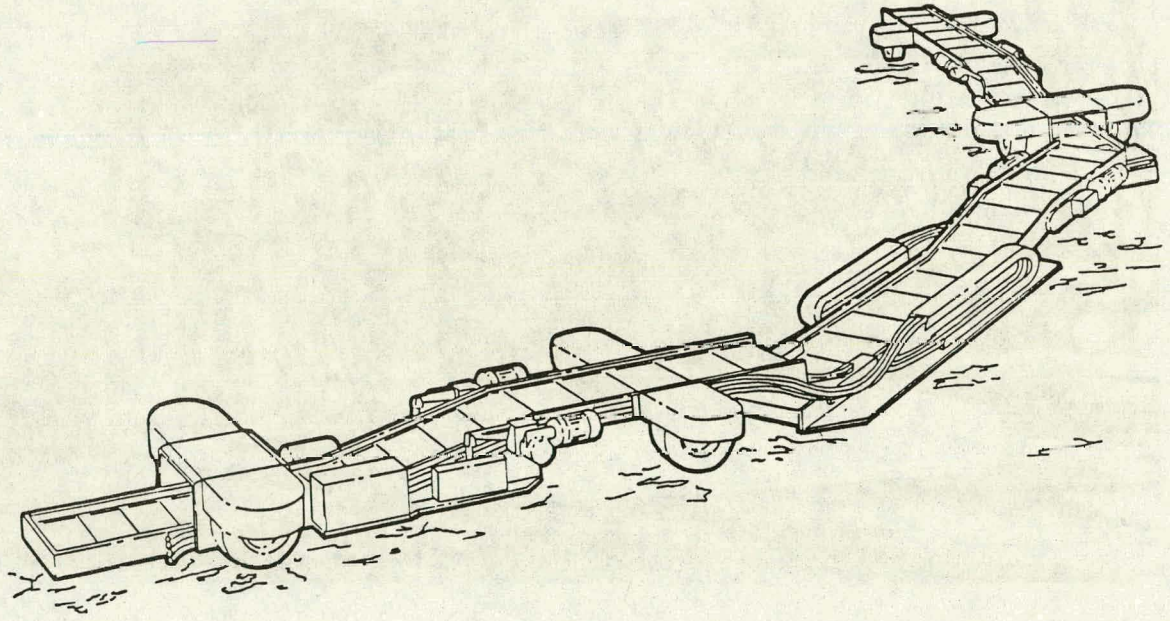
Concurrent with the development of these prototype miner-bolters concepts, efforts were initiated to develop more efficient roof bolting

components. A bolt bender/inserter was developed and two flex drills are in the final stages of development.

One of the flex drills, utilizing a segmented drill steel has been field tested to determine its endurance at the Roadside Mine in Grand Junction, Colorado. The other flex type drill, which uses counterwound springs, is undergoing field endurance tests. In both systems the application of torque causes the shaft to straighten and become rigid. Bolter modules incorporating these subsystems have been brought along in a parallel development effort. These low-profile modules are sufficiently advanced to warrant initiation of a development effort on thinseam (1.2 to 1.5 meter) miner/bolter to begin in FY 1980.

The development of a continuous face haulage system is necessary for the miner/bolter to realize its full productive capabilities. With the present technology, the continuous miner must wait until another shuttle car is spotted under the miner tailboom. Delays due to waiting for shuttle cars can take 25 percent of the continuous miner's cycle-time.

In order to address this need, research efforts have been undertaken to evaluate a broad spectrum of haulage concepts such as the following systems. The Auto-Track Bridge Conveyor consists of a series of bridge conveyor units which follow an electric cable laid down by the lead unit. Sensors straddling the cable input to a computer system that makes necessary trajectory corrections through wheel motors. After undergoing extensive testing at the DOE's Surface Test Facility in FY 1980, the device is scheduled for field trials in FY 1981.



Auto Track Bridge Conveyor

Another approach is the Multiple-Unit Conveyor Hauler (MUCH) system, developed by Jeffrey Mfg. The system employs a linked series of conveyor

carts. Following plant testing, the system underwent extensive testing on an off-road course at the Ohio Transportation Research Center. Field trials are scheduled for FY 1981.

Monorail mounted conveyor systems are also being investigated. These are roof-hung systems which require track installation for movement into all of the entries and crosscuts. One such system, the flexible conveyor train, is a 400-foot-long monorail system which has completed underground trials and is undergoing evaluation. Another monorail system under examination is the sideloading conveyor. This system involves an interconnected series of 3-foot pans. Underground trials are being conducted at Pittston Coal Company's A5 mine in Stone, Kentucky.

Alternatives to improve the efficiency of cyclic haulage of shuttle cars are also being investigated. Conventional units are electric powered and use a trailing cable to transmit power to the vehicle. This umbilical cord connection is a safety hazard, restricts underground travel, and generally limits the system to two operating vehicles. Development of a satisfactory self-contained power source would eliminate the restrictive trailing cable, reduce costs, enhance miner safety, and permit use of more than two vehicles. A smaller and lighter iron-nickel battery is being developed for coal mine use. The battery has significantly greater energy density than current systems and will withstand four to five times the number of recharge cycles. It has been installed in a scoop and successfully surface tested, and is to undergo field trials in FY 1981.

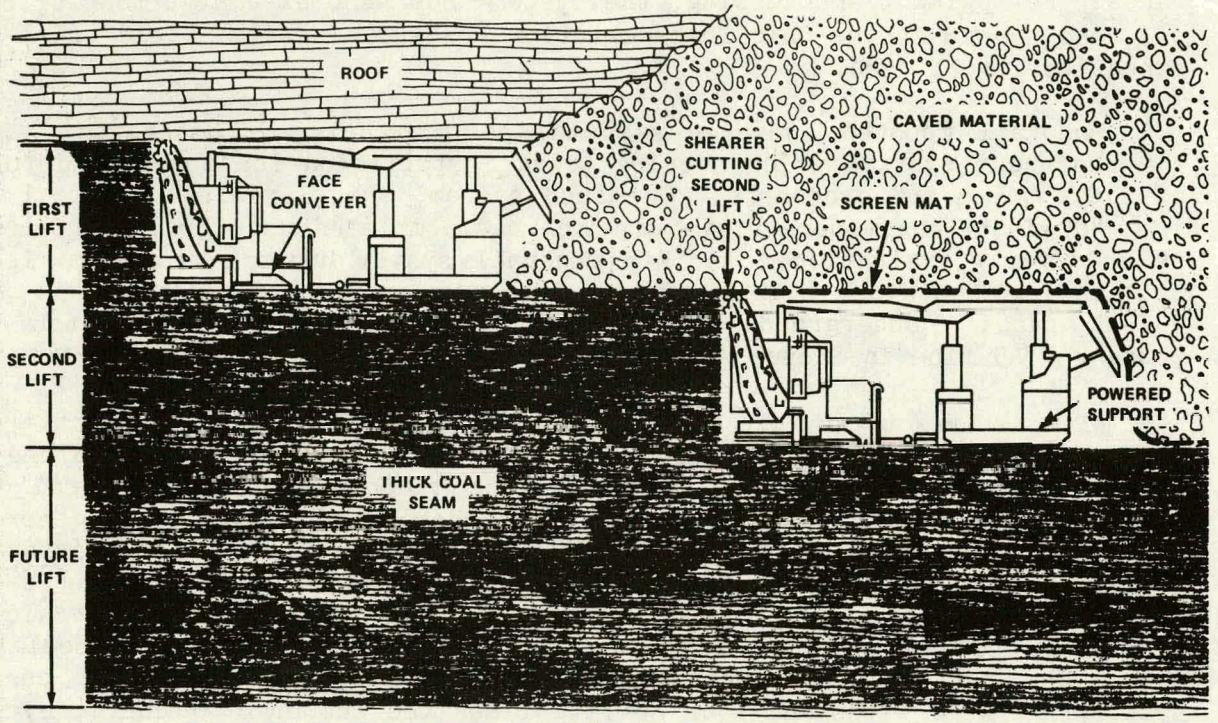
Another new technology which has potential application to shuttle cars is the energy accumulator and storage system of the flywheel. The flywheel can be recharged while the car is unloading and has the potential of producing three to five times more energy per pound than is available from lead-acid batteries. Design and fabrication will take place through FY 1981, and will be followed by field trials.

Longwall mining offers potential for increased coal production and productivity as well as improved health and safety in underground mining. In this system, large rectangular blocks of coal are defined and then extracted by successive slicing of one of the sides.

DOE's longwall mining research has two basic objectives:

- To evaluate and adapt foreign longwall technology to U.S. mining conditions
- To develop new technology to increase system efficiency.

Although longwall mining equipment requires a high capital investment, it can potentially mine coal at a low cost per ton. Examples of evaluation and adaptation of foreign technology include the trial of shield supports at the Old Ben Mine in Illinois and the York Canyon Mine in New Mexico.

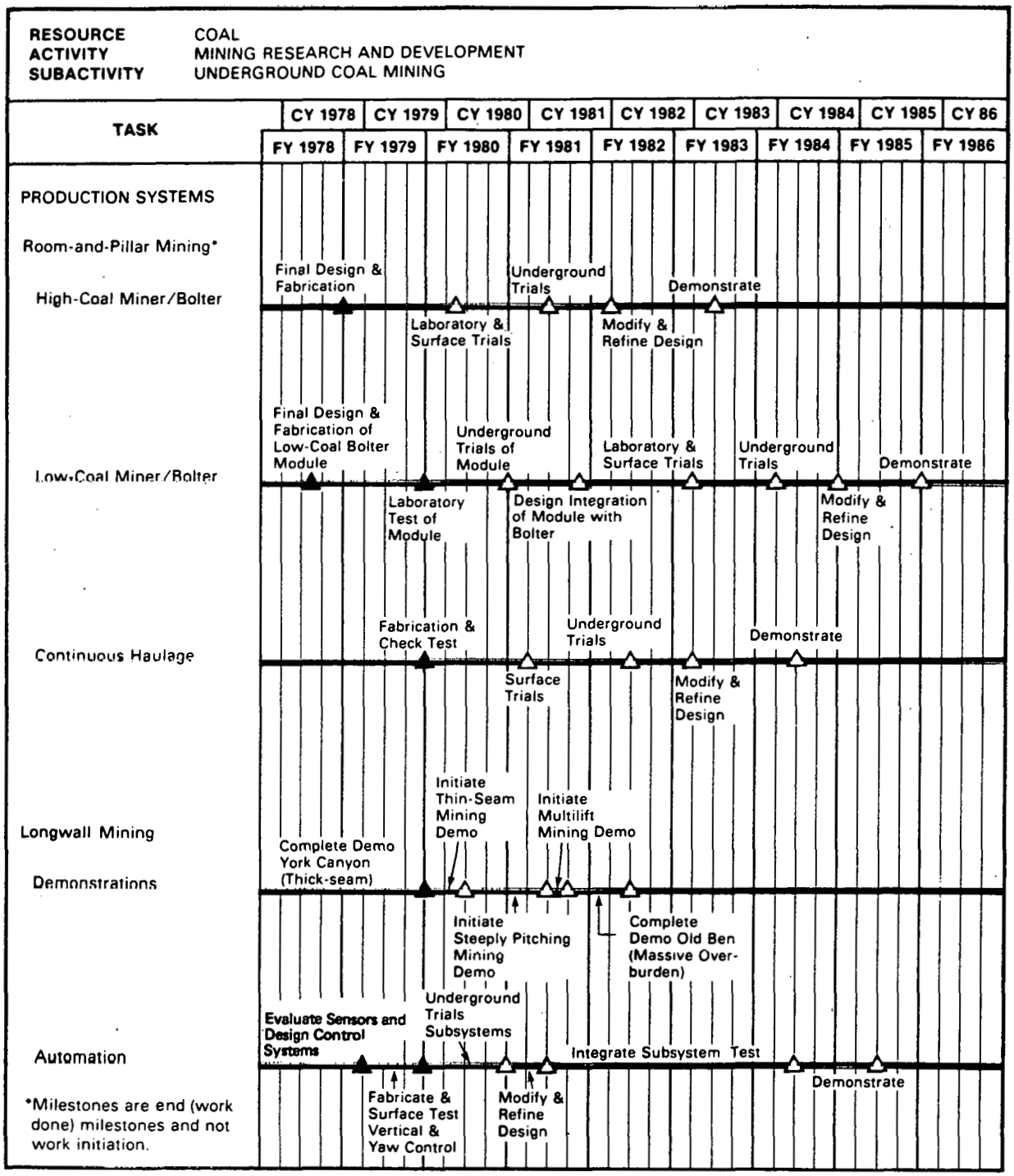


Longwall Multilift Mining Method

At the Old Ben Mine, shield supports are being demonstrated under difficult strata conditions. Previous longwall applications were unsuccessful and it was thought that longwall mining would not be applicable to the Illinois basin. The shield supports in use at the Old Ben Mine have been successfully demonstrated with four panels completed to date. At the York Canyon Mine, shield supports have been successfully demonstrated under thick (3-meter) coal seam conditions. It was feared supports in that height range would be unstable.

Although most of the U.S. coal reserves are relatively thin and flat, a significant portion of the western reserves are thick or pitching. Trials of longwall mining of a steeply pitching seam are underway at the Snow Mass Mine in Colorado. Multiple-lift mining, a potentially efficient method for thick seams, wherein longwall mining machines take successive passes, is being demonstrated in a 25-foot seam at the Mid-Continent Coal Co., in Colorado.

In the area of increasing system efficiency, emphasis is on development of guidance and control technology leading to remote and automated operation. Trials of equipment of this type are being conducted at the DOE Surface Test Facility. Key equipment being tested there are coal interface detectors and yaw angle measuring devices that provide improved mining accuracy and reliability. Ten coal interface detectors have been tested, with two showing excellent results. The yaw angle measuring device also shows promise.



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Transport and Supporting Services

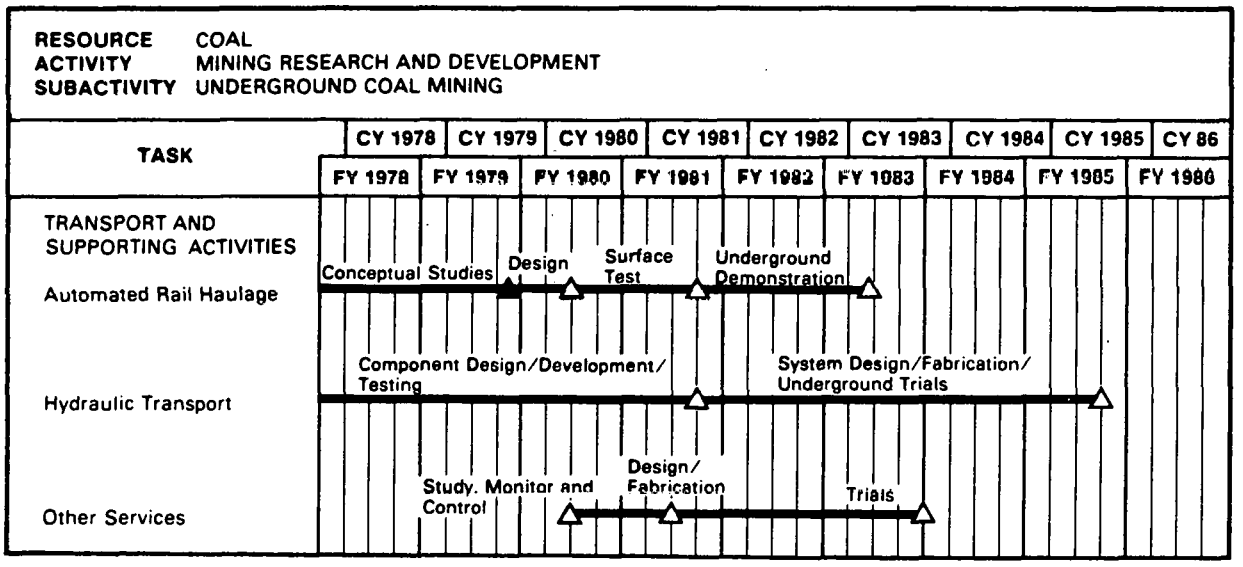
The objective of this work is to provide the needed new and improved technology and equipment development within a mine to optimize logistical support. Achievement of these objectives requires that the research program address the problem of providing improved methods of transport of men, coal, supplies, and material to and from the working face within a mine area.

Further, operations support should be improved such that face operations are provided with necessary utilities in a timely and reliable manner. Systems and technology must also be developed which will provide all the mine-wide support services necessary for safe operation on a sustained basis. This includes mine-wide monitoring and necessary management tools.

An automated rail haulage system is being developed which uses unit trains which circulate within the mine, without operator assistance, from various loading sites to the unloading point and back to the same or to an alternative site. The system requires a locomotive designed specifically for automation, with controls and sensors throughout the entire system for unmanned operation. The overall system eliminates workers from the most hazardous portions of the rail haulage operation. A production prototype will undergo surface testing in FY 1981.

Hydraulic transport offers another potentially effective means of transporting large volumes of coal from the face to the surface. DOE's surface test facility contains an extensive facility for testing all stages of slurry transport. Using this facility, engineering data necessary to design systems compatible with mine operations will be developed. Current plans call for work to be initiated during FY 1980 and to continue through FY 1981.

Work is also underway on two very promising coal injector units. One uses a unique device which can inject dry coal into a pipeline at 95 psi. Another very simple compact unit uses a high-pressure jet, approximately 125 psi, and a diffuser to induce coal into the pipeline at 25 psi. Scaled-down versions of these systems have successfully completed tests and full-scale units are being constructed for testing during FY 1980.



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2.0 SURFACE COAL MINING

Since the advent of large shovels (about 1915) capable of stripping overburden, surface mining has provided an increasingly greater percentage of the Nation's coal production. In 1970, surface mining accounted for approximately 44 percent of the total coal production. In 1981, it is projected that surface mining will account for approximately 64 percent of the total coal production. Surface mining has become more attractive for several reasons. The costs of production are less than for underground mining, resource recovery is greater, and there are fewer health and safety problems. However, surface mining productivity, like underground mining, has been decreasing; current productivity is only about 70 percent of that achieved in 1970.

Surface mining technology is faced with some severe problems. First, there is a need for better and more efficient equipment to expand the capabilities of surface mining. This is especially true for the development of large western mines to satisfy the increasing demand for low-sulfur coal. Secondly, there is a need for new surface mining equipment to meet environmental and reclamation requirements, while avoiding declines in productivity. The passage of Federal and state reclamation regulations has added a whole new dimension to surface mining. Equipment must now be designed to efficiently remove overburden and coal while allowing for the placement and distribution of spoil to permit reclamation at minimal cost. Today reclamation must be made an integral part of the surface coal mining cycle.

In order to address these technology problems the Surface Coal Mining subactivity has been organized into the following project areas:

- Mine planning and development
- Production systems
- Logistics.

Mine Planning and Development

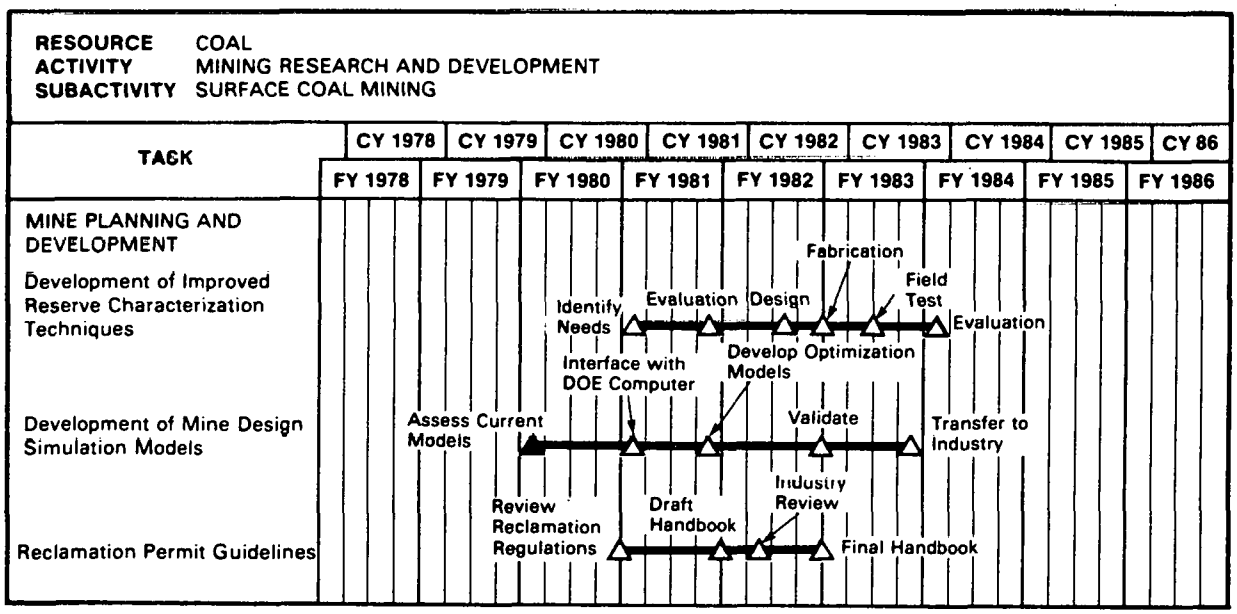
With the advent of Federal and state mining regulations, mine planning has become a critical element in developing new surface mines to support increased coal production demands. Major elements in mine planning are: initially, establishing the pertinent geotechnical, economic, socioeconomic and environmental factors applicable to a specific reserve; secondly, determining the feasibility of mining the reserve; and lastly, selecting the optimal mining and reclamation system for development of the reserve.

The major objectives of mine planning research are (1) development of techniques and systems for use in coal reserve characterization, and (2) development of improved methods to facilitate mine design.

In the area of reserve characterization, studies to date have been directed toward assessing the environmental effects of surface coal mining, development of data collection and analysis methods for amassing the information required for permit application, and evaluation of the utility of employing aerial photography and other remote sensing techniques for monitoring of mining and reclamation operations and permit data collection.

In FY 1981, a feasibility study will be initiated to evaluate alternative geophysical techniques for overburden and interburden characterization. Development of geophysical techniques will reduce the mine operator's dependency on costly core drilling procedures for overburden/interburden characterization and will subsequently aid in decreasing the lead time between the mine planning and production phases.

Mine design R&D will be directed toward developing technology to improve the mine design process through (1) development of simulation models to aid the mine planner in designing mine layouts, haulage configurations, and equipment selection; (2) development of design guidelines for planning efficient, effective mining operations, and (3) the development of guidelines for cost-effective compliance with surface mining regulations. In FY 1981, an existing DOE surface mining optimization model will be adapted for use on more widely used computer systems to increase its accessibility to the mining community. The passage of the Surface Mining and Reclamation Act of 1977 (P.L. 95-87) has necessitated the design and preparation of a handbook for coal operators which (1) clearly describes a sequential approach for preparing permit application; (2) includes model permit applications; and (3) includes relevant engineering methodologies and data for preparation of the application material. This handbook will be completed in FY 1981.



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Production Systems

Surface coal mining production systems can be classified into one of two general groups, i.e., area mining or contour mining systems, depending on the mining approach used. Area mining systems are generally employed for the exploitation of reserves in relatively flat terrain typical of the midwestern

and western coal fields. Contour mining systems are employed for exploitation of reserves in rugged, mountainous terrain typical of Appalachia.

In area mining an initial box cut is made through the overburden to expose the coal seam. Following coal extraction, succeeding parallel cuts are made with the resultant spoil placed into the previously excavated cut. The final cut leaves an open trench as deep as the thickness of the overburden plus the coal recovered, bounded on one side by the last spoil bank and on the other by the undisturbed highwall.

Contour mining is practiced in mountainous or hilly terrain typical of the coal fields of Appalachia. Presently, the two basic methods employed are haulback mining and mountaintop removal. In haulback mining, overburden removal commences at the coal outcrop and follows the contour of the mountain. This method involves developing an initial cut at the coal outcrop, penetrating into the hillside until the economic stripping limit is reached. Topsoil is removed by front-end loaders, bulldozers, or scrapers as dictated by local conditions, and is stored for later use in reclamation. A bench is created from which coal is extracted and loaded into haulage vehicles. The fragmented overburden from each succeeding cut is removed by dozers and front-end loaders, placed in haulage vehicles, and then deposited in the previously excavated cut where the coal has been removed.

The mountaintop removal method of contour mining allows for the economical recovery of coal located near the tops of mountains, ridges and knolls. The mountaintop is not necessarily restored to its original contour, but rather may be sculptured to a gently rolling terrain. Construction equipment is commonly used for overburden removal. Typical mountaintop mining operations leave some coal and overburden untouched on the mountaintop where the stripping ratio is considered uneconomical, resulting in a lost resource and an environmental reclamation problem.

The greatest potential for increasing the performance of surface mining operations lies in the development of new and improved mining equipment and techniques. Consequently the major R&D thrusts in the production systems area are:

- Develop new equipment and systems to increase production resource recovery and productivity.
- Improve mining methods, based on existing equipment to increase resource recovery.
- Modify existing equipment and improve operating and maintenance techniques.

In area mining the primary piece of equipment employed for overburden removal is the dragline. Many mines employ draglines with bucket capacities ranging between 60 and 75 cubic yards and boom lengths ranging from 150 to 300 feet. Their effectiveness is constrained by factors such as the dumping radius limits and the ability to cast a substantial proportion of the overburden without rehandling. Present dragline stripping methods require

approximately 10 to 40 percent of the overburden to be rehandled, which adds substantially to production costs.

A preliminary analysis of the effectiveness of conventional mining equipment in handling overburden is being performed in FY 1980. During FY 1981, a new equipment design program will be initiated. Fabrication of prototype equipment and field testing will commence in FY 1982.

Area mine production and productivity are strongly affected by the rates of overburden removal and spoil placement, which in turn is a function of the dragline operator's skill. In FY 1981, field testing of a prototype dragline training system to improve operator efficiency will be completed.

Additional FY 1981 studies will focus on development of optimal dragline operating procedures for multiple-seam mining conditions, and development of an onboard display system for stripping shovels to provide the operator with a real-time production monitoring capability. During 1981, the previously developed dragline operating aids and the dragline simulation model will be evaluated for potential application to stripping shovels, and the system upgraded to incorporate recent advances in data acquisition technology.

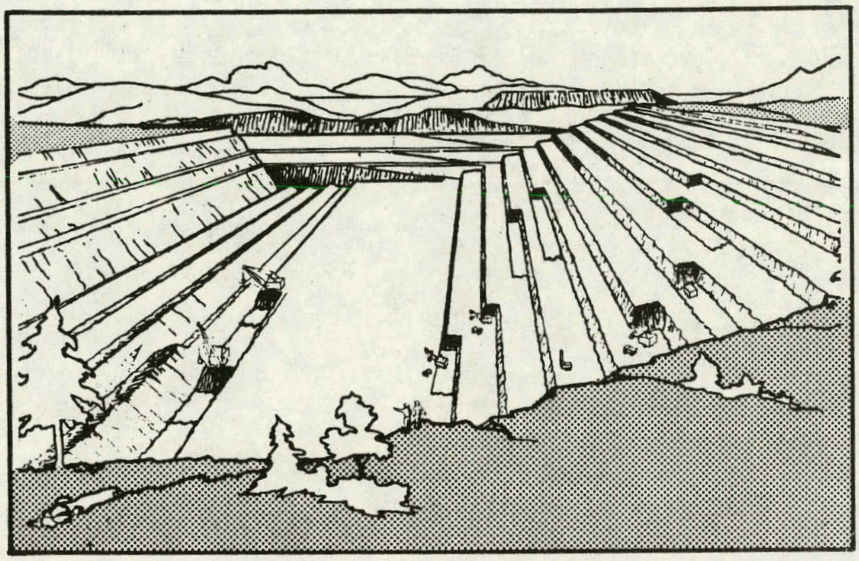
Wire rope failure is a common problem with dragline operations, resulting in production losses due to lengthy dragline down times for rope replacement. The wire rope testing program initiated in FY 1978 will continue to evaluate rope stress, wear and failure with the specific objective of developing means of improving rope life. In FY 1981, a feedback control system to prevent overstressing of rope will be developed and field tested.

Continuous excavators offering high mobility and production rates are being evaluated for use in area mining operations for both coal and overburden cutting applications. In FY 1979, efforts were initiated for modification of a forward-rotating wheel excavator for overburden excavation. Fabrication of modified equipment commenced in FY 1980, with field testing and system evaluation scheduled for FY 1981.

Feasibility studies of another continuous miner concept, the Breaker Plow, were initiated in FY 1979. This concept employs an array of vertically mounted hydraulic breakers to "peel off" a thick layer of the coal seam and load it via a conveyor into haulage trucks. Field testing of the cutting assembly will be conducted during FY 1980 and FY 1981 to determine the energy requirements and design configurations necessary to effectively break coal or overburden.

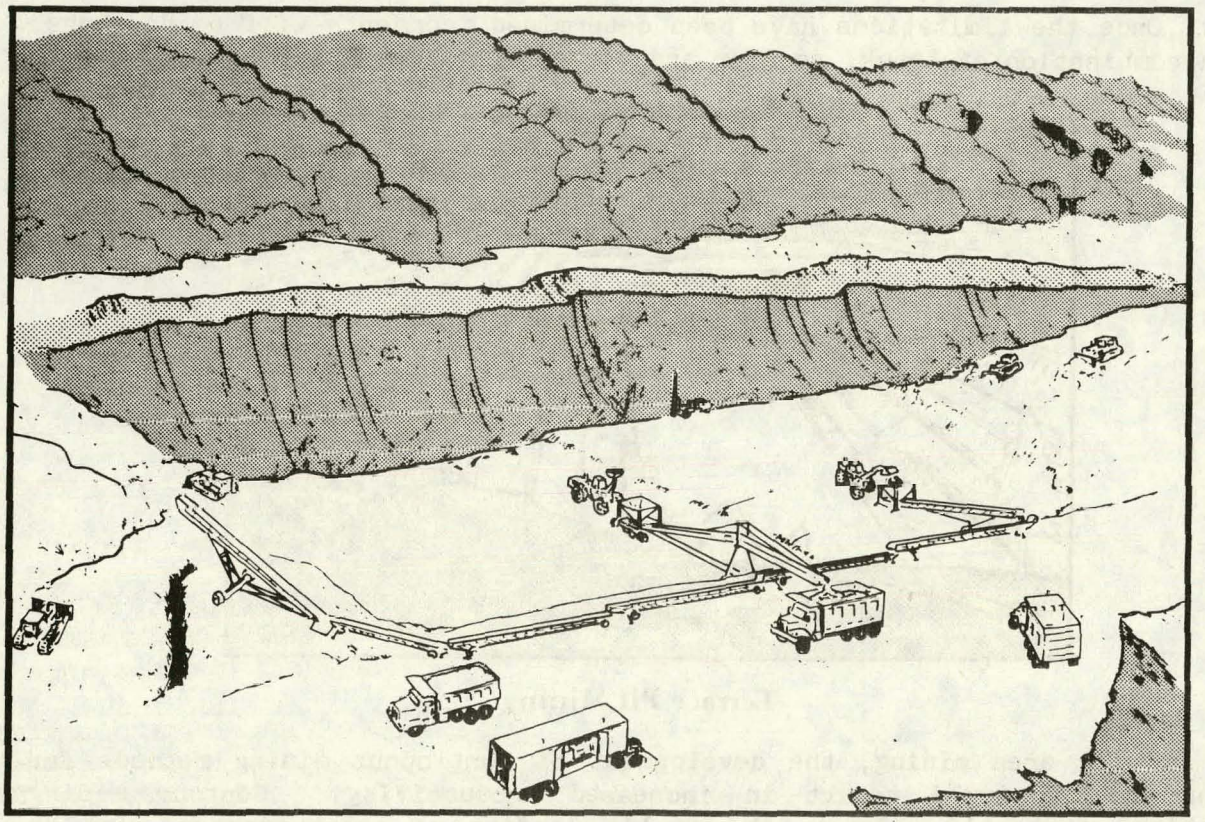
The development of a novel mining system was initiated in FY 1979. This system called the "Terrace Pit System" will allow for the recovery of single and multiple seams under a variety of geological conditions. Previous studies have shown terrace pit concepts to be the most cost-effective alternatives to conventional area mining methods due to their applicability to a wide range of surface terrains, coal seam pitches, and area shapes. The physical limitations of the terrace pit system will be identified during FY

1981. Once the limitations have been determined, concepts will be developed for a combination of truck, scraper and conveyor haulage equipment.



Terrace Pit Mining

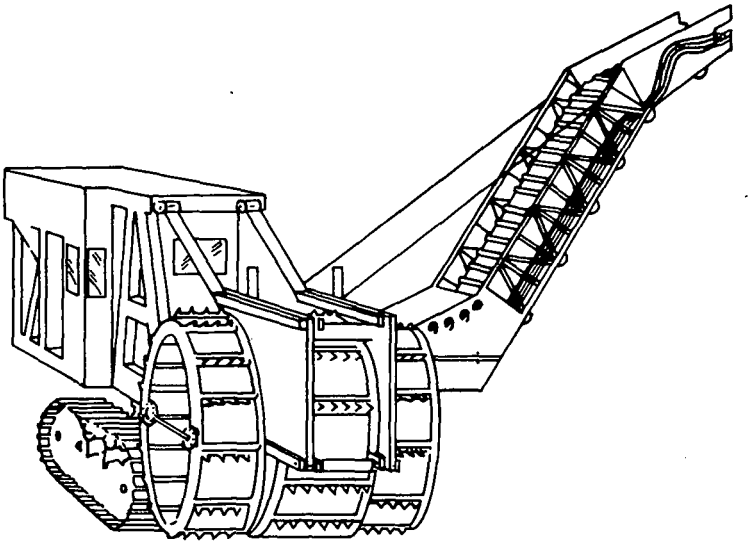
As with area mining, the development of continuous mining methods for contour mining would result in increased productivity. Contour mining operations currently rely on the cyclic loading of overburden or coal by front-end loaders into haulage trucks. This cyclic operation is both labor and equipment intensive and results in equipment congestion problems in the mine. However, continuous systems would reduce these manpower and equipment congestion problems. Consequently, research efforts in FY 1979 and FY 1980 were directed toward the development of continuous systems for haulback and mountaintop removal mining situations. Field evaluation of a low-wall conveyor system for application to haulback mining operations will be completed in FY 1980. During FY 1981, other continuous methods will be evaluated relative to their feasibility for haulback mining applications.



Low-Wall Conveyor Haulage

A conveyor system for transporting and stacking spoils in conjunction with small draglines in modified open-pit mines is also under development. The combined dragline/conveyor system will eliminate overburden rehandling. Field evaluation in a production mining situation was initiated in FY 1980. A $2.50 per ton of coal savings and a 23 percent increase in production over conventional systems is predicted.

Monitoring of the field trials of the new cross-ridge mountaintop mining commenced in FY 1980, and will continue through FY 1983. In this method (employing conventional equipment), mining progresses in a series of parallel cuts made perpendicular to the long axis of the mountaintop. Advantages offered by this method include improved cash flow, increased resource recovery and decreased environmental disturbance.



Bucket Wheel

A supplementary form of contour mining production is highwall mining. Auger mining (a form of highwall mining) to recover coal beyond the highwall currently accounts for about 2.5 percent of bituminous coal production. The relative shallow depth of auger penetration supports the development of extended depth highwall mining systems to recover additional reserves. It is estimated that if the augering depth can be extended to 800 feet, 20 billion tons can be added to domestic coal reserves. In addition to improved resource recovery, savings in overall mining costs will be realized since less land would be disturbed per ton of coal mined.

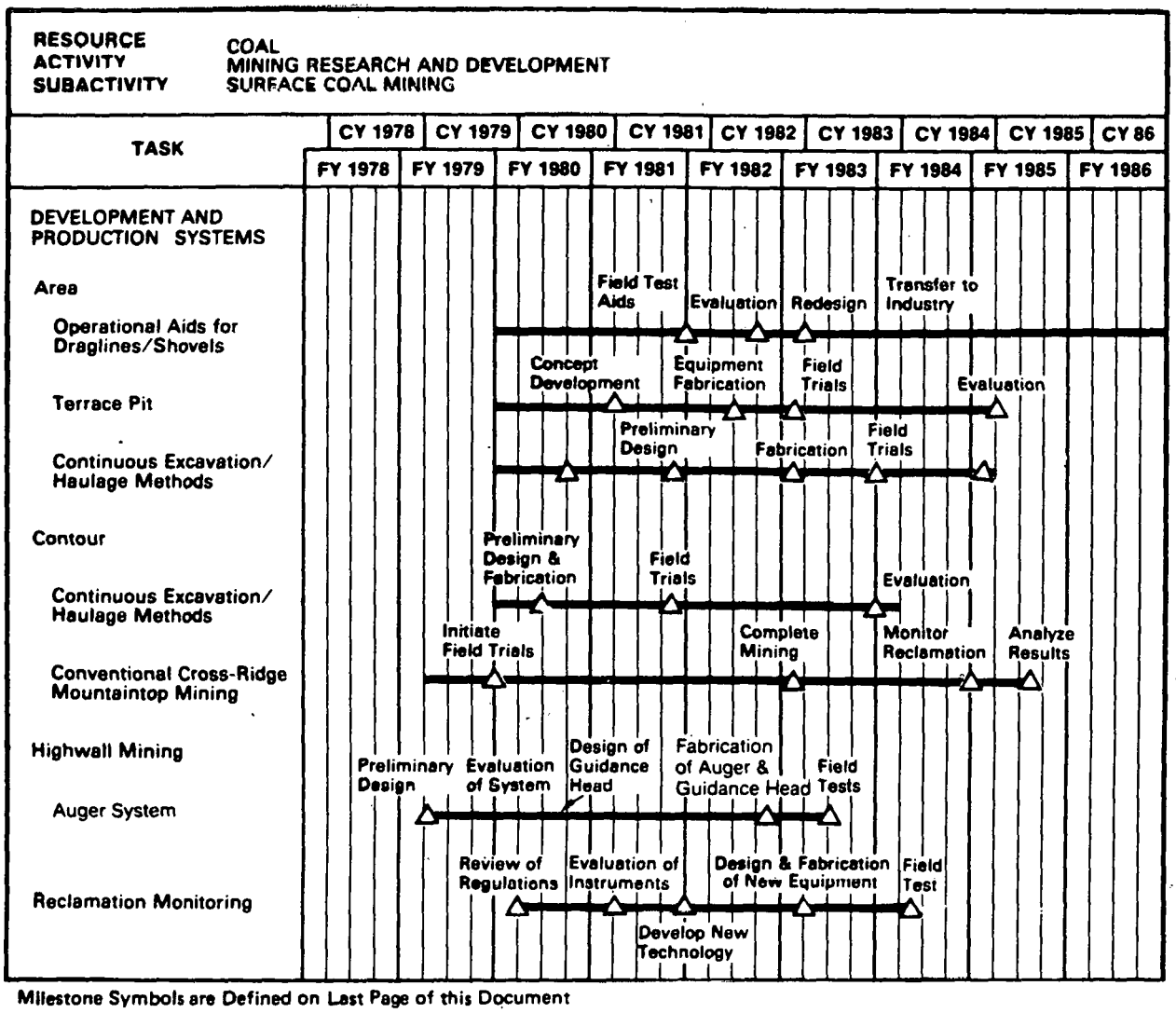
Concept designs for experimental extended-depth highwall auger systems have been completed and critical components were field tested during FY 1979. Based on the results of these tests, improved auger head guidance, coal transport and cutter head designs were initiated in FY 1980. Development of high-recovery highwall mining equipment is scheduled to commence in FY 1981, with the adaption of a higher recovery auger head to a conventional highwall auger. In addition, concepts for hydraulic highwall mining will be evaluated in FY 1980, and the most promising concept will undergo fabrication and field trials commencing in FY 1981.

Today, reclamation is a necessary adjunct of mining operations throughout United States' coal fields. Previously, the mining industry relied on existing mining and civil construction industry equipment to satisfy immediate reclamation needs. However, this was an expensive compromise since the selected equipment was not designed or developed to effectively handle the specific requirements of reclamation functions, such as contouring spoil banks. Because of stringent environmental standards and the lack of an effective reclamation technology, reclamation activities constitute up to 28 percent of coal production costs.

Reclamation R&D efforts seek to increase the efficiency and effectiveness of reclamation both within and outside the limits of the actual

mining operation. Emphasis is given to the development of integrated mining and reclamation systems that can significantly reduce the costs of compliance with environmental standards. Integrated systems will be developed for the range of mining conditions and environmental quality standards encountered in U.S. coal fields.

The development of reclamation monitoring techniques is a major task being initiated in FY 1981. The objectives of this task are (1) to evaluate available monitoring techniques, (2) to provide industry with a user's manual for applying these techniques, and (3) to design, develop, and field test reclamation monitoring equipment based on new concepts evolving from this study.



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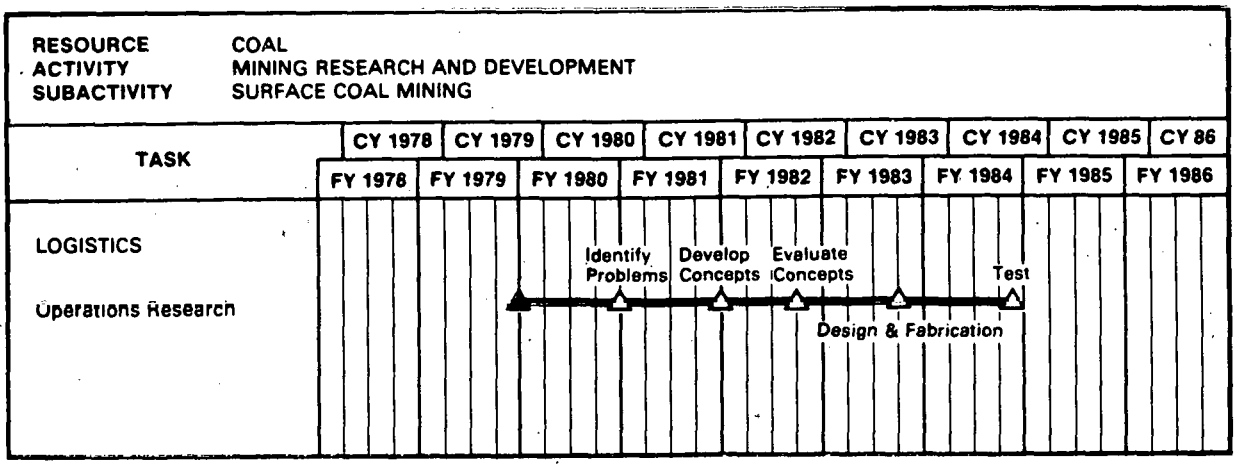
Logistics

Productive surface coal mining is a function of good auxiliary support operations, as well as thorough mine planning, efficient development, and the use of appropriate production equipment. Logistic research and development

must keep pace with ongoing efforts in the other aspects of surface mining to ensure that the full capabilities of new technology are realized. Some of the support functions logistic R&D efforts will address are:

- Supply systems for mining materials
- Supervisory control system, including communication, production and environmental monitoring, and data reporting
- Mine maintenance system
- Training system
- Ancillary operations such as mine surface water and groundwater control, and haul road maintenance.

In FY 1981, concepts will be developed to reduce the hindrance of mine auxiliary support systems on realization of the full potential of mining equipment. Emphasis will be on development of electrical power distribution system concepts that reduce production problems associated with trailing cables of continuous mining and transport systems. In the ancillary support area, emphasis will be on the development of a mine-wide maintenance system based on onboard diagnostic equipment, such as the BITE system for front-end loaders and the DOA system for draglines. Such a system will also enable mine-wide monitoring of productivity. Computer software packages will also be developed for improving operations.



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Alternative Coal Mining Technologies (Surface Mining Act R&D Section 908)

The Office of Coal Mining has developed an adjunct program in alternative coal mining technologies to implement programmatic requirements

delineated in Section 908 P.L. 95-87, the Surface Mining Control and Reclamation Act of 1977. It is stated in Section 908 that:

> The Administrator is authorized to conduct...research relating to (1) the development and application of coal mining technologies which provide alternatives to surface disturbance and which maximize the recovery of available coal resources including the improvement of present underground mining methods, methods for the return of underground mining wastes to the mine void, the methods for the underground mining of thick coal seams and very deep seams; and (2) safety and health in the application of such technologies...

The OCM's initial program in FY 1979 identified the following three mining research areas: the mining of unusually thick seams; in-mine underground waste disposal; and health and safety projects associated with alternative mining technologies.

Almost all of the coal mined in the U.S. by underground methods comes from working areas less than 10 feet in height. While this is satisfactory for most coal seams, there are significant quantities of coal reserves associated with seams thicker than 20 feet for which there is no proven U.S. technology. These thick seam deposits are particularly prevalent in the western coal fields. If technology was developed to enable the recovery of these thick coal seams, our coal reserves could be significantly increased. One promising technique for recovery of thick seams is the longwall multilift technique, in which two or more levels would be mined in vertical sequence. Although multilift mining has been practiced in other countries, it has never been applied in the U.S. The Office of Coal Mining multilift field project is expected to demonstrate a resource recovery that will double that obtained with existing technology.

Underground disposal of coal waste would eliminate the environmental problems associated with traditional surface disposal methods. Backfilling of operating and abandoned mines with waste would mitigate subsidence and permit reclamation of valuable land that otherwise would be covered by refuse banks. However, prior to the development of in-mine disposal techniques, it is necessary to develop an in-depth knowledge of the chemical and mechanical properties of coal waste.

The focus of the waste disposal effort is to characterize the properties of coal waste materials on a regional basis. Once this characterization has been completed, the development of cost-effective procedures to minimize undesirable environmental effects of waste disposal will be pursued and completed in FY 1981.

The 908 Health and Safety Section studies areas that may obstruct the implementation of alternative mining technologies. To date, funded projects include studies on face ventilation, safety analysis of shaft boring technology, and pneumatic transport system.

The FY 1980, Section 908 funds will be expended to implement additional health and safety studies to initiate development of the advanced technology longwall face (ATLF). The ATLF will be employed to test innovative longwall

systems or individual pieces of equipment that show promise under adverse mining conditions. This consideration is critical as domestic underground coal mines deplete the shallow underground reserves and mining operations concentrate more heavily on more difficult reserves (deeper and/or thicker seams).

3.0 COAL PREPARATION AND ANALYSIS

Coal preparation is the process by which raw coal containing impurities such as sulfur, ash, and trace elements is cleaned into a salable product. Through various coal cleaning operations, increasing amounts of coal are being prepared annually in preparation plants. One factor contributing to this increase in coal cleaning is the expanded use of continuous mining techniques, which introduces larger amounts of impurities into the run-of-mine coal. Another factor is the Clean Air Act Amendments of 1977, mandating limitations on sulfur content.

The sulfur in coal occurs in two major forms--inorganic sulfur (pyrite) and organic sulfur (chemically bound in the coal structure). Coal preparation processes use physical coal cleaning techniques (e.g., separation of coal and impurities by taking advantage of their specific gravity differences) in cleaning the raw coal. Physical coal cleaning, which removes only the inorganic sulfur, has no effect on the organic sulfur content. Many coals have organic sulfur levels above the sulfur dioxide emission standards when burned, and no amount of physical cleaning will bring these coals into compliance.

By developing chemical cleaning processes, a major portion of the total (inorganic and organic) sulfur in coals can be removed. Unlike physical coal cleaning, which produces a coal like the parent feedstock, chemical coal cleaning can result in a product whose physical and chemical properties are modified from those of the feed. Coking properties or chemical balances can be modified in the chemical reaction to produce the ideal feed for a given utilization or conversion process. However, there are presently no commercial chemical coal cleaning techniques.

In order to reduce coal preparation costs and to facilitate the use of coal, the objectives of the Coal Preparation activity are to:

- Develop a data base on the chemical and physical properties of coal.
- Extend and improve contemporary physical beneficiation processes.
- Develop chemical coal cleaning processes and evaluate their sulfur reduction potential.
- Develop new processes and improve existing technology in coal preparation-related operations.

To meet these objectives, the following program structure has been developed:

- Coal Characterization
- Physical Beneficiation
- Physicochemical Beneficiation
- Ancillary Unit Operations.

Coal Characterization

The heterogeneous composition of coals makes it essential to develop an extensive data base on the physical and chemical characteristics.

With the increased emphasis on substituting coal for oil and natural gas, greater attention will be given to methods which efficiently extract, process, and combust domestic coal resources. Such methods must comply with increasingly stringent environmental standards. The development of effective utilization, processing, and conversion technology is strongly dependent upon the state of knowledge of the complex coal molecule.

Past research has demonstrated that controlled laboratory cleaning of run-of-mine coals results in significant reductions of trace elements in the usable coal. Unknown, however, is the effectiveness of commercial coal cleaning plants in reducing trace element concentrations, and the environmental problems related to fugitive elements that might occur at the cleaning plant site.

A major thrust of coal characterization is aimed towards gaining a better understanding of the quantity and quality of coal contained in the waste piles produced by coal cleaning plants. Almost all washed coals produce considerable fine material consisting of clay and particles of rock and coal, which are discharged into large impoundments. Although some washing plants include circuits for recovering the fine coal, most plants continue to discharge fine coal and waste into impoundments. Some of these impoundments contain as much as several million tons of waste averaging 50 to 70 percent coal. This coal is an important resource that can potentially be recovered at low costs. Furthermore, the volume of the impoundments can be significantly reduced when the coal is recovered, thus reducing the safety hazard of the ponds and their degrading effect on the environment.

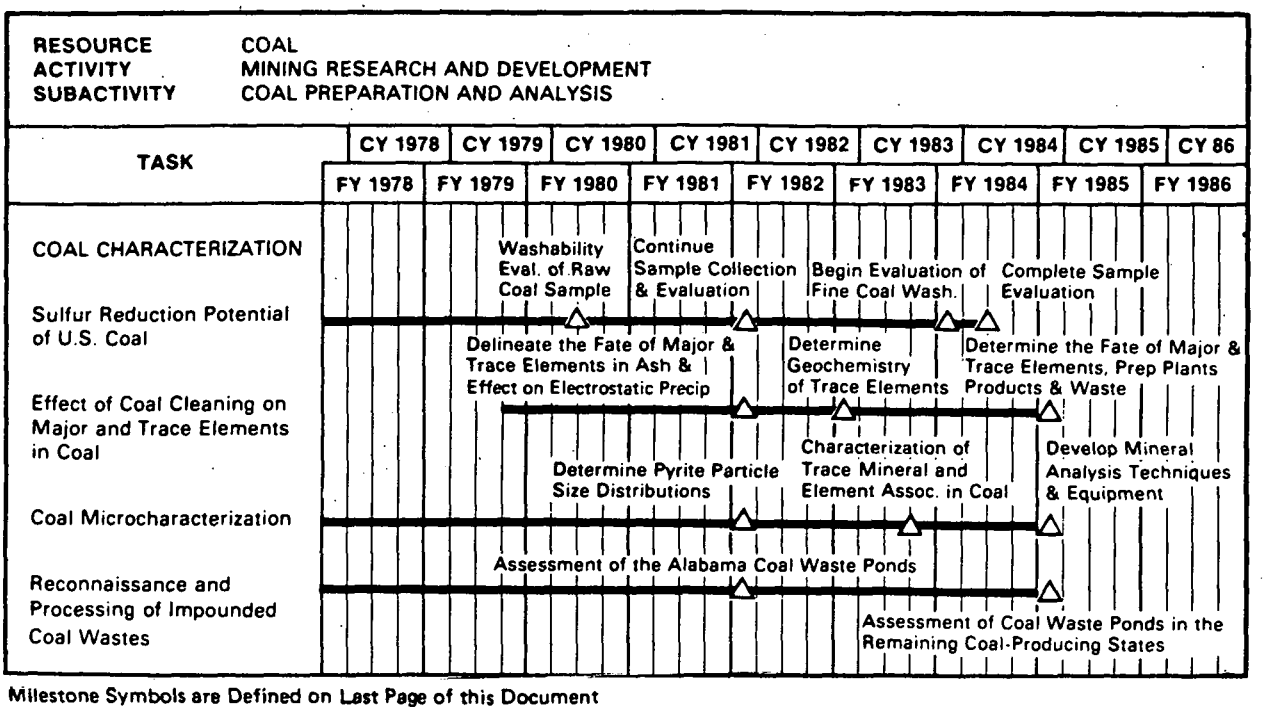
To satisfy the requirements of the coal characterization project, several areas will continue to receive support during FY 1981. Determination of the sulfur reduction potential of U.S. coals will require the collection of raw coal channel samples and evaluation of the subsequent washability analysis. The coals emphasized during FY 1981 will include those of the western, midwestern and Alaskan coal fields. The Alaskan study, being conducted by the University of Alaska, will complete channel sample collection by December 1980, with evaluation of the washability analysis to be finished by April 1981. A final report will be submitted during 1982. The western and midwestern evaluation will proceed throughout FY 1981, with completion scheduled for early in FY 1983.

To better determine the effects of coal cleaning on the major and trace elements present in coal, research into the geochemistry of trace elements begun in early FY 1980 under the direction of the USGS, will continue throughout FY 1981. The purpose is to determine the concentration levels of trace elements in coal and to organize the resulting data by individual coal-bearing formations within specific geological regions. In all, over 12,000 coal samples will be collected and analyzed, representing all major U.S. coal-bearing regions. Completion of this task should occur by the end of FY 1982. Related studies by Bituminous Coal Research, Inc. (BCR) focus on delineating the effects of coal cleaning on:

- Major and trace elements in coal preparation plant products and effluents
- Mineral compounds in the ash
- Electrical resistivity of the ash.

In the area of coal microcharacterization, research will continue on the microstructure of coal, and studies will continue on developing methods to accurately and rapidly characterize the mineral content of coals. Using procedures developed at Ames Laboratory, the time required to perform pyritic sulfur analysis could be reduced from hours to less than 5 minutes per sample.

Another task during FY 1981 involves the development of a coal characterization scheme, by which the specificity of various coal preparation unit operations is determined. Also, investigations will begin on new solid-state coal and coal-associated mineral analysis systems.



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Lastly, studies of impounded coal wastes and their coal content, conducted by the University of Alabama, are scheduled for completion by the beginning of FY 1982. The data obtained will be used to draw profiles and contour maps and calculate the tonnage of recoverable coal.

Physical Beneficiation

Physical beneficiation is the least expensive and most environmentally acceptable technique for the separation of impurities from run-of-mine coal. Although coal preparation (and thus the physical beneficiation step itself) has been a viable technology throughout the 20th Century, it is in the current era of rising fuel costs and environmental constraints that the vast potential for improving and extending established beneficiation processes has gained recognition.

In the United States today, approximately 500 million tons of coal are fired by utilities to generate electricity. Of this, only about 20 percent is washed. Preliminary estimates indicate that burning washed coal instead of run-of-mine coal could result in a savings to the utilty industy in the billion dollar range.

DOE's physical beneficiation research program is directed toward the cleaning of fine coal and its recovery, and establishment of the benefits of coal cleaning for steam raising in the utility industry. Research is underway to develop and demonstrate technology for effectively and efficiently separating the fine particles of coal from those of ash and pyrite. Techniques under consideration include high-gradient magnetic separation (HGMS) and dense-medium cycloning.

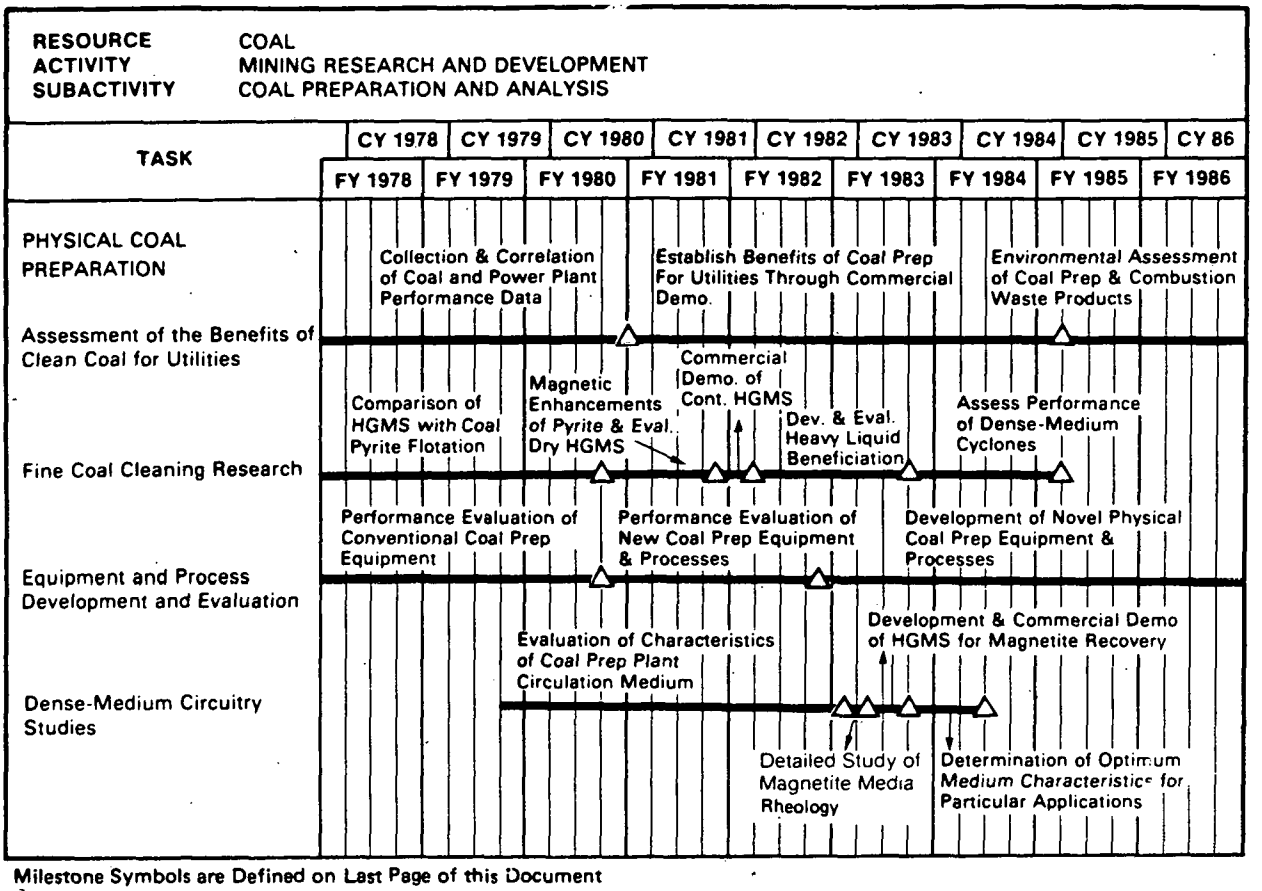
New and existing coal preparation equipment and processes are evaluated for their actual performance on a commercial scale. An equipment performance evaluation of Baum and Batac jigs is nearing completion, and work will soon begin on coal sizing and dewatering devices. Dewatering devices such as screens, filters, and centrifuges will be evaluated. Development of novel physical beneficiation equipment includes examination of several dry techniques, such as a fluidized-bed medium, a pneumatic separator, and high-gradient magnetic separation.

The increased emphasis on fine coal cleaning has led to close examination of dense-medium circuitry. Characteristics of magnetite, which is used for effecting a dense medium to separate fine coal from impurities having a different specific gravity, are being examined. In addition, the use of high-gradient magnetic separation to recover magnetite from such dense-medium circuits for re-use is being investigated.

The assessment of the benefits of clean coal for utilities is a major effort currently underway. The objective of this joint research by DOE and the Tennessee Valley Authority (TVA) is to determine the impact of coal cleaning on power plant operations and maintenance.

In FY 1981, TVA will continue the evaluation of the relationship between coal characteristics and the performance of utility power plants with completion set for June 1981.

In the area of fine coal cleaning research, work scheduled for FY 1981 will include continuation of the development of HGMS for the recovery of magnetite from dense-medium circuits. Testing of the process in a continuous carousel separator will be undertaken at MIT.



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The development of physical coal preparation equipment and processes during FY 1981 will concentrate on evaluating equipment performance. Current emphasis is given to sampling coarse and fine coal vibrating screens, processing and analyzing the samples, and determining the size separation and dewatering efficiency. A final report on the performance of the screening devices will be prepared in early FY 1982.

Heavy liquid beneficiation technology will also receive support in FY 1981. In late FY 1980, candidate liquids for heavy liquid separation (HLS) will be identified, and a study of the rheology (change in form or flow) of coal-liquid slurries will begin. Subsequent lab tests and the design of an HLS circuit is planned during FY 1981, and construction of a pilot plant is to be completed by August 1981, with testing to continue into FY 1982.

PHYSICOCHEMICAL BENEFICIATION

Coal is a plentiful resource in the United States, and increased use of coal is vital to satisfy the Nation's energy needs. However, environmental

problems arise from the sulfur content of coals which, upon combustion, release sulfur dioxide into the atmosphere. Chemical coal cleaning is the principal organic-sulfur reduction method currently being investigated.

Identification of the chemical makeup of coal (i.e., sulfur) is essential in developing effective chemical coal cleaning processes. In order to generate data and determine the organic sulfur content of coal, research on basic chemistry will be conducted with respect to the functional group distribution of sulfur and its mechanisms of reaction.

Chemical desulfurization processes under investigation to determine their technical and economic feasibility will continue to be funded in FY 1981. Oxydesulfurization, one method of desulfurization, is being evaluated at DOE's Multi-Use Fuel Processing Test Facility. This facility, built under the direction of the EPA at a cost of $2.5 million, is capable of providing pilot plant data for the continuous testing of oxydesulfurization. The Multi-Use Fuel Processing Test Facility represents a new and useful class of energy test installations. This class, having multiple functions, can save considerable time and cost in the development of needed energy technology. It will not be necessary to design, construct and operate specialty plants for evaluation of each new process.

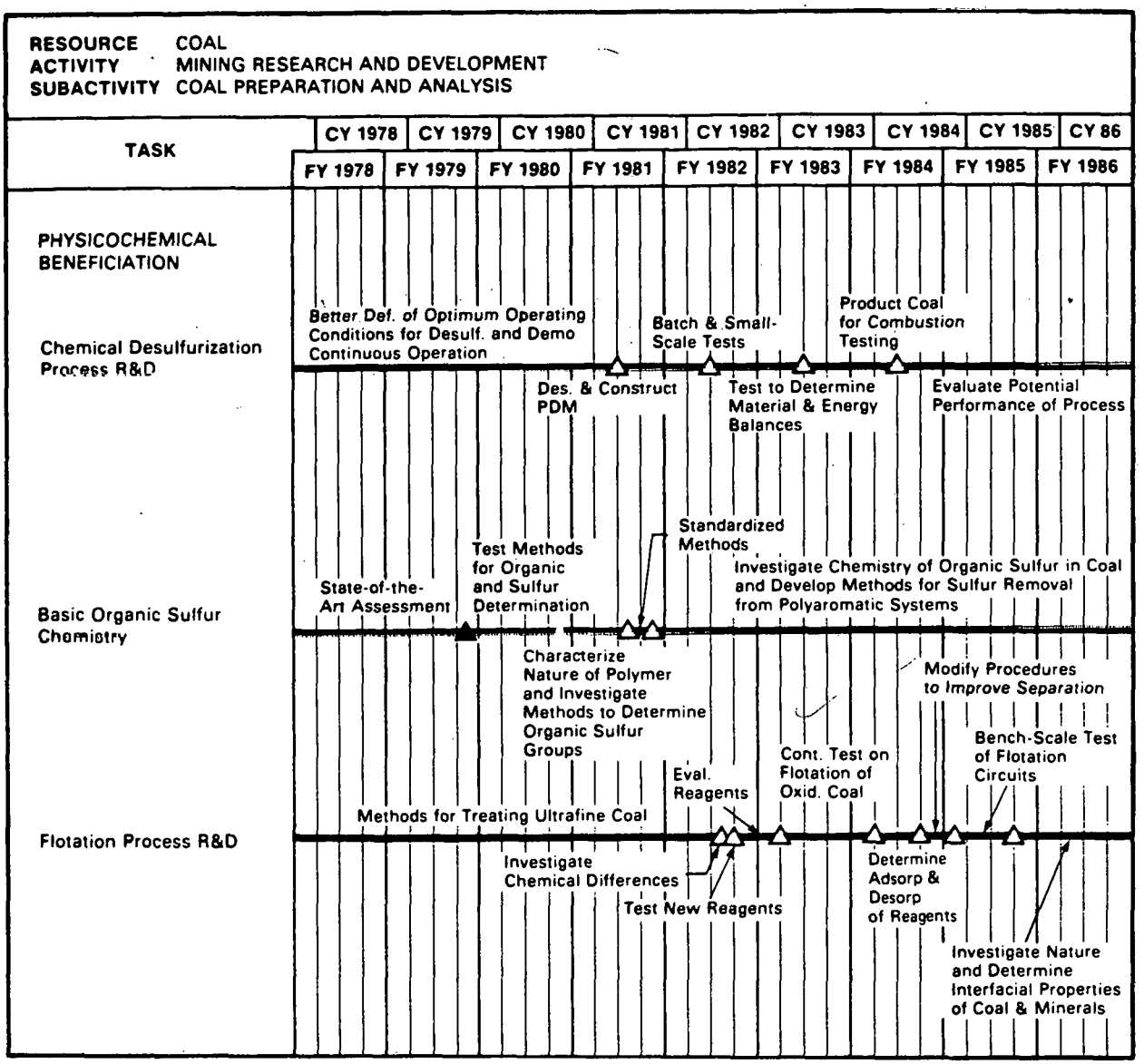
Oxydesulfurization works by oxidizing the organic sulfur impurities which can then be separated from the coal. The oxydesulfurization processes currently being evaluated include those by Ames, Ledgemont, and PETC. These processes differ mainly in reacting chemicals, temperatures and pressures employed.

Low-temperature chlorinolysis (JPL Process) is another type of chemical coal cleaning process being investigated. The advantage of low-temperature chlorinolysis is that it does not need heat input to drive the process and does not oxidize the Btu value. Other chemical desulfurization techniques being studied include:

- KVB NO_2 oxidation desulfurization process
- TRW Gravimelt process
- General Electric microwave desulfurization process.

Research methodology will involve defining the operating conditions to effect efficient desulfurization, developing and demonstrating continuous operation of the processes, and evaluating the potential performance of each process.

Flotation is a method for separating coal fines from contaminants. Research on flotation will include demonstration of the coal-pyrite flotation process in a commercial preparation plant, development of new methods for flotation of ultrafine coal and basic research on the surface chemistry of coal-refuse particles.



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Fine coal flotation studies, being conducted by Ames, seek to improve both the froth flotation and oil agglomeration methods of cleaning and recovering fine coal by developing a supplementary chemical pretreatment step. Flotation research in FYs 1980 and 1981 will include interpretation of experimental results and testing of a large bench-scale unit for demonstrating chemical pretreatment, froth flotation, and oil agglomeration methods. Novel flotation research and development work to be conducted will investigate the nature of the surface chemical interactions of coal and coal mineral matter in aqueous slurries; this may help to optimize physicochemical beneficiation processes such as froth flotation and oil agglomeration. The work is divided into two tasks; one, beginning in early FY 1981, will investigate the nature of the surface of coal and associated minerals in aqueous slurries, using current techniques such as contact angle measurement and surface tension measurements. The second task is now ongoing and consists of determining the adsorption-desorption characteristics of reagents

on coal and coal mineral surfaces and the effect of such reagents on other surface chemical properties.

Physicochemical beneficiation support studies in FY 1980 will include establishment of a coal repository. Sufficient quantities of designated coal samples will be collected and distributed to organizations involved in chemical coal cleaning and related research so that a uniform data base for evaluation and comparison of coal beneficiation processes can be developed.

Ancillary Unit Operations

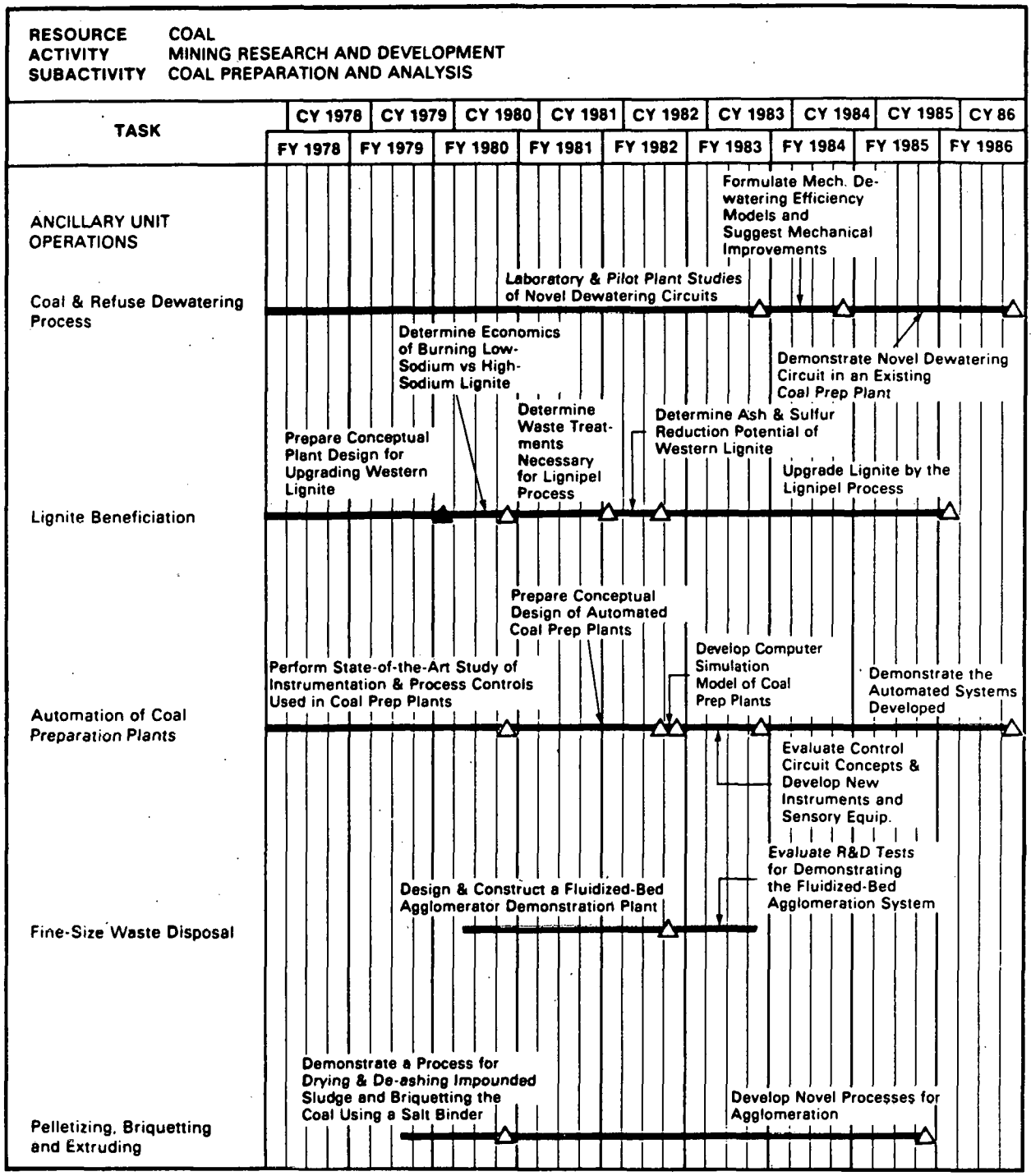
The effectiveness and economics of coal cleaning processes are particularly affected by the ancillary unit operations. Such operations include comminution, classification, dewatering and drying, and pelletizing of coal. The limitation of these conventional ancillary unit operations in coal preparation plants has prompted the undertaking of research and development programs to improve their operation.

Automated control of coal preparation plants through continuous, online instrumentation is necessary to achieve the goal of supplying the optimum yield of a clean coal product with a consistent quality. To meet this goal, advanced computer-based monitoring control systems and sensory equipment are being developed.

Reclamation of fine coal from sedimentation ponds is another area needing additional research. Much of this coal is finer than 74 microns and, in order to handle and use this coal, it must be agglomerated. Research is underway to develop procedures for pelletizing, briquetting, or extruding this material.

A major area of concern is the safe and economical disposal of dilute tailings generated during the cleaning of coal. Exploratory investigations are being conducted to develop efficient and reliable methods that may result in environmentally sound disposal.

Lignite deposits represent one of the largest fossil fuel reserves in the United States. However, use of this fuel has been limited by its high moisture content. Because lignite contains about 35 percent water, its market area is limited to about a 300-mile range. A reduction in moisture content to 15 percent would make lignite competitive over a wider market area. Other problems associated with lignite include freezing in railroad cars during cold weather, and fouling of boiler tubes. Lignite is also extremely reactive with oxygen making it susceptible to spontaneous combustion.



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DOE has successfully demonstrated a new process for drying and compressing lignite coal into more economical and easily transportable pellets. This process, called "Lignipel," eliminates the problems associated with lignite by reducing the moisture content to about 15 percent and creating a hard pellet that is resistant to spontaneous combustion. Lignite

pelletizing could significantly increase the use of low-ash, low-sulfur lignite in power plants.

Commercial demonstration of the Lignipel process will begin in June 1981. Tests will be devised and carried out to establish conditions for the most effective and economical removal of sodium from lignite by ion exchange and agglomeration of lignite by pelletizing.

A study by the University of Pittsburgh of dewatering of fine coal and refuse will be extended into FY 1981. The objective of this study is to formulate model(s) for predicting the efficiency of mechanical dewatering, the rate of dewatering, the residual moisture content of dewatered coal/refuse, and for suggesting improved mechanical dewatering methods.

Coal Preparation Energy Security Trust Fund

In order to foster greater utilization of domestic coal, the OCM's Coal Preparation program will operate at a level of effort greater than the FY 1980 budget level. Expanded research is required to meet synfuel feedstock coal requirements and to develop optimal coal feedstocks for emerging coal utilization technologies.

The marginally documented analysis of the flow of trace elements through both coal gasification and liquefaction indicates that while certain environmentally hazardous trace elements are retained within the process char, others escape during volatilization episodes of the various reactions. It has also been suggested that certain trace elements in coal may actually stimulate the liquefaction and gasification processes by serving as reaction catalysts, while still others impede the reaction by serving as "poison catalysts."

The overall objective of any study designed to better prepare coal for utilization in the liquefaction or gasification process should be to develop element specific techniques for removing dangerous trace elements from coal and to enhance the presence of those elements serving as catalysts in the reaction. Potentially useful techniques might include chemical coal cleaning methods, and should it be necessary to remove most, if not all, of the trace elements present in a subject coal, traditional fine coal cleaning techniques such as froth flotation might be utilized.

FY 1981 efforts will be initiated on developing technology to efficiently dewater and dry peat on a larger scale. It is anticipated in the future that properly prepared peat will be a commercially viable fuel for combustion as well as a fuel for gasification.

Program efforts will be expanded to develop new ash- and sulfur-reducing physical and physicochemical processes to insure that synfuel feedstock coal quality requirements can be met. Efforts concerned with removing constituents from coal chemically, such as the removal of trace elements and the removal of organic sulfur from coal, will be the primary focus of this accelerated effort. It is foreseen that research in chemical cleaning of coal will ultimately result in the development of techniques that will be capable of altering the composition of feedstock coal.

The development of new comminution technology is necessary to attain the efficient controlled size reduction required for preparation of synfuel feedstocks. Current grinding techniques dissipate all but one percent of the total energy input, produce too broad a particle size spread, and abrade machinery parts.

In contrast, technology developments of other mechanisms for size reduction, such as ultrasonics or chemical comminution preferentially fracture along normal cementation planes with the potential result that energy input will be more productive, product particle sizes can be controlled, and the harder mineral inclusions will remain intact.

The development of dense-medium cyclones for maximum recovery of by-zero material is another effort to be initiated. Dense-medium cyclones make sharp, efficient separations on 1-inch by 35-mesh coal. They utilize a dense-medium liquid which separates the coal and refuse by centrifugal force.

Evaluation of novel coal beneficiation equipment used to recover coal from gob piles and slurry ponds and examination into the feed size consist of coal on froth and bulk oil flotation will also be explored under new research. Other additional projects will focus on feedstock requirements for atmospheric fluidized-bed combustion, MHD, and coal-oil mixtures. The use of coal-in-oil as an alternate fuel and an extender of the Nation's oil supply appears very attractive and can, in fact, be a near-term technology. The use of a beneficiated coal as the extender also appears to have a number of technical advantages which must be evaluated to determine if there is a cost benefit to be had by preparing a cleaner coal-oil mixture.

The preparation of coal-oil mixtures lends itself to deep beneficiation since fine grinding (particles less than 70u) is one of the processing steps in its production. Thus, a COM (coal-oil mixture) preparation plant with integrated beneficiation appears to be desirable.

Following is a proposed technical approach:

- Evaluate the economics of beneficiated coal-oil mixtures produced by various methods versus flue gas clean-up.
- Pursue new techniques to enhance beneficiation and/or coal-oil mixture stabilization.

B. COAL LIQUEFACTION

The development of commercial coal liquefaction processes will provide a route, within environmental guidelines, to increase domestic production of clean fossil fuels and feedstocks. Synthetic fuels derived from coal liquefaction processes can replace petroleum-refined products most effectively in two distinct markets. One market uses low-ash, low-sulfur boiler fuels suitable for clean generation of electric power and industrial steam. The other market uses high-grade fuels such as jet and diesel fuel, gasoline, heating oil, and chemical feedstocks.

The objective of the Liquefaction Activity is to facilitate the establishment of a synthetic liquid fuels industry. Specifically, the activity is planned to:

- Demonstrate the technical capability to commercially produce clean liquid and solid fuels from coal by at least four direct liquefaction processes (SRC-I, SRC-II, H-Coal, EDS) by the late 1980s.
- Develop improved indirect liquefaction processes to produce liquid fuels from synthesis gas made from coal by the late 1980s.
- Promote the development of more advanced third-generation coal liquefaction processes which can be demonstrated to be commercially viable in the 1990-2000 time frame.

The general strategy of the Liquefaction Activity is to support several liquefaction processes in parallel from laboratory scale through process development unit (PDU). Only the most promising candidates are selected for advancement to the pilot plant stage, and only those processes identified as meeting commercial market needs are considered for technical demonstration. This approach is based on a number of considerations. First, market requirements for a wide range of fuels produced from a variety of coals, coupled with the need for a large number of plants to produce significant quantities, may require demonstration of several liquefaction processes. This variety of processes is evident in today's crude-oil-based liquid fuels industry. By the same token, the future synthetic liquid fuels industry, which will replace a large share of this fuel market, cannot rely on any single process configuration. Second, the processes under development provide complementary support to each other in many ways. Third, all processes under development require supporting research to improve overall operability, increase efficiency, and reduce costs.

Four direct liquefaction processes (SRC-I, SRC-II, H-Coal, and EDS) are in advanced development stages:

- Solvent Refined Coal (SRC) processes I and II are being tested in 6 t/d and 50 t/d (coal) pilot plants that are currently in operation. Technical demonstration plants of 6000 t/d size (one for each process) are in design stages.

- H-Coal is undergoing continued development in a 600 t/d pilot plant which began operation in FY 1980. Continued support work involves a 3 t/d PDU.

- Exxon Donor Solvent (EDS) is undergoing development in a 250 t/d pilot plant which began operation during FY 1980. Continued laboratory and engineering research support backs up the pilot plant operation.

Third-generation (direct liquefaction) processes include disposable catalyst processes, a two-stage liquefaction process (TSL), and flash hydropyrolysis. Bench-scale and PDU studies continue in order to define the potential of these and newer processes for scaled up engineering studies.

Indirect liquefaction processes (liquid fuels via synthesis gas from coal) include the Sasol process, now commercial in South Africa. An accelerated effort is underway in the U.S. to develop new and improved indirect processes tailored to U.S. coals and markets. Design and construction of a small (100 bbl/d) methanol-to-gasoline pilot plant based on a Mobil process is underway and a 35 bbl/d liquid phase/slurry phase syngas to methanol plant is being prepared for operation.

Support research and development activities provide critical backup to the specific processes with improvements in the technology which in turn can provide significant improvements in process economics. Two major problem areas common to most liquefaction processes are under study: utilization of solid-containing bottoms for hydrogen production and durability of auxiliary equipment. Significant effort is devoted to engineering studies and analyses which are required to guide and evaluate process development work.

A major effort is directed towards environmental concerns associated with coal liquefaction processes:

- Presence of potentially toxic and carcinogenic organic compounds in coal liquid products and residues

- Presence of potentially toxic trace minerals in the products and by-products.

The environmental impact of coal liquefaction processes is being investigated under a program designed to analyze/characterize hazardous materials contained in various process streams or emitted from operating

installations. Studies are also being conducted at pilot plant level to develop adequate occupational safety and health procedures for worker protection.

The following table provides the funding levels by subactivity for the FY 1979 through FY 1981 period.

COAL LIQUEFACTION	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Direct Hydrogenation	35,389	64,500	57,000
Solvent Extraction	35,140	30,000	32,000
Third-Generation Processes	13,811	25,000	19,200
Support Studies/Engineering Evaluations	14,286	14,506	12,000
Liquefaction Demonstration Plants	119,100	116,000	403,000
Capital Equipment	200	300	700
Total Direct Appropriations	217,926	250,306	523,900
Energy Security Trust Fund	0	0	33,000
TOTAL	217,926	250,306	556,900

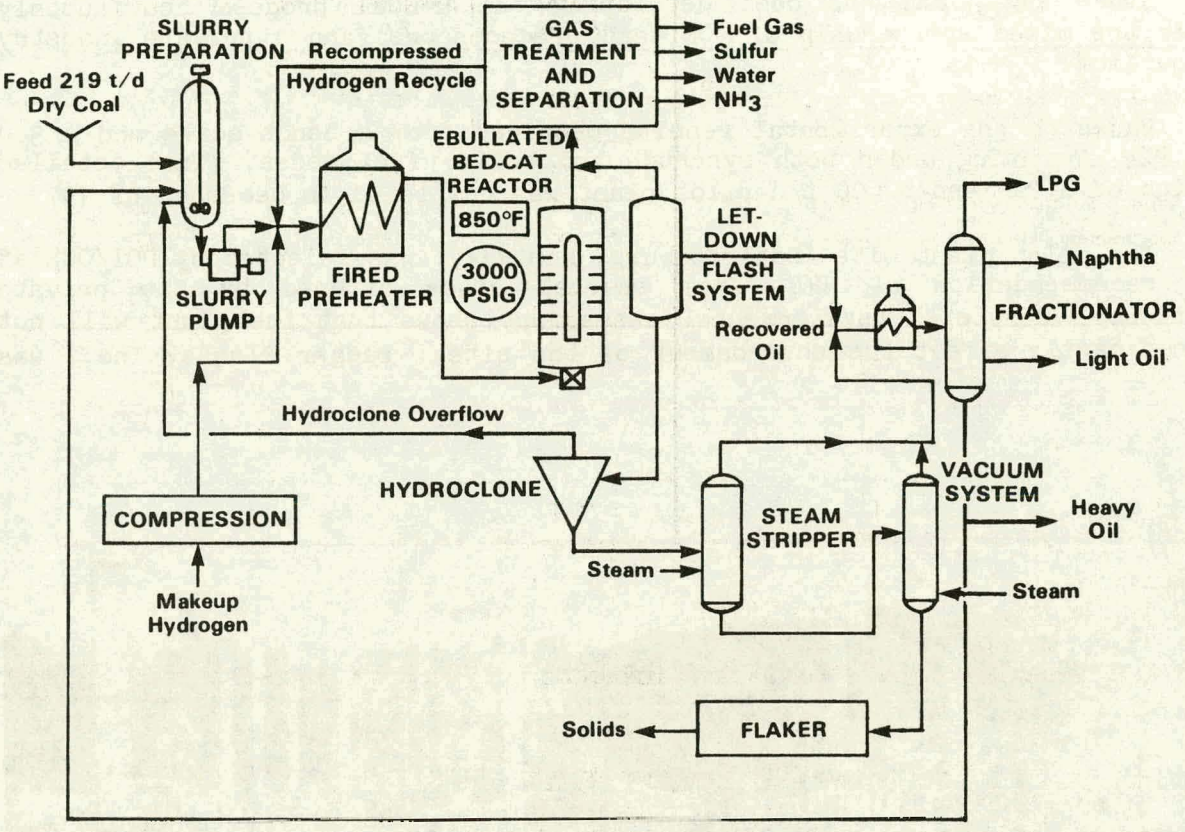
1.0 DIRECT HYDROGENATION

In FY 1981, this subactivity includes one active project, the H-Coal process.

1.1 EBULLATED-BED (H-COAL) PILOT PLANT

The H-Coal process is a catalytic hydroliquefaction process that converts high-sulfur coal to either a boiler fuel that will meet sulfur emission regulations or to a refinery syncrude. Coal is dried and crushed to minus 40 mesh, then slurried with recycled oil and pumped to a pressure of 200 atm. Compressed hydrogen is added to the slurry, and the mixture is preheated and charged continuously to the bottom of the ebullated-bed catalytic reactor. Upward passage of the internally recycled reaction mixture maintains the catalyst in a fluidized state (catalyst activity is maintained by the semicontinuous addition of fresh catalyst and the withdrawal of spent catalyst). The temperature of the ebullated-bed catalytic reactor is controlled by adjusting the temperature of reactants entering from the preheater. Typically, the mixing temperature entering the reactor is 650° to 700°F. Control of the ebullated-bed of catalyst is a function of many process parameters. The interrelationships of these parameters are the subject of ongoing research.

The vapor product leaving the top of the reactor is cooled to condense the heavier components as a liquid. Light hydrocarbons, ammonia and hydrogen sulfide, are absorbed and separated from the remaining gas, leaving a hydrogen-rich gas which is recompressed and recycled to be combined with the input slurry. The liquid-solid product, containing unconverted coal, ash, and oil, is fed into a flash separator. The material that boils off is passed to an atmospheric distillation unit. The bottoms product containing solids and heavy oil is further separated with a hydroclone, a liquid-solid separation, and a vacuum still.



H-Coal Process, Syncrude Mode

The gas and liquid products (hydrocarbons gas, hydrogen sulfide, ammonia, light and heavy distillates, and residual fuel) may be further refined as necessary. Heavy distillate is recycled as the slurry medium. In the commercial configuration, the vacuum bottoms stream containing unreacted carbon and some liquid will eventually be processed onsite to produce hydrogen needed for the process. In the H-Coal pilot plant, hydrogen will be supplied by the adjacent Ashland Oil Refinery.

The specific conditions of the H-Coal process affect the type of fuel produced. For example, to produce refinery syncrude, more hydrogen is required and there is a lower yield of bottoms by-product. To produce a clean fuel gas and low-sulfur liquid boiler fuel, the throughput of the ebullated-bed reactor is increased while hydrogen consumption is decreased.

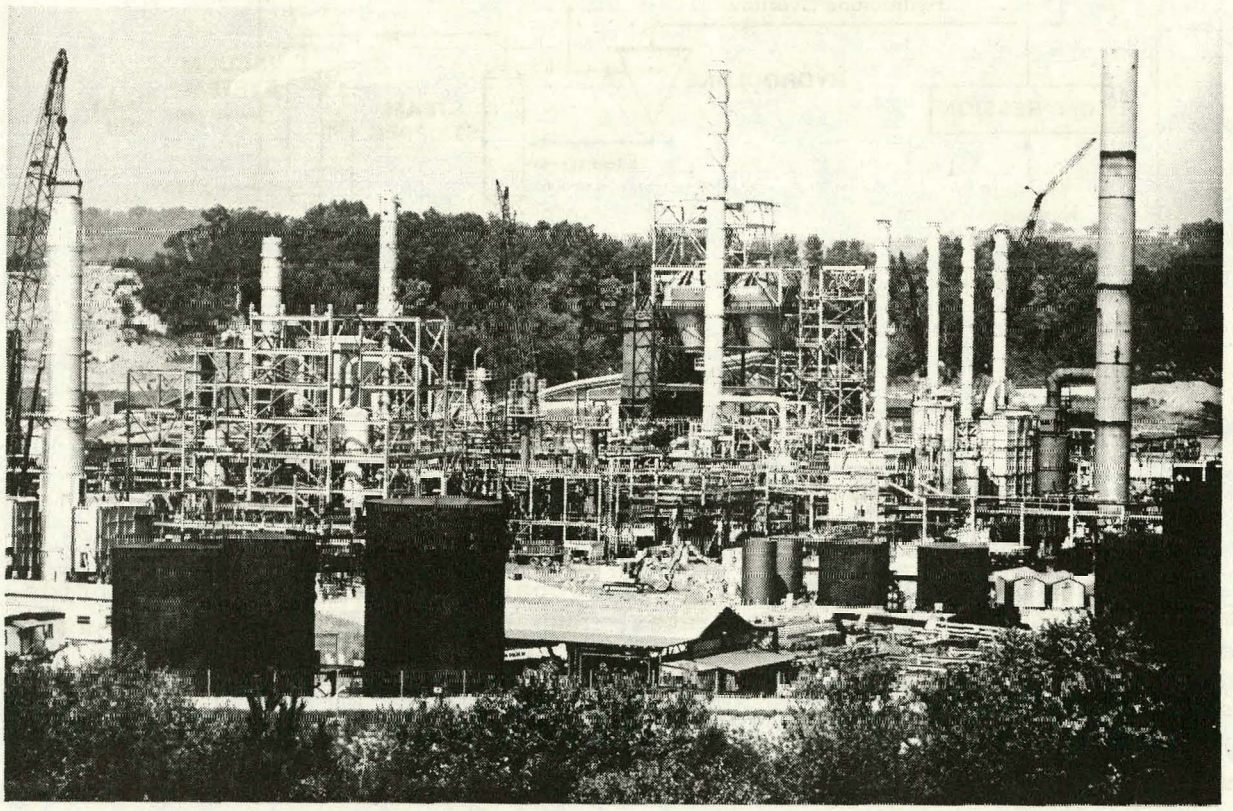
Project Status

The H-Coal process was developed by Hydrocarbon Research, Inc., (HRI) as a further application of the ebullated-bed processing technology originally used to convert heavy oil petroleum residues into lighter fractions (H-Oil process). Early development of the H-Coal process involved research with a bench- scale unit and a PDU, as well as preparation of a conceptual process design. Independent evaluations in 1963 and in 1976 supported the technical feasibility of the H-Coal process.

Since 1964, HRI has been developing the H-Coal process continuously under the mixed sponsorship of DOE (and predecessors) and a private industry consortium.

Based on the experimental results obtained from a bench-scale and a 3.0 t/d PDU operating under both syncrude and boiler fuel modes, final detailed design of a 200 and a 600 t/d pilot plant was completed in December of 1977.

The pilot plant site (Catlettsburg, Kentucky) was selected by DOI/OCR at the recommendation of HRI, from several sites offered by the private partners. Completed environmental assessment shows that the plant will not significantly affect the environment of the site. Badger Plants, Inc., was



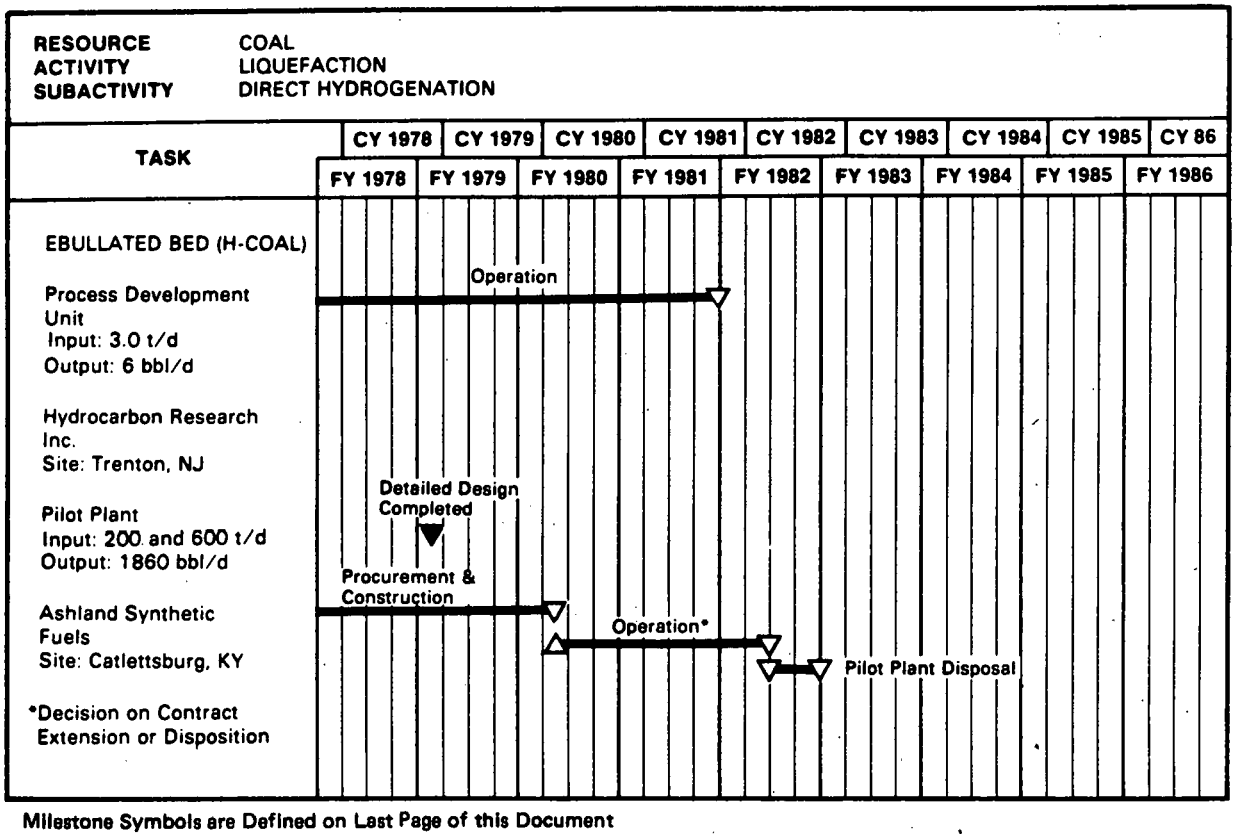
Catlettsburg, Kentucky, H-Coal Liquefaction Pilot Plant

responsible for construction of the pilot plant. Its operation is the responsibility of Ashland Synthetic Fuels with technical support by subcontract with HRI.

Operation of the H-Coal liquefaction pilot plant, shown in the final stages of construction, began in FY 1980. The plant, the largest to be built in the U.S., can convert up to 600 tons of coal per day into as much as 1,860 barrels of synthetic oil.

The industry consortium sponsoring the H-Coal project is composed of the Electric Power Research Institute (EPRI), Ashland Oil, Inc., Standard Oil of Indiana, CONOCO Coal Development Company, Mobil Oil Company, and the Commonwealth of Kentucky.

Construction of the pilot plant began in January of 1977, and was completed in late FY 1979. Plant startup and operation in both syncrude and boiler fuel modes were begun in FY 1980. Material balance data will be used to establish process yield data as a function of coal type and operating conditions.



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The Phase Zero H-Coal Commercialization Study is continuing and will be completed in FY 1981. A conceptual design, cost estimate, construction, schedule for a 20,000 ton/day commercial H-Coal plant will be the products of the study. The study is also expected to identify any areas that might require additional data before embarking upon the detailed plant design. In such cases the additional data will be obtained by extending the PDU and

pilot plant operations. Pilot plant operations will also be conducted on the coal chosen for the commercial plant to verify product yields and characteristics.

2.0 SOLVENT EXTRACTION

Solvent extraction projects involve the use of a solvent to obtain a liquefied product from coal. The solvent acts as the agent which transfers hydrogen to the coal to promote liquefaction. Solvent refined coal projects are described in subsection 7.

2.1 DONOR SOLVENT LIQUEFACTION (EDS) PILOT PLANT

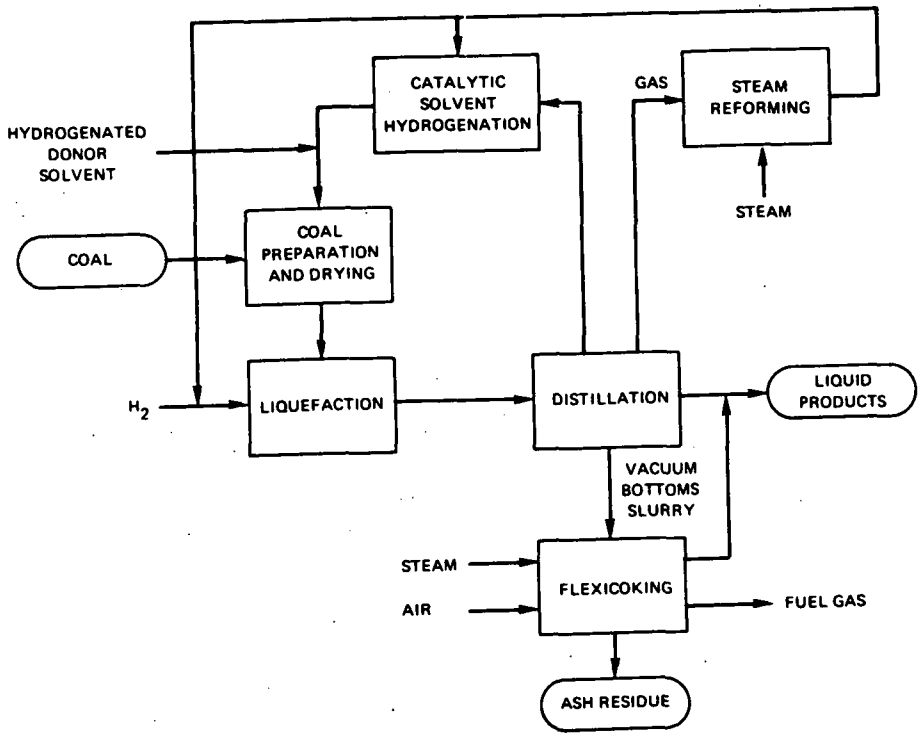
The Donor Solvent process is a noncatalytic process that liquefies coal by the use of a hydrogen donor solvent obtained from coal-derived distillate. The donor solvent transfers hydrogen to the coal, thus promoting liquefaction of the coal. The process utilizes engineering and design technology similar to that practiced in the petroleum industry. It is sufficiently flexible to allow for different varieties of coal feed and produces a wide spectrum of liquid products depending on market demands.

Coal is ground and slurried with the recycle donor solvent. The slurry is heated by a fired heater, and preheated gaseous hydrogen is added. The reaction is carried out in a tubular reactor with no internals. Products from the liquefaction reactor are sent to several stages of separation units for recovery of gas, naphtha, middle distillate, and bottoms comprised primarily of unreacted coal and mineral matter. Distillation is the means for solid-liquid product separation.

The heavy bottoms from distillation are sent to a FLEXICOKER to produce additional liquids and low-Btu gas for in-plant fuel use. Hydrogen for in-plant use is provided by steam reforming of C_1-C_2 gases produced in the process or by partial oxidation. The hydrogen is recycled to the liquefaction and solvent hydrogenation sections.

A portion of the middle distillate product is sent to the solvent hydrogenation step, using a catalytic fixed-bed reactor to produce donor solvent to be recycled to the slurry preparation step. Depending on the ultimate product utilization, the primary liquid products may be further refined.

The plant is balanced in that it is self-sufficient in both process fuel and H_2 requirements. The process gives high yields of low-sulfur liquids from either bituminous, or subbituminous coals or lignites. For Illinois bituminous coal, the liquid yield is determined to be 2.8 barrels of C_4/1000°F liquids per ton of dry coal feed.



Donor Solvent Process

Project Status

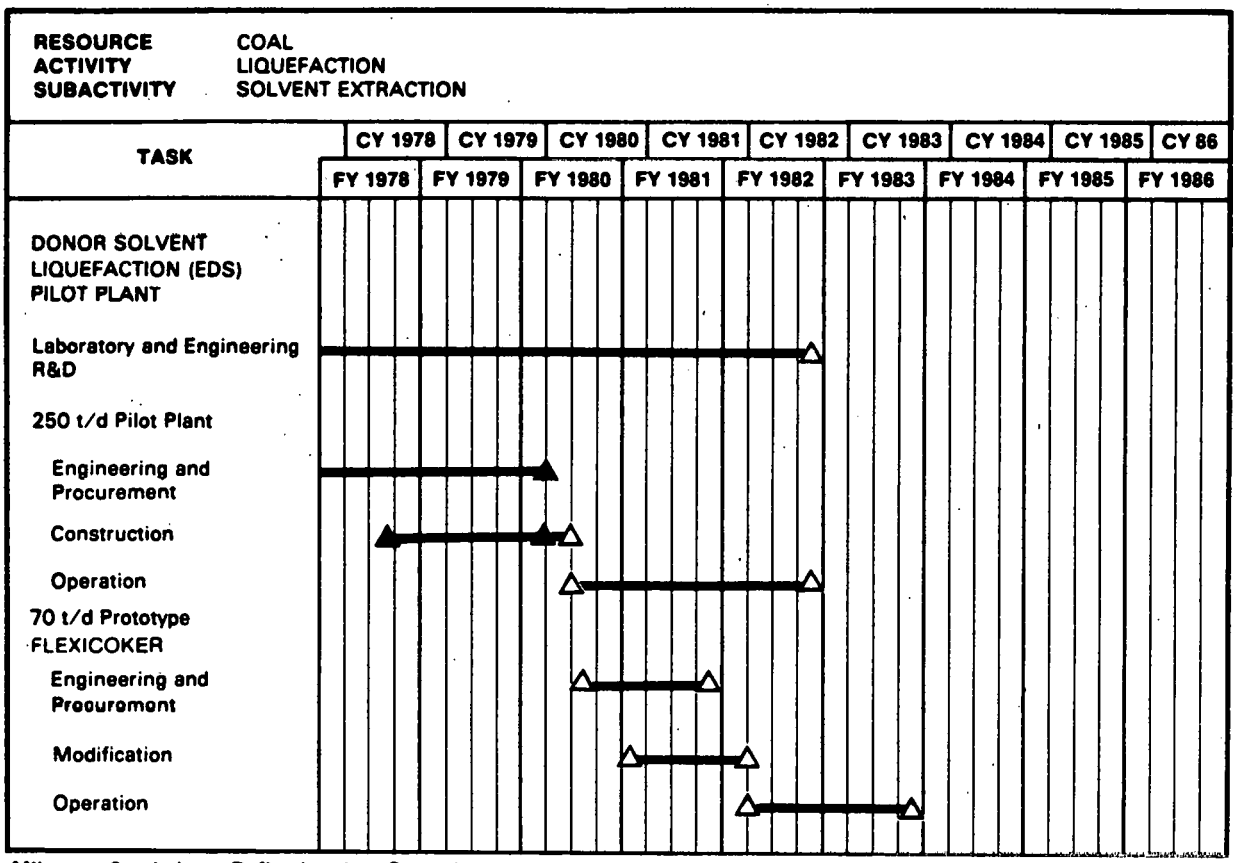
The project was started in 1966 with Exxon Research and Engineering Company (ER&E) funding. The developmental program is structured into five phases: Predevelopment, Planning and Design, Detailed Engineering, Construction, and Operation. Through 1975, cumulative ER&E funds of $32 million were expended on Phases I and II, resulting in the development and demonstration of the process in laboratory-scale reactors of up to .5 t/d.

In August 1975, ER&E submitted an unsolicited proposal to ERDA (now DOE) to cost-share an estimated $268 million future-development cost on a 50/50 basis. Because the project cost was substantial, ER&E also sought financial participation from other industrial partners. Because industrial cost-sharing participants were not firmed up at the time ER&E could start Phase III, it was divided into two separate phases to permit discrete funding.

- Phase III-A: laboratory and engineering research and development
- Phase III-B: detailed engineering.

Phase III-A spanned the period between January of 1976 and mid-1977. Total cost of this phase was $13 million, shared between ERDA and ER&E on a 50/50 basis.

Phases III-B to V span the period between mid-1977 and late 1983. Total cost is expected to be $268[1] million plus contingency that will be cost-shared on a 50/50 basis by the Federal Government and private industry.



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During FY 1981 work emphasis will be to:

- Complete operation of the pilot plant on the first bituminous coal.
- Begin pilot plant operations on a subbituminous coal.
- Start revamp of the prototype FLEXICOKER, if approved.

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[1]It has become increasingly clear that processing of the vacuum tower bottoms to produce hydrogen or a fuel gas is the time-limiting step in bringing any coal liquefaction process to commercial readiness. Therefore, DOE strongly supports the development of FLEXICOKING while simultaneously pushing alternative bottoms processes such as partial oxidation and direct combustion of the vacuum tower bottoms. This estimate does not include these processes.

- Investigate liquefaction/bottoms processing interactions.
- Evaluate process improvements.
- Select preferred liquefaction/solvent hydrogenation configuration for comprehensive design studies.
- Select preferred bottoms/H_2 process for comprehensive design studies.
- Start conceptual design study for a pioneer plant.

The major effort in FY 1981 will be in operation of the 250 t/d pilot plant and revamp of the prototype FLEXICOKER, if approved.

3.0 THIRD-GENERATION PROCESSES

This subactivity includes research and technology development for third-generation processes that offer potentially significant advantages over second-generation processes now in technical demonstration or pilot plant phases of development. These advanced processes are in various developmental phases, from the laboratory and bench scale to larger continuous process units, including PDUs. Processes which are selected for support offer significant improvements in one or more of the following areas:

- Hydrogen utilization
- Operability
- Product quality and yield
- Plant investment and operating costs
- Types of coal utilized.

Future development of these advanced processes beyond the laboratory or "process research" scale are expected to benefit from the availability of many existing PDUs and pilot plants, since these facilities can be modified to serve the purpose of scaleup experimentation and demonstration. Furthermore, the experience accumulated from development of second-generation processes can be utilized as guidelines for technical direction.

3.1 ZINC CHLORIDE CATALYST PDU

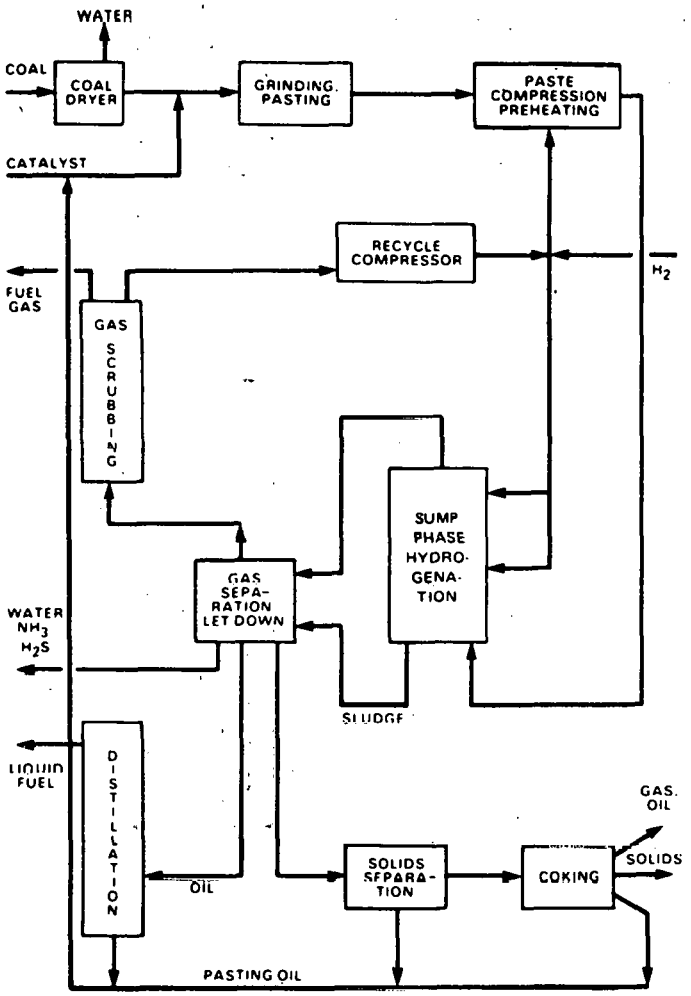
The $ZnCl_2$ Catalyst process is designed to convert bituminous and subbituminous coal into distillates (in the gasoline range) by severe catalytic hydrocracking. The process showed promise based on conceptual analyses, but after repeated evidence of scaleup difficulties in the 1 t/d PDU, the project was terminated early in FY 1980. It appears that this process cannot be scaled up to commercial acceptance in order to meet the objectives of the Coal Liquefaction program.

3.2 DISPOSABLE CATALYST HYDROGENATION

This process uses inexpensive catalysts, in particular the mineral matter in coal, as coal liquefaction catalysts to avoid the extra complexity/cost of catalyst recovery and regeneration. A substantial

reduction in hydrogen consumption and increased selectivity of liquids are also possible due to a reduction in reaction severity.

Coal is dried and mixed with a process-derived oil and the disposable catalyst. The paste is compressed to 2,000-3,000 psi and preheated. Recycle gas and makeup hydrogen are added to the paste before hydrogenation reactions occur in a pressure vessel in liquid phase. Gaseous and coal oil-catalyst slurry discharge from the reactor are sent to a gas separator and letdown system. Part of the gas is recycled. The gaseous fuel product is composed of light hydrocarbons. The oil is distilled to obtain liquid fuel and pasting oil, while the residue and heavy oil are processed to recover light fractions, pasting oil, and heavy liquid products.



Disposable Catalyst Hydrogenation Process

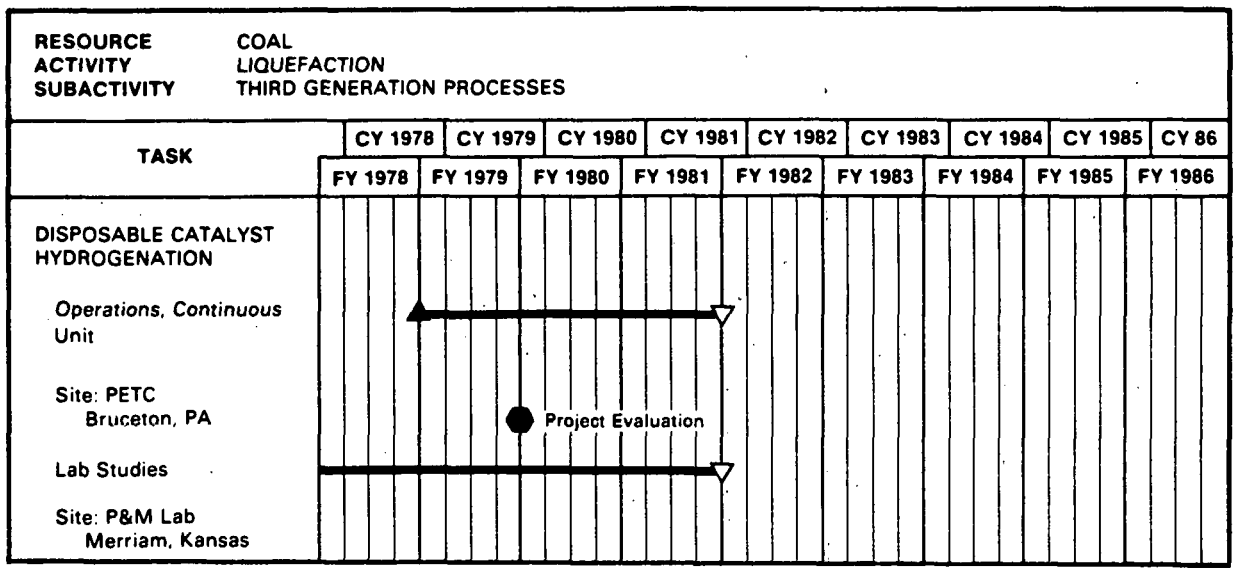
Project Status

During FY 1980 a major coordinated program was carried out with very significant results at Merriam P&M, Air Products, Auburn University, Penn

State, University of North Dakota, Sandia, and Pittsburgh and Grand Forks Energy Technology Centers. The mineral matter has been characterized and techniques developed to activate the most powerful species. It has been shown that adding pyrite can greatly reduce reaction temperatures without significant loss of liquid yield. The goal of the current effort is to find more active catalyst species that will allow a reduction in catalyst concentration.

During FY 1981 the already promising leads will be further pursued in all of the above laboratories and larger scale testing will be intensified.

In particular the successful synthesis of a colloidal, highly active form of iron sulfide will be further developed and utilized in continuous unit testing. A major effort will involve (1) operations of a 24 lb/day liquefaction facility at the Merriam P&M laboratory which has correlated well with the Ft. Lewis pilot plant results for SRC-I and -II processes; and (2) extended operations of a 1,200 lb/day coal liquefaction facility at the PETC. The most promising catalyst will be tested in existing DOE pilot plant facilities. An independent engineering evaluation of this process will be conducted and the process compared with others already in the pilot plant stage.



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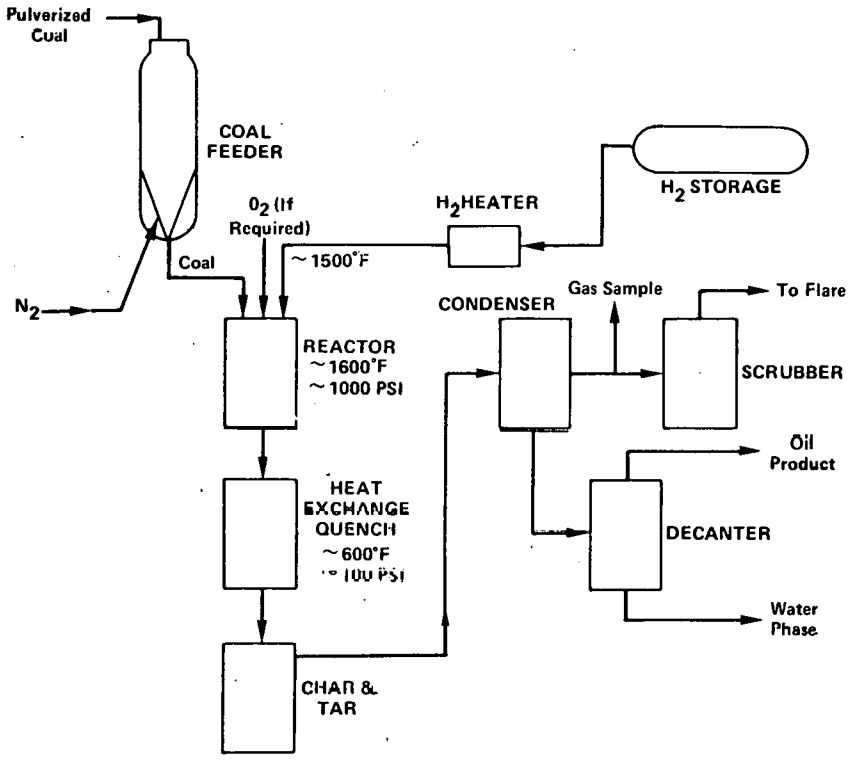
3.3 FLASH LIQUEFACTION PROCESS

The Flash Liquefaction process is being developed to evaluate the concept of direct hydrogenation of pulverized coal when it is entrained in a stream of hydrogen. If required, some oxygen will be reacted with the hydrogen to provide heat to bring the reactants to the required temperature (1600°F). Rapid mixing and reaction of coal with hydrogen takes place in the reactor at about 1,000 psi in about 100 milliseconds. The product mixture is then quenched. Char is separated from the vapor, and the oil products are condensed and separated from the gases. Gaseous products will be separated from the unreacted hydrogen which will be recycled.

The process offers a new approach to liquefaction which avoids the problems of slurrying coal in oil, the pressurizing and depressurizing of abrasive slurries, and the separation of large amounts of residual solids from the product oil.

The process uses existing rocket technology for rapid mixing and reaction of solids with gases. However, adaptation of this technology to continuous chemical processing at the required extremes of temperature and chemical environment must be proven. Also, the availability of techniques for the economic separation of the lower boiling liquid-oil products and of the unreacted hydrogen from the gaseous products requires confirmation.

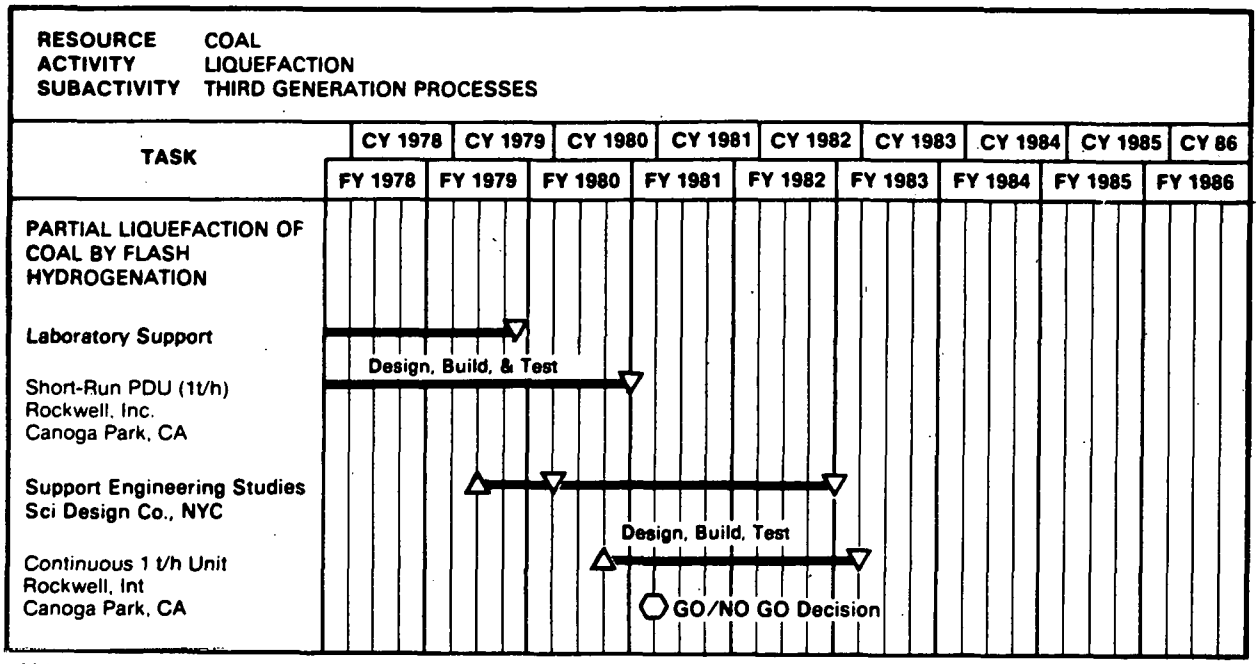


Partial Liquefaction by Direct Hydrogenation (Flash Liquefaction) PDU

Project Status

For pneumatic transport and injection of the pulverized coal into the entrained-bed reactor, only minor quantities of transport gas can be tolerated. During 1976, a suitable method was developed through cold flow tests. A .25 ton/hr reactor system was built to confirm the effects of reactor configuration and operating conditions. Based on the experimental findings, a 1 ton/hr PDU was designed for runs of up to 3 hours, built and tested to define process parameters. Such tests were conducted during FYs 1979 and 1980, and indicated that 35 percent carbon conversion to liquids

plus 30 percent to gas should be possible in 150 milliseconds at 1650°F and 500 psi. Modification of this PDU will provide data on use of a heat exchanger-quench to improve the thermal efficiency and the collection of the lighter portion of the liquid product. Preliminary design, engineering, and economic studies will estimate whether the reactor will prove operable on a continuous basis and whether a commercial design is feasible and economically attractive. If so, the 1 ton/hr reactor system will be rebuilt to make continuous operation possible, to eliminate the necessity for remote operation, and to make it able to generate such other data as the engineering survey showed to be lacking. Thereafter, long-term tests will establish whether the system is reliable enough at the physical and chemical conditions required by the process, to (1) further confirm the parameters at which the process would operate, and (2) provide data for continuing engineering evaluation.



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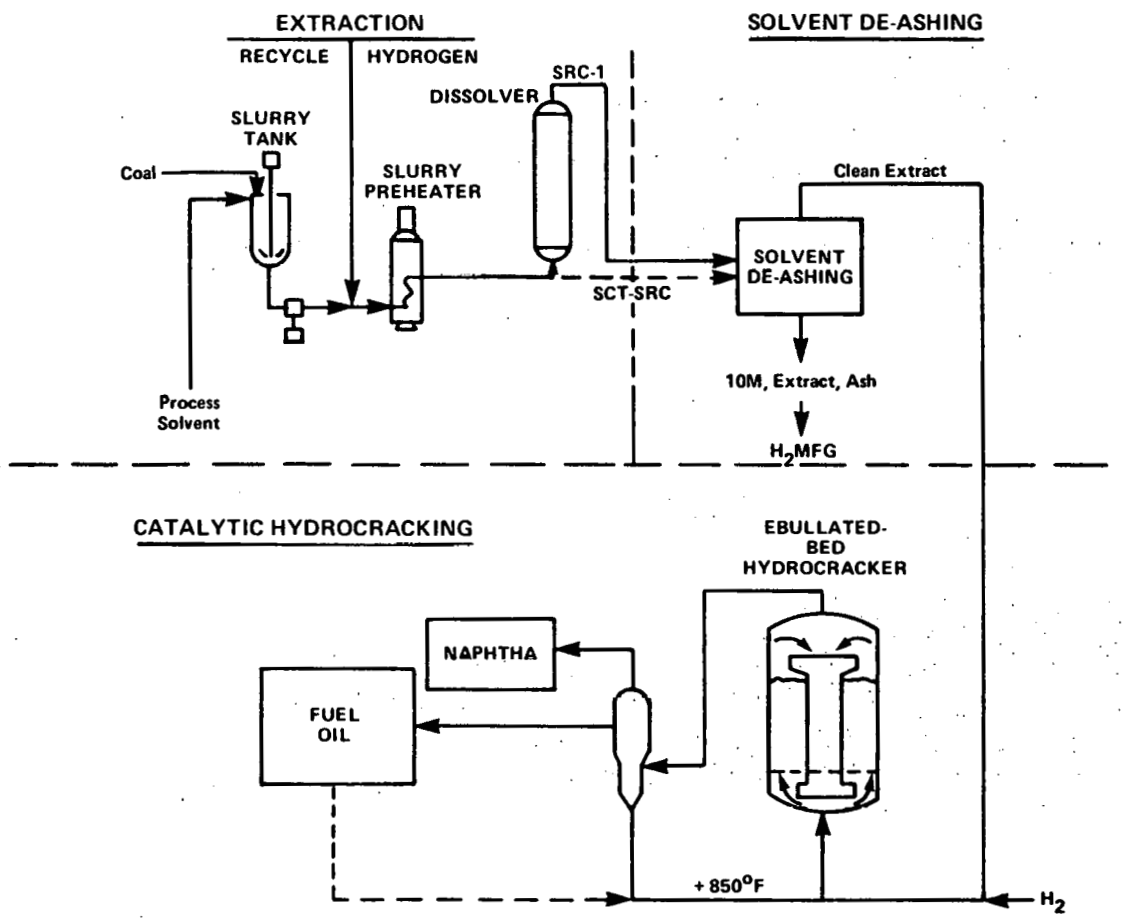
3.4 PROCESS RESEARCH/TECHNOLOGY DEVELOPMENT

The FY 1981 request for this research area will provide for the technology data base which can be immediately applied to coal liquefaction processes under development. Four program areas are to be pursued: catalyst development, engineering technology, analytical chemistry, and lignite liquefaction.

The catalyst development program will be conducted at PETC, Amoco, and HRI, directed toward developing substantially improved catalysts for H-Coal. Substantial progress has been made on bench units in optimizing catalyst pore sizes. It is expected that improved catalysts for processing both eastern and western coals will be developed and tested in the H-Coal PDU during FY 1981.

An engineering technology program will include a reactor hydrodynamics study at Amoco (H-Coal reactor) and PETC (SRC reactor), and coal liquids thermodynamics study at BETC. During FY 1981 it is expected that a mathematical model for a coal liquefaction reactor, developed in prior years, will be validated experimentally, and hydrogen solubility data in coal liquids under process conditions will be obtained and correlated. The analytical chemistry program to be carried out at PETC during FY 1981, will continue to improve existing analytical techniques and explore new techniques for improved characterization of first-stage products in the TSL process. The lignite liquefaction program will be continuing at GFETC during FY 1981, and is expected to produce results which will indicate how the SRC process can be adapted to processing lignites.

The TSL process is designed to convert coal into high-quality distillate fuels at higher liquid yields and with more effective management of hydrogen consumption. TSL involves hydroextraction of coal and expanded-bed hydrocracking of the extract with an intervening solvent de-ashing step to separate the extract from the solids.

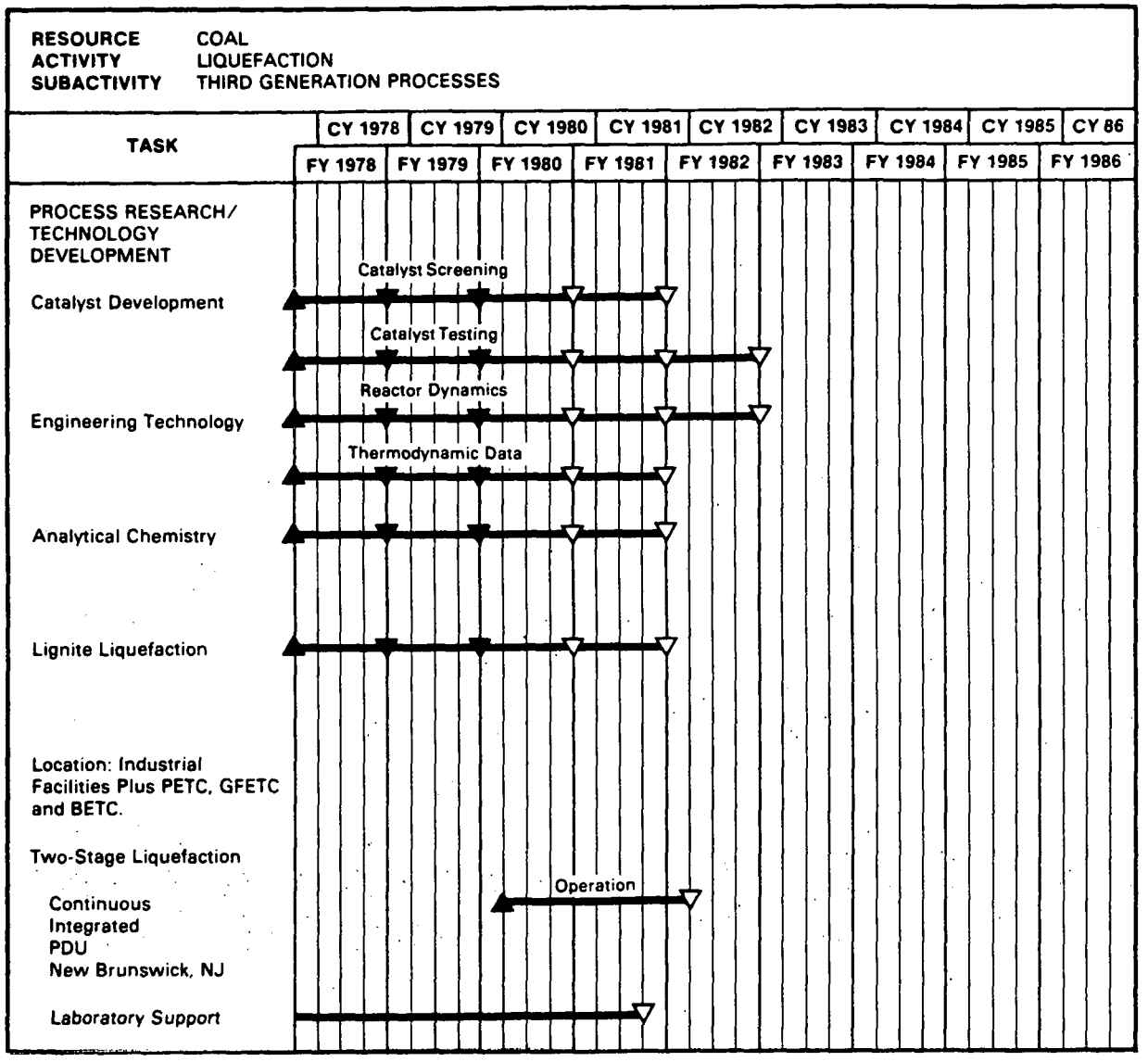


Two-Stage Liquefaction Process

Coal is dried and mixed with a process-derived oil and charged to a fired heater where the slurry is heated to a temperature of 750° to 850°F. The residence time in the preheater is adjusted to dissolve about 90 percent of the coal with minimal hydrogen consumption. The effluent slurry is topped to remove -500°F distillate and solvent de-ashed using the Lummus antisolvent process. The overflow is pumped to the LC-fining unit for catalytic hydrocracking into naphtha and fuel oil. The underflow is transferred to a gasification unit for production of hydrogen and fuel gas.

Project Status

During FY 1980, the laboratory parametric study of upgrading SRC-I and short-contact-time SRC-I was supplemented with extensive operations of a 1 t/d integrated two-stage process development unit. A coordinated program



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with Amoco was established to test novel and improved catalysts for the second stage, expanded-bed hydrocracking. An independent economic evaluation was made based on product yields and hydrogen consumption data from the recent laboratory work.

During FY 1980, five of the best catalysts provided by Amoco are undergoing testing in the LC-fining laboratory unit. The coal selected for the SRC-I demonstration plant will be processed in the integrated developmental unit to provide both the Wilsonville pilot plant and the SRC-I demonstration plant with data for scaleup.

A more definitive economic evaluation will be based on the data obtained from the continuous integrated operations, with optimum operating conditions for each stage.

3.5 COAL LIQUIDS REFINING

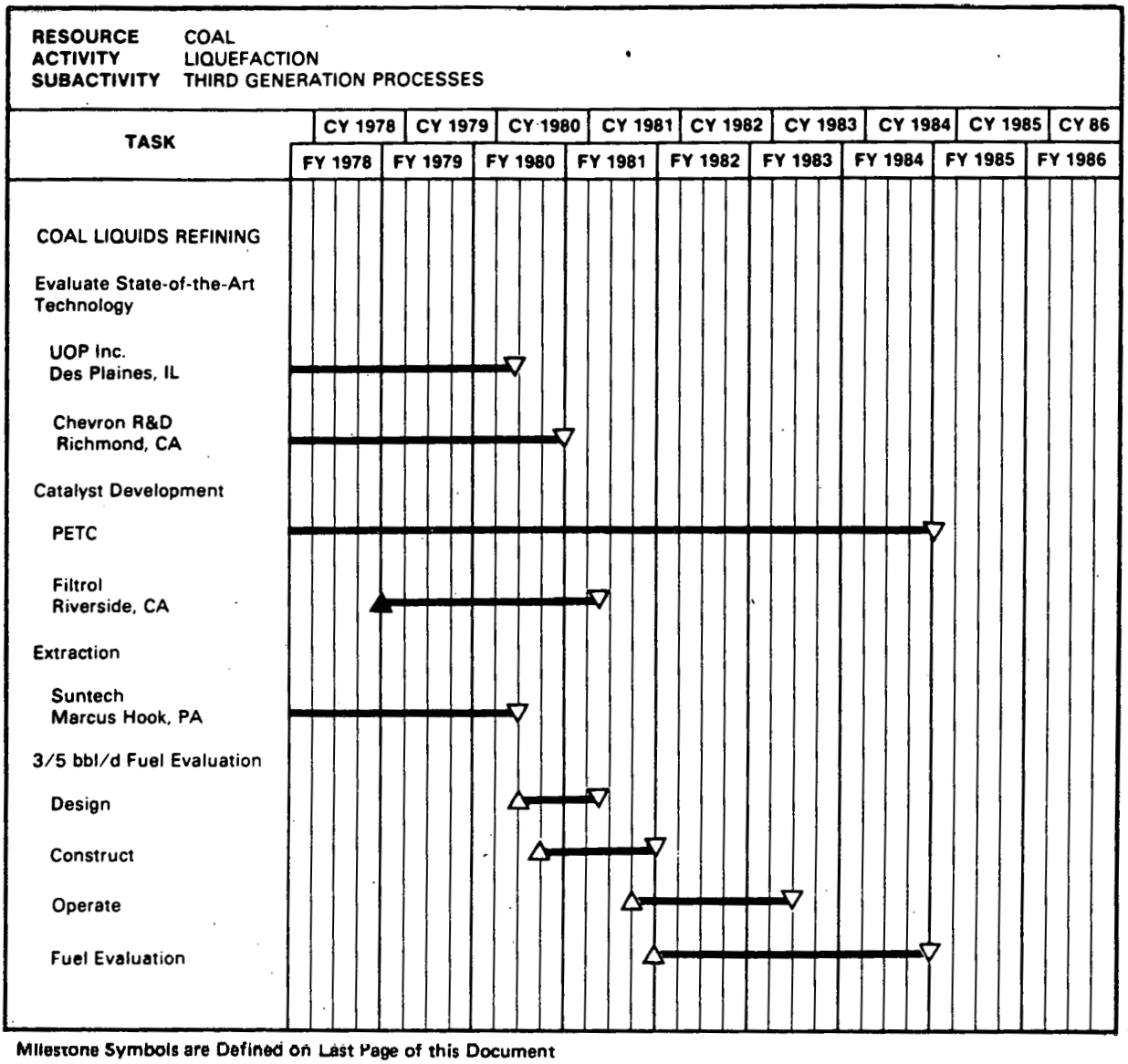
Coal liquids provide a source of liquid hydrocarbons which could be used as a petroleum substitute. However, these materials have unique properties (e.g., low hydrogen content, high aromatic content) which make them significantly different from petroleum. The objectives of the coal liquid refining project are to:

- Evaluate state-of-the-art petroleum refining technology for coal liquids refining.
- Develop new technology for refining coal liquids.
- Determine the relationship between refining severity and product toxicity and end use characteristics.

During FYs 1978 and 1979, both Chevron R&D and UOP, Inc. obtained substantial bench-scale data on the refining of H-Coal, EDS and SRC-II liquid. This data allows an accurate estimate (± 20 percent) of the cost of refining coal liquids with existing technology. This work will be completed in FY 1980.

New catalysts and process approaches are being developed by PETC, Filtrol Corporation and Suntech, respectively.

The existing data base that relates refining to product performance is in a large measure empirical and is only valid for petroleum. No such data exist for coal liquids. In order to fill this void, a minimum quantity of 1,000 to 2,000 barrels of refined products is needed for end use and toxicity testing. For the data to be meaningful, it is essential that these liquids be refined in an integrated fashion using the best available technology. A project to accomplish this is commencing in FY 1980. Every effort will be made to obtain the maximum amount of end use data from the limited sample volume.



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4.0 INDIRECT LIQUEFACTION

This is a broad-based R&D program which seeks to develop new, efficient methods of converting coal-derived synthesis gas to quality liquid fuels. The prime technical goals of the program are to:

- Improve the integration of gasification with liquefaction by developing process technology that can use low-ratio H_2/CO directly.
- Improve process selectivity by use of shape selective catalysts.

- Achieve higher process efficiency by using large, thermally efficient liquid or slurry phase reactors.
- Develop a simpler method of upgrading conventional Fischer- Tropsch liquids.

Work in this area also was funded as part of the AR&TD and third-generation activities in FYs 1979 and 1980.

In order to achieve a substantial improvement over existing indirect liquefaction methods, new technology will be developed that integrates efficiently with second-generation coal gasification systems. Existing technology requires hydrogen-rich feed gas and results in a low thermal efficiency. Catalysts and reactor systems that allow the direct use of the clean synthesis gas will be evaluated at bench scale and the most promising candidates tested at pilot scale. There are three candidate fuels that could be produced:

- Methanol
- Fuel-grade alcohols
- Hydrocarbons.

The preferred route would be via the hydrocarbons since this requires the lowest H_2 content in the synthesis gas per Btu of fuel produced. However, the technology for the alcohols route is further developed and will also be evaluated. This program is being expanded in FY 1981 in order to complement the development of second-generation coal gasifiers in the mid- to late-1980s.

A limitation of existing technology is the inability to produce a quality product in a selective fashion. The use of modern zeolite-based catalysts provides a potential solution to this problem. This effort will build on the pioneering work done under prior DOE funding. Data will also be obtained on the ability of zeolite catalysts to upgrade Fischer-Tropsch liquids in a simple, efficient process to high-octane gasoline.

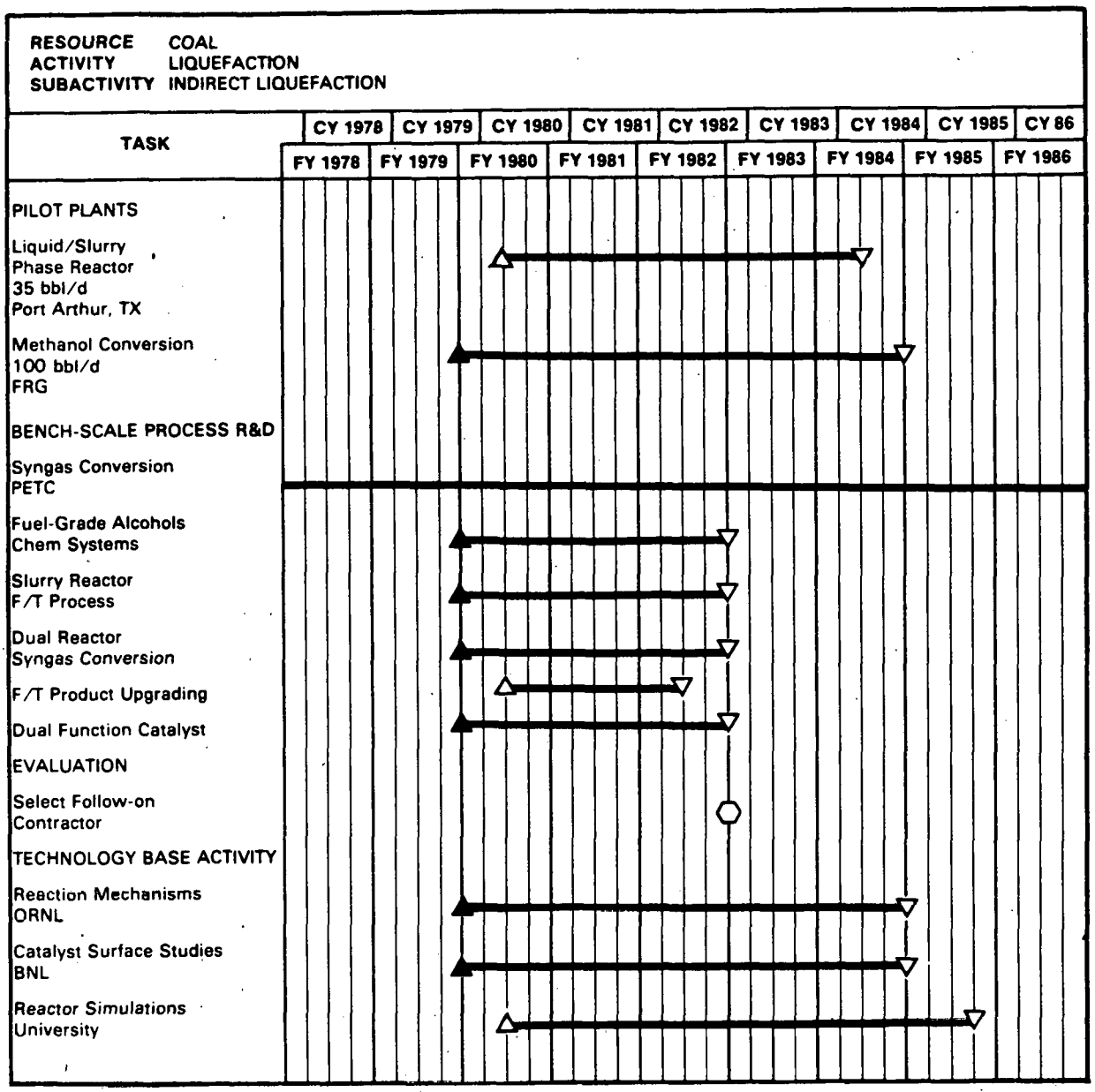
A major engineering difficulty in synthesis gas conversion is the high exotherm that occurs when the gas is converted to liquid. Liquid phase and slurry phase reactors have a potential to provide very good temperature control and allow efficient recovery of the heat produced. These reaction systems will be evaluated at both the bench and pilot scales and the data will be used to develop detailed design models.

Project Status

Prior to FY 1980, a major laboratory-based effort was carried out to develop the M-Gasoline process (conversion of methanol to gasoline).

In FY 1980 it is expected that at least five new industrial R&D contracts will be started. Also smaller scale projects at Oak Ridge and Brookhaven and various universities, will be initiated on reaction mechanisms and catalyst surface properties. It is expected that two pilot plant projects will be initiated in FY 1980: a fluid-bed methanol-to- gasoline unit in conjunction with the Federal Republic of Germany, and a liquid

phase/slurry phase syngas-to-methanol pilot plant. This latter unit will be converted to hydrocarbon synthesis on successful completion of bench-scale projects on use of low-ratio hydrogen-to-carbon monoxide- synthesis gas.



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5.0 DIRECT LIQUEFACTION

See the descriptions of all projects other than "Indirect Liquefaction." H-Coal, SRC-I, SRC-II, EDS, Zinc Chloride, Disposable Catalyst, Flash Liquefaction (Hydropyrolysis) and Two-Stage Liquefaction are all direct liquefaction processes.

6.0 SUPPORT STUDIES/ENGINEERING EVALUATIONS

This program supports generic studies applicable to liquefaction projects and provides support to new project starts. These studies include environmental and toxicology assessments, coordination of environmental data among liquefaction processes, engineering assessments and independent technical status review, ancillary processing studies such as hydrogen generation, and standby and maintenance funding for unused liquefaction facilities. These studies are important in maintaining the forward momentum of coal liquefaction process development by providing, on a timely basis, studies not appropriate to or limited to a single process.

A coordinated SRC biomedical testing program with cofunding by FE and EV, has been initiated. These studies include cellular through whole animal testing of SRC products and intermediate streams. A similar toxicology program is being initiated for H-Coal and EDS products, as well as upgraded coal liquids in support of commercialization plans. Environmental studies are underway at PETC to assess state-of-the-art and advanced environmental control technologies for liquefaction process applications.

Experienced architect-engineering firms are engaged under this program to conduct reviews, monitor projects, and to help appraise the technical status, commercial feasibility and economic impact of various liquefaction processes. Cost estimates are evaluated to assess the economic viability of alternate processes. These engineering and commercial economic studies expedite and assure that selection of the most promising processes can be made to meet the variety of liquid fuel needs of the Nation.

As part of this program, studies are underway to establish the requirements for generating the hydrogen necessary in liquefaction processes directly from residuals produced in liquefaction. This is a critical element in coal liquefaction processes in that the thermal efficiency of a liquefaction plant is dependent on successfully gasifying the nonliquefied coal contained in the residual material from liquefaction. Current activities include a continuation of the project to evaluate the Texaco Partial Oxidation (TPO) process. Results to date, based on short- term tests at the pilot plant scale, have established that TPO can be used to gasify liquefaction bottoms material. Longer term tests will be completed on SRC-I, SRC-II, H-Coal, and EDS to further establish process operability and evaluate refractory lining life and burner erosion. Efforts are underway to explore the possibility of further testing at larger TPO facilities and possible alternatives to TPO are also being investigated.

Also included in this program is standby and maintenance support for presently unused coal liquefaction facilities. The Bruceton Liquefaction Process Development Unit and the Cresap Pilot Plant are now in this category. DOE is exploring the possibility of using the Cresap facility in future programs.

7.0 LIQUEFACTION DEMONSTRATION PLANTS

7.1 SOLVENT REFINED COAL DEMONSTRATION PLANT-I (SRC-I SOLID PRODUCT)

The objective of this activity is to demonstrate the technical, economic, and environmental acceptability of the SRC-I process for conversion of high-sulfur coal to clean-burning solid fuel.

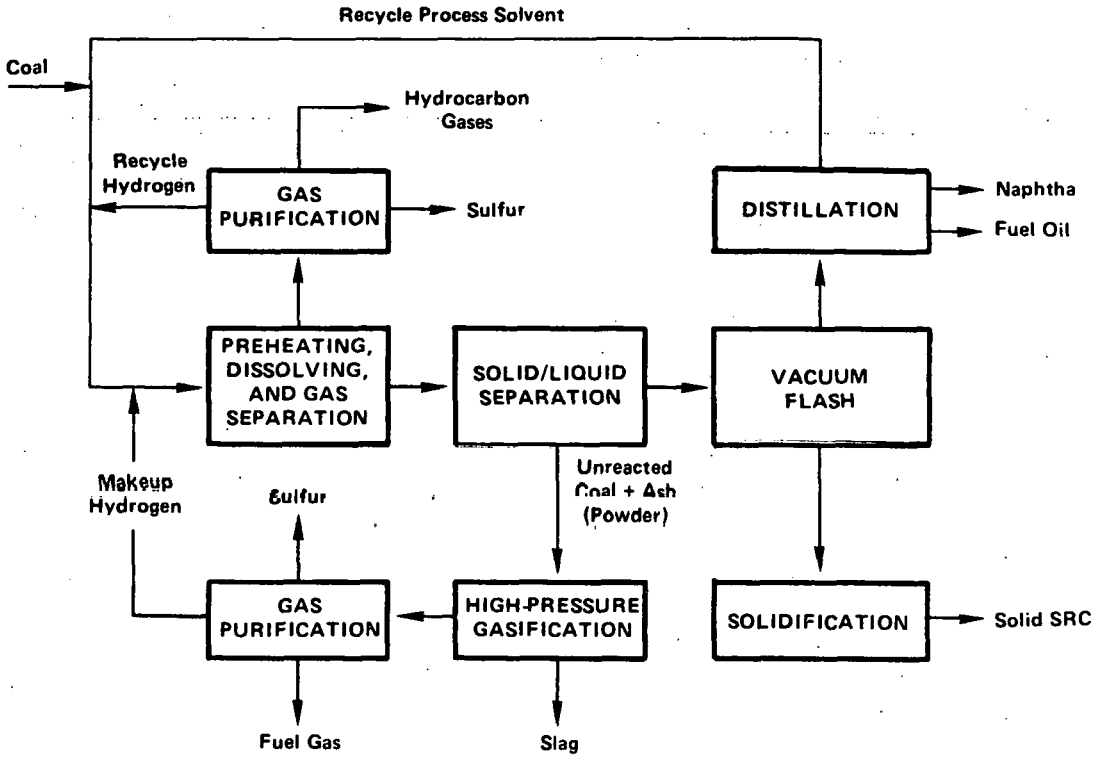
The SRC process converts high-sulfur, high-ash coals to a substantially ash-free low-sulfur fuel. The diagram below illustrates the SRC-I process. Feed coal is pulverized and mixed with a process-derived solvent and then combined with hydrogen produced from other steps in the process. The mixture is pumped through a fired preheater and reacted in a dissolver where about 90 percent of the coal (on a moisture- and ash-free basis) is dissolved. Several reactions occur simultaneously in the dissolver to produce liquid: coal is depolymerized and hydrogenated, resulting in an overall decrease in molecular weight; the liquid is hydrocracked to form yet lower molecular-weight hydrocarbons that range from methane to light oil; and much of the organic sulfur is removed by hydrogenation in the form of hydrogen sulfide.

The mixture passes from the dissolver on to a separator where raw product gas is separated from the slurry of undissolved solids and coal solution. Raw gas is sent to gas purification which includes a hydrogen recovery and a gas desulfurization unit. Recovered hydrogen is recycled with the coal slurry coming from a slurry mix tank. Hydrocarbon gases are recovered and hydrogen sulfide is converted to elemental sulfur.

Undissolved solids and the coal solution are separated in a solid-liquid separation unit. The solids, consisting of unreacted coal and ash, are sent to a gasifier where they react with steam and oxygen to produce makeup hydrogen which is purified to remove sulfur and fuel gas and added to the feed stream. The liquid from the solid-liquid separation step is distilled to use naphtha and fuel oil as products and to recover process solvent for recycling to slurry the coal feed. The material which remains as vacuum flash underflow is solidified and is the primary final product, solvent refined coal.

Typical properties of the SRC-I product obtained from a western Kentucky bituminous coal feed having 7.1 percent ash and 3.4 percent sulfur are 0.1 percent ash and 0.8 percent sulfur. It has a solidification point of around 350° to 400°F and a heating value of about 16,000 Btu/lb.

The SRC-I Demonstration Plant to be located near Newman, KY, is being designed on the basis of information obtained from a 50 t/d SRC pilot plant in Ft. Lewis, WA, and a 6 t/d SRC pilot plant in Wilsonville, AL.



SRC-I (Solid) Process

Project Status

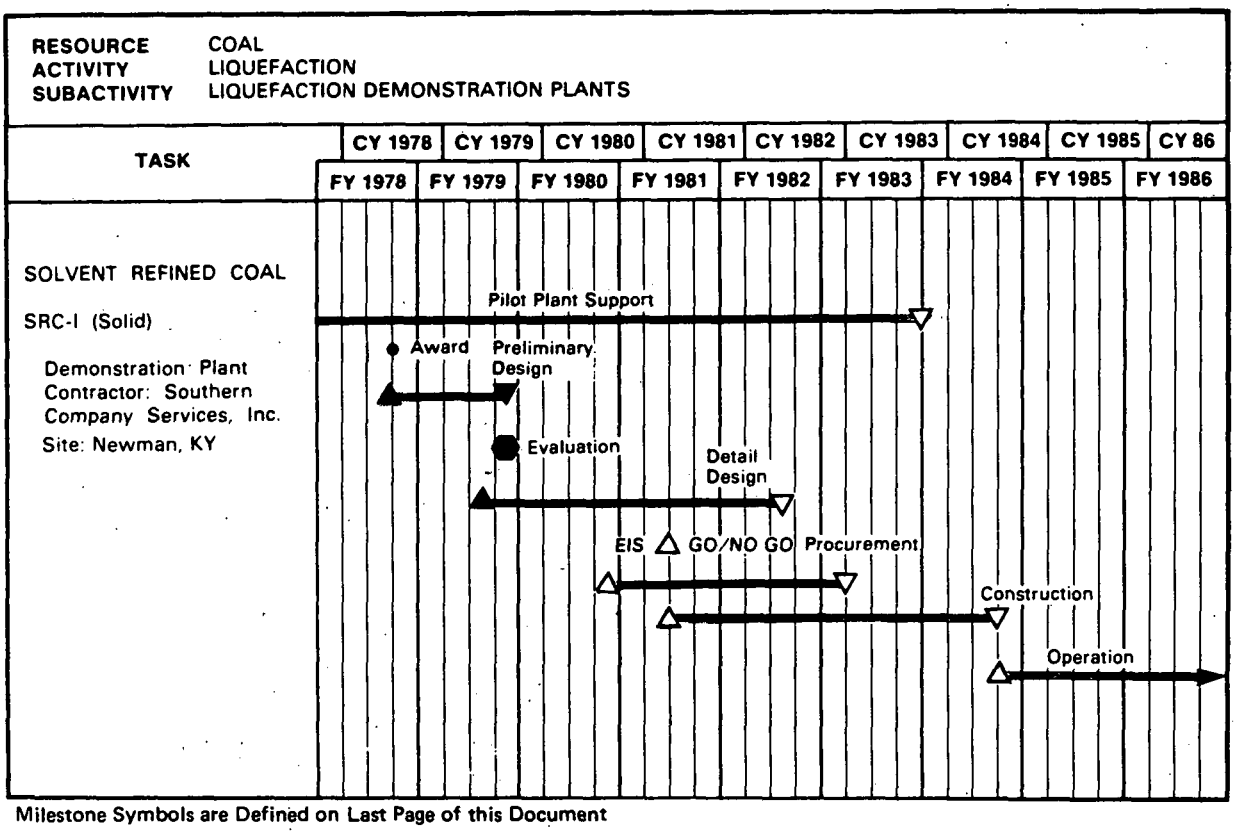
The SRC-I process was selected for demonstration in FY 1978 because: (1) the production of the solid SRC-I product is expected to be responsive to the market for fuel for utility boilers; (2) the technology is the most mature of the liquefaction processes by virtue of the successful operation of the Wilsonville and Fort Lewis pilot plants which have produced clean-burning solid fuel from high-sulfur coals; and (3) preliminary economic evaluations indicate that this process is cost competitive with other liquefaction processes. Operation of the SRC-I demonstration plant will:

- Provide an accurate basis for determining investment and operation costs for commercial-sized applications of this technology.
- Ascertain the environmental acceptability of this fuel product for direct use in electric power generation.
- Assess the marketability of SRC-I and of a range of fuel products that are produced in conjunction with SRC-I from a given coal.
- Determine the acceptability and degree of burner retrofit required of this fuel product by utilities and industry.

- Demonstrate the technical viability of certain process steps such as solid-liquid separation, hydrogen generation and residue extraction systems. Other technical aspects such as materials of construction, equipment design, and fabrication technologies needed for commercial-scale applications will also be demonstrated.

The SRC-I demonstration program was initiated in July of 1978, with the award of a multiphased contract to Southern Company Services, Inc., for demonstration of the solid SRC-I process. The demonstration plant will be a full-scale "first module" of multimodule commercial plants to be completed by the sponsoring industrial partner.

Principal subcontractors are Air Products and Chemicals, Inc., Wheelabrator-Frye, Inc., Catalytic, Inc., and Rust Engineering, Inc. The proposed site is near Newman, KY. The plant will be designed to process western Kentucky (No. 9/14) coal to produce a low-ash, low-sulfur, environmentally acceptable solid fuel that readily substitutes in conventional coal transportation and handling facilities and burns in coal-burning boilers without significant modification. The principal market for solid SRC-I is the coal-burning utilities in the Midwest and Southwest that will be required to install scrubbers or convert to oil or gas to meet environmental standards.



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The contractor completed work on Phase Zero, Preliminary Design, on July 31, 1979. In Phase Zero, the contractor prepared a preliminary demonstration plant design and cost estimate, long-lead procurement plans, market and economic assessments, a detailed management plan for subsequent phases, a cost-sharing proposal and environmental analyses for the project.

It was decided to continue the project based upon an evaluation of Phase Zero results, and based upon consideration of the critical need to develop the capability to convert abundant coal reserves to fuels that can be substituted for imported petroleum. Phase I, Detailed Design, was initiated October 1, 1979 and completion of construction for the SRC-I Demonstration Plant is scheduled for mid-1984.

Design and Technology Support

The Design and Technology Support for the SRC-I Demonstration Plant covers the following:

- Equipment Development and Component Testing: Successful operation of large-scale equipment and components is essential for commercial-plant success. There is an array of such equipments (i.e., large valves and coal feeders) that are generic to the operation of all demonstration plants and must, therefore, be developed and tested hand-in-hand with the balance of the plant. Funding is largely for continuation of work previously started.

- Engineering Support: Project technical support will be provided by the national laboratories, energy technology centers, and various private engineering firms.

- Environmental and Socioeconomic Studies: Analysis of the environmental impact of large coal liquefaction pilot/demonstration plants and future commercial installations will continue. Potential social, ecological, aesthetic, and economic impacts and methods for achieving their equilibrium are studied.

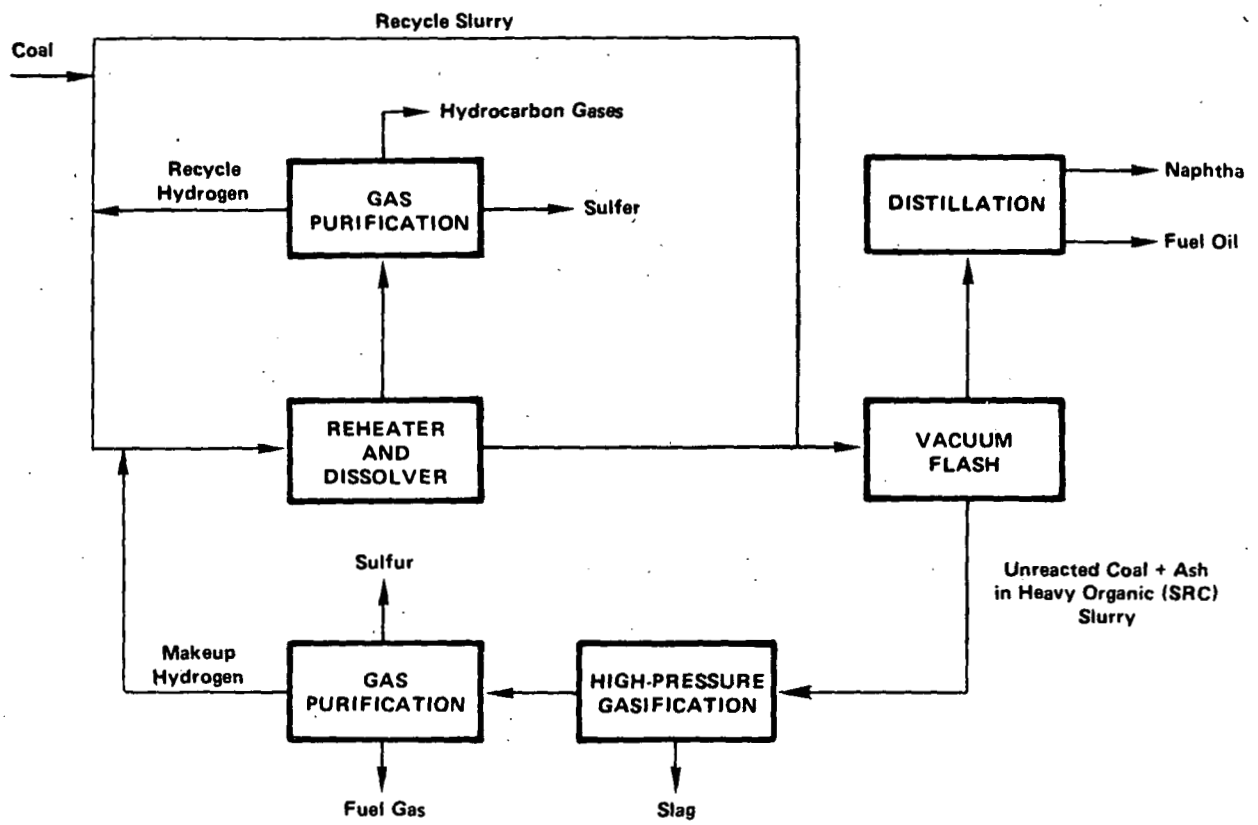
- Planning and Program Support: These support tasks are largely a continuation of established activities. They include modeling and system studies, economic and financial analyses, technical reports, and management support.

7.2 SOLVENT REFINED COAL DEMONSTRATION PLANT-II (SRC-II LIQUID PRODUCT)

The objective of the SRC-II Demonstration Plant activity is to demonstrate the technical, economic, and environmental acceptability of the SRC-II process for conversion of high-sulfur coal to clean-burning liquid fuel.

As a result of continuing effort since 1962, the SRC-I (described above) and SRC-II processes were incorporated in two pilot plants now included in the DOE Coal Liquefaction Program.

The SRC-II process is illustrated below.



SRC-II (Liquid) Process

This is designed to produce clean, nonpolluting liquid fuel from high-sulfur bituminous coal. The demonstration plant is designed to process a nominal 6,000 tons per stream day of Pittsburgh seam coal. Principal products from the plant are expected to be low-sulfur fuel oil, pipeline-quality gas, liquefied propane and butane gases, and naphtha, as well as sulfur, ammonia and tar acid by-products. The heating value of the hydrocarbon products produced in the plant is expected to be approximately equivalent to the production from a 20,000 barrel per day petroleum refinery. The plant will be designed to be self sufficient with regard to all utilities, except for electric power which will be purchased.

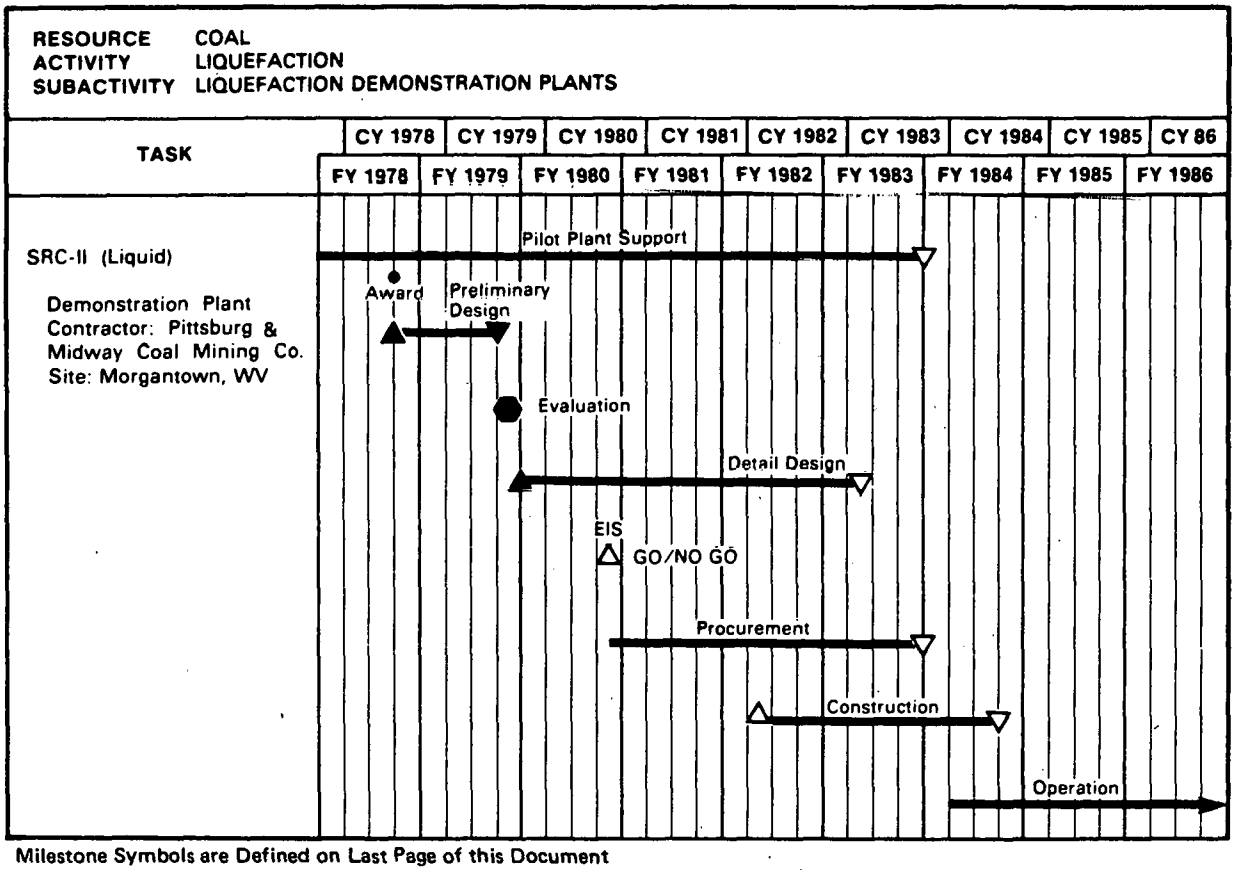
Raw coal is pulverized and mixed with a recycle slurry stream from the process. Hydrogen is added and the slurry passes through a preheater and dissolver where hydrogenation and liquefaction reactions convert the coal into liquid and gaseous products. Liquid products from the dissolver are refined in the fractionation section and separated into naphtha, light fuel oil, heavy fuel oil, and vacuum tower bottoms which are processed to produce makeup hydrogen. The sulfur content of the liquid products is reduced to environmentally acceptable levels. The gas products from the dissolver are sent to the gas purification to remove sulfur and recover hydrogen for recycle. The hydrocarbon gases are sent to gas plants to produce ethane, methane and propanes.

Project Status

A multiphased contract for the SRC-II demonstration plant was signed by the Secretary on July 10, 1978, with the P&M Coal Mining Company, a subsidiary of the Gulf Oil Corporation. The proposed site is near Morgantown, West Virginia. The plant will be designed to process Powhatten (Pittsburgh seam) coal to produce a virtually ash-free, low-sulfur, environmentally acceptable liquid fuel that readily substitutes in conventional liquid fuel transportation and handling facilities and burns in oil-fired utility boilers without significant modification. The principal market for liquid SRC-II is the oil-burning utilities in the urban Northeast that are currently burning imported oil.

During Phase Zero the contractor prepared a preliminary design and cost estimate, a long lead procurement plan, a market and economic assessment, detailed management plans for subsequent phases, a cost-sharing proposal, and an environmental analysis. Phase Zero was completed on July 31, 1979.

Agreements have been reached with the Federal Republic of Germany (FRG) and Japan for each to contribute 25 percent of the total cost of the demonstration plant.



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It was decided to continue the project based upon an evaluation of Phase Zero results, and based upon consideration of the critical need to develop the capability to convert abundant coal reserves to fuels that can be

substituted for imported petroleum. Phase I, Detailed Design, was initiated October 1, 1979, and completion of construction for the SRC-II demonstration plant is scheduled for mid-1984.

Design and Technology Support

Design and Technology Support for the SRC-II Demonstration Plant covers the following:

- Equipment Development and Component Testing: Successful operation of large-scale equipment and components is essential for commercial-plant success. There is an array of such equipments (i.e., large valves and coal feeders) that are generic to the operation of all demonstration plants and must, therefore, be developed and tested hand-in-hand with the balance of the plant. Funding is largely for continuation of work previously started.

- Engineering Support: Project technical support will be provided by the national laboratories, energy technology centers, and various private engineering firms.

- Environmental and Socioeconomic Studies: Analysis of the environmental impact of large coal liquefaction pilot/demonstration plants and future commercial installations will continue. Potential social, ecological, aesthetic, and economic impacts and methods for achieving their equilibrium are studied.

- Planning and Program Support: These support tasks are largely a continuation of established activities. They include modeling and system studies, economic and financial analyses, technical reports, and management support.

7.3 SOLVENT REFINED COAL PILOT PLANTS

Descriptions of SRC-I and SRC-II processes are provided in subsections 7.1 and 7.2.

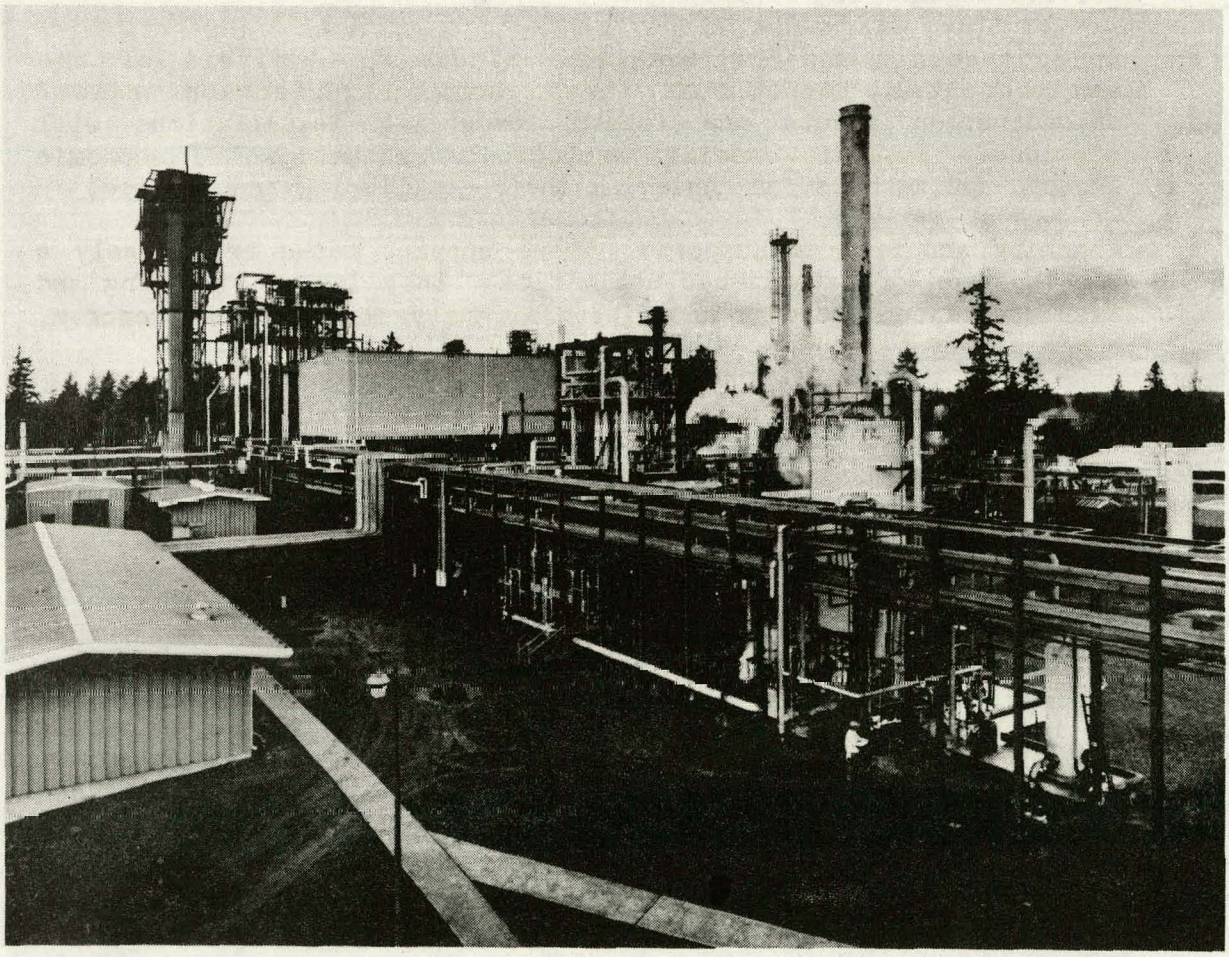
Project Status

The SRC project was begun in 1962, when Spencer Chemical Company was awarded a research contract to study the technical feasibility of a coal de-ashing process. In 1965, the process was successfully demonstrated in a 50 lb/hr continuous flow unit, and work on the original contract scope was completed. During the term of the contract, Gulf Oil Corporation acquired Spencer Chemical Company. After reorganization, the contract was extended and assigned to the research department of Pittsburg & Midway (P&M) Coal Mining Company, another subsidiary of the Gulf Oil Corporation. Current efforts are underway at the Ft. Lewis, Washington, and the Wilsonville, Alabama, pilot plants.

Demonstration plants are being designed to evaluate large-scale operation of both the SRC-I and SRC-II processes.

Ft. Lewis Pilot Plant

The objectives of the pilot plant located at Ft. Lewis, Washington, are to provide technical support to the SRC-I and SRC-II demonstration plant projects and to continue process development studies of the SRC process. Construction was completed by Rust Engineering in FY 1975. Operations to produce 3,000 tons of solid product for full-scale combustion tests were completed in FY 1977. Pilot plant modifications, providing capability to recycle unconverted coal in the SRC-II mode of operation were completed in FY 1977. This modified pilot plant produced over 5,000 barrels of distillate fuel oil for successful full-scale combustion testing during FYs 1977 and 1978. An evaluation of an improved filter for SRC-I operation was also completed during FY 1978. In FY 1979 an evaluation of a solvent de-ashing system for SRC-I solids/liquid separation was completed and studies in the SRC-II mode continued to provide the data base required to establish the demonstration plant baseline design operating conditions. During FY 1980 and FY 1981, studies in support of the demonstration plant programs will provide data for slurry preheater design, slurry mixing design, component evaluation and for continuation of process studies.

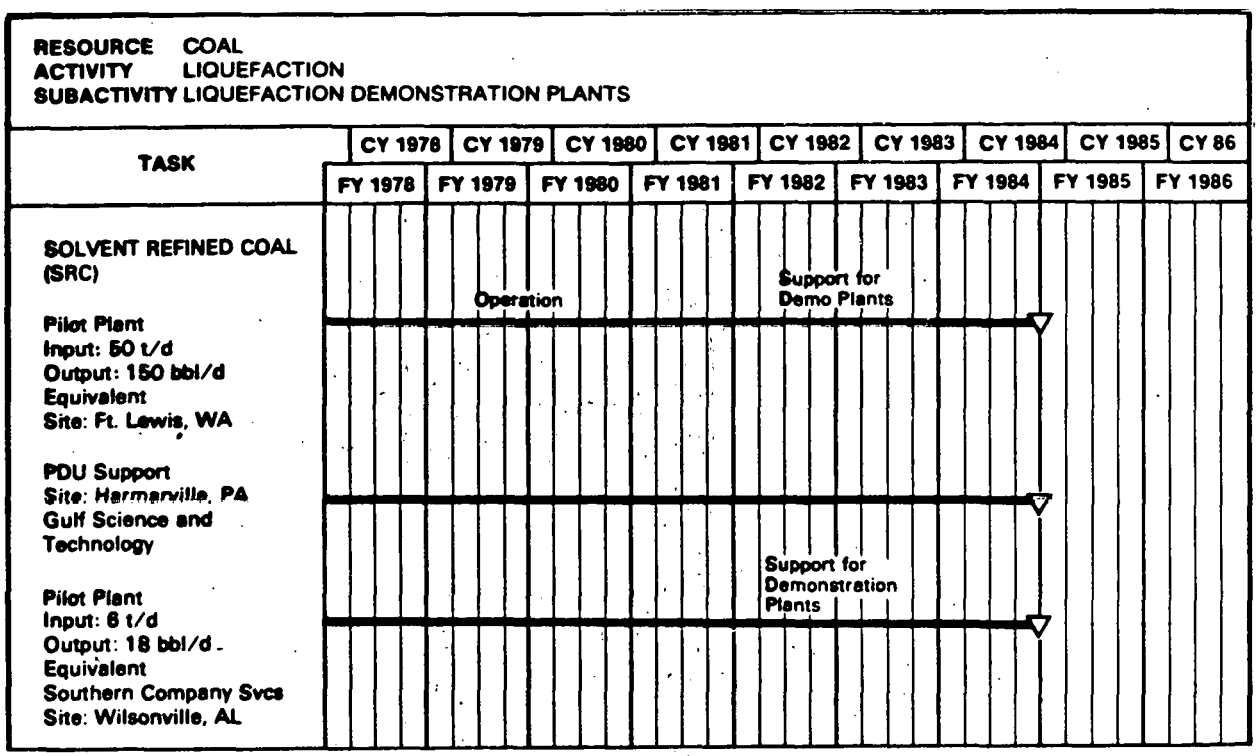


Ft. Lewis, Washington, SRC Pilot Plant

The Ft. Lewis pilot plant operation includes both onsite and offsite environmental monitoring programs to document the quality of the working and neighboring plant environment. In addition, the toxicology characteristics of process liquids and solid are being studied.

Wilsonville Pilot Plant

Operation of the 6 t/d SRC-I pilot plant at Wilsonville, Alabama, was originally financed by industry through EPRI. Since 1976 it has been supported jointly by DOE and EPRI to continue process development work in SRC-I. Wilsonville provides a flexible test unit for investigating process performance on a variety of coals and for evaluating various component and process improvement options. To date process performance data have been obtained on nine coals and significant progress has been made in developing solid/liquid separation options. During FY 1979, an initial evaluation of an improved solvent de-ashing process was completed and SRC-I process studies provided the data base required to establish the demonstration plant process design base. During FYs 1980 and 1981, evaluations will be completed on several improved filters, additional process studies on the solvent de-ashing process will be undertaken, and process studies on additional coals will be initiated. During this period SRC-I process improvement options will be investigated, including hydrotreating all or selected fractions of SRC to reduce sulfur levels and improve yield structure.



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C. SURFACE COAL GASIFICATION

Successful development of the technology needed for surface gasification of coal will enable the United States to use its large deposits of coal to produce a wide variety of energy products and chemical feedstocks. The flexibility of this technology as it can be used to convert coal into alternate products suitable for the demands of many markets is shown in the following figure.

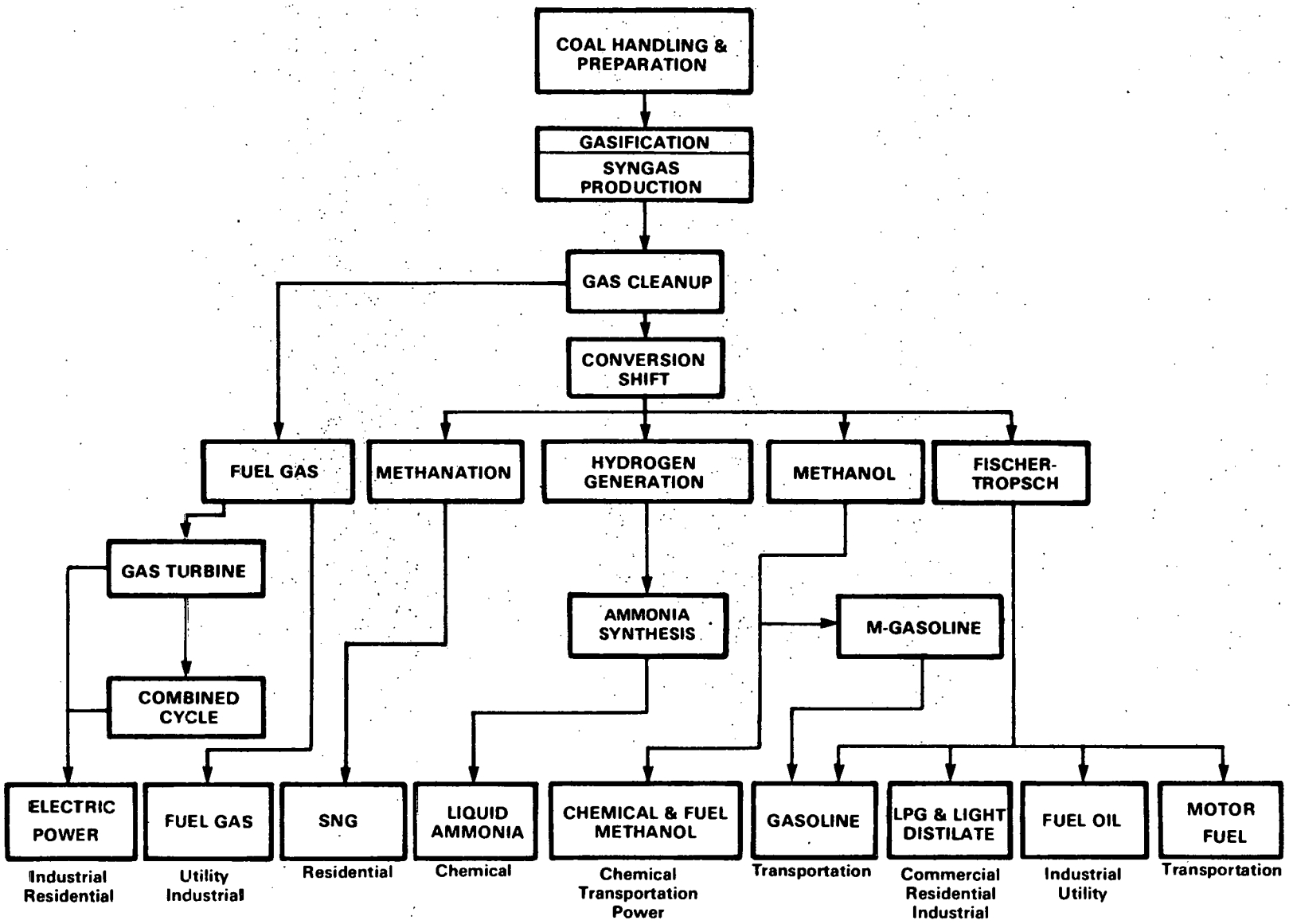
Accordingly, the Surface Coal Gasification Activity has as its objective the development and demonstration of that technology. The successful completion of the projects in this activity will provide the means to convert coal into a number of clean synthetic gaseous and liquid fuels as well as a synthesis gas suitable for continued conversion into other fuels and chemicals. The synthetic gaseous fuels include high-Btu gas having a heating value of approximately 950 Btu/scf and low- and medium-Btu gases having heating values which range from approximately 100 to 500 Btu/scf.

The high-Btu gas is intended for use principally as a fuel for residential and commercial heating as well as for industrial applications which require clean high-energy fuel. The low-/medium-Btu gas is used for industrial process heat and electric power generation. As shown in the figure, this same technology can be used as the first step in producing synthesis gas which can be subsequently processed into chemical feedstocks and liquid fuels.

The intended end uses of high-Btu gases differ from those of medium-/low-Btu gases, thus the program objectives are different.

The objectives of the High-Btu Gasification program are:

- Evaluate the technological and economic status of existing first-generation processes and assess their suitability for meeting the U.S. market needs.
- Promote the development and demonstration of new and improved second-generation technology for commercial-scale plants to convert domestic coals (caking as well as noncaking) to synthetic natural gas of pipeline quality.
- Continue the development of third-generation gasification processes.
- Promote commercial-scale implementation of second-generation local gasification processes through the continued implementation of the Demonstration Plant program for high-Btu gasification.



Flexibility of Coal Gasification

The objectives of the Low-Btu Coal Gasification program are to:

- Promote the development and demonstration of improved gasification technologies for commercial-scale plants to convert coal to environmentally acceptable gaseous fuels for use in electricity generation, as an industrial fuel, and as a chemical feedstock.

- Ensure that technological advances in low-Btu gasification are made available to users of existing commercial gasification systems and provide operating data sufficient to establish the confidence level necessary for other potential industries and utilities to use this technology.

- Acquire a commercial experience base in specific applications or industries to eliminate uncertainties such as capital and operating costs, retrofit problems and the effect of using gas from coal on the end product.

- Establish the availability, through development and/or demonstration, of cleanup equipment and systems suitable for use with low-Btu gasifiers in satisfying current as well as projected environmental requirements.

It should be noted that as the above objectives of the High- and Low-Btu Gasification programs are achieved, the technology needed for the production of a medium-Btu as well as a synthesis gas will also be developed.

Early identification and characterization of potential environmental contaminants is necessary to minimize ultimate impacts. Standards of environmental performance serve as goals for developmental efforts to reduce environmental impacts, to minimize the severity of any impact should it occur, and to minimize the costs of technology and equipment required to accomplish these goals.

Environmental control is an integral part of this program and is thus accorded a high priority within each developmental project.

The Surface Coal Gasification Activity consists of the following subactivities:

- High-Btu Gasification
- Low-Btu Gasification
- Third-Generation Processes
- Special Projects and Support Studies
- Technical Support
- Gasification Demonstration Plants.

As noted, the technology for the implementation of a medium-Btu industry as well as for the production of a synthesis gas is being developed simultaneously as part of the High- and Low-Btu Gasification programs. Each of these subactivities is supported by special projects, studies, and evaluations.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

SURFACE COAL GASIFICATION	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
High-Btu Gasification	15,000	16,500	23,000
Low-Btu Gasification	12,980	17,500	19,000
Third-Generation Processes	23,075	20,000	30,000
Special Projects and Support Studies	– 29,500*	7,000	0
Technical Support	15,023	8,350	10,000
Gasification Demonstration Plants	79,300	46,000	56,000
Prior Year Funds	– 4,000	0	0
Capital Equipment	500	500	500
TOTAL	112,398	115,850	138,500

*Includes $34.1 million prior year funds

1.0 HIGH-BTU GASIFICATION

National patterns of growth in population and economic activity require increasing consumption of natural gas. At the same time, proven reserves have decreased, despite intensified drilling activity. These forces have, in the short term, caused local and regional shortages. In the long term, the country will be faced with ultimate resource depletion. Development of alternative domestic fuel resources of a quality and convenience equal to natural gas is a high national priority. The High-Btu Gasification subactivity is meeting that priority by:

- Identifying and accelerating the development of promising third-generation technology to improve process economics on a commercial scale for the 1985-2000 period

- Developing and demonstrating, in cooperation with industry, new and improved second-generation gasification technology necessary for the construction and operation of a modular plant using commercial-size equipment prerequisite to the construction of commercial-scale plants.

These efforts will produce the technology that can convert coal into a substitute natural gas with the following specifications:

- Heating value: 950 to 1,000 Btu/scf

- Purity level: essentially free of sulfur and other potential pollutants and hazardous impurities

- Process gas exit pressure: approximately 1,000 psi
- Combustion characteristics: similar to natural gas; exhaust gases should meet EPA and other regulations.

The Government-supported High-Btu Gasification subactivity includes four major second-generation projects for development of improved processes to manufacture substitute natural gas (SNG) from coal and the evaluation of peat also as a potential feedstock for these or other processes that can be used to produce a SNG. The second-generation development projects include the following processes:

- Bi-Gas
- HYGAS
- British Gas/Lurgi Slagger (see subsection 6.0, Gasification Demonstration Plants)
- COGAS (see subsection 6.0, Gasification Demonstration Plants).

Although many gasification processes under development have the same objectives, each is characterized by important differences that warrant concurrent development. These differences include reaction conditions, coal pretreatment, method of feed, reactor configuration, heat supply, gas purification, and methanation process. The Lurgi gasification process has been utilized as a benchmark for measuring process economics of those processes currently under development. Improvements to present technology will be measured primarily in terms of comparative capital and operating costs, as well as ability to operate successfully with U.S. caking-type coals. Development of each candidate process will continue to a point where industry can construct, with an acceptable degree of risk, a commercial plant based on one or more of the concepts.

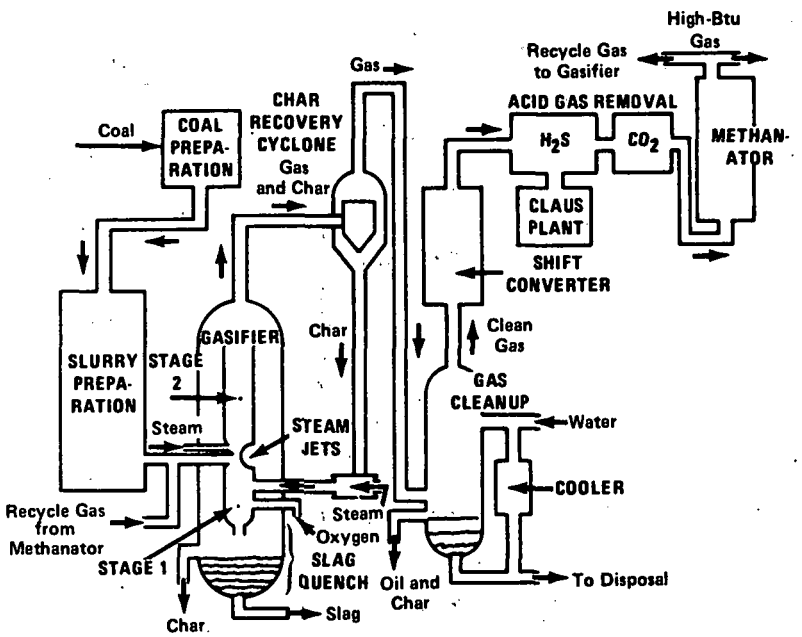
1.1 GASIFICATION PILOT PLANTS

Bi-Gas Pilot Plant

The Bi-Gas Pilot Plant located in Homer City, Pennsylvania, is a facility designed to study a new process for converting coal into pipeline-quality gas. The principal feature of the plant is a two-stage, entrained-bed, high-pressure (1,500 psig maximum), oxygen-blown, and ash slagging gasifier unit. The gasifier has three sections separated by formed restrictions. Stage two (top-most) receives dense-phase coal in gas-entrained flow-through injectors located in a throat between stages two and one. Steam is also injected there. Process gas and char flow from the top of stage two of the gasifier to a cyclone. The char is recycled from the cyclone and fed to a steam injector nozzle and then, with oxygen and steam, to the bottom of stage one. The products of char gasification in stage one are hot gas feeding into stage two and slag dropping into stage three, the slag quench section. Molten slag runs down the walls of stage one of the pressurized gasifier.

Raw gas leaves the char recovery cyclone, passes through a water wash column and flows to the shift reactor where the H_2-to-CO ratio is adjusted to the desired value. H_2S and part of the CO_2 are removed in the Selexol unit upstream of the methanator. H_2S gas goes to a Claus unit. The product gas from the methanator goes through final CO_2 removal in the Selexol unit. The methanator, a fluidized bed with embedded water-cooled tubes, offers great potential for commercial development.

The Bi-Gas reactor can handle all types of coal. Due to its high operating temperature of over 2500°F, there is no tar in the product gas, thus simplifying the gas cleanup step. High methane yields are achieved without methanation, and coals can be gasified without prior treatment since the process uses an entrained- rather than a fixed- or fluidized-bed system.



Bi-Gas Process

Project Status

The Bi-Gas project was initiated in December of 1963 by the Office of Coal Research (OCR) and later became a part of the Office of Coal Research/ American Gas Association combined program. Since December 1978, the Department of Energy has been solely funding the project. The development of this process by Bituminous Coal Research, Inc. (BCR), started with rocking autoclave testing (1965), followed by 5 lb/hr continuous (externally heated) flow reactor (CFR) testing (1967), 100 lb/hr internally fired PDU testing (1968), cold flow model testing (1972), and at present, operation of a 10,000 lb/hr (120 t/d) pilot plant. Stearns-Rogers completed the construction of

the 120 t/d pilot plant (at Homer City) in July 1976, and startup operations commenced in August of 1976.

Pilot plant support work is being conducted at the facilities of BCR in Monroeville, Pennsylvania. Stearns-Rogers has the overall technical and administrative management responsibility for development of the Bi-Gas process, as well as the responsibility for operating and maintaining the plant.

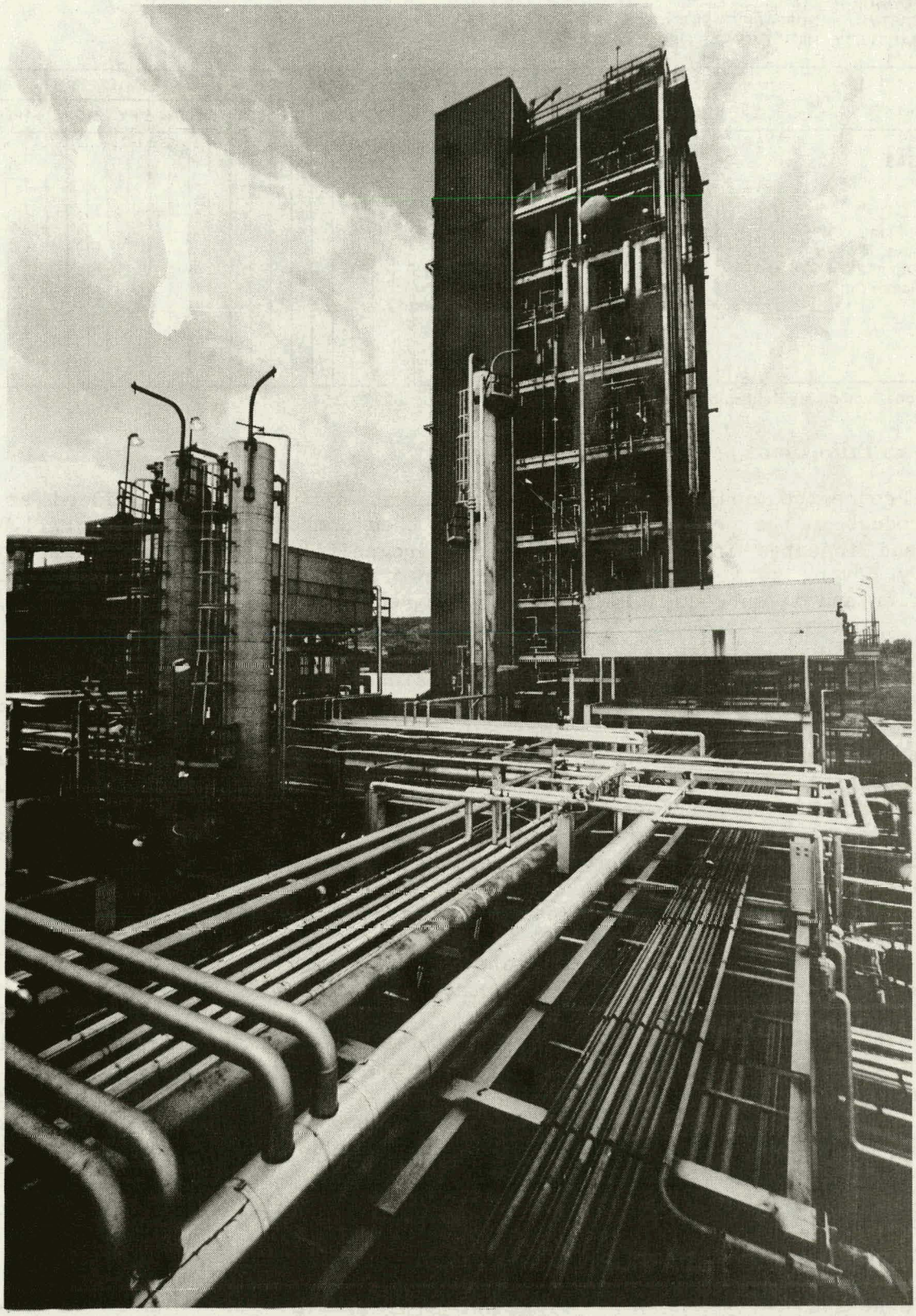
Significant milestones achieved at the Bi-Gas pilot plant include:

- Successful operation of the coal slurry feed spray-drying system at 750 psig
- 500 hours of operation with coal feed to the gasifier
- Successful demonstration of slag tapping without the addition of flux
- Attainment of stage-two carbon conversions in excess of 40 weight percent. (Forty weight percent was anticipated from PDU studies.)
- Continuous operation of the pilot plant for up to 39 hours.

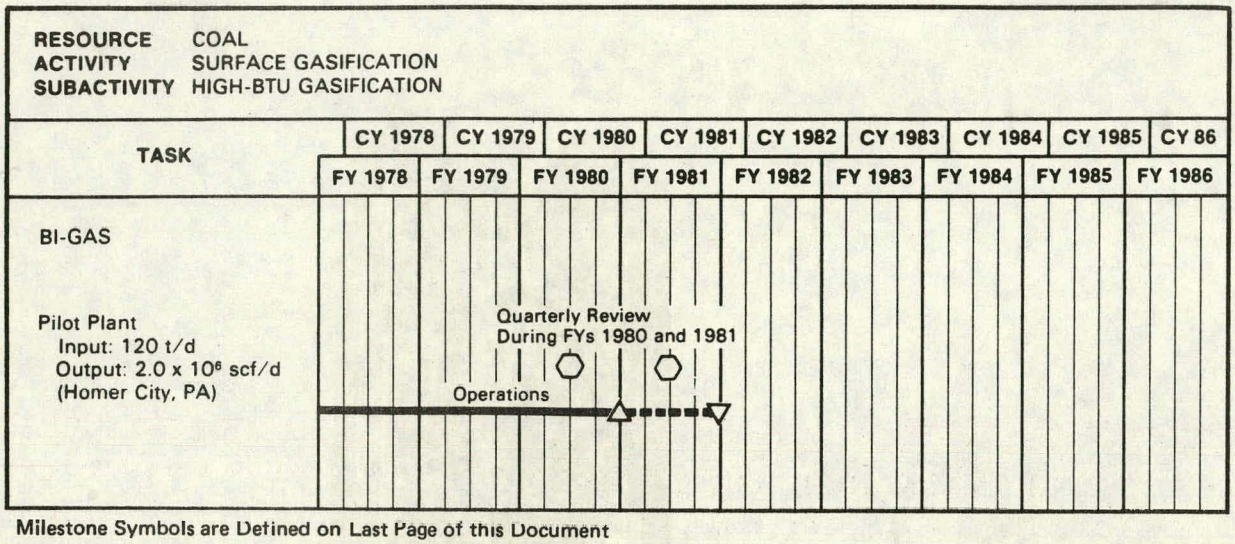
It is planned to operate the Bi-Gas pilot plant for at least 24 additional months in order to develop an effective data base for scaleup purposes.

The Bi-Gas pilot plant must be developed to the point where steady state operations can be attained for adequate periods to obtain scaleup data. In addition it is necessary that improved solids flow and temperature instrumentation techniques be developed in the Bi-Gas process for process optimization.

During FY 1981, the gasifier will be operated to acquire the experience necessary to achieve integrated operation of stage I and stage II. This same experience will provide data needed for further refinement of the control instrumentation and preparation of the downstream gas processing systems for operations in conjunction with the gasifier.



Bi-Gas Pilot Plant



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HYGAS Pilot Plant

Pretreated coal is slurried with light oil which is produced as a by-product in the process. The slurry is then pumped to approximately 1,000 psi and injected into the top of the hydrogasifier. In the fluidized-bed slurry drying section, the oil is driven off as a vapor which leaves the gasifier and is subsequently recovered for reuse.

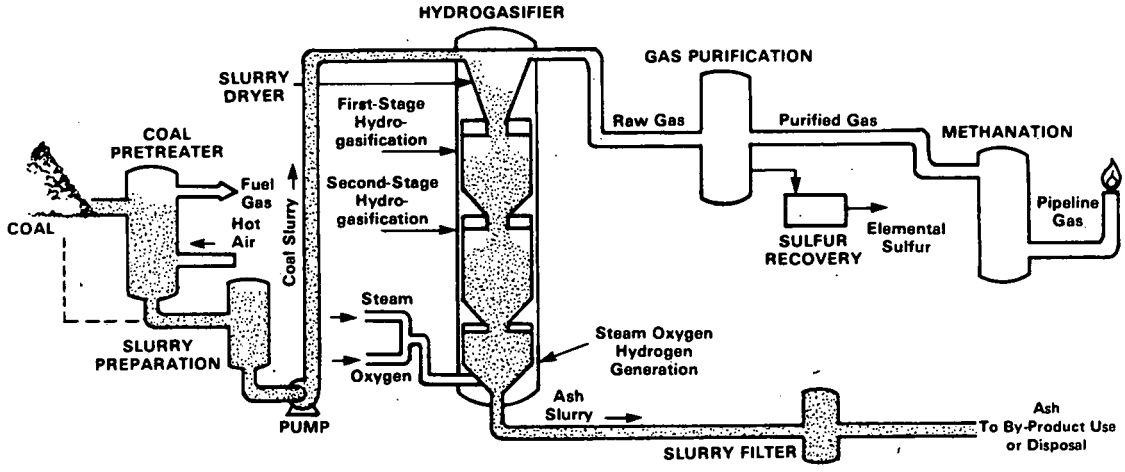
In hydrogasification, the carbon-hydrogen reaction is promoted to produce methane exothermally. This heat is used to decompose steam on carbon to produce additional hydrogen. In the HYGAS hydrogasifier, two stages are used to achieve the above reactions. Dry coal particles at about 600°F from the slurry drying section flow by gravity through a dipleg into a lift pipe. The lift pipe serves as the first stage of hydrogasification. Here, a dilute phase contact occurs between the coal or pretreated char and the gases from the second stage. The gases are at approximately 1500°F. The gas lifts the solids to the gas-solid disengaging section. As the dried coal is lifted, it is flash heated in the presence of hydrogen to 1200° to 1300°F, and converts approximately 20 percent of the coal to methane.

The partially gasified char flows into the second-stage hydrogasification section and is contacted with the H_2-rich gas from the steam-oxygen gasifier. This stage is a dense-phase, fluidized-bed reactor operating at 1600° to 1700°F. Here, methane is formed simultaneously with the H_2 and CO produced by the steam-carbon reaction. Approximately 25 percent additional coal is converted, thus 45 to 50 percent of the total feed coal is converted by hydrogasification reactions. In this stage, with steam present, any rise in temperature accelerates the endothermic steam-char reaction; a temperature drop slows down the reaction. The hot gases rise to the first stage and to the dryer, where much of the heat is used to vaporize and dry the feed coal.

The partially depleted coal char leaving the second-stage hydrogasification zone is used to produce hydrogen in the steam-oxygen gasification section. The steam and high-purity oxygen convert the char into hydrogen and carbon oxides. Ash is discharged from this stage without being

slagged. The ash is discharged into a tank where water is added to make a slurry which is then depressurized. The ash is recovered by filtering and the water is recycled.

The raw gas leaves from the top of the slurry drying section through a quench tower which removes dust, the slurry oil, and excess steam. Gas purification occurs in an acid removal system which consists of an amine-water scrub followed by a caustic wash. CO_2 and H_2S removal are essentially complete following the amine scrub. A Claus plant converts the sulfur products to elemental sulfur. Methanation occurs in two packed-bed down-flow reactors. Heat release control is carried out by the (IGT) split-flow cold-gas recycle method.



HYGAS Pilot Plant Configuration

Project Status

Prior to 1964, research on the HYGAS process was sponsored by the American Gas Association (now the Gas Research Institute). Beginning in 1964, these studies were continued under the joint sponsorship of the Office of Coal Research and the American Gas Association. Since June 1979, the HYGAS process has been solely funded by the Department of Energy. Early efforts were limited to bench-scale and PDU studies of the basic process parameters and their effects on the reaction chemistry. In 1967 the design and construction of a large-scale integrated pilot plant was initiated. The plant was designed to convert 80 tons of coal per day to 1.5 million cubic feet of pipeline-quality gas with the capability to handle lignite, bituminous and subbituminous coals. Operation of the pilot plant began in 1971. From 1971 to 1974 operations were carried out with a hydrogen source from the steam reforming of natural gas. During 1974 a larger steam-oxygen gasification unit was designed, constructed and integrated into the bottom of the HYGAS reactor.

The HYGAS pilot plant has processed lignite, subbituminous, and Illinois No. 6 (medium- and highly caking) coals into a high-Btu gas.

In July 1977, the major program emphasis was placed on providing the design concepts for a commercial demonstration plant. The design was completed in April of 1979.

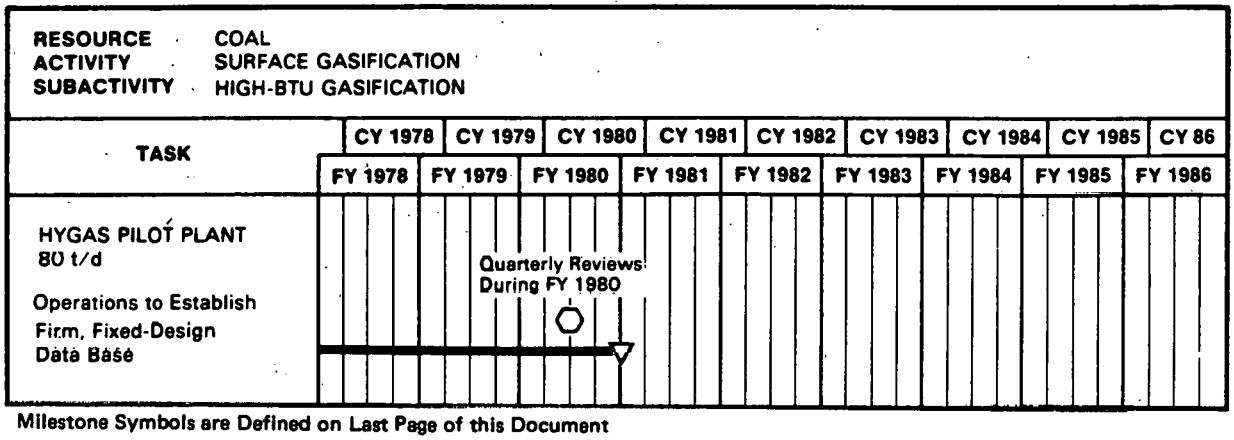
During the operational phase to support the process design work, several periods of steady state operation were achieved. The longest steady state period was 59 hours at a char conversion of 77 percent. Subsequent to completion of the Procon design work, one of the most significant tests accomplished in the HYGAS plant was test run No. 79. A run-of-mine coal was processed during a 178-hour (7.5 days) steady-state period. Char conversion averaged 75 percent. Only one interruption of 40 minutes, caused by the faulty operation of a slurry feed pump, occurred during the entire test.

Additional operations are necessary in attempts to establish a firm design data base. Major problems still occurring in the pilot plant are clinker formations and solids flow problems within the reactor. It is planned, therefore, to operate the HYGAS pilot plant through September 30, 1980 in an attempt to solve these problems.

A western Kentucky bituminous coal (seams 9 and 11) was tested for the first time in the HYGAS pilot plant during test run No. 83 which was conducted during the latter part of October 1979.

A conceptual commercial design effort was completed as part of the Demonstration Plant program. This effort is described in subsection 6.

In FY 1980, this pilot plant effort will be directed towards gathering data on a site-specific coal. These data will be used to further define some variables of a conceptual commercial design. The final design will permit the evaluation of the commercial potential of this concept of coal gasification.



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1.2 PEAT GASIFICATION

The Department of Energy has continued a peat gasification project begun in mid-1976. The purpose of this project, which is jointly supported by DOE and the Minnesota Gas Company (Minnegasco), has been to investigate the

kinetics and fluid mechanics of peat gasification. Fuel peats from Minnesota, North Carolina, and Maine have been studied in several laboratory reactors. The gasification reactivity of peat is two to three times higher than lignite for a broad range of temperatures and pressures. Rockwell has extended these results for more severe reaction conditions in a task also funded by DOE. The DOE/Minnegasco project (with the actual work conducted by the Institute of Gas Technology,(IGT) has also performed preliminary economic studies for converting peat to SNG. The results should not be interpreted too literally, since only bench-scale pilot gasification data were available. However, the estimates indicate that an expanded DOE peat gasification program is justifiable from an economic as well as a technical standpoint.

A broad-based Federal peat program has been formulated and is presently being implemented. The overall program strategy is to develop a technology for converting peat to substitute natural gas in an economical and environmentally acceptable manner.

The following program objectives address the technical problems and issues that must be resolved satisfactorily before committing the peat resources in the United States to a large-scale program for converting peat to SNG:

- Determine more precisely the locations and amounts of fuel-peat reserves in the United States.
- Determine in an expeditious manner the environmental and socioeconomic impacts of large-scale peat utilization.
- Develop an economic and commercial peat hydraulic harvesting technology.
- Develop an economically feasible method for reducing the moisture content of peat to 50 percent or less.

The DOE Peat Gasification subactivity is comprised of five project areas:

- Resource Estimation
- Dewatering
- Gasification Development
- Environmental Impact Assessment
- Socioeconomic Impact Assessment.

Project Status

Resource Estimation

The DOE objective is to determine the amount and location of fuel-grade peat that may be harvested and utilized in an environmentally acceptable manner. DOE has been encouraging participation in the Federal peat program of states having significant peat deposits and which are interested in determining the energy potential of peat. At the present time, six states

(Maine, Minnesota, Michigan, North Carolina, South Carolina, and Alaska) are participating in joint DOE/State Peat Resource Estimation projects.

Dewatering

The most significant technical obstacle to gasifying peat is the reduction of its moisture content to acceptable levels (approximately 50 percent). Peat dewatering poses a severe technical obstacle for direct combustion, liquefaction, and other energy applications.

The U.S. Department of Energy is supporting the development of alternative peat dewatering techniques:

- Wet Carbonization: Minnegasco is jointly supporting this task (performed by IGT) to study the chemistry (kinetics, selectivity, etc.) of wet carbonization.

- Solvent Extraction: Minnegasco is also providing joint support for this task. The major focus of this investigation is to test the performance of various organic solvents in removing water from peat. Preliminary economics will be estimated.

- Long-Range Research and Development: In the future, DOE will be sponsoring studies for determining the nature of the affinity of peat for water, e.g., colloidal, hydrogen bonding, etc., and the development of novel dewatering techniques.

Gasification Development

There are several DOE gasification projects that are being performed in parallel. It has already been determined that peat is very reactive to gasification. In addition, a considerable amount of information that has been derived from the operation of coal gasification pilot plants can be judiciously extrapolated and utilized for the special case of peat gasification. It is expected that the equipment required downstream of a peat gasifier to process the raw product gas would be virtually identical to the downstream processing requirements for coal-derived raw product gas.

The following gasification projects directly address the technical concerns associated with gasifying peat and reflect the DOE position to develop promising long-range alternative technologies for converting peat to substitute natural gas:

DOE/Minnegasco Peat Gasification: This study (performed by IGT) is determining the kinetics and fluid mechanics of peat gasification. The preliminary economics of converting peat to SNG are also being estimated.

DOE/Minnegasco Low-Severity Hydropyrolysis: The chemistry of peat gasification is being studied at lower temperatures and pressures. It is of particular importance to understand the effect of gasification conditions upon the yield of liquids (benzene and other gasoline blends).

DOE/Minnegasco Peat Biogasification: This is a laboratory-scale project to develop the concept previously described for converting peat directly to

methane using a partial oxidation reactor and biological reactor (bacterial digestion). This project is focusing on the effect of the specificity of the partial oxidation reactions on the performance of the biological reactor.

Rockwell Peat Gasification: A task has been initiated to study the gasification of peat in the Rockwell short-residence-time (SRT) entrained-bed gasifier. The results will complement the IGT kinetic work and complete the peat kinetic envelope (since the experiments will be performed at severe conditions of temperature and pressure).

UOP/SDC Peat Gasifier Assessment: UOP/SDC, as part of its support contract to DOE, will recommend a peat gasifier configuration (fluidized bed, entrained bed, etc.) for testing in a DOE peat gasification pilot plant project. This recommendation will be based on a review of available peat gasification results and application of fundamental chemical reaction engineering principles.

Pilot Plant Modification: DOE is preparing to conduct peat gasification tests at a pilot-plant scale. These preparations include the procurement of equipment necessary to modify the pilot plant selected for these studies. This equipment includes a peat dryer and grinder, and a peat storage and preparation facility. Further modifications include a dual lockhopper feed system and a peat gasifier, depending on results of independent UOP/SDC study.

Environmental and Socioeconomic Impact Assessments

Each of these project areas will be performed in three phases:

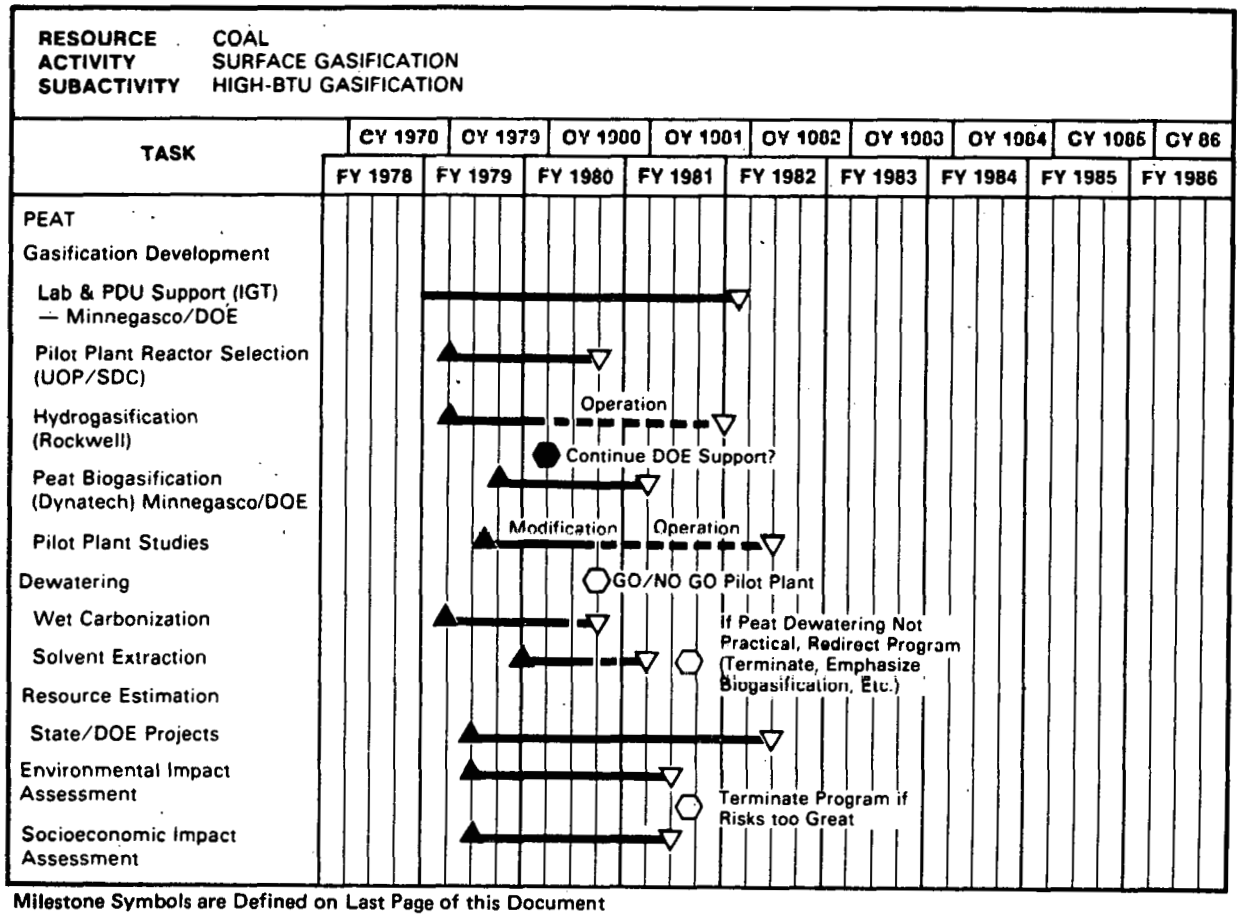
- Phase I. Identification of Problems and Issues: UOP/SDC (Environmental) and Radian Corporation (Socioeconomic) are identifying the problems and issues associated with large-scale peat gasification. A list of items to be considered will be prepared. UOP/SDC and Radian Corporation will also establish a mechanism whereby the states participating in joint projects (resource estimation) can address the identified issues.

- Phase II. Gathering Data on Identified Issues: The joint DOE/state projects will be expanded to include tasks to gather the environmental and socioeconomic data for the issues identified in Phase I. These data will serve as inputs for Phase III.

- Phase III. Overall Environmental and Socioeconomic Impact Assessments: Several case studies will be performed to assess the environmental and socioeconomic impacts of an integrated gasification process in representative regions. The evaluation criteria will be uniform for each case study. This approach is designed specifically to provide a reasonable cross section of environmental circumstances. This will enable localities to interpolate between case studies to extract information, which is applicable to their peatland, in order to formulate specific environmental and socioeconomic impact assessments. The intent is for the complementary environmental and socioeconomic impact assessments to provide information that would be required for a

locality to decide whether to utilize its peat resources. The contracts to perform these assessments will be awarded in the beginning of FY 1981.

A GO/NO GO decision concerning DOE support of a peat gasification pilot plant project will be made during FY 1980. The decision on whether to commence pilot plant testing at the beginning of FY 1981 will depend upon the preliminary results from the dewatering, environmental, and economic impact assessment tasks.



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Engineering Evaluations

The engineering evaluations task supports the joint DOE/GRI High-Btu Gasification program. The following projects, with the exception of those noted, represent the current combined DOE/GRI program:

- HYGAS (Steam Oxygen)[1]
- Bi-Gas[1]
- Peat Gasification
- Exxon Catalytic Process
- Westinghouse Fluidized-Bed Process
- Rockwell Short-Residence-Time Hydrogasifier
- Bell Aerospace Textron-High Mass Flux Gasifier.

The objectives of this program are to (1) develop each process to its maximum potential, (2) gather data essential for process evaluation, (3) identify candidate processes or a combination of component processing steps that will have the greatest commercial potential, (4) carry out commercial plant concept designs, and (5) identify knowledge gaps; i.e., data, materials, and equipment required to construct a commercial gasification facility.

Specifically the significant efforts for FY 1980 include:

- Continuing and monitoring all operational activities for those projects mentioned herein.

- Performing design reviews, data analyses, and engineering evaluations of proposals, cost estimates and monthly progress reports to provide information considered essential to the overall objectives of the combined DOE/GRI program.

- Conducting mechanical design studies in those areas deemed necessary since mechanical problems are concerned with those items ultimately influencing the economics of the equipment.

- Providing recommendations based on technical and economic considerations, to identify programs which show advantages over existing technology. PDU screening evaluations (economics, operability, and safety) have been underway and are nearing completion.

- Continuing safety assurance studies for the PDU developmental projects, and updating previous studies of the pilot plant programs. A detailed investigation of the pilot plant and PDU gasifiers will be performed to identify operating conditions on equipment deficiencies that could lead to potential hazards.

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[1]Since these projects were previously in the DOE/GRI combined program, there was mutual agreement that these programs would be included as part of the technical evaluation program that Pullman-Kellogg is presently conducting.

- Conducting certain process studies to determine the most practical means for performing the unit process steps that will be investigated.

- Carrying out factored estimates and conceptual designs studies as warranted.

- Continuing the evaluation, in conjunction with the Metals Properties Council, of materials of construction for commercial plant designs. This evaluation includes monitoring of and recommendations to ongoing materials test programs.

2.0 LOW-BTU GASIFICATION

The potential market for clean-burning low-Btu gas as a fuel for electric utilities and industrial users has increased as a result of the energy crisis, the decrease in natural gas reserves, and more stringent environmental regulations. The Low-Btu Gasification subactivity is attempting to satisfy the demands of this increasing market by:

- Developing and demonstrating in cooperation with industry, the technology needed for construction of commercial-scale plants to convert coal to environmentally acceptable gaseous fuels with a heating value of 100 to 500 Btu/scf

- Establishing the required techniques for utilizing these coal-derived gaseous fuels for chemical feedstocks, and industrial fuels

- Developing and demonstrating new and improved gasification processes for the production of either a medium- or low-Btu gas as well as a synthesis gas.

Low-Btu gasification is a promising method of using coal as a utility and industrial fuel in an economic and environmentally acceptable manner. The generation of low-Btu gas from coal requires a less complex plant than that required for production of high-Btu gas. As a result, capital and operating costs are lower per equivalent Btu. In addition low- as well as high-Btu gasification technology can be used to produce a medium-Btu gas. This coal-derived fuel/synthesis gas with a heating value of 240 to 375 Btu/scf can be produced at less cost than pipeline gas. It may be utilized with only minor modifications in most existing facilities designed for burning natural gas or fuel oil. This same gas can be used as a feedstock for several conversion processes that can convert these synthesis gases to a number of liquid fuels and chemicals.

As part of this subactivity, promising new concepts for improved gasification techniques are being actively developed at the PDU and pilot plant levels. These include fixed-bed, entrained-bed, fluidized-bed, and molten salt systems.

2.1 FIXED-BED GASIFICATION

In a fixed-bed coal gasification reactor the coal is fed from the lockhopper into the top of the gasifier. This coal moves slowly downward

counter-current to the gas streams moving upward. The reactor has three distinct areas. In the top of the reactor, coal is heated by the hot product gases and is partially devolatilized. In the middle section, the coal reacts with the hot gases coming from the bottom of the reactor to produce volatile products and char. Char is gasified in the bottom section with air/oxygen and steam leaving the ash behind. The steam and air/oxygen are introduced below an ash-discharge grate near the bottom of the gasifier. Gasifier temperatures range from 2400°F just above the grate to 800° to 1200°F at the gas exit. In most cases a water-cooled stirrer is used to control caking of the coal and to eliminate voids.

From the gasifier, the off-gas is passed through a cyclone and a tar condensor to remove particulates and tar. It is subsequently scrubbed with water in a venturi scrubber, passed through a disengaging chamber and a direct cooler/scrubber for final cleanup and cooling. H_2S is removed and converted to sulfur in a Stretford plant. The clean, pressurized fuel gas is suitable for a number of end uses or further processing.

Project Status

The 42-inch diameter, stirred fixed-bed gasifier at Morgantown Energy Technology Center (METC) has been in operation for several years. Continuing improvements in the gasifier and its support systems have resulted in a versatile system for the study of fixed-bed gasification phenomena. A recently completed Holmes-Stretford gas cleanup system will provide increased capabilities to perform complex fixed-bed test programs on a pilot plant scale. The data from these studies can be used to design fixed-bed gasification systems capable of operating in caking coals containing large percentages of fine material. In addition, these data taken with sophisticated instrumentation systems will contribute greatly to the understanding of coal gasification phenomena.

During FY 1980, the new Holmes-Stretford system will be connected and made operational. Concurrent with this activity the operation of the gasifier will be continued to further explore the parameters that control the gasification process. The movable stirrer will be used to the maximum advantage in these studies.

Slagging Fixed-Bed Gasification Process

In a slagging fixed-bed gasifier, the coal periodically charged by means of a lockhopper moves by gravity flow into the reactor. Some cooled product gas is compressed and recycled through the coal lock to prevent steam and tar vapors from entering the coal lock and condensing on the incoming coal. The coal moves through the gasifier in the same manner as in a dry ash system. However, in the slagging gasifier the coal is continuously gasified by an oxygen-steam mixture introduced through four water-cooled layers located near the bottom of the gasifier. In this system, higher temperatures at the hearth form molten slag which flows out of the gasifier through a central tap hole into a water quench bath. Gas from the high-temperature reaction zone can be drawn through the tap hole to promote slag flow. This gas is cooled and metered in a separate circuit.

The product gas leaving the gasifier at temperatures similar to those from a dry ash system (800° to 1200°F) contains water vapor and tar products. To remove these condensible impurities the gas is scrubbed in a spray cooler. The gas liquor collected in the spray cooler is periodically discharged to a settling tank. The washed gas is cooled to 60°F before being metered, sampled and flared. The heating value of the gas is approximately 350 Btu/scf.

Project Status

The slagging fixed-bed gasification facility at the Grand Forks Energy Technology Center was constructed and operated under the Bureau of Mines during the period 1958-1966, to demonstrate the feasibility of slagging operation and assess operational parameters. Operations were resumed in 1976 to investigate the environmental concerns associated with commercial-scale fixed-bed coal gasification. In September 1978, gasifier operation was suspended for modification to update the existing equipment and to expand the operational capabilities. The gasifier is expected to handle both caking and noncaking coals for plants with a duration of five to seven days.

The modification and installation was completed in 1979. Shakedown will be accomplished during FY 1980 by gasifying lignite. Following that, tests are planned on coals of increasing caking tendency. Products, by-products, and effluents will be characterized to support environmental assessment and industrial hygiene studies. Laboratory studies on biological and physical/chemical treatment of gas liquor will be continued.

2.2 FLUIDIZED-BED GASIFICATION (PRESSURIZED)

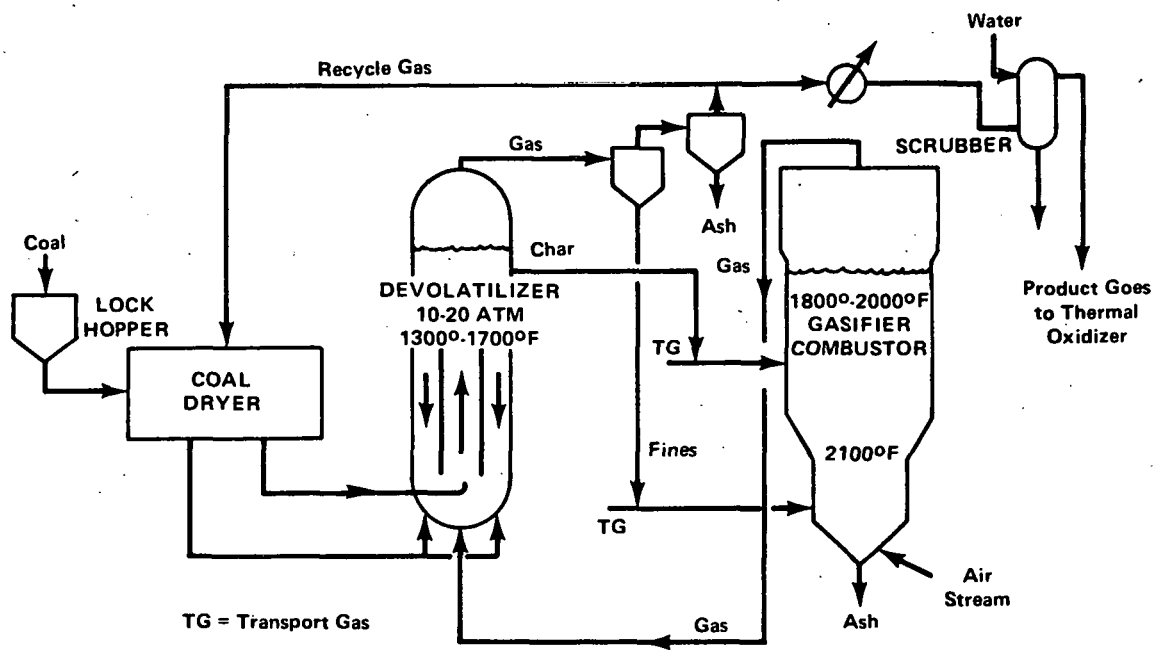
Two-Stage Pressurized Process

This project focuses on development of a low-Btu gasification process capable of using caking coals without pretreatment. The conceptual process consists of two principal process units: a pressurized fluid-bed devolatilizer and a fluidized-bed gasifier-combustor.

Crushed coal is dried and introduced to the devolatilizer unit through a central draft tube. The coal and recirculating char are carried upward by hot gas flowing from the gasifier-combustor. This gas provides most of the heat to the unit; it devolatilizes and partially hydrogasifies the coal. The recycle solids, descending in the annular downcomer, are needed to dilute the feed coal and to temper the hot inlet gases. A high ratio (up to 40:1) of recycle solids to coal feed is maintained to prevent or control agglomeration of the coal as it passes through its plastic phase. A dense, dry char is withdrawn at the top of the draft tube.

Char from the devolatilizer and fines removed from the product gas are burned with air in the lower leg of the gasifier-combustor at 2100°F to provide gasification heat. Steam is injected into the same area for temperature control and to provide hydrogen for gasification. Ash from fines combustion agglomerates on the char ash and segregates in the lower leg for removal. Gasification occurs in a fluidized bed in the upper portion of the gasifier-combustor.

The hot low-Btu gas from the gasifier-combustor improves in heating value as it passes through the devolatilizer. The product gas from the devolatilizer is stripped of fines and ash in cyclones, cooled, and then scrubbed with water. The product gas heating value is 120 to 150 Btu/scf.



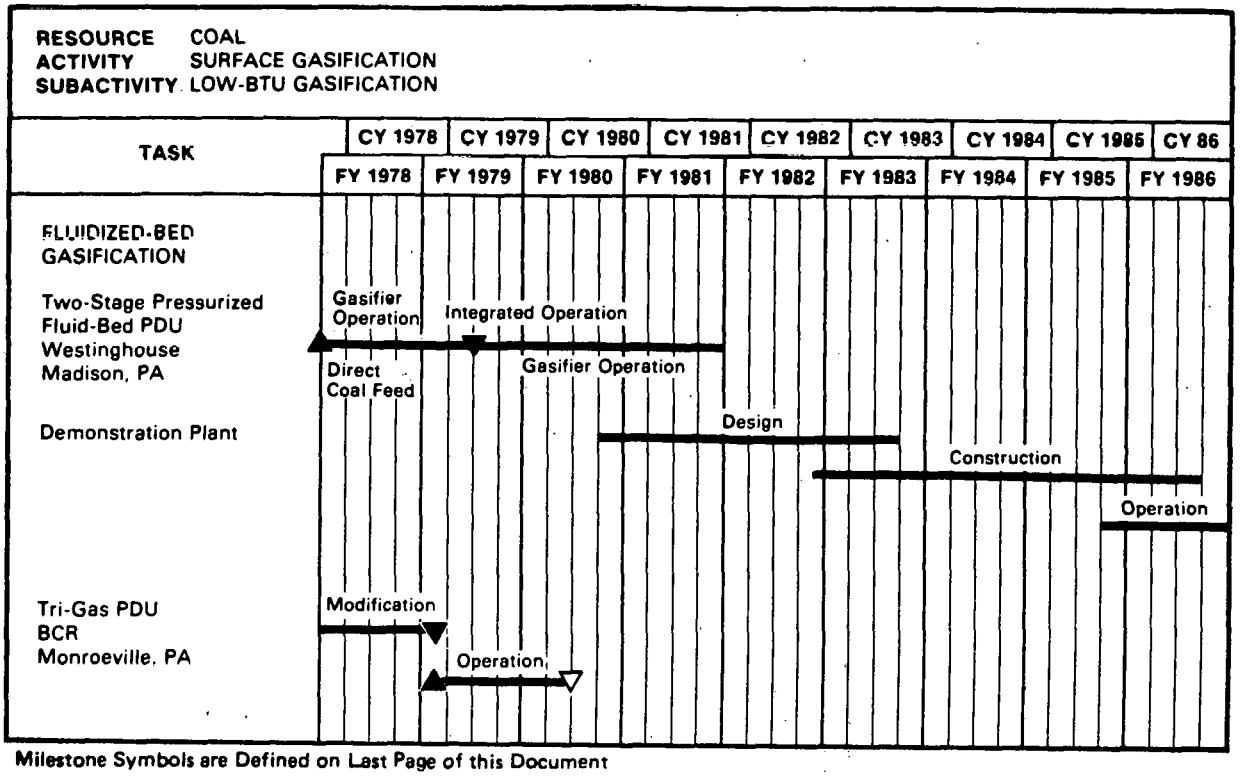
Fluidized-Bed Gasification, Two-Stage Pressurized Process

Project Status

During CY 1979, the two-stage PDU was run in the integrated mode. Two air-blown gasification tests were accomplished during the March-May 1979 period with successful gasification of Pittsburgh seam 8 coal. The PDU was then converted to single-stage oxygen-blown operation, and testing with Pittsburgh No. 8 and Ohio No. 9 coal was conducted through August. The purpose of this testing was to optimize gasifier performance; however, difficulties were encountered when operating at low steam-to-coal ratios. At the end of August, it was decided to modify the coal/oxygen steam feed system to remedy these problems. The PDU was then converted to the air-blown single-stage mode, and tests were conducted in this mode for the remainder of the year. Accomplishments for the year include successful demonstration of two-stage integrated process operation; data on enhanced methane production in the two-stage mode over single-stage gasification; significant process performance and optimization data for oxygen-blown gasification, with operation at low steam-to-coal ratios, which is an indication of good efficiency and low-cost gas production; significant process performance and optimization data for air-blown gasification with several coals. Since results to date indicate that single-stage gasification will be a simpler and more economical system, testing during CY 1980 will emphasize that mode of operation. Tests will be run with both air and oxygen.

Tri-Gas Process

It is anticipated that this effort on a three-stage pressurized fluidized-bed concept of coal gasification will be terminated in February 1980, when the current contract is scheduled to expire. No further developmental effort is anticipated at this time.



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2.3 ENTRAINED-BED GASIFICATION, ATMOSPHERIC PROCESS

This project includes the development of a gasification and cleanup system that can be integrated with an electric generation plant.

The Combustion Engineering, Inc. (C-E) gasifier consists of two sections: a combustion chamber that burns a portion of the pulverized coal and recycle char to provide heat to the gasifier, and a reducing chamber where the remainder of the pulverized coal is reacted with steam and hot gases from the combustor to produce low-Btu gas. Nearly all of the ash in the system is withdrawn from the combustor as molten slag. The gasifier is an entrained-bed reactor operating at atmospheric pressure.

The product gas, with a heating value of approximately 120 Btu/scf, leaves the gasifier at 1600°F and enters the heat recovery train mounted on the gasifier. In this section, the hot gases pass over an evaporator and economizer to provide high-pressure steam for the steam turbine. A process steam boiler provides steam for the gasifier. The gas leaves the heat recovery train at less than 300°F.

The gas cleanup section includes a spray dryer, cyclone, and raw gas scrubber. Chars and fines from this operation are recycled to the combustor, and H_2S is removed by the Stretford absorber.

Product gas is burned with preheated air in a boiler providing additional heat to the steam from the evaporator-economizer system. Water and CO_2 in the gas feed assist in reducing NO_x in the flue gas by reducing the temperature.

The atmospheric entrained-bed gasifier offers the following advantages:

- All coals can be processed without pretreatment.
- There is no net char production.
- Fused ash is produced, minimizing disposal problems.
- Virtually all carbon in the coal can be consumed.
- All components except the gasifier are commercially available items with predictable operating characteristics.

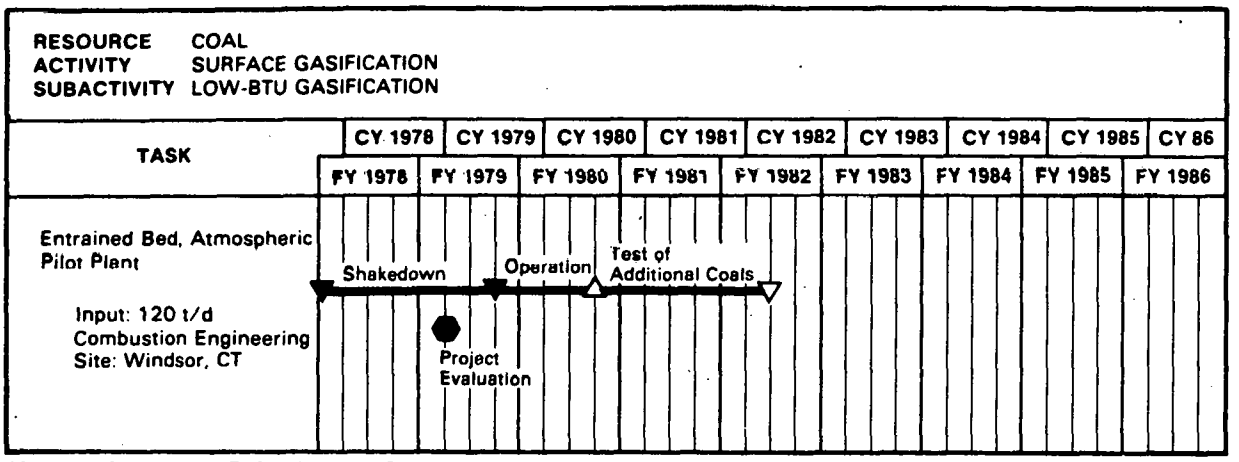
Project Status

C-E has contracted for a 3-phase project consisting of design, construction, and operation of a 5-ton/hr pilot plant at Windsor, Connecticut. Under Phase I of the project, the pilot plant was designed and evaluated to determine technical and economic feasibility of the process. This phase included the detailed engineering design of all components, an evaluation of materials of construction, a safety analysis, sampling requirements, an automatic data logging system, an environmental review, and mathematical modeling of the process. R&D support consists of studies on corrosion and erosion of refractory material, and a dynamic flow model to provide design information for the optimization of gasifier geometry and for nozzle design and placement. A study of expected operating characteristics and control requirements of a commercial-size system was conducted to develop control system designs. A test project for operation of the pilot plant was defined.

Phase II, pilot plant construction, was completed in FY 1977. This phase involved site preparation, purchase and fabrication of equipment, and installation. Phase III, shakedown testing, was started in December 1977. The parametric test program was initiated in June 1978. During operation through CY 1979, only one coal has been tested, but the C-E system already has demonstrated many of the merits necessary for successful application to electric power plant use. No tar has been detected in the product gas at the pilot plant. Good ash slagging performance of the gasifier's combustor has been demonstrated. Typically less than 0.5 percent carbon is analyzed in the gasifier ash. The gasifier has demonstrated the capability for quick shutdowns and restarts, and is expected to follow load easily. The Stretford H_2S removal system at the pilot plant has consistently demonstrated the ability to reduce H_2S concentration in the product gas to the 20 to 50 ppm level, and possible testing of CO_2 removal equipment to further reduce sulfur emissions is now under consideration. Finally, the atmospheric pressure construction

and operation of the system has proven that it is easy to build and maintain and safe to operate with minimum operating personnel. Over 1,600 hours of gas-making test operation was accomplished during FY 1979.

The test program with the design coal will be completed during FY 1980. Preparations will be made for testing additional types of coal, and for oxygen-enriched, air-blown gasification testing during 1981.



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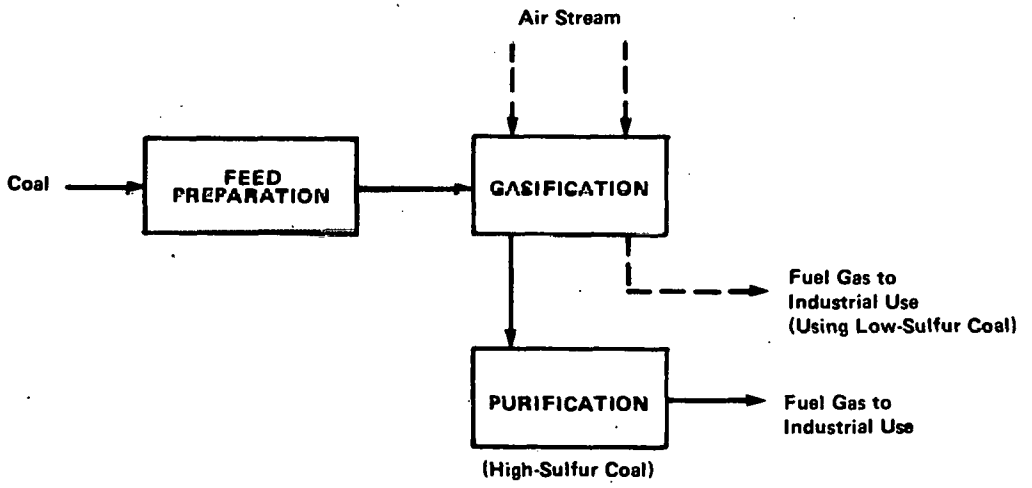
2.4 GASIFIERS IN INDUSTRY

This program promotes the use of low-Btu gas in one or more industrial processes, for steam boilers and chillers for direct process heat, and in industrial dryers and kilns. Its objective is to demonstrate the integration of a low-Btu gasification system with industrial end-uses, using present day state-of-the art components.



Gasifiers in Industry

Coal will be gasified at the industrial plant, and the resulting gas will be cleaned as required for the specific application. Transportation costs dictate that low-Btu gas be utilized near its point of production. Therefore, factors controlling the connection of the gasifier to an end-user of the gas must be evaluated. These factors will determine acceptability of coming advanced gasification techniques.

Project Status

Small-sized individual gasifiers are commercially available. Under this program they will be the forerunners of synthetic fuel conversion from coal in industry. The Federal program is of short duration. It focuses on the use of caking coals, of two-stage gasifiers which have not yet been demonstrated on U.S. coals, on the modernization of single-stage gasifiers, and on the evaluation of environmental acceptability. A PON called for proposals to achieve these objectives. Seven contractors were selected. Projects are discussed individually below and significant milestones are shown.

1. The Glen Gery Brick Company (with Acurex-Aerotherm) has instrumented an existing Wellman-Galusha gasifier. This gasifier is producing low-Btu gas from anthracite coal, and the gas is being used to fire a brick kiln at Glen Gery's plant in York, Pennsylvania. Valuable information has been obtained on selection and operation of instruments for measuring gasifier performance. Operational data, including material and energy balances have been collected. Operation of this gasifier under the DOE agreement was completed in June 1979, and a complete operational report will be available January 1980. Total estimated cost was $1.47 million. DOE's share was $0.72 million (50 percent cost-sharing).

2. University of Minnesota (with Foster Wheeler) will use a low-sulfur Wyoming bituminous coal to produce low-Btu gas as fuel for an existing natural-gas-fired boiler. A two-stage STOIC gasifier will be used to produce a gas low in particulate matter. The heavy oil contained in the top gas will be removed by an electrostatic precipitator and collected. This oil has properties similar to No. 6 oil and will be stored for use during the coldest months.

The design effort on this project has shown that substantial modifications of existing foreign designs are required to provide reliable, environmentally acceptable operation in the United States. Startup of the gasifier was completed in mid-CY 1979. The first year of continuous operation and detailed data gathering is planned for FY 1980. Four additional years' operating and maintenance data will be collected. The total estimated cost of this project is $5.5 million. The DOE share is $2.5 million (46 percent cost-sharing).

DOE is planning an environmental monitoring program for this project which will define and characterize emissions and their effects on the environment. This program is being coordinated with EPA and NIOSH.

3. Pike County, Kentucky (with Stearns-Rogers) will produce gas from a Kentucky bituminous coal, a caking variety which requires a gasifier with an agitator. Thus, a Wellman-Galusha gasifier equipped with particulate removal

devices will be used. Gas produced will fire a steam boiler, used for heating and cooling several facilities within the Douglas site, including housing, a school, a nursing home, a fire station, and commercial facilities.

Detailed design, procurement and installation of the gasifiers, chillers, and boilers were completed. Due to an expansion of the original job scope to include a gas desulfurization unit, construction halted until an integrated plant design could be completed. It is anticipated that construction will resume in November 1980, after a new cost estimate and project baseline have been established.

The environmental aspects of this installation will also be monitored in the joint DOE, EPA, NIOSH program. Details are currently being developed.

4. Can-Do (EBECO) will use anthracite to produce a low-Btu gas as a fuel for an industrial park in Hazelton, Pa. A single-stage Wellman-Galusha will be used to produce a cold and clean fuel gas. The design of the facility is complete and construction began the beginning of FY 1980. DOE will contribute funding of $0.8 million for startup and two years of operation.

5. General Refractories (with Holly, Kenney, Schott, and Woodall-Duckham), now terminated, was to use gas to fuel tunnel kilns, periodic kilns, and dryers at its Hitchins, Kentucky, plant. A Woodall-Duckham two-stage gasifier was to be used.

Process and preliminary designs, as well as the cost estimate, were completed during FY 1978. Due to the cost of retrofitting the kiln burners and additional pollution control equipment, General Refractories terminated the project.

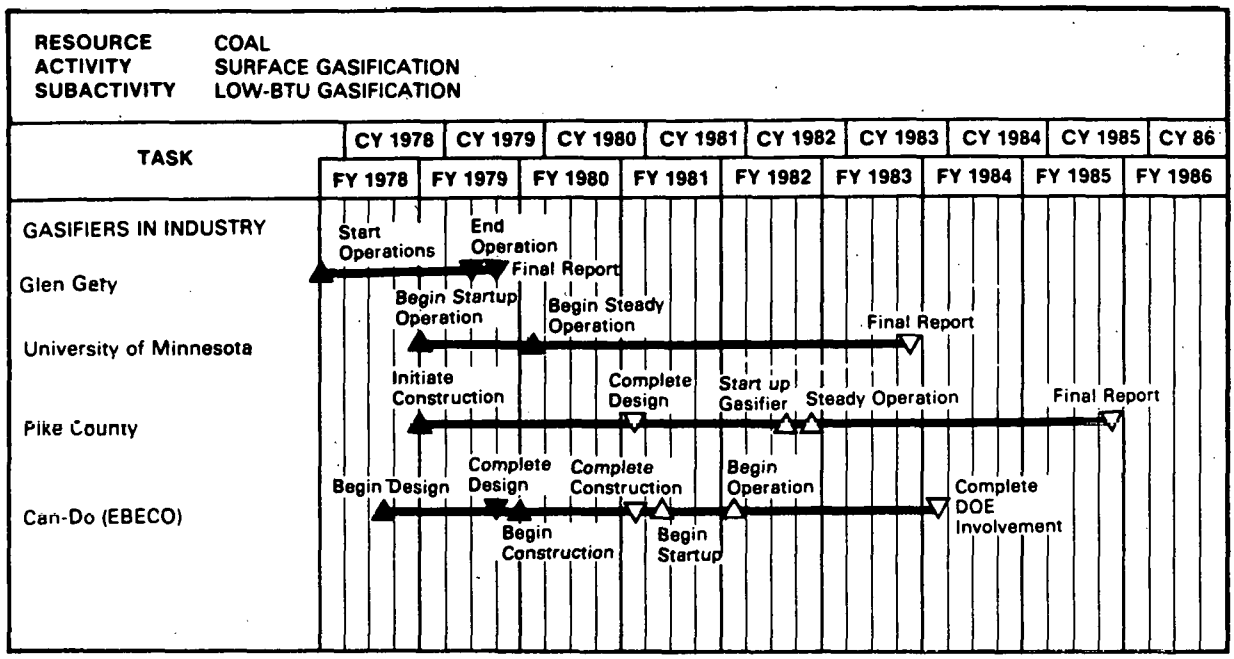
Estimated project cost was $4.2 million, of which the DOE share was $2.1 million (50 percent cost-sharing). DOE money expended prior to termination was $250,000.

6. Land O'Lakes, now terminated, was to use low-Btu gas to fire a boiler and a spray dryer at its Perham, Minnesota, plant. The use of low-Btu gas to spray-dry dairy products was unique and required careful design and extensive testing.

A two-stage gasifier was to be used. The design was to include extensive particulate removal for the stream used in spray drying. Particulates and condensibles were to be removed from the remainder of the gas. A low-sulfur, nonagglomerating bituminous coal from Utah was to be used. As a result of preliminary estimates, Land O'Lakes terminated the project because the projected return on investment was not sufficient.

Total estimated cost was $6.5 million. DOE's share was $3.25 million (50 percent cost-sharing). DOE expended $50,000 prior to termination.

7. Irvin Industries (with Mason and Hanger and the Kentucky Center for Energy Research), now terminated, proposed to use gas as fuel for a 172-acre industrial park at Georgetown, Kentucky. DOE evaluated the project and decided against its continuation into FY 1980.



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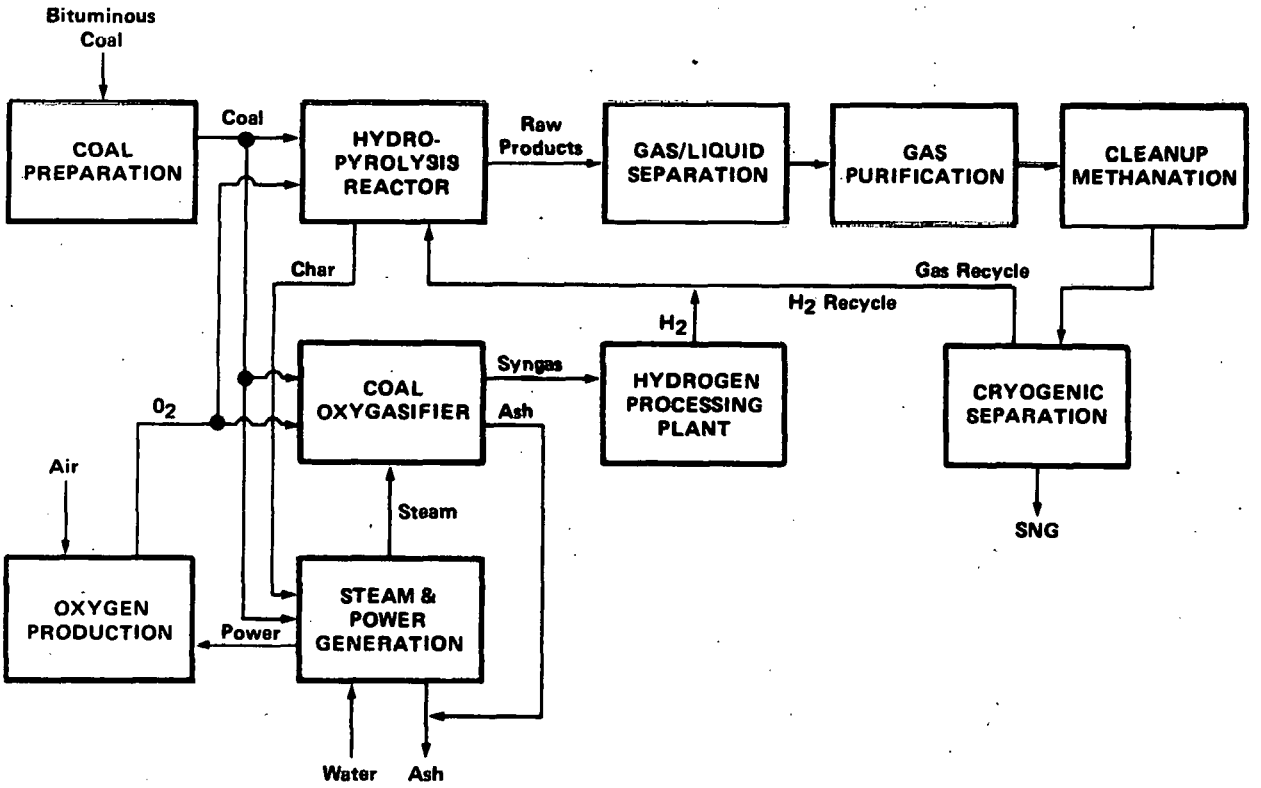
3.0 THIRD-GENERATION PROCESSES

In addition to the gasification projects described above, there are several newer advanced gasification concepts now at the bench scale or process development unit stage of development. These concepts, if successfully developed, offer the opportunity to reduce the costs associated with generating a substitute natural gas or synthesis gas from coal. The magnitude of the potential cost reduction serves as the incentive for the continued development of these concepts to the stage that the predicted advantages can be established. For pipeline gas applications, the following technology options are being developed: catalytic coal gasification, hydrogasification, and high mass flux gasifiers. In a similar manner, a molten salt gasification process is being developed for medium-Btu or synthesis gas applications.

3.1 HYDROGASIFICATION

Hydrogasification produces high-Btu gas by the direct reaction of hydrogen with coal. From a thermodynamics standpoint, this method has excellent potential for maximizing thermal efficiency and producing economical pipeline gas. The hydrogasification of coal to produce methane has an inherent thermochemical advantage in comparison with the catalytic methanation of synthesis gas produced by gasifying coal with oxygen and steam. This advantage was exploited in the early hydropyrolysis experimentation at the Bureau of Mines, which led to the development of the two-stage Hydrane process. As this process matured to pilot plant status, two independent developments occurred. In the first, Cities Service demonstrated a laboratory-scale, entrained-bed, single-stage hydrogasifier with short-residence-time characteristics. In the second, Rocketdyne showed potential for using rocket combustor technology to achieve improved mixing

with high feed throughput in a hydrogen/coal reactor. It was determined that the two-stage Hydrane reactor was too complex for commercial application, and that a single-stage, short-residence-time hydrogasifier based on rocket principles was a more attractive option. A conceptual flowsheet for the overall process is shown below.



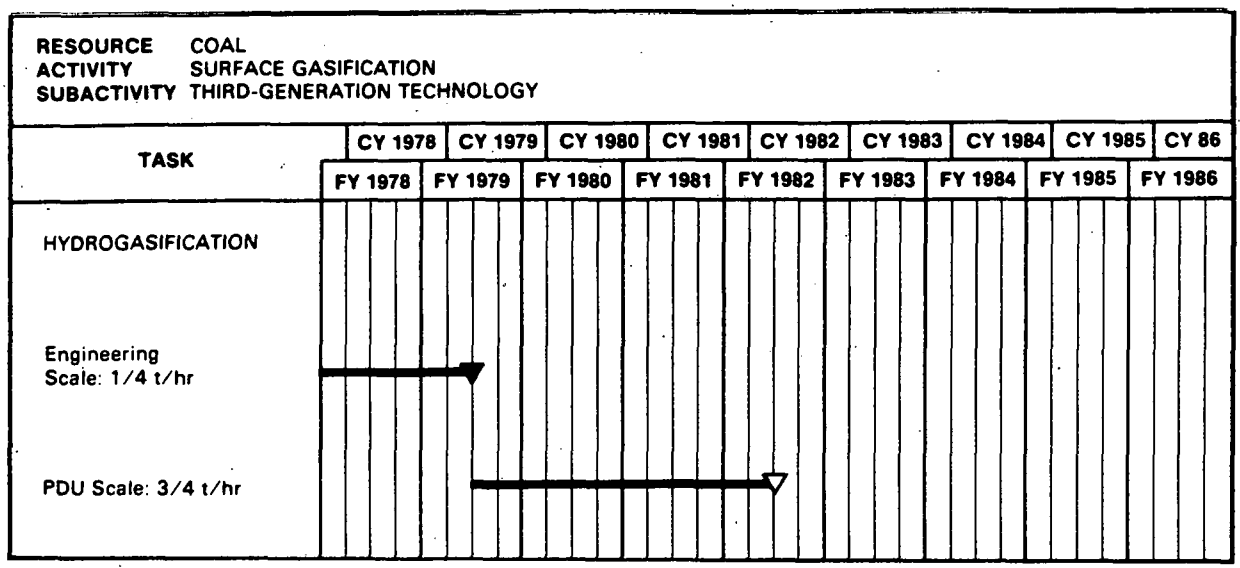
Hydrogasification Process

Project Status

Hydrogasification has been under development at the Pittsburgh Energy Technology Center since the early 1960s. A principal result was the Hydrane reactor. Current contractual efforts are geared to development of an advanced reactor concept with superior commercial potential. Strategy involves testing and development to generate data for use in commercial-scale plant design.

Exploratory development work under Contract EX-77-C-01-2518 was completed in August 1978. Work on this phase was performed at 2 levels of operation: 2 to 4 lbs/hr and 1/4 ton/hr. A new contract (ET-78-C-01-3125) was signed with Rockwell International for advanced development studies. The contract period for this is 3 years and tests were initially planned at 1/4 and 4 ton/hr levels. In January of 1979, Gas Research Institute joined the program. In subsequent reviews of the project, it was determined that 3/4 ton/hr was a more suitable scale of operation. Changes are currently underway to revise the work plan for this modification.

Currently, a 3/4 ton/hr experimental reactor development unit (RDU) is in place and operational. A 4 ton/hr hydrogasifier facility design was completed and "shelved." Work was accomplished on preparing a test site and ordering priority equipment. In addition, there was extensive progress on selection of an architect/engineer firm for a preliminary commercial-scale design. Design efforts are underway to complete an integrated PDU (3/4 ton/hr capacity) that will have sufficient operating flexibility to demonstrate all critical unit operations.



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3.2 CATALYTIC GASIFICATION PILOT PLANT

In the Exxon Catalytic Coal Gasification process, carbon monoxide and hydrogen are recycled to the reactor to keep the CO/H_2 content as high as possible, thus forcing the net products of gasification reactions to be CO_2 and CH_4. The recycle rate is set such that there is no net yield of CO and H_2 in the gasifier. Methane is separated cryogenically from the CO and H_2 and is removed as the only product.

Coal entering the system is impregnated with a potassium hydroxide catalyst prior to entering the reaction vessel, where the coal is gasified with steam at 1200° to 1300°F in the presence of equilibrium concentrations of CO and H_2. The gasifier product gas exchanges heat with incoming water, generating steam. The steam and recycled CO/H_2 are preheated to about 150°F above gasification temperatures prior to injection to balance system heat loss.

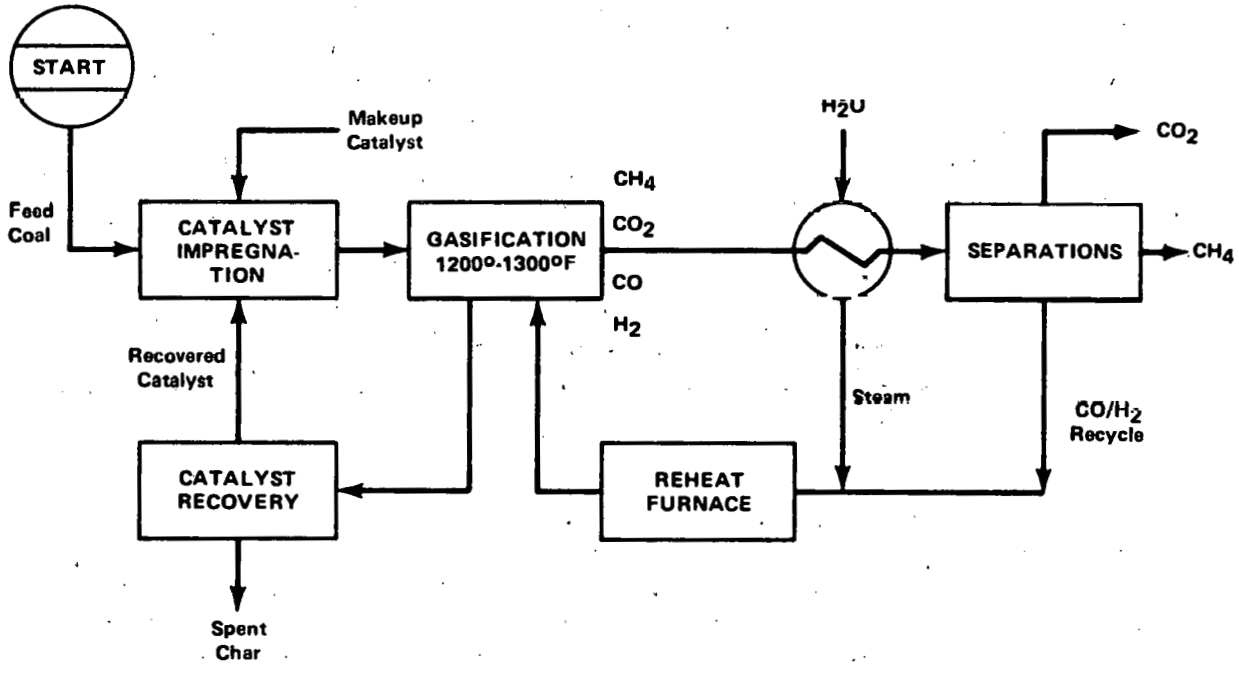
Char/ash residue containing catalyst is removed from the gasifier. Catalyst is recovered by water leaching through a countercurrent leaching operation. It is estimated that 80 to 90 percent of the catalyst may be reclaimed in this manner. Some catalyst reacts with coal-ash to form an insoluble potassium aluminosilicate, with about 5 percent weight of coal feed estimated lost in the insoluble form. Recovery of up to 90 percent of the

potassium by routes such as acid wash of char will undergo further investigation.

After cooling the product gas and generating the steam required for the process, the gas is sent to a series of separation steps to produce CO_2 (which is vented), product methane, and recycle CO/H_2.

Advantages of the Catalytic SNG process are:

- Pretreatment is not required for caking coals.
- The need for oxygen as a means of providing high-level heat directly in the gasifier is eliminated, so no separation plant is required.
- Gasifier temperatures are reduced to moderate levels.
- Shift and methanation steps are eliminated.
- Potentially higher thermal efficiency than that of thermal coal gasification processes is possible because of a reduced need for high-level heat input, thus greatly reducing heating and cooling of gas streams.

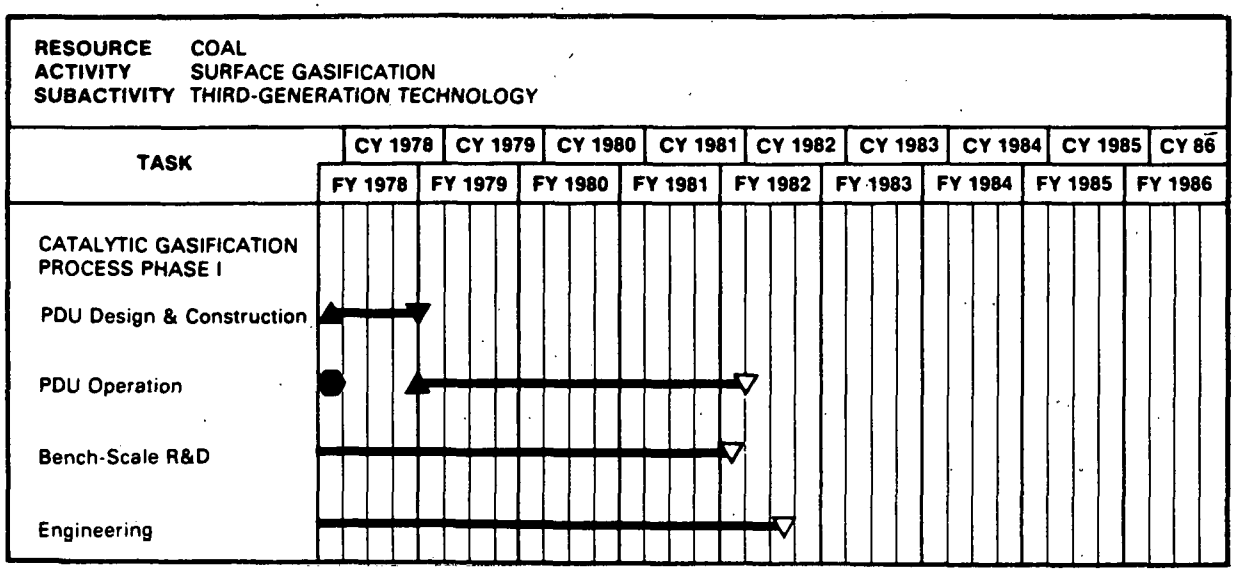


Catalytic Gasification Process

Project Status

The Catalytic Coal Gasification process is under development at Exxon's research facilities in Baytown, Texas, with DOE support. Exxon has performed support bench-work on catalytic gasification since 1968. The current plan is to continue bench-scale development to obtain information for design and operation of a pilot plant. PDU construction was initiated during FY 1978. Operation started in FY 1979 and will continue through FY 1980. Bench-scale R&D and engineering will be continuous through mid-FY 1981. An RFP for the transfer of technology from Exxon to a third-party process development company (possible licensor) is underway with competitive selection scheduled for late FY 1980.

A feasibility study, performed in October of 1978 by the Exxon Research and Engineering Company (ER&E), examined the alternatives of testing this process in a converted pilot plant vis-a-vis a new facility. The study concluded that retrofit of an existing plant was not cost effective. Basic and detailed design studies are continuing during FY 1980.



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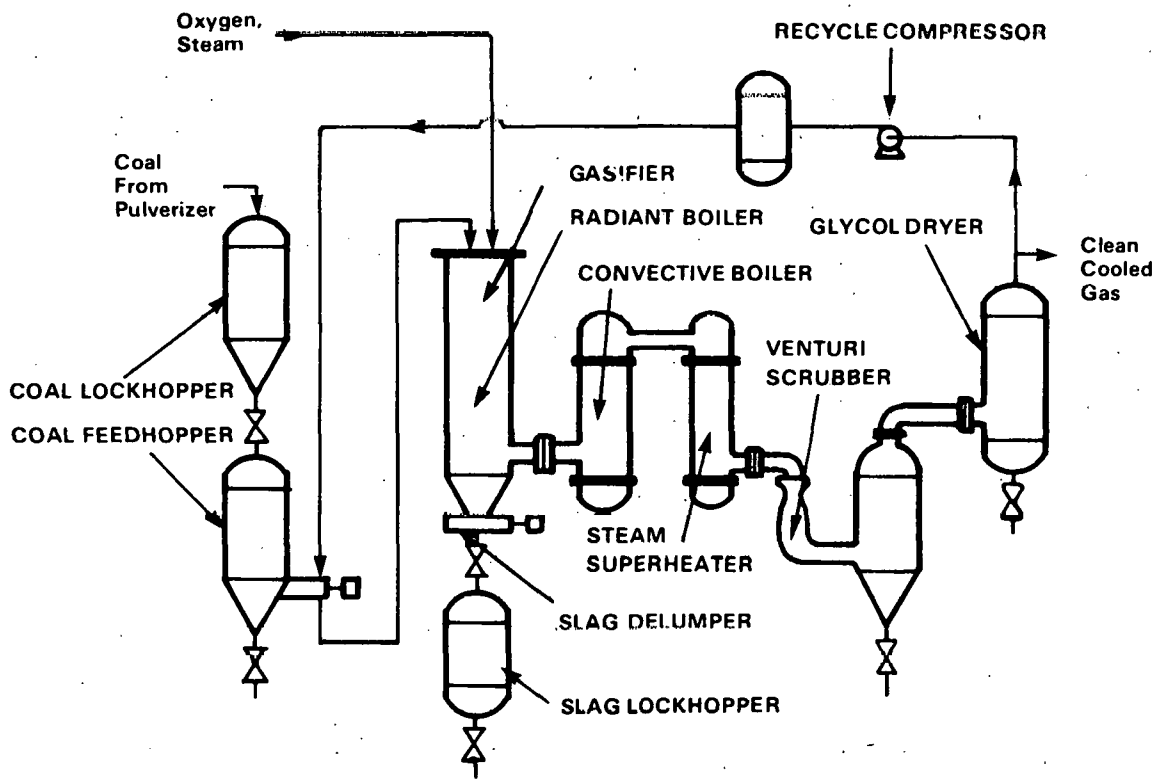
3.3 HIGH-RATE ENTRAINED-FLOW GASIFICATION

Development of a pressurized high-rate entrained downflow gasification process has proceeded from extensive laboratory testing to the detailed design of a 30 t/d PDU. The laboratory work was begun at the Eyring Research Institute in 1974 under sponsorship of the U.S. Office of Coal Research. An integrated system capable of continuous operation at feed rates up to 0.5 t/d was constructed and extensive testing has been carried out.

DOE is currently preparing to contract with Mountain Fuel Resources, Inc., (with Ford, Bacon and Davis Utah, Inc., as a subcontractor) on a 50/50 cost-share basis, for the construction and operation of a 30 ton/day PDU to be situated at the Interstate Brick Company located near Salt Lake City.

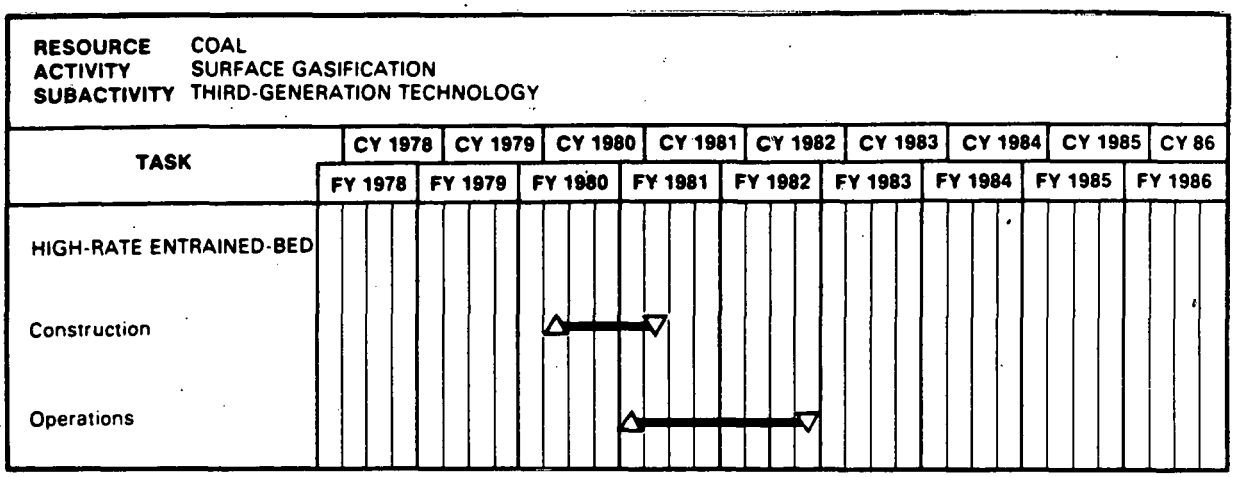
The work done to date indicates that the process offers the potential for two significant advantages over the current coal gasification technology. These advantages are: (1) lower capital costs, and (2) higher overall energy conversion efficiency. The principal technical questions that remain to be resolved during continued development are the design of feed nozzles and a high-temperature heat recovery unit that will provide reliable, long-term service. The planned project will seek to resolve these problems as well as to provide scaleup and long-term operational data. The following is a simplified flow design for the overall PDU.



30 Ton/Day Process Development Unit

Project Status

The detailed design of the 30 ton/day PDU is nearing completion. The cofunded project will take approximately 2-1/2 years and will cover two phases: construction and operation. It is anticipated that contract negotiations will be completed during the second quarter of FY 1980 and construction of the pilot plant will start thereafter.



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3.4 PROCESS RESEARCH/TECHNOLOGY DEVELOPMENT

High Mass Flux Gasifier

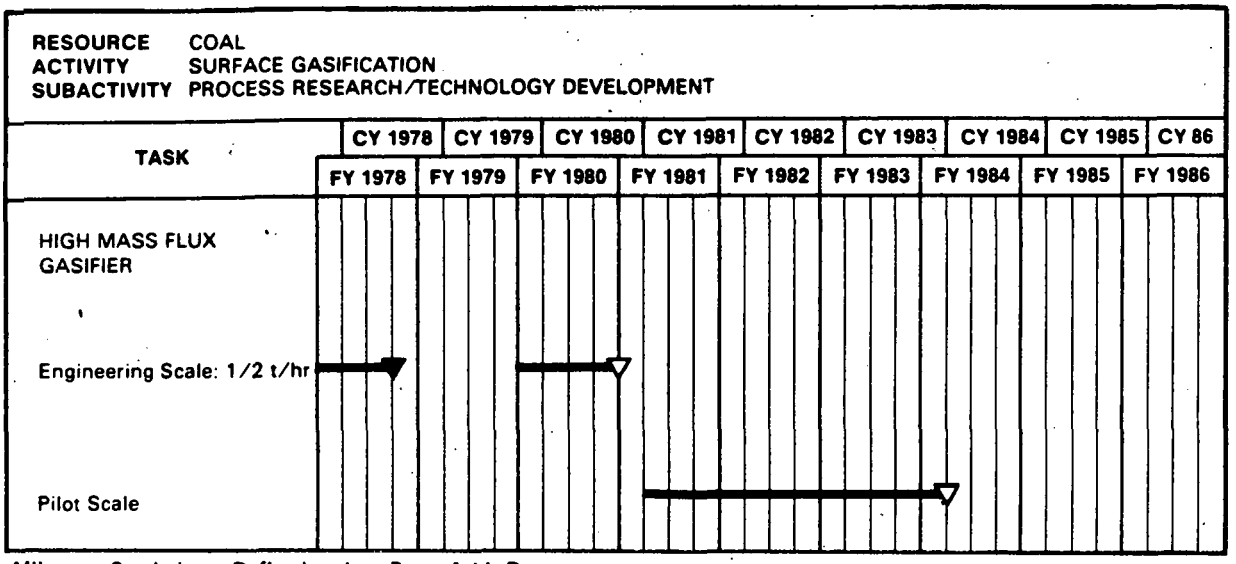
This program concerns the development of third-generation gasification technology based on techniques derived from rocket engine experience. In particular, it involves the investigation of a high mass flux reactor using coal, steam, and oxygen reactants to produce a medium-Btu synthesis gas.

The Bell HMF gasification principles were first applied to the production of low-Btu gas under Contract EX-76-C-01-2204. That program, which was funded at $1.2 million, was directed at demonstrating the feasibility of an air-blown system. It was initiated by ERDA in January 1976, and was effective through July 1978. Tests were conducted at a coal flow rate of 1/2 t/hr. The early portion of the program demonstrated the ability to achieve smooth ignition, stable operation, and reasonable performance in short duration tests. In the latter phase of that contract, attention was given to evaluating durability and performance of the gasifier in tests of up to one hour duration. Three coals were evaluated in 66 tests, most of these having been executed with lignite.

The current program, which is being co-shared by GRI, will be conducted at a coal flow rate of 1/2 t/hr. Testing will be performed at a reactor pressure of 225 psi. Particular attention is being focused on key technical factors, namely operation with steam, oxygen, and bituminous coal, secondary coal injection, performance efficiency, slagging operation, and material durability.

Project Status

During FY 1979, the High Mass Flux process was evaluated using a coal/steam-oxygen mixture as opposed to previous work using a coal/air mixture. Experimental work using coal/steam-oxygen mixtures will be continued by Bell Aerospace Corporation in FY 1980. In these studies, operating parameters will be optimized and scaleup factors investigated. Analysis and design efforts will be initiated toward the possible construction of a scaled-up HMF pilot plant.



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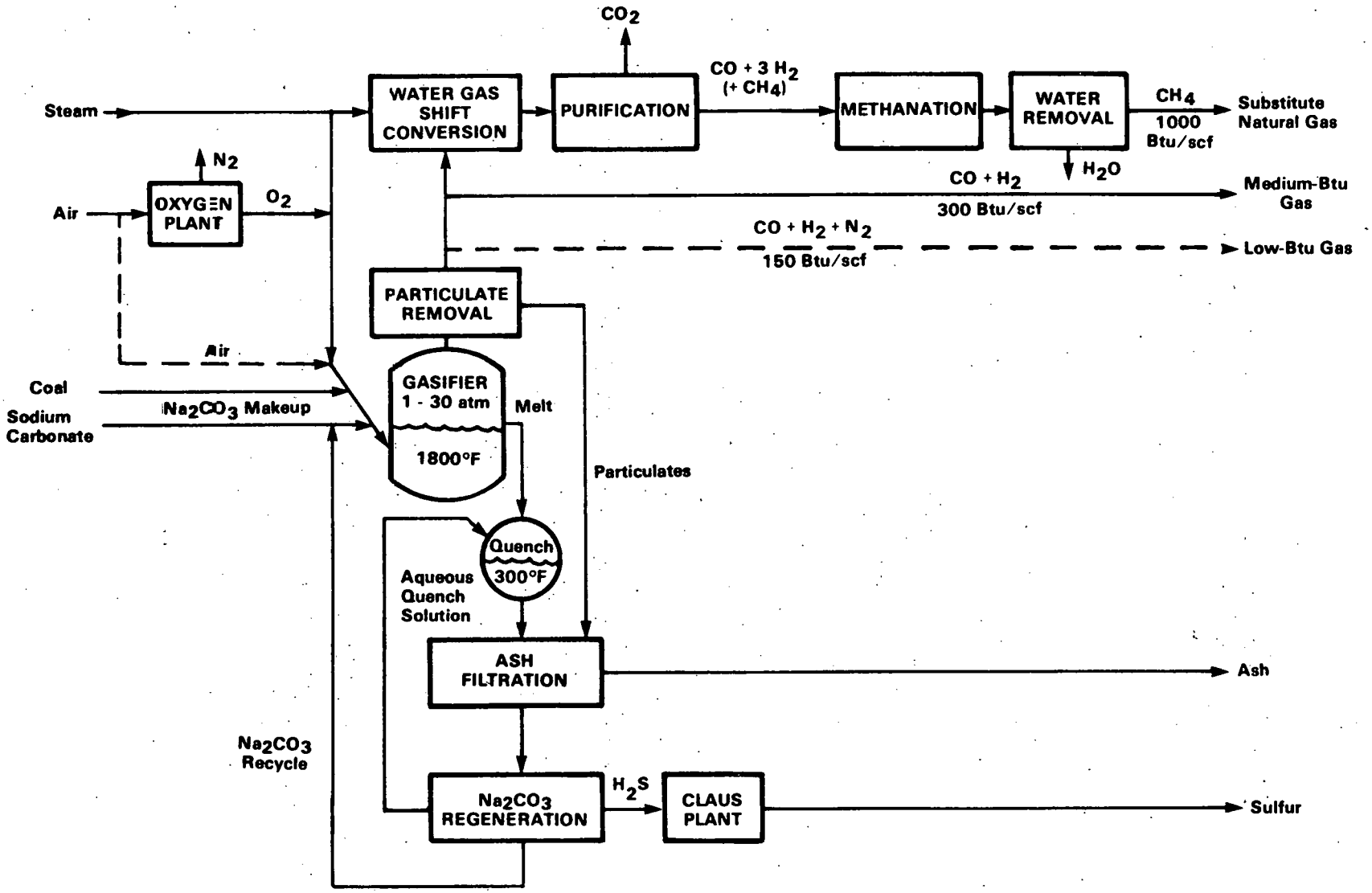
Molten Salt Pressurized Process

The molten salt coal gasification process offers a number of potential advantages:

- The process can handle caking coals without pretreatment.
- The coal need not be finely pulverized, yet fines can be handled effectively.
- The gas as it comes from the gasifier is essentially free of sulfur compounds, ash, coal tar, and nitrogen oxides.
- The gasification reaction zone and hence the gasifier vessel are small because of the catalytic effect of the molten salt.
- The process has good load-following capability because gasifier operation is not strongly affected by gas velocity.
- A major part (about 90 percent) of the heating value of the coal is retained in the product gas.

In the molten salt process, coal is crushed, dried, and sent to storage. From storage it goes to the feedhopper where it is conveyed by nitrogen and air to the molten salt reactor. The sodium carbonate also is conveyed by air from the carbonate feedhopper to the reactor.

In the molten salt reactor, coal is gasified in a molten pool of sodium carbonate, sulfide, and sulfate through which air is blown. Conducting gasification reactions in the molten salt medium permits very high oxidation rates (about five times higher than the corresponding gas-solid reaction rates) and results in trapping ash and sulfur in the melt. Process economics favor operation of the gasifier at elevated pressure (e.g., 10 atm) with recovery of energy from the product gas.



Molten Salt Gasification Process Development Systems

Since ash and sulfur are retained in the molten salt pool, the melt must be continuously withdrawn from the gasifier and fresh sodium carbonate added. The melt stream is regenerated by an aqueous process in which the melt is quenched and mixed with water to dissolve the salt; insoluble ash components are removed by settling and/or filtration; and the dissolved sodium sulfide is converted to hydrogen sulfide and sodium carbonate (or bicarbonate) by reaction with carbon dioxide. The resulting hydrogen sulfide is oxidized to elemental sulfur in a Claus sulfur plant, and the regenerated sodium carbonate is returned to the gasfier vessel.

The product gas has a heating value on the order of 150 Btu/scf and is predominantly carbon monoxide, hydrogen, and nitrogen. The product gas is cooled and cleaned of entrained-salt particles; it can then be used as a low-Btu feed to a conventional boiler or a combined-cycle system.

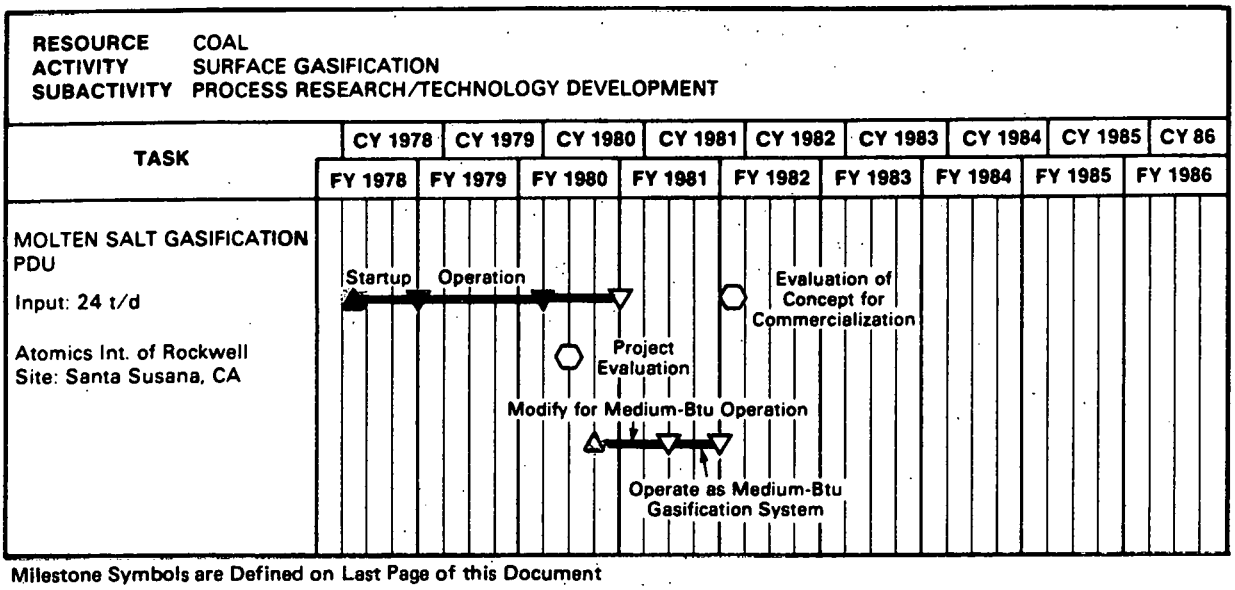
Project Status

Before December 1974, Atomics International Division of Rockwell International did extensive experimental work to develop the molten salt gasification process. Tests were carried out, first in a laboratory and later in a bench-scale unit. Based on these experiments, Atomics International concluded that the molten salt process was sound and that a pilot plant should be constructed and operated to further explore and demonstrate its potential for commercialization.

The tactics involved conducting a development test program which included the operation of Rockwell International's 3-foot inside diameter test reactor. This was conducted during FY 1976. The preliminary engineering of a 120-ton/day PDU was conducted concurrently with this activity. The preliminary engineering phase of the project included preliminary sizing of components, identification of long-lead items, and preliminary mass and energy balances. This project was terminated in March 1976.

A new project was initiated in March 1976, to design, construct, and operate a 1 ton/hr PDU at Santa Susana, California. It is designed for operation at 1800°F and pressures up to 20 atm. Preliminary engineering was completed in August 1976. Detail design began in June 1976 and was completed in June 1977. To avoid delay in construction of the PDU, key components were ordered in the first quarter of FY 1977. The construction of the facility was started in March of 1977 and was completed in FY 1978. Since that time the facility has been started up and a number of successful runs completed.

It is anticipated that during FY 1980 the feasibility of this coal gasification concept will be demonstrated. In addition, a design will be prepared for modification to the unit that will permit its operation to produce a medium-Btu fuel/synthesis gas.



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4.0 SPECIAL PROJECTS AND SUPPORT STUDIES

In FY 1979, three projects were supported in this gasification activity. These three projects included:

- Hot gas cleanup by means of a molten salt process
- Hot gas cleanup by means of an iron oxide process
- Gasification test facility.

During FY 1979 evaluations were performed on the two hot gas cleanup processes. The results did not demonstrate any basis for continuing the effort and the projects were terminated.

4.1 GASIFICATION TEST FACILITY

In evaluations similar to those performed on hot-gas cleanup technologies, it was established that there was not a basis for continuing work on the design and subsequent implementation of a gasification test facility. Although this effort was terminated, sufficient funding was requested to evaluate and complete a conceptual design of a gasifier that was being considered for the test facility. This advanced gasifier may have the potential to become one of the leading commercial coal gasification systems. It is anticipated that this design work will be completed in FY 1980.

5.0 TECHNICAL SUPPORT

5.1 DESIGN AND TECHNOLOGY SUPPORT

The coal gasification development program is characterized by the development of a number of gasification techniques that offer the opportunity to convert coal into alternate liquid and gaseous fuels as well as other products that will meet the demands of a complex and varied market. As would be expected, each project is directed specifically at achieving success in

resolving key process development problems which are in most cases associated with the development of the gasifier or its associated key unit operations. There are, however, a number of development issues that are common to the technology of coal gasification which can be studied as individual projects. These studies can provide applicable data prior to the time that such data is needed for the continued development of the individual gasification concepts.

Studies may proceed concurrently to acquire data that will greatly reduce the time and costs associated with the development of a gasification concept and its associated processing equipment and materials. The Design and Technology Support program studies underway will provide data for:

- Process evaluation, system trade-off analysis and estimates of economic viability
- Understanding of observed kinetic and thermodynamic behavior patterns
- Design, development and reliability of key items of equipment and instrumentation
- Testing the validity of computer models and thereby establishing their use as design tools and diagnostic devices for understanding and resolving process problems encountered in coal gasification.

In addition, this activity provides the support required to accumulate, correlate, interpret and record the immense amount of data being generated in a number of coal gasification programs as sponsored by industry as well as by the Government. This effort has resulted in a Coal Conversion Systems Technical Data Book which is one of the first attempts to provide a systematic method for recording and recalling gasification data. This system will make these data available in a usable fashion to system designers and process developers.

Those projects which were supported as part of this activity in FY 1980 will be continued in FY 1981. In addition, several new high-priority projects will be included as part of this activity in FY 1981.

6.0 GASIFICATION DEMONSTRATION PLANTS

6.1 HIGH-BTU DEMONSTRATION PLANTS

This program includes the following demonstration plant projects for producing pipeline-quality synthetic gas:

- Project A: The Continental Oil Company (CONOCO) contract employs the British Gas/Lurgi slagging gasifier as the basic coal gasification technique, and demonstrated downstream processes, such as Lurgi technology, for gas purification and water cleanup.
- Project B: The Illinois Coal Gasification Group (ICGG) contract employs the COGAS process. This concept for pyrolysis and gasification consists of three subunits: multistage fluid bed pyrolyzers, a fluid bed gasifier, and a slagging char fines combustor.

- HYGAS (Conceptual Design Only): The contract with Procon, Inc., employs technology developed by IGT.

Congress has authorized the initial engineering of Projects A and B (CONOCO and ICGG) leading to detailed engineering design, construction, and operation of one demonstration plant. Therefore, a selection will be made, when adequate design and other relevant technical and economic information have been generated to permit an equitable and viable choice. The project not selected may be considered for continuation, at much slower pace, as a candidate for a second demonstration plant for which funds have been authorized and appropriated.

Additionally, a contract was awarded to Procon, Inc., for the conceptual design of a HYGAS commercial plant and a demonstration plant. The contract was completed in April 1979. The HYGAS pilot plant operation to validate the process design parameters and technology has been continued.

The primary goal of these projects is production of synthetic pipeline-quality gas (approximately 1,000 Btu/scf) to be used as a substitute for natural gas.

The CONOCO and ICGG projects resulted from an RFP issued by ERDA in October 1975 for the design, construction, and operation of a demonstration plant. Five proposals were received, and CONOCO and ICGG were selected, contracts awarded, and work begun in mid-1977. Both contracts provided for the use of Appalachian, eastern, midwestern agglomerating (caking) coals and operation of existing pilot plants in technical support programs to confirm technical adaptability of essential process features.

The CONOCO proposal is based upon the British Gas/Lurgi Fixed-Bed Gasifier developed by British Gas at Westfield, Scotland; this project has been identified as the "High-Btu Pipeline Gas A" project.

The ICGG proposal, "High-Btu Pipeline Gas B" is based upon the COGAS process (the COGAS pilot plant is located at Leatherhead, England), but includes the COGAS Development Company's COED coal pyrolysis process developed in Princeton, New Jersey, at a large pilot plant during the early 1970s. The COGAS Development Company is comprised of FMC Corporation, Consolidated Gas Supply Co., Panhandle Eastern Pipe Line Co., and Tennessee Gas Pipeline Co.

Both CONOCO and ICGG have prepared conceptual designs of commercial-scale plants, established capacity and general concepts for the demonstration facility, performed considerable site-specific evaluations of the demonstration plants in the locations proposed, and completed the confirmatory technical support programs to validate basic data; and have developed certain business considerations for the government-contractor cost-shared plant. An evaluation of this information was undertaken in November 1978 as the basis for an evaluation between CONOCO and ICGG. A re-evaluation of the project is planned in March/April 1980 to select one of the two contractors to proceed to completion of the demonstration plant design. At the end of Phase I a determination will be made to proceed or not to proceed through construction.

When a selection is made, if justified by the design merit of the project not selected, the Joint Appropriations Committee has required that a

recommendation be submitted for continuation of the nonselected project as a candidate in competition for a second high-Btu demonstration plant.

Management of the project is broken down into three separate phases for both contract and control purposes.

- Phase I includes conceptual designs of a commercial plant and a demonstration plant including a gasifier and other components suitable for commercial design.
- Phase II includes demonstration plant design, construction and all supporting activities, equipment purchases, etc.
- Phase III includes operation of the plant and final process evaluation.

The following schedules represent activities for both the CONOCO and ICGG projects, as planned by the contractors.

In FY 1981 the construction of the demonstration plant will be initiated, and the foundation preparation and long-lead equipment procurement will be completed.

CONOCO (Project A) and ICGG (Project B) will be evaluated together as part of the high-Btu pipeline gas program. The main features of the two projects are outlined below.

Technical Approach

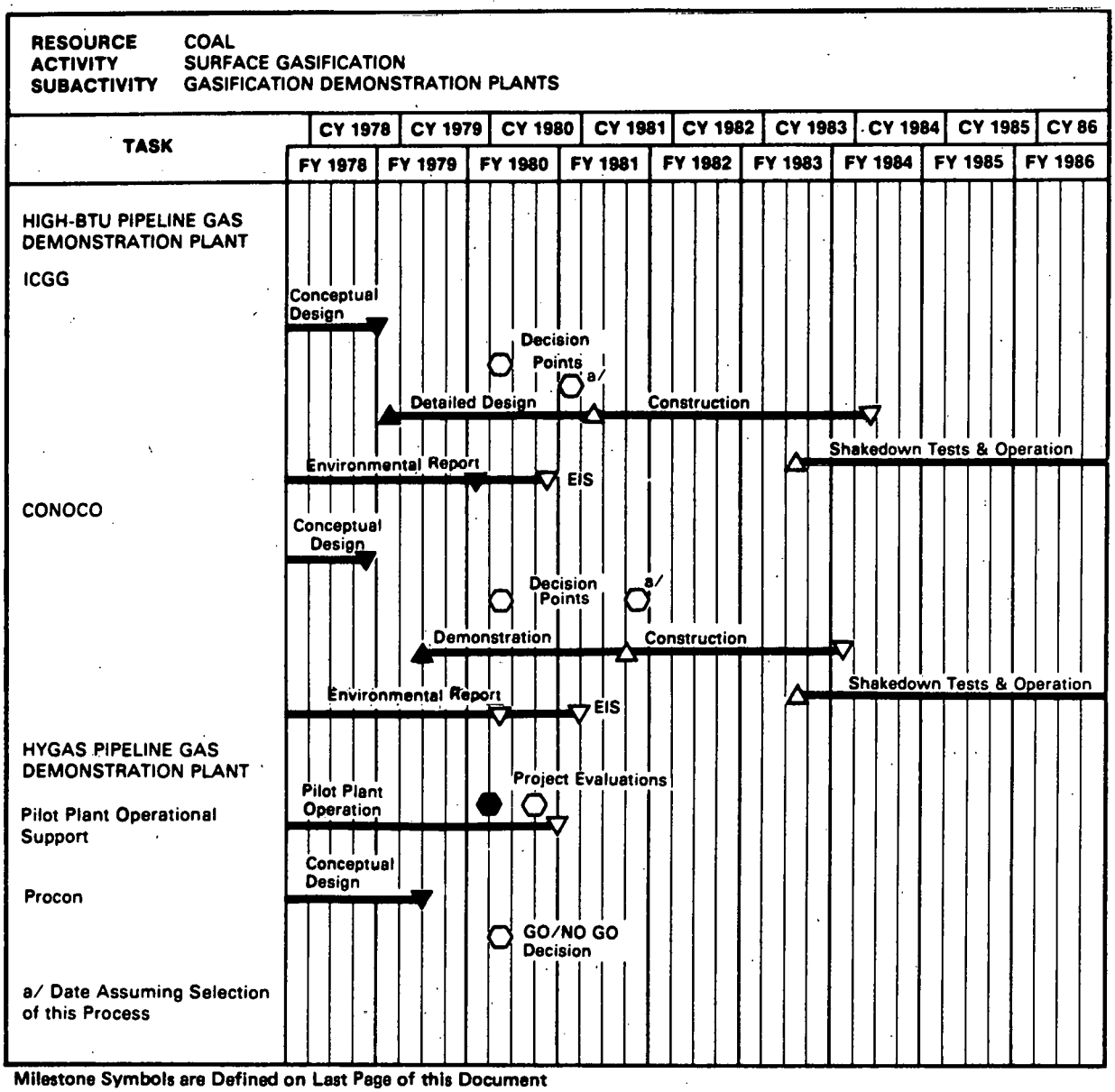
CONOCO (Project A)

- Convert eastern coal to gas in a fixed-bed British Gas/Lurgi slagging gasifier
- British Gas Corporation (BGC)/Lurgi slagging gasifier is a major advance over dry-ash Lurgi
- Improved conversion of synthesis gas to high-Btu gas
- Product compatible with natural gas in pipeline
- Minimize environmental impact by waste products.

ICGG (Project B)

- Convert coal to liquids (low-sulfur fuel No. 2 and No. 6 oil equivalents) and char; convert char to synthesis gas
- Apply COGAS gasifier (high-efficiency, low-pressure) development
- Convert synthesis gas efficiently to high-Btu gas

- Produce gas and liquid products compatible with market standards
- Minimize environmental impact of waste products.



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Performance Requirements

The following table shows estimated performance of the two processes compared to technical performance baselines.

TECHNICAL PERFORMANCE	CONOCO		ICGG	
	Baseline	Ohio No. 9	Baseline	Illinois No. 6
Coal Feed (t/d)	1270	1256	2210	2210
Prime Product Gas (Mscf/d)	19	19.0	23.2	23.2
Naphtha (bbl/d)	108	145.9	360	390
Fuel Oils (bbl/d)	38	197.9*	1543	1543
Sulfur (t/d)	56	54.2	69.5	56.3
Ammonia (t/d)	4.5	8.2	3.7	8.7

*522°F FBP; higher BP oils recycled 308 bbl/d.

British Gas/Slagging Lurgi Process (Project A)

The objective of the CONOCO project is to verify the technical, economic, and environmental acceptability of the British Gas/Lurgi process by building, operating, and evaluating a demonstration plant.

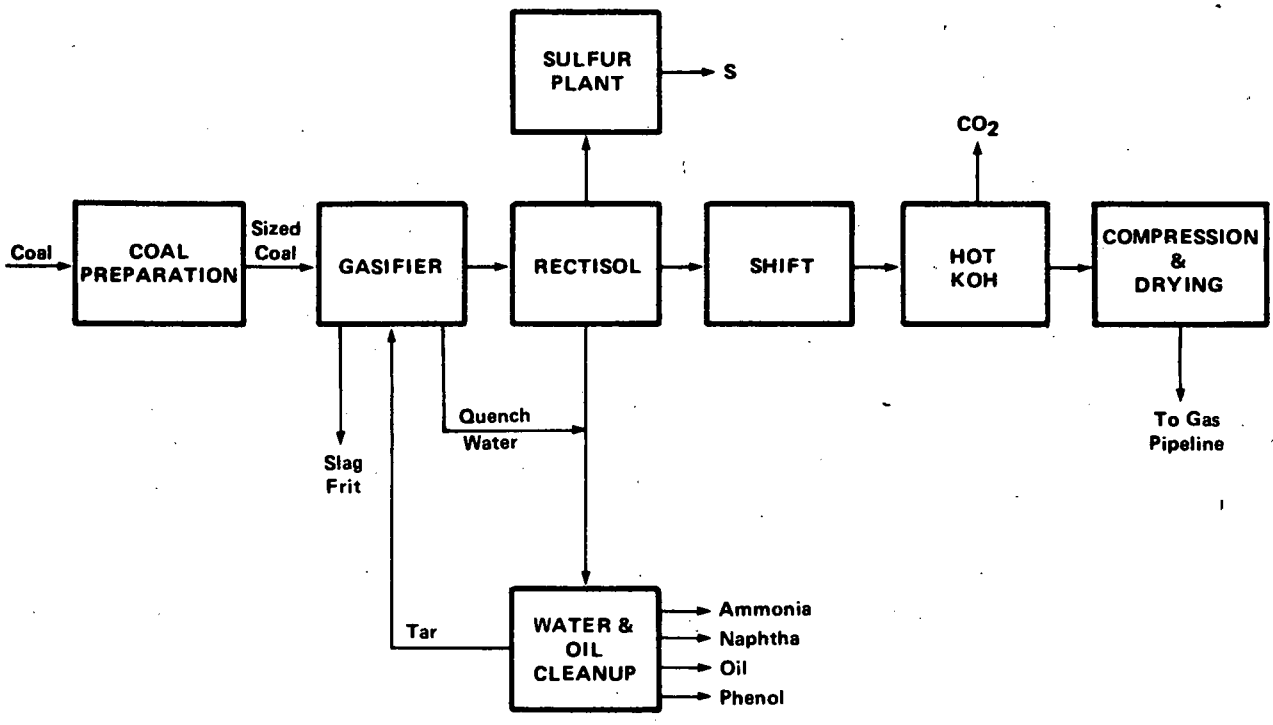
The slagging process is a modification on the existing commercial Lurgi process in that it will accept caking coals and operate at higher temperatures. The process reduces the carbon content of the molten ash stream and thereby increases the conversion of carbon in coal to gas. Carbon conversion to products is better than 99.9 percent. The process also produces less tar, phenol, and heavy hydrocarbons than the older-type commercial Lurgi coal gasification units. The tars recycled to the gasifier produce a higher yield of gas.

Gases leaving the gasifiers are cooled by quenching with a gas liquor (recycled water) spray. Following the classic syngas processing scheme, the H_2/CO ratio as required for downstream methanation is adjusted through the converter while the remainder bypasses the converter. In the purification step, naphtha and water are separated by condensation, while hydrogen sulfide and carbon dioxide are removed by the Lurgi Rectisol process. In the methanation step, methane is produced from carbon monoxide and hydrogen over a fixed-bed nickel catalyst. A catalyst life study conducted in a PDU operation is expected to confirm the improved processing scheme.

In the gas liquor separator, coal fines, tar, and tar oil are removed from water. The fines with tar and oil are recycled to extinction in the gasifiers. The Lurgi Phenosolvan process extracts phenols from the water. Ammonia is removed from the gas by the Phosam W process to produce aqueous ammonia. An air separation plant will produce the oxygen used in the gasifier, a requirement for making pipeline-quality gas.

In addition to tar precipitation, oil separation, and phenol extraction processes, the plant will include all the service sections required, such as steam production, water purification, air separation, incineration, waste treatment, as well as product loading, tankage, and buildings.

The British Gas Corporation, as support for this project, ran extensive coal gasification test periods on its nominal 300 t/d prototype semiworks-scale slagger at Westfield, Scotland, first under private funding, and in 1978, under DOE funding. Successful operation was achieved when operated on caking U.S. coal (Pittsburgh 8). More challenging operation occurred on another coal (Ohio 9) under the DOE program.



British Gas/Slagging Lurgi Technical Process — CONOCO

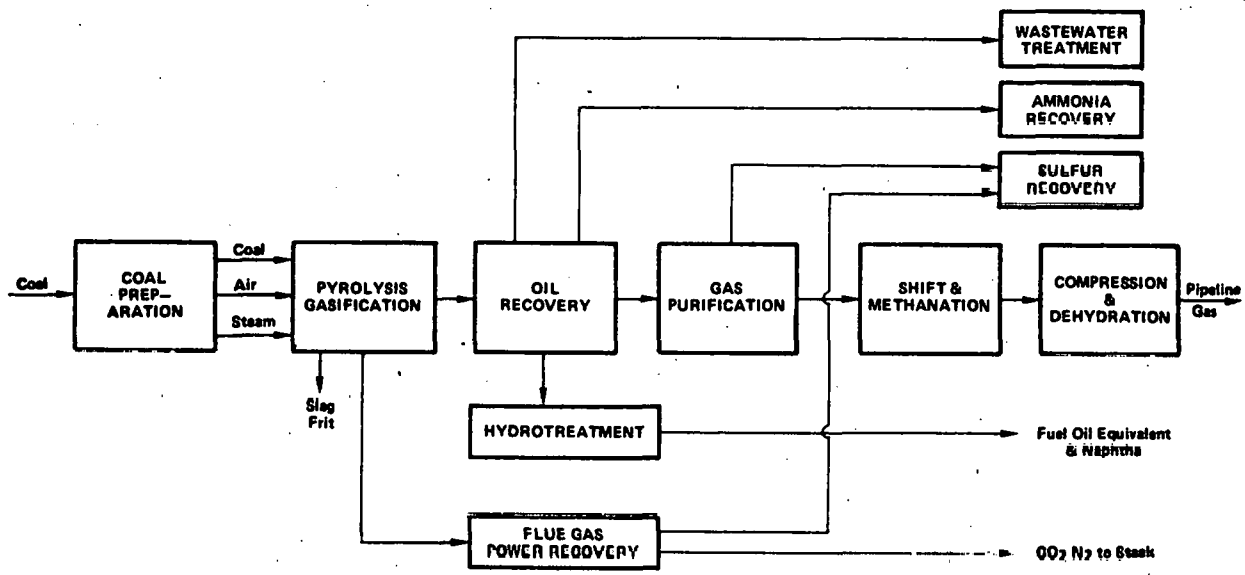
COGAS Process (Project B)

Dried crushed coal is treated in three (and in some cases four) fluidized-bed stages at successively higher temperatures until the major fraction of the volatile matter of the coal is volatilized. Heat for this pyrolysis is obtained from the gasifier by burning a portion of the char with air. Air is rejected as a slag "frit" from the combustor section of the

gasifier. Hot gases from the gasifier then flow counter-currently to the coal and constitute the fluidizing gas and heat supply for the third and second stages in order. Hot char from the last stage may be recycled to supplement the heat from the gases. The first-stage fluidizing medium is supplied as flue gas from the gasifier where a portion of the char is burned with air. Gas and oil are recovered by cooling and condensing the volatiles from the pyrolysis.

The char product of pyrolysis is fed to the gasifier while the remaining product, the raw oil, is upgraded by hydrogenation to a high-grade naphtha and synthetic low-sulfur No. 2 and No. 6 fuel oils. The hydrogen for this oil hydrotreating is supplied by reforming a portion of the product gas. The synthesis gas from the gasifier is compressed to intermediate pressure and cleaned to reduce particulates and sulfur compounds to a level acceptable for methanation. The resultant product gas is then methanated, dried, and compressed for utilization as a pipeline gas.

Successful pilot plant operation has been achieved for both the "COED" pyrolysis and COGAS gasifier parts of this process. A pilot plant for the pyrolysis of 36 t/d of coal operated between 1970 and 1975 in Princeton, New Jersey. A 50 t/d char gasifier pilot plant at Leatherhead, England, completed a test program in 1978, validating the technological concepts of the gasifier section.



COGAS Technical Process — ICGG

HYGAS Process Conceptual Design Project

This project, contracted to Procon, Inc. and completed in 1979, provided the conceptual design of both commercial- and demonstration-scale HYGAS plants. The primary advantage of the HYGAS process is the formation of up to

60 percent of the methane in the gasifier itself, which reduces the downstream equipment and oxygen requirement.

IGT, the process developer, is operating the pilot plant to confirm design parameters and determine the inherent operability of the process technology. This work has been continued beyond the contract end date of June 1979.

On completion of this work, information will be available to determine the merits of constructing a demonstration plant.

The HYGAS process is described in subsection 1.

6.2 LOW-/MEDIUM-BTU DEMONSTRATION PLANT, INDUSTRIAL

This program includes the following demonstration plants:

- Fuel gas, industrial (A&B Conceptual Designs)
- Fuel gas, utility
- Fuel gas, small industrial.

Fuel gas technologies have widespread potential for substitution for natural gas, especially for industrial and electric utility users. In February 1976 DOE issued an RFP to invite consideration of plants to demonstrate coal-to-fuel gas conversion for: (1) industrial use (i.e., a large gasifier supplying an industrial community, synthesis gas for chemicals production); (2) small industrial/institutional use (a single industrial user, a hospital, a commercial/residential complex, etc.); and (3) utility use (to substitute for natural gas for direct boiler firing, or as a source of energy for combined-cycle (steam/gas turbine) generation).

Fuel Gas, Industrial — A & B

Contracts for the large industrial-user-dedicated plants have been executed with W.R. Grace & Co. and with the Memphis Light, Gas and Water Division for a design competition which will lead to the construction and operation of a demonstration plant. The two competing projects, Fuel Gas Industrial A&B, are described below.

Fuel Gas, Industrial "A" — Conceptual Design

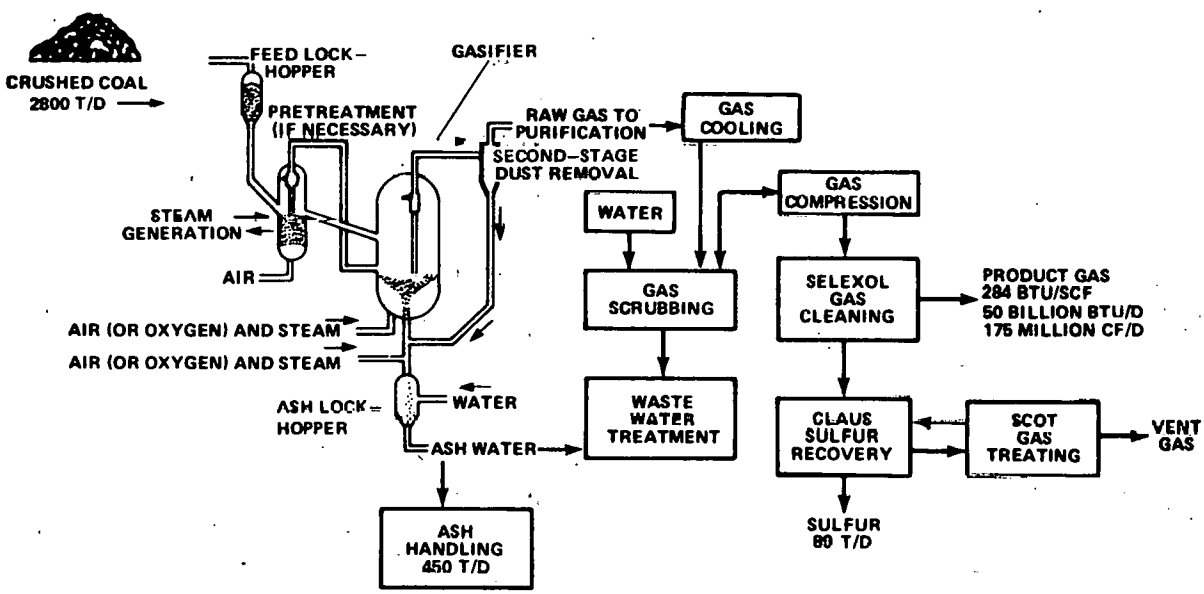
The Memphis Light, Gas and Water Division (a department of the city of Memphis), in association with Delta Refining Company, Foster Wheeler Energy Corporation, and IGT, has a fuel gas demonstration program based upon the U-GAS process to produce and deliver to Memphis industrial consumers, via a pipeline distribution system, 175 million scf/d (50 billion Btu/day) of industrial fuel gas having a nominal gross heating value of 284 Btu/scf. This is equivalent to 50 million scf/d of natural gas. The IGT U-GAS process is a fluidized-bed, oxygen-steam gasification process operating under conditions which promote the formulation of ash agglomerates in the lower part of the bed.

The conceptual design of the gasifier for this project is an extension of the U-GAS reactor concept under development by IGT. The principal new

development is operation of the gasifier at 90 psig and scaleup of a 3-foot-diameter reactor to one in the range of 13 to 15 feet.

Crushed coal is fed to the gasifier with an oxygen-steam mixture in a fluidized bed. Operating temperatures are in the range of 1870° to 2050°F. Fines entrained from the fluidized bed with the raw fuel gas are returned to the gasifier through external cyclones. The ash agglomerates produced in the bottom of the gasifier fall out through the bottom injection throat or venturi. The agglomerates are quenched with water and the resulting slurry is transported to ash separation and water reclamation. The hot, raw fuel gas is cooled in a waste heat recovery exchanger and fed to a venturi scrubber for the removal of ammonia, hydrogen sulfide, and coal dust. The fuel gas is then compressed to 195 psig and treated in Selexol acid-gas absorption process to remove essentially all of the hydrogen sulfide and organic sulfur compounds and part of the carbon dioxide. The purified gas from the Selexol unit is ready for distribution.

Acid gas containing hydrogen sulfide is fed to a conventional Claus process. In the Claus unit the H_2S is partially oxidized to form elemental sulfur and water. The off-gas from the Claus unit is processed to a SCOT tail-gas unit, to recover remaining H_2S and recycle it back to the Claus plant. The off-gas from the SCOT process is environmentally acceptable to vent.



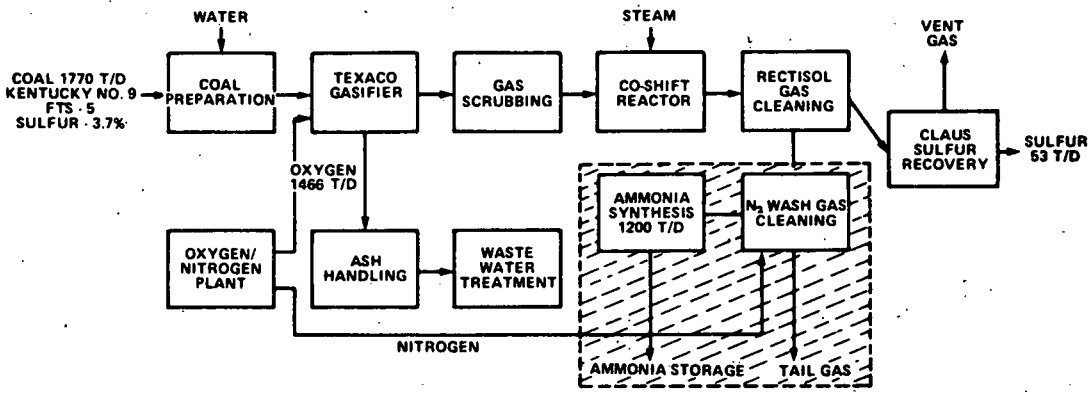
Low-Btu Fuel Gas, Industrial "A"

Fuel Gas, Industrial "B" — Conceptual Design

W.R. Grace & Co., in association with Ebasco Services, Inc., Humphreys-Glasco and Texaco, proposes a facility to produce synthesis gas (a mixture of hydrogen and nitrogen) for ammonia production. The demonstration plant would be located in western Kentucky. Because ammonia formation is

favored at high pressure, the synthesis step requires pressure exceeding 3,500 psig. Accordingly, the Texaco Coal Gasification process, operating at 1,200 psig has been chosen for this project.

Coal feedstock is prepared by grinding the coal and slurrying it in water, with the coal content of the slurry ranging from 50 to 60 percent by weight. The slurry is blended with oxygen for high-pressure injection into the gasifier. The resultant gas, containing carbon and fly ash, flows to a scrubber where carbon is recovered and recycled to the gas generator. The synthesis gas from the gas generator, rich in carbon monoxide, is converted to hydrogen by the water gas shift reaction. Hydrogen sulfide and carbon dioxide removal is accomplished by physical absorption in refrigerated methanol. Liquid nitrogen scrubbing is utilized for final removal of residual unconverted carbon monoxide, residual methane and argon gases. The product gas is blended with nitrogen and is the feedstock for the ammonia synthesis step.

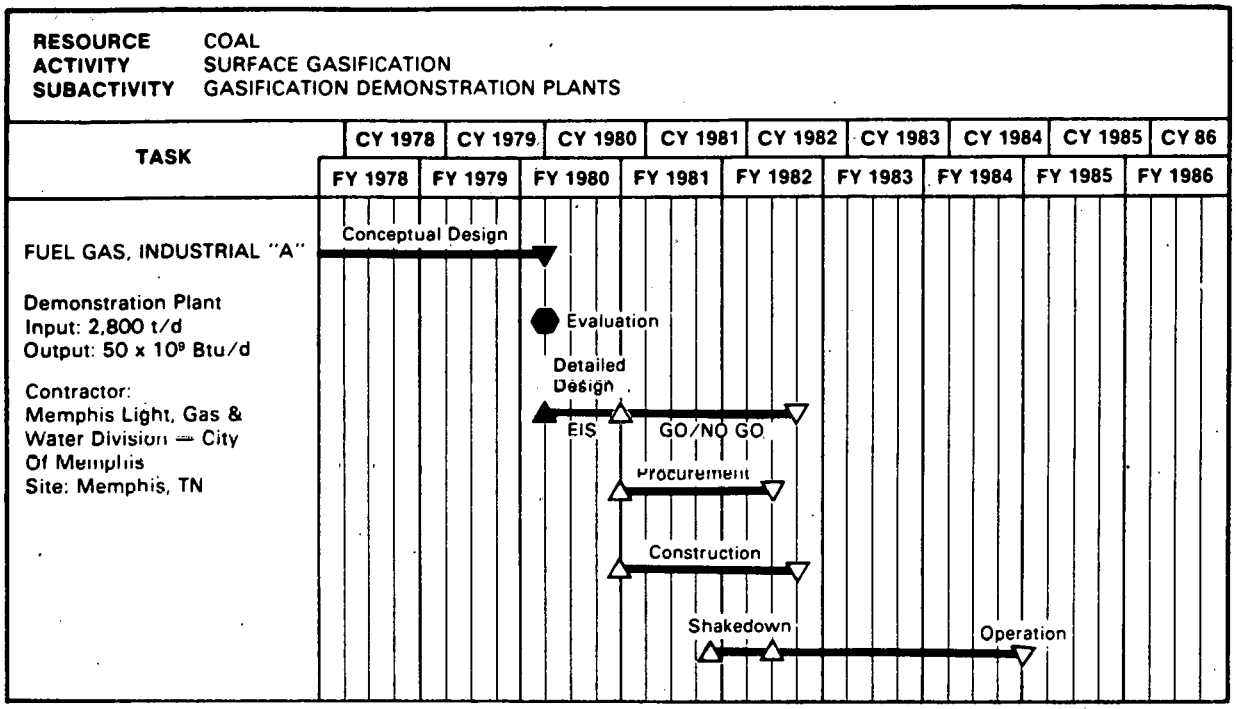


Low-Btu Fuel Gas Industrial "B"

Project Status

Fuel Gas, Industrial "A" — Memphis

The Phase I conceptual design effort was completed in December 1979. An evaluation and a GO/NO GO decision to proceed beyond Phase I was made during the second quarter of FY 1980. Development of the environmental impact statement continued through FY 1980 and is ready for final issue. Fifty million dollars in deferred prior year funds will carry the program through FY 1980 and one project into FY 1981. Additional funds will be required in FY 1981 to maintain schedule.



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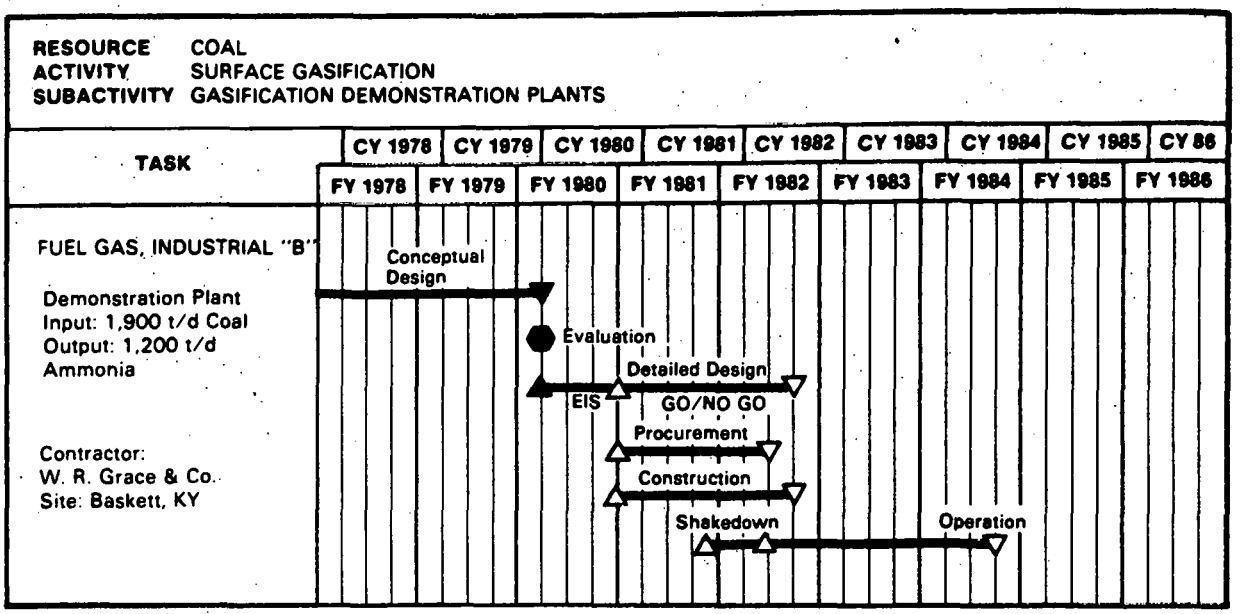
Fuel Gas, Industrial "B" — Grace

The Phase I conceptual design effort was completed in December 1979. An evaluation and a GO/NO GO decision to proceed beyond Phase I was made during the second quarter of FY 1980. Development of the environmental impact statement continued through FY 1980 and is ready for final issue. Fifty million dollars in deferred prior year funds will carry the program through FY 1980 and one project into FY 1981. Additional funds will be required in FY 1981 to maintain schedule.



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Fuel Gas, Utility A&B

Contracts for the utility plants have been executed with Foster Wheeler Development Corporation (FWDC) and Combustion Engineering, Inc. (C-E) for a design competition which could lead to the construction and operation of a demonstration plant. The two competing projects, Fuel Gas Utility A&B, are described below.

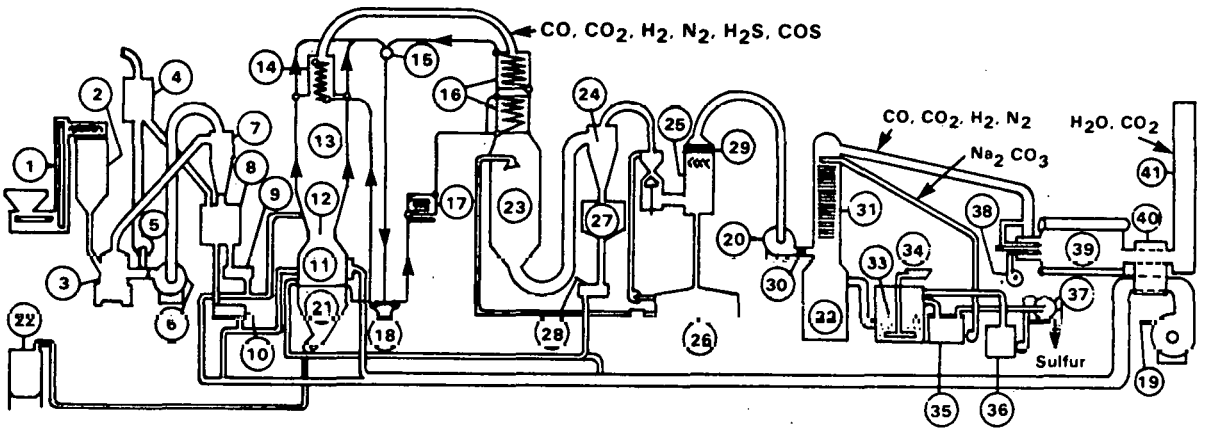
Fuel Gas, Utility "A" — Conceptual Design

Combustion Engineering and Gulf States Utilities have a fuel gas demonstration program based upon an air-blown, atmospheric pressure, entrainment-type gasification system developed by C-E. The proposed site is the Gulf States Utilities' Nelson Plant at Lake Charles, LA. A 150 MW natural gas-/oil-fired boiler will be retrofitted to burn the low-Btu gas. The C-E gasifier will convert 1,344 t/d of high-sulfur midwest bituminous coal to 29 billion Btu/d of 112 Btu/scf fuel gas to fire the boiler.

The conceptual design of the gasifier for this project is a scaleup of the 120 t/d process and development unit sponsored by the Department of Energy and the Electric Power Research Institute at the C-E facility in Windsor, CT.

Crushed coal is fed to the gasifier which consists of two reaction stages. The first stage of combustion occurs at essentially stoichiometric conditions in the combustor section located in the lower portion of the gasifier. The hot combustion gases (3200°F) leave the combustor and enter the diffuser where they mix with and rapidly devolatilize the remainder of the coal feed. The remaining height of the gasifier (reductor section) provides the residence time required to react the devolatilized coal with any remaining CO_2, H_2O, or O_2 in the gas phase. This reaction is endothermic and will continue until the temperature drops to a point where the reaction is

minimal. The low-Btu gas leaving the reductor section undergoes gas cleanup including sulfur removal by the Stretford process.



AREA 100
1. Coal Unloading Equipment
2. Coal Storage Silo

AREA 200
3. Pulverizer
4. Bag Filters
5. Vent Fan
6. Recirculation Fan
7. Pulverized Coal Cyclone
8. Pulverized Coal Storage Bin
9. Reductor Pulverized Coal Feeder
10. Combustor Pulverized Coal Feeder

AREA 300
11. Gasifier Combustor
12. Gasifier Diffuser
13. Gasifier Reductor
14. Primary Cooler
15. Mixing Sphere
16. Secondary Coolers
17. Water Cooler
18. Circulating Pumps
19. Forced Draft Fan
20. Induced Draft Fan

AREA 400
21. Ash Hopper
22. Dewatering Bin

AREA 500
23. Sludge Spray Dryer
24. Char Cyclone Separator
25. Wet Venturi Scrubber Chevron Separator
26. Sludge Thickener

AREA 600
27. Char Receiving Bin
28. Char Feeder
29. Gas Reheater
30. Gas Cooler

AREA 700
31. H_2S Absorber
32. Reaction Tank
33. Oxidizer
34. Air Compressor
35. Solution Tank
36. Sulfur Slurry Tank
37. Rotary Vacuum Filter

AREA 800
38. Forced Draft Fan
39. Incinerator Boiler
40. Tubular Air Heater
41. Stack

Low-Btu Fuel Gas, Utility "A"

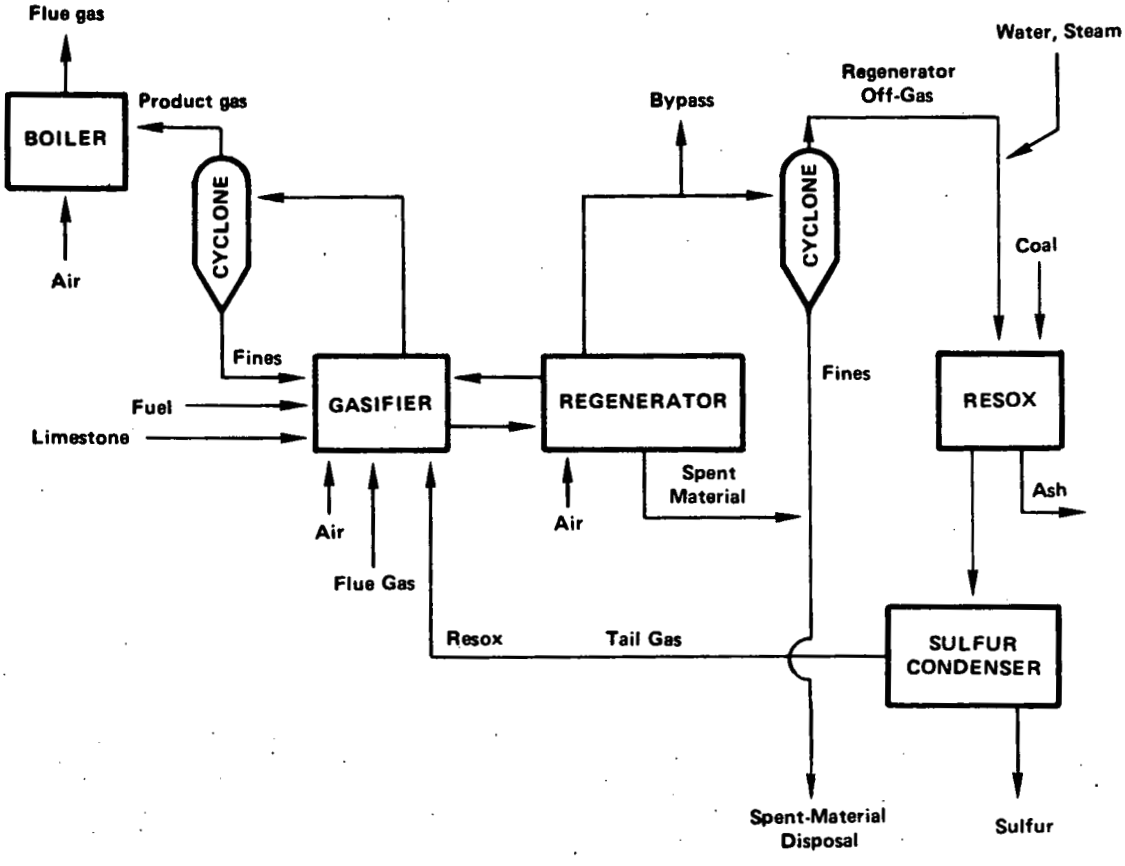
Fuel Gas, Utility "B" — Conceptual Design

Foster Wheeler Development Corporation and American Electric Power have a utility fuel gas demonstration project based upon the Chemically Active Fluid-Bed (CAFB) process which was developed at the Esso Research Center in England. They plan to build the demonstration plant at the Appalachian power plant in Cabin Creek, WV. During the demonstration program, the fuel gas and steam produced will be utilized in operation of a 90 MW power plant. Coal will be processed at a rate of 1,150 tons/day to produce approximately 24.9 billion Btu/d of 218 Btu/scf fuel gas.

The conceptual design of the gasifier will be a scaleup of the 20 MW CAFB pilot plant at San Benito, Texas.

In the process, high-sulfur coal is fed into a 1600°F limestone bed that is fluidized by a mixture of flue gas and air. Approximately 22 percent stoichiometric air is admitted to limit the amount of combustion and heat release. Hydrogen sulfide (H_2S) formed during the partial combustion reacts

with the lime and produces calcium sulfide (CaS) and steam. The 1600°F product gas, essentially sulfur-free, will be burned in the steam generator, using specially designed low-Btu gas burners. To maintain the sulfur removal capacity of the CAFB process, the calcium sulfide is removed from the gasification zone to the regenerator where sulfur is driven from the lime in the form of a relatively concentrated SO_2 off-gas by reacting calcium sulfide with air at 1900°F. The RESOX catalytic system cools the gases from the regenerator to about 1200°F by injecting steam or water. The elemental sulfur formed is condensed in a direct-contact, counter-current scrubbing tower. Up to 90 percent of the sulfur from the regenerator can be recovered. The remaining sulfur is recycled back to the gasifier.



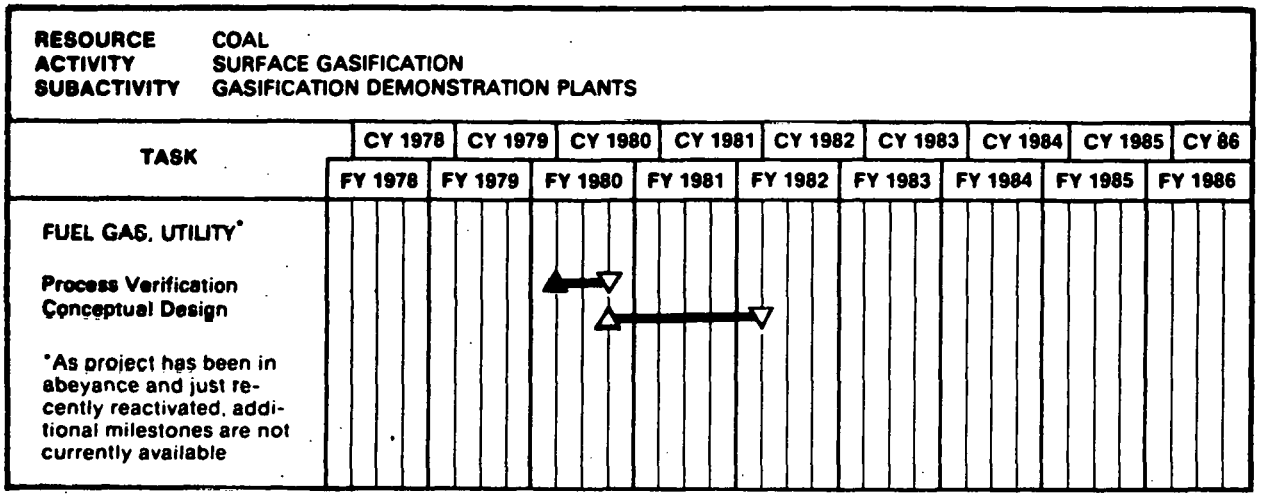
Chemically Active Fluid-Bed Process

Project Status

Fuel Gas, Utility A&B

The phase zero Management System Development and Process Verification effort was undertaken by both contractors during FY 1980. The Phase I conceptual design effort will span FY 1981 and extend two months into FY

1982. Development of an environmental assessment continued through FY 1980 and when completed in FY 1981 will be the basis for determining the necessity for an EIS.



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6.3 LOW-BTU FUEL GAS DEMONSTRATION PLANT, SMALL INDUSTRIAL

After completion of the Phase I conceptual design effort in the third quarter of FY 1979, the government and the industrial partner, Erie Mining Company, mutually agreed not to proceed beyond Phase I because of unacceptable growth of estimated costs of building and operating the plant in addition to problems concerning the ability to process the candidate coal.

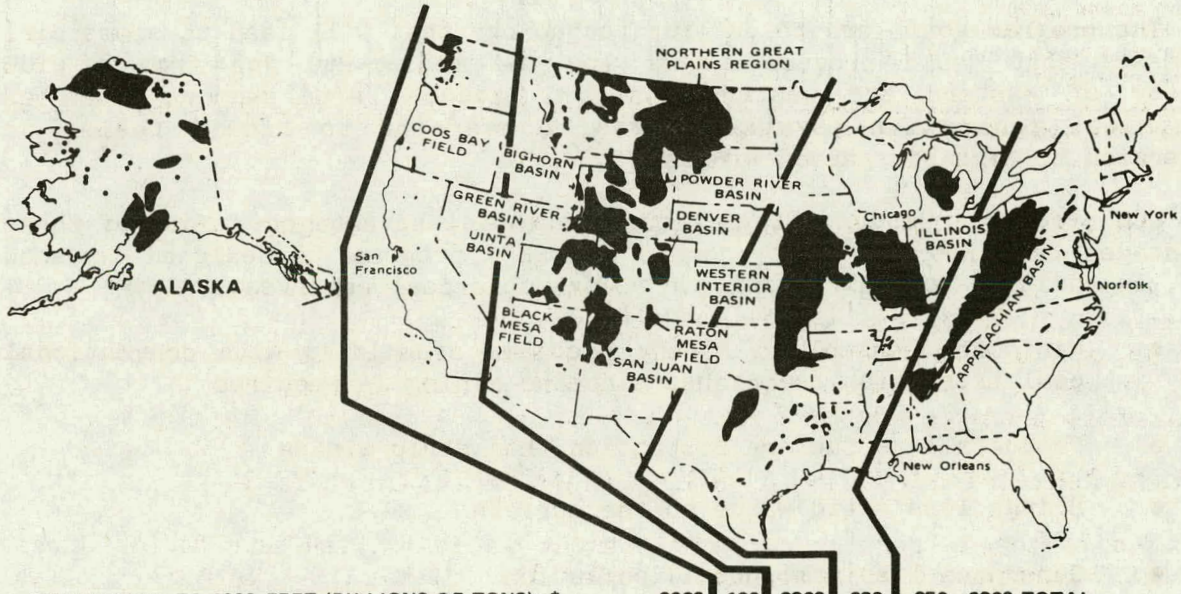
6.4 COMPONENT AND INSTRUMENTATION DEVELOPMENT

The component portion of this element is identified and defined under the AR&TD portion of this report, Chapter III, Section E-3.0, Materials and Components, with attendant development supplied by specific major coal conversion plants.

Reliable components, instruments, automatic process controls, and attendant systems will be essential to the efficient, continuous, and safe operation of gasification demonstration plants. Many critical items are not available or require modification before they can be adopted to the hostile environment found in the coal conversion plants. Funding for these development efforts is provided by individual programs where the needs are most pronounced. Positive results will apply to other fossil energy areas and especially in the liquefaction demonstration plant programs. Technical information dissemination, such as symposia and workshops, has been conducted and has a goal of early industry sponsorship.

D. IN SITU COAL GASIFICATION

Approximately 93 percent of our Nation's vast coal resource is not technically or economically recoverable by conventional underground or strip mining. Underground coal conversion processes could increase the recoverable portion to nearly 28 percent by converting it to clean-burning gaseous and liquid fuels (see figure below). As a complement to mining plus surface-based coal conversion, the development of underground conversion processes could significantly expand the economic extraction of energy from coal in environmentally acceptable ways, and may provide a viable domestic source of competitively priced transportation fuels.



TOTAL COAL TO 6000 FEET (BILLIONS OF TONS): *	2030	100	3260	620	350 - 6360 TOTAL
ESTIMATED MINEABLE RESERVE BASE (BILLIONS OF TONS): *	10	2	200	110	110 - 432 TOTAL
ESTIMATED UCG RESOURCE (BILLIONS OF TONS): *	640	30	920	140	80 - 1800 TOTAL

* DIVIDE THESE NUMBERS BY 1.1 TO OBTAIN TONNES

Coal Fields of the United States

Underground Coal Gasification (UCG) can produce low- or medium-Btu gas for electric power generation, industrial heating, or for feedstock for production of various chemicals, synthetic natural gas (SNG), or transportation fuels such as methanol, gasoline, or diesel. One recent study by SRI[1] has shown that the UCG-derived power can capture up to 1 Quad/year of low-Btu gas and 0.5 Quad/year of SNG in the 19-state region around the Rockies.

The objective of the DOE In Situ Coal Gasification Activity is to develop commercially viable underground conversion processes for extracting energy from coal. Through government and industry joint participation, the technology will be developed, proven on a large scale, and transferred to the private sector. Data will also be provided to predict the economics of a commercial operation. The near-term goal is to develop at least one commercial underground conversion process by 1985 to 1987 and assure technology transfer to the industrial sector. The mid-term goal is to develop advanced concepts, i.e., increased resource recovery, reduced water usage, and reduced dependence on underground characteristics.

The program goals are to develop technology that will lead to commercial processes that could produce either low- or medium-Btu gas from a wide variety of eastern and western coals to address area markets such as electrical generation, synthesis gas, conversion to liquid fuels, or conversion to high-Btu gaseous fuels.

UCG offers a number of significant potential advantages. Some of these advantages have not yet been proven, but FE's program is designed to show that, in addition to quadrupling our recoverable coal reserves, UCG:

- Minimizes health and safety problems associated with conventional coal extraction techniques since no mining is required
- Produces less surface disruption than strip mining
- Brings less solid waste to the surface
- Generates less atmospheric pollution
- Reduces the socioeconomic impact since fewer operators are required
- Reduces both capital investment and gas costs by at least 25 percent.

The potential problems of UCG are possible contamination of surface water and underground aquifers, surface and well leaks, and subsidence of the surface. In order to minimize the impact of these potential problems, extensive environmental monitoring before, during, and after each field test

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[1] A.J. Molland and D.L. Olsen, "Preliminary Evaluation of Western Market for UCG-Derived Fuel Gas," SRI International, Proceedings of the Fourth Annual Underground Coal Conversion Symposium, Steamboat Springs, Colorado, July 17-20, 1978.

along with the development of environmental control technology, laboratory simulations, and analytical modeling are included as integral parts of each field project.

The technical feasibility of UCG has been proven by the British and, most notably, the Soviets, who have had commercial UCG plants in operation for 20 years. Building on the available UCG technology, DOE's Laramie Energy Technology Center (LETC), Morgantown Energy Technology Center (METC), and Lawrence Livermore Laboratory (LLL) have conducted highly successful subpilot-scale field tests at Hanna, Wyoming; Pricetown, West Virginia; and Hoe Creek (near Gillette), Wyoming, respectively. Low- and medium-Btu gases have been produced for sustained periods, and successful control of important process variables has been demonstrated. Proving economic feasibility is the key to commercialization of UCG in this country and will require demonstration of efficient use of the coal resource, controllability of the underground process (including environmental effects), reliable long-term operation at high production rates, and verification of the process design at several sites.

These requirements are being fulfilled through an integrated program of field tests, instrumentation and process model development, and laboratory supporting research.

The four major UCG process options being developed as part of DOE's In Situ Coal Gasification Activity address the wide range of chemical and physical properties of the coal seams and surrounding geology found in the United States.

- A Low-Btu Gasification project is concentrating on gasifying shrinking subbituminous coal with air injection after linking pairs of wells using reverse combustion.

- A project is concentrating on gasifying shrinking bituminous or subbituminous coal with oxygen and steam injection after linking pairs of wells using directionally drilled holes.

- A Steeply Dipping Bed (SDB) project is concentrating on gasifying coal seams which dip more than 35° and are not commercially exploitable with conventional mining technology.

- A project is concentrating on gasifying swelling bituminous coals using the best available technology.

The Environmental Support and the Supporting Research projects contribute to all four major projects by developing new technology for the program. One example is the development of inverted thermocouples to monitor gasification cavity growth.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

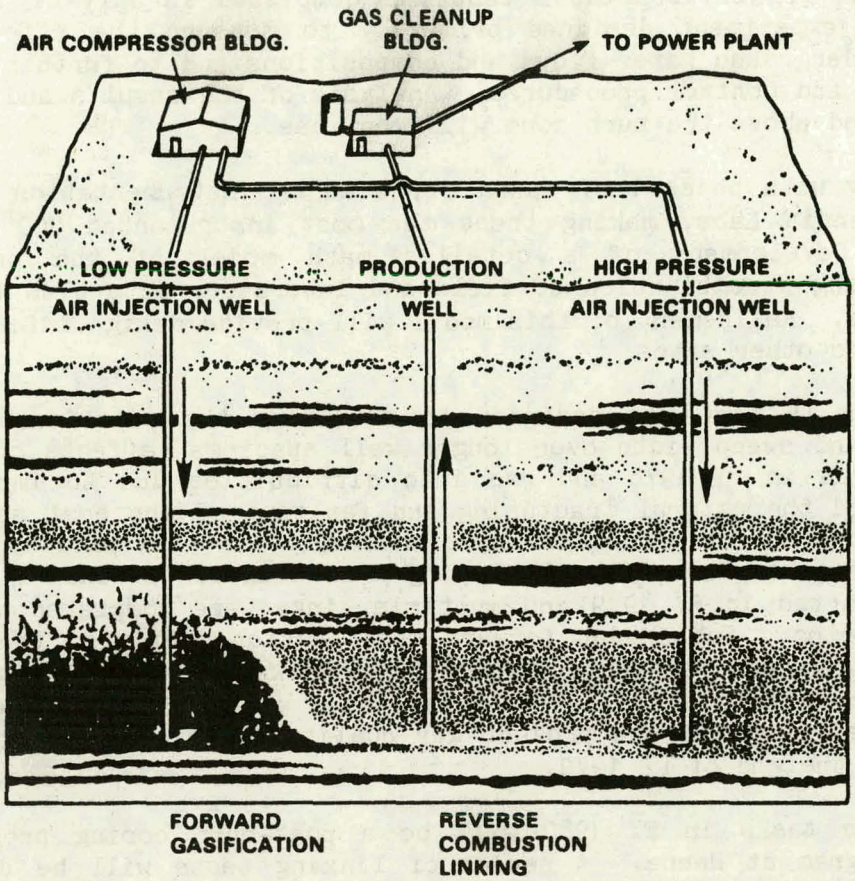
IN SITU COAL GASIFICATION	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Western Low-Btu Gasification (Linked Vertical Wells)	4,300	2,700	6,500
Western Medium-Btu Gasification (Packed Bed)	2,450	3,200	2,700
Steeply Dipping Beds	4,550	3,000	0
Environmental Support	900	600	500
Supporting Research	2,100	400	200
Capital Equipment	700	100	100
Total Direct Appropriations	15,000	10,000	10,000
Energy Security Trust Fund	0	0	10,000
TOTAL	15,000	10,000	20,000

1.0 LOW-BTU GASIFICATION

The Laramie Energy Technology Center is conducting the low-Btu gas project in a 30-foot-thick subbituminous coal seam in the Hanna Field in Wyoming. The objective of this project is to develop a process for gasifying coal in place to produce a low-Btu gas for utility power generation or industrial use. Linked Vertical Wells (LVW) with air injection is one of the processes being studied. It requires minimal seam preparation and has a good probability of success in coal seams that have adequate natural permeability.

The LVW process is applied by drilling vertical wells into the coal seam to provide for injection of air and collection of product gases. Reverse combustion is used to link the wells through the coal seam, followed by forward gasification of the coal between the linked wells.

In the following diagram, the center and right wells are linked by reverse combustion. High-pressure air is injected in the right well and flows to the center production well through naturally occurring cracks and paths in the coal. The combustion zone advances from center well to right well (injection well) against the gas flow, creating a hot char channel between the wells. Once two wells are linked, the gasification front direction is reversed, moving with the gas flow. This second stage, called forward gasification, is shown between left and center wells in the diagram. Forward gasification proceeds along the linked passage, which widens and caves in to expose more coal.



Linked Vertical Wells Process

As illustrated, one pair of wells (one module) can be linked while the coal between a second pair is being gasified. When the gasification zone passes the center well, that well is switched to injection and the right well is switched to production. A link is then started to a new well, yet farther to the right. Thus, the gasification proceeds in a line although it expands appreciably to either side of the line. Lines of wells are drilled closely enough so the gasification cavities overlap, using as much of the coal as possible. Success of the process depends on controlled movement of the reaction zone between wells and efficient use of the coal resource.

Project Status

Development of the LVW process started in 1972. In Hanna I, the first field test, gas with an average heating value of 126 Btu/scf was produced for about six months, ending in March 1974. The test was quite successful since energy production was four times greater than energy use. Hanna II, phases 2 and 3, completed in the summer of 1976, produced an average of 8.5 million scf/d of 172 Btu/scf gas. This is equivalent to the electrical requirements of a town with a population of 6,000 which would require 6 to 8 MW of electrical power. This test demonstrated a very high areal-sweep efficiency by gasifying a total of 6,700 tons of coal from a 4-well square pattern.

The Hanna III environmental test was completed in July of 1977. This was a 2-well experiment designed primarily to measure the effects of the process on underground water flows and compositions and to further refine the LVW operating and control procedures. Analysis of the results and monitoring of water in and above the burn zone will continue.

Beginning with phase 1 of Hanna II, a major instrumentation effort was fielded by Sandia Labs, making these the most instrumented UCG tests ever conducted. Development of a detailed math model of the process was initiated, using a combination of field and laboratory data plus theoretical considerations. Refinement of this model will provide design information for applying LVW to other sites.

The Hanna IV test was designed to determine the relationship between well spacing and sweep width over longer well spacings (effects of scaling). This test began in FY 1978 and ran into difficulties due to improper well completions and the natural fracturing and faulting of the coal seam. These resulted in an override condition where the major air flow pathway was at the coal-overburden interface, thus bypassing a substantial amount of coal. The test was restarted in FY 1979 and multiple links were completed over a 112-foot well spacing. Subsequent forward gasification confirmed that multiple air flow pathways were present. After three weeks of acceptable gas quality production, the gasification cavity intersected an air flow pathway near the top of the coal seam and the product gas quality deteriorated. The test was terminated at the end of FY 1979.

The major tasks in FY 1980 will be a post-burn coring program and a hydrology program at Hanna. A series of linking tests will be designed to determine the effect of natural fracture systems on the UCG process. Beginning in FY 1980, LETC will be involved in an industrial cost-shared development program to assess the environmental, technical, operational, and economic problems facing commercialization of low- and/or medium-Btu gas.

The Sandia Laboratories (SL) program for instrumentation and process control development addresses the problem of obtaining a thorough technical understanding of the chemical and physical mechanisms of the in situ reaction and the problem of process control. Preliminary instrumentation efforts on the Hanna I experiment during 1973 to 1974 demonstrated that process-related effects could be detected by electrical, acoustic, and thermal techniques. Based upon these results, a comprehensive instrumentation effort was designed as an integral part of the Hanna II experiment conducted in 1975 to 1976. Currently SL is actively involved in the instrumentation effort for the Hanna IV test. The planned milestones for the project are shown below.

2.0 MEDIUM-BTU GASIFICATION

Lawrence Livermore Laboratory is conducting the Medium-Btu Gasification project in a 25-foot-thick subbituminous coal seam at Hoe Creek, Wyoming. The objective of this project is to develop a commercial process using oxygen and steam injection to produce medium-Btu gas for use as a chemical feedstock or upgrading to SNG. Well-linking methods, other than reverse combustion, will be developed for application of this technology to a wide variety of resource/process combinations (especially very deep, thick coal seams).

Project Status

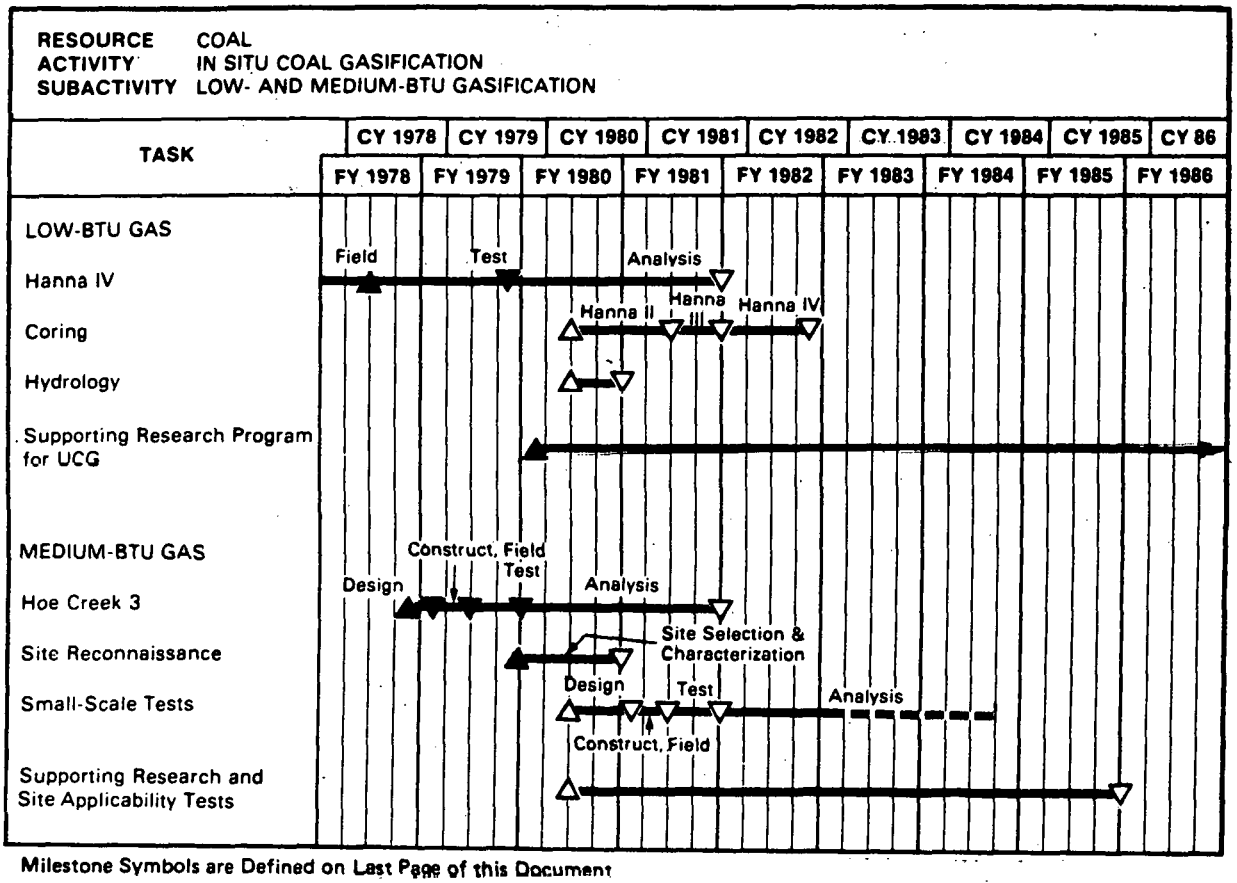
LLL has been running the Medium-Btu Gasification project since its inception in FY 1975. The suitability of a site at Hoe Creek in the Powder River Basin near Gillette, Wyoming, was verified. In FY 1977 a preliminary test of a 2-shot fracture and forward gasification with air was run in a shallow coal seam at the Hoe Creek site. Although the desired permeability distribution was not achieved, the reverse linking step was successfully omitted. Data reduction, groundwater monitoring, and post-burn coring activities are complete.

One site-applicability test for the LVW process was completed in FY 1978. This test (Hoe Creek 2) used coal that was more uniform, considerably wetter, and more reactive than the coal at Hanna. During this test, oxygen and steam were injected for two days. Medium-Btu gas was successfully produced with a heating value that averaged 260 Btu/scf and ranged up to 300 Btu/scf.

In FY 1979 the Hoe Creek 3 test was completed using oxygen/steam injection. The 57-day experiment consumed about 4,000 tons of coal. A directionally drilled borehole provided the link between the vertical wells. During the first six days of gasification, air was injected. After the initial gasification cavity was created, injection was switched to steam/oxygen and gasification conditions were maintained for 48 days. Average gas quality was 210 Btu/scf, which was lower than the expected gas quality of about 265 Btu/scf. This was probably a result of the geology of the Hoe Creek area. The overburden is water-bearing and as the coal was gasified, the overburden collapsed into the coal seam. The influxing water cooled the gasification zone absorbing energy that would have gone into gas production.

The major tasks in FY 1980 include the cleanup and restoration of the Hoe Creek 3 site and the analysis and documentation of the data. Site monitoring will continue for five years. Within one month of the completion of Hoe Creek 3, there were two incidents of subsidence between the process wells. The DOE is working with the Wyoming Department of Environmental Quality to investigate these events.

Other FY 1980 tasks are support for the UCG Program Opportunity Notice (PON) and new site reconnaissance. A new site will be selected for a series of small-scale tests to complement and support the PON activities. These tests will utilize the directional drilling and steam/oxygen techniques in deep subbituminous coal seams.



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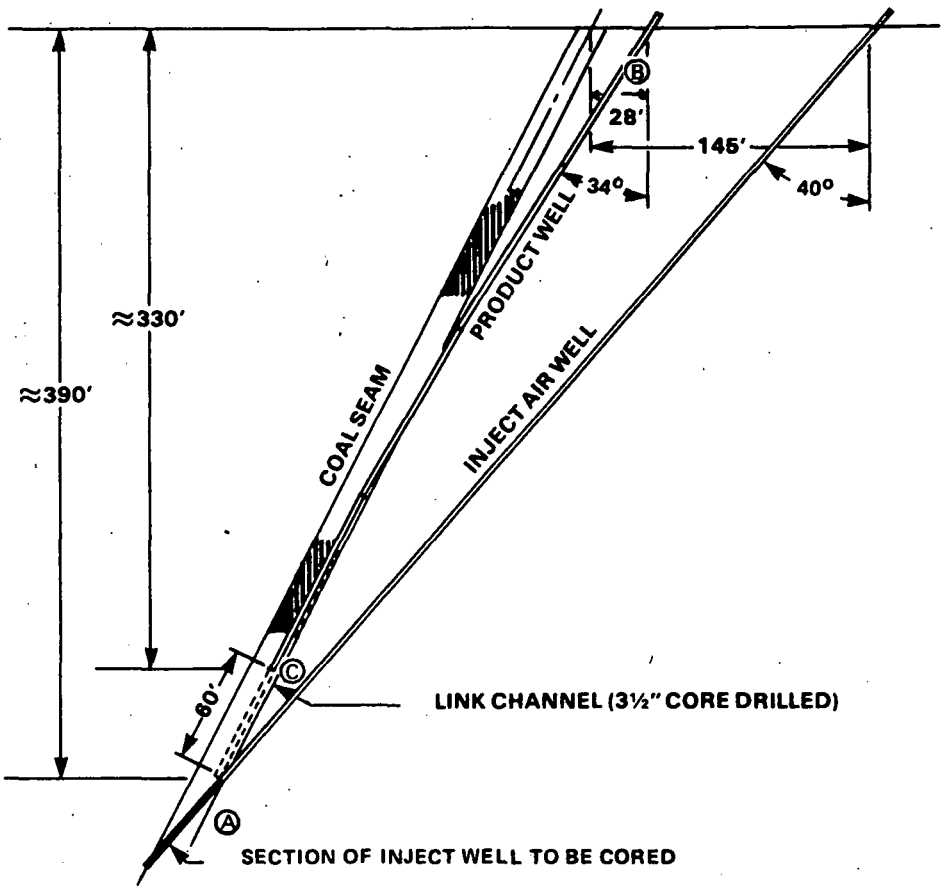
3.0 STEEPLY DIPPING BEDS

The steeply dipping beds process is designed for seams that dip greater than 35° relative to the earth's surface. This coal is generally not recoverable by existing mining methods. The use of slant drill holes will require the use of sophisticated directional drilling techniques. Subsidence problems are more difficult for the SDB process than for the other in situ gasification processes (more localized). The SDB project is cost shared with industry and is studying the production of either low- or medium-Btu gas.

Over 100 billion tons of SDB coal are estimated to exist in the United States. A large percentage of the Pacific Coast coal is steeply dipping, so commercialization of an SDB process could contribute to the future energy supply of the populous West Coast. There are also substantial SDB deposits in the Rocky Mountain area and lesser amounts in the Appalachian and interior coal regions.

In order to develop the necessary cost data for the SDB pilot-scale field test, this project incorporates the execution of several test "burns." The first burn, Rawlins 1, (see following figure) will serve the purpose of developing the necessary skills and procedures for demonstrating gasification using the simplest module configuration at the most convenient location.



Ⓐ The Air Inject Well will be Drilled First Spudding in at 40° and at the Point Where the Bit Enters the Coal Seam. Drilling will Stop and 6 5/8" Casing Set, at this Point the Seam will be Cored in Order to Establish Seam Location at this Depth.

Ⓑ In Order to Avoid Thermal/Leak Well Problems, Product Well will be Spudded in at ~34° and Deflected Towards the Coal Seam Foot Wall 2 1/2" Per 100 Feet, Once Inside the Seam, the Bore Hole will be Straightened so that the Product Well will be Located Parallel to the Seam Foot Wall and Within the Lower Third.

Ⓒ The Link Zone Between the Inject Well and Product Well will be Cored with a Small Size Bit to a Point Near the Inject Air Well, at least within 10-15'.

Steeply Dipping Beds, Rawlins 1 Experiment

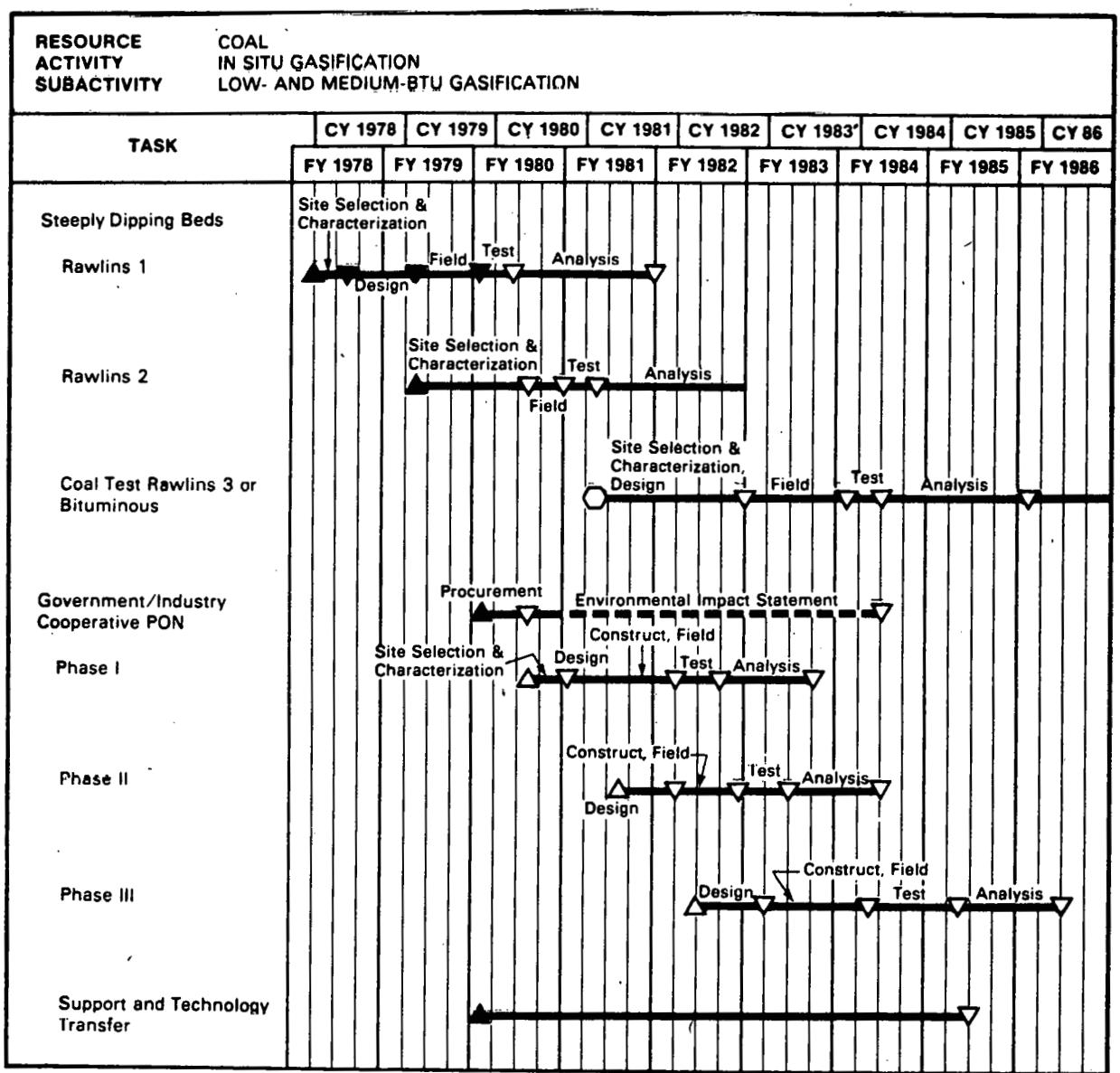
The Rawlins 1 test was designed, fielded, and completed in FYs 1978 and 1979. The injection and production wells, completed using slant drilling techniques, were linked by reverse combustion. Forward gasification using air injection continued for 21 days and was followed by 5 days of water-oxygen-air injection for production of medium-Btu gas. Air injection produced 150 Btu/scf gas, and the steam/oxygen test period produced gas averaging over 290 Btu/scf.

The major FY 1980 tasks include the completion of the Rawlins 1 test, analysis and documentation of the data, and the design of the Rawlins 2 test. The fielding of the Rawlins 2 test will begin in FY 1981 and operation of the test will begin in mid-FY 1981. After the second test, a decision

will be made as to whether the SDB technology is advanced sufficiently for testing in bituminous seams.

Project Status

A PON for the "Development of In Situ Coal Gasification Technology for Production of Low- and/or Medium-Btu Gas," was issued in November of 1979 for award in FY 1980. The objective of this program is to join with industry in a phased research and development project leading through a pilot-scale demonstration of UCG. The work proposed in the PON entails a cost-shared three-phase effort over a five-year period. No preliminary decision has been



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made as to whether low- or medium-Btu gas for power generation, for chemical feedstock, or for upgrading to synthetic natural gas is the most logical choice for industrial heat.. Phase I of this work involves an air and/or steam-oxygen test to determine gasification areal extent, product gas quality, and the geologic suitability of the deposit to UCG. Phase II constitutes a multiple-process well test of sufficiently large scale to verify technical, environmental, and economic parameters. Phase III is a pilot-scale test to refine parameters such that industry can design and implement commercial operations with confidence.

In addition to the work under the PON to be conducted by industry, a major supporting research effort coordinated by LETC will be conducted by LETC, LLL, SL, universities, and contractors. The effort will include development of essential data in such areas as linking and process control as well as refining of prediction and control models. This work to be coordinated with the PON and conducted concurrently is essential to insure the optimum probability for success of the R&D project.

4.0 ENVIRONMENTAL SUPPORT

Environmental problems associated with in situ coal conversion may be less serious than those with mining and surface gasification. The biggest problem could be the disruption and contamination of local aquifers, but this area requires further research. Overall water usage should be lower for in situ than for surface gasification. Air emissions should be no worse than those from surface gasification and will be controllable by similar methods. Surface disruption due to subsidence should be minimal and easily repaired in comparison to strip mining.

Environmental support work determines the true impact of environmental problems associated with in situ coal gasification and methods for their control. Since environmental problems are common to all in situ concepts, environmental support crosscuts all major projects.

The UCG process by its nature has potential environmental advantages. It may be possible to minimize surface disruption due to subsidence by adjusting the process design. In any case, surface disruption will be much less than that for strip mining. Most of the solid wastes remain underground. Since there is less equipment in a UCG versus a surface gasification plant, there is lower demand for cooling water, which is an important factor in the arid West. In addition, the seam water will enter the underground reactor and be produced. Part of this will be recovered and can be used as process water. Since coal mining is avoided or at least reduced, mine safety problems will also be reduced.

On the other hand, uncontrolled subsidence could leak gases to the atmosphere through cracks to the surface. Subsidence can also break overhead aquifers and allow their waters to enter the reaction zone during and after gasification when pollutants can be picked up and carried away by the subsurface flows. Location of the best UCG resources in a part of the United States that has limited potable water and population could lead to socioeconomic problems. The western deposits in regions with almost pristine air quality that are protected by strict laws will require stringent control technology.

Project Status

An Environmental Development Plan has been issued. It will provide for the implementation of a comprehensive environmental plan for in situ coal gasification projects to ensure that all environmental issues are fully considered in decision making.

Baseline water quality and post-burn changes have been measured in both the Hanna and Hoe Creek tests. Detailed hydrologic and geologic studies were made in the Pricetown site area (described in subsection 5.0) to provide baseline environmental data. LLL has run laboratory tests which show that surrounding coal can cleanse subsurface water of harmful pollutants. The tar produced in the Hanna II test revealed potentially carcinogenic compounds. Evidently these components were trapped and reacted underground.

The primary objective of Hanna III was measuring underground water quality and determining how it is affected by in situ coal gasification. Longer and more detailed air-emission measurements were planned on Hanna IV.

LLL has a cooperative agreement with the Environmental Protection Agency to conduct a more extensive laboratory program to determine the amount of water cleanup required to remove organic and inorganic contaminants.

5.0 SUPPORTING RESEARCH

The program's approach to determining the technical and economic feasibility of UCG in coal seams includes laboratory experimentation, process modeling, and the investigation of alternative linking techniques and gasification concepts in well-instrumented field tests. The objective of the laboratory research and modeling efforts is to support the field program by investigating process parameters, alternative linking methods, ignition techniques, and developing instrumentation and software for field use. This work is being performed as follows:

- Morgantown Energy Technology Center's laboratory and modeling program centered on determining the mechanical and physical properties (especially natural permeability and fracturing characteristics) of coal under overburden stress. A series of experiments that simulate the field tests using the Longwall Generator (LG) concept was completed. The supporting research program also includes theoretical modeling and developing of methods to control the gasification process.

- The Argonne National Laboratory's project provides kinetic data on the important chemical reactions that occur during in situ gasification and to determine the important process parameters for the control of these reactions.

- The Oak Ridge National Laboratory's project is collecting experimental data on the thermal conductivity of the coal samples of interest.

- The Los Alamos Scientific Laboratory's project is studying the technical and economic feasibility of a two-stage CO_2-O_2 underground coal utilization scheme with minimal water requirements.

- The University of Pittsburgh project is measuring and rationalizing the gas-liquid relative permeabilities of coals-from-lignite samples.

- An energy contractor is providing planning support for the costs of a UCG pilot plant facility.

- Stanford Research Institute has completed a market study for low- and medium-Btu gases produced from UCG in the Green River, Fort Union, Powder River, and San Juan River regions.

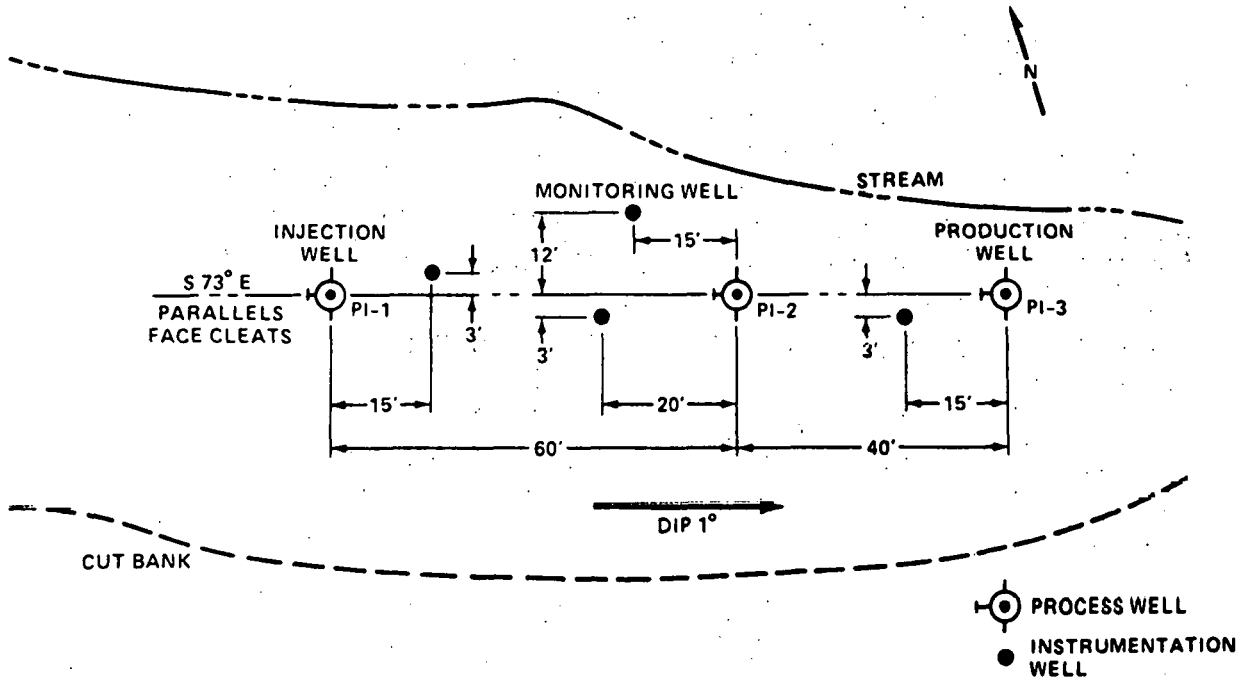
Eastern Coal Technology: Morgantown Energy Technology Center

Another supporting research effort is the Eastern Coal Technology project. Its objective is to develop a method of gasification for eastern coals that cannot be easily mined. Such reserves amount to approximately 220 billion tons. Thin, low-permeability, high-swelling, eastern coal seams are most difficult to gasify by in situ methods. Rugged terrain and densely populated areas in the East make drilling closely spaced (100 feet or less) vertical wells difficult. Directional drilling may solve this problem. Deviated holes provide the best means of developing the underground manifold if they can be drilled economically.

Project Status

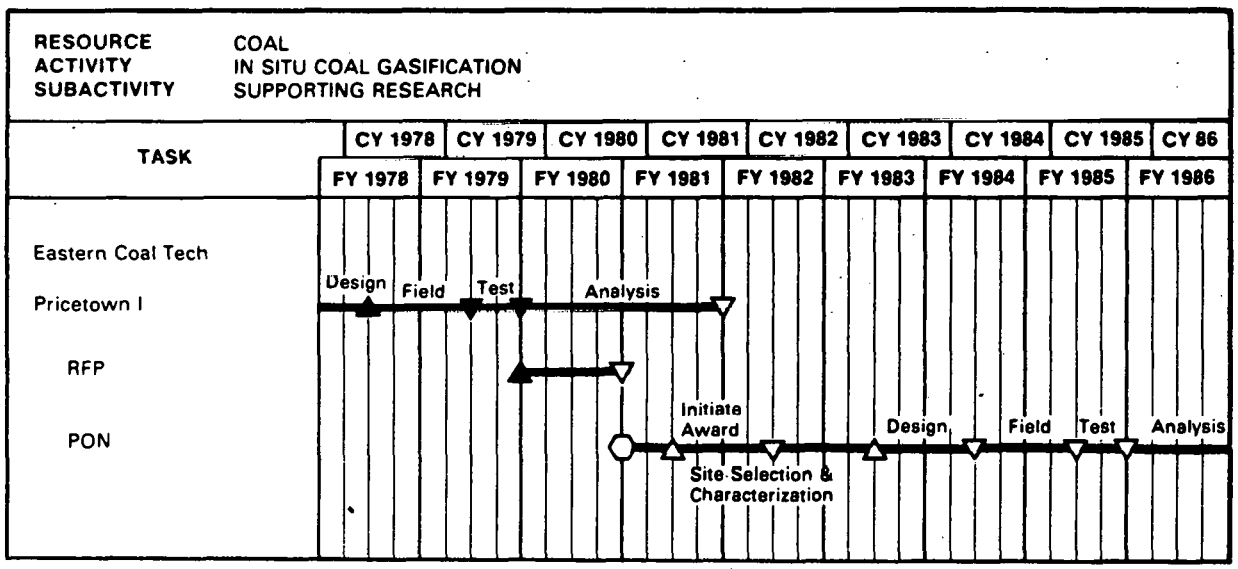
Field experimentation has concentrated on site, resource, and environmental assessment (EA). A site near Pricetown, West Virginia, was selected for the initial test in the bituminous Pittsburgh seam. An LVW minitest (Pricetown I) was operated in FY 1979 (see following figure). The test gave data on the maximum well spacing that can be used in future tests using directionally drilled wells.

The Pricetown I test was a 3-well pattern in a 6-foot-thick seam approximately 900 feet. The wells were linked by reverse combustion, and gasification was accomplished using air injection. The average gas quality was in excess of 200 Btu/scf. The gas quality during the steady-state gasification period averaged 130 Btu/scf. This feasibility test showed that (1) coal seams can be ignited at depth, (2) the LVW process and forward gasification are successful in thin, deep, bituminous coal seams, and (3) environmental effects are minimal.



Pricetown I Experiment

Major tasks in FY 1980 are the analysis and documentation of the data from Pricetown I, and the continued environmental monitoring of the site. A contract based on an RFP for the assessment of bituminous coal in the U.S. will be awarded, and this may be followed by further work with industry to develop the bituminous UCG technology to commercialization.



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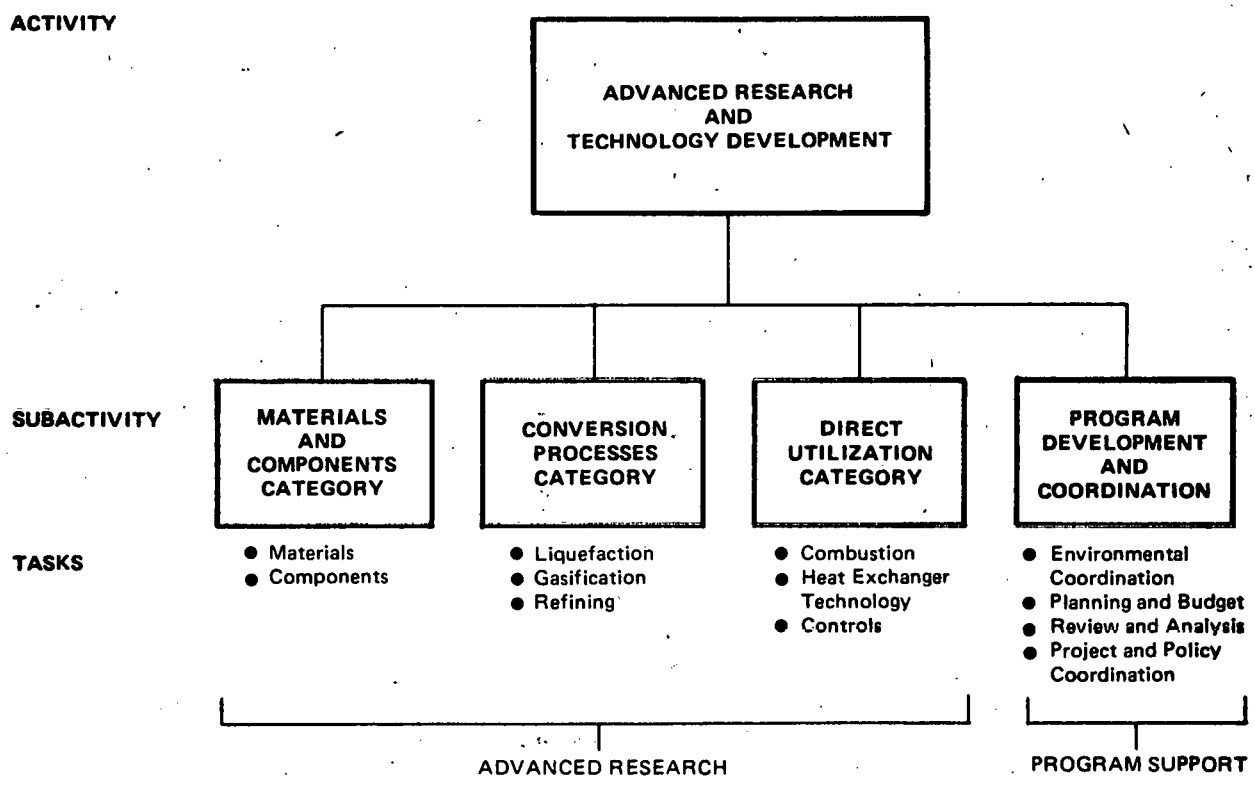
E. ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

The Advanced Research and Technology Development (AR&TD) Activity covers a diverse group of activities ranging from applied research to R&D supporting activities.

The Office of Advanced Research and Technology provides oversight on all aspects of advanced research and manages a newly established University Coal Research program.

Applied research is the responsibility of the respective offices having primary cognizance:

- Materials: Office of Advanced Research and Technology
- Components and Conversion Processes: Office of Coal Processing
- Direct Utilization: Office of Coal Utilization.



Advanced Research and Technology Development Activity
Subactivity and Task Support Structure

Support for program development and coordination is provided by:

- Office of Budgets and Administration: long-term strategy and planning, program review and analysis, financial planning, and program integration support

- Office of Plans and Technical Assessment: process engineering, economics, and all aspects of environmental planning and assessment covering all Fossil Energy facilities and programs.

Principal objectives of this budget activity are to:

- Provide for a central research focus and program coordination for all program areas of Fossil Energy.

- Provide a foundation for innovative technology leading to advanced processes through programs in the DOE Energy Technology Centers (ETCs), National Laboratories (NLs), other Government agencies, private industry, and universities.

- Facilitate reliable and efficient operation of synthetic fuel plants through materials and components research.

- Accelerate direct utilization of coal or coal-derived synfuels through technology development for combustion systems, heat exchangers and control systems, including applications to heat engines and fuel cells.

- Ensure an adequate supply of trained technical personnel from the Nation's university system.

- Assess the viability of Fossil Energy processes under development in terms of national needs, economic, social and environmental constraints and benefits.

- Provide technical assessment, environmental and systems assurance support for Fossil Energy programs.

The current research program explores the following areas discussed in subsequent sections:

- Advanced fossil fuel conversion processes, involving coal gasification, liquefaction, and refining of coal-derived syncrudes to produce transportation and distillate fuels

- Advanced, environmentally acceptable direct combustion and utilization processes for both coal and synfuels

- Supporting research on materials and components, waste use and disposal, and fossil fuel science and engineering

- Systems studies contributing to development of a logical, integrated strategy and rationale for selection and development of Fossil Energy options.

Approximately 50 percent of AR&TD projects are conducted by industry, 25 percent by ETCs, NLs, and other Government agencies, and 25 percent by universities. ETC and NL activities are discussed in Chapter VI. University programs are discussed in greater detail in Section E-5.0 and Chapter XI.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Processes	7,850	14,800	20,400
Direct Utilization	9,450	7,100	11,000
Materials and Components	9,290	12,900	9,000
Program Development and Coordination	13,158	7,700	7,861
University Coal Research	0	5,000	5,000
Capital Equipment	375	400	500
Construction	6,350	8,250	10,700
TOTAL	46,473	56,150	64,461

1.0 PROCESSES

There is an urgent need for a better scientific and engineering base for the ongoing research and development programs as well as for process improvements, i.e., truly advanced, lower cost technology which entails fewer steps, is simpler, and permits substantially higher production rates per unit volume of reactor at reasonably high thermal efficiencies. To meet such needs, a comprehensive basic/applied and exploratory process research program is being supported in the areas of coal gasification, coal liquefaction, and refining of coal-derived syncrudes and shale oil to produce distillate fuels, including gasoline.

The overall objectives of this process research are to:

- Develop basic chemical and engineering knowledge to facilitate the inception and successful development of new and/or modified coal gasification and liquefaction processes and to provide leads to new processes.
- Determine the technical feasibility of new process concepts under steady-state conditions.
- Conduct supporting research in selected areas, such as catalyst development, to complement known processes under development, and/or to provide improvements in these processes.

Liquefaction

The goals of this research are to (1) develop through the bench scale, advanced processes that show promise for the direct or indirect liquefaction of coal to low-sulfur, liquid boiler fuels, and distillate syncrudes; and (2) develop processes for direct production of fuels such as gasoline, diesel fuel, and furnace oil by upgrading and refining coal-derived syncrudes.

The major research categories are:

- Extraction
  - Short-residence-time liquefaction
  - Donor solvent interactions
- Catalytic Hydroliquefaction
  - Mechanism of catalyst deactivation
  - Slurry catalyst process
- Indirect Liquefaction
  - Exploratory catalyst research
  - Reaction mechanisms
- Supporting Research
  - Examples include: structure of coal and preasphaltenes; mechanism of coal hydroliquefaction; catalytic reactor modeling/design; thermodynamics; analytical chemistry of coal and coal liquids; and organic chemistry of coal.

Specific needs include development of a better understanding of the basic chemical and engineering aspects of the preheater stage in direct hydroliquefaction; determination of the effect of coal mineral matter in the early stage of liquefaction, particularly in minimizing thermal repolymerization; definition of the applicability of catalysis in direct liquefaction; determination of the relationship of coal cleaning with coal liquefaction; discovery of improved shape selective catalysts for conversion of synthesis gas to high-quality transportation fuels; and exploration of the use of the liquid phase reactor to improve the efficiency for converting synthesis gas to high-quality fuels.

Major accomplishments in FYs 1979 and 1980 are:

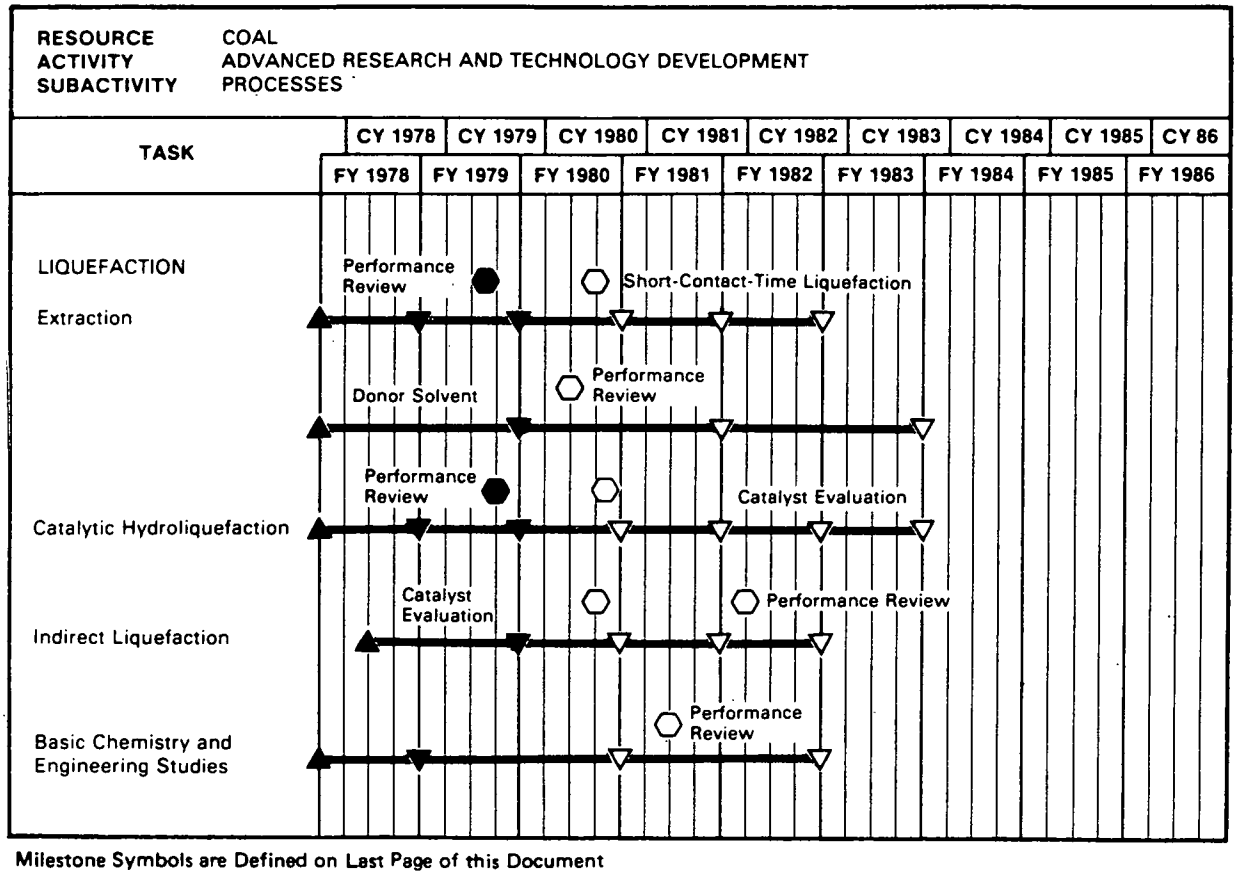
- Demonstrated that iron pyrite is the catalytically active component of mineral matter
- Showed that the addition of pyrite as a catalyst for coal liquefaction can result in significant improvements in selectivity to liquids and lead to significantly lower hydrogen consumption

- Demonstrated that coal syncrudes (i.e., SRC-II, EDS, H-Coal Syncrude) can be refined by known refining processes. Showed that, on a grassroots basis, the cost of refining coal liquids is similar to the cost of refining medium-gravity sour petroleum crude oil (typical of incremental imported oil)

- Exploited a novel oxidative-degradation-of-coal technique to obtain new insight into the structure of coal as well as to provide a significantly improved method for classifying coals

- Formulated a process model for coal preheaters and correlated the model with experimental data

- Developed a method for evaluating the donor solvent capability of model compounds. This method is now being extended to actual process-derived solvents.



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Key projects will be closely coupled to the technology development programs and will, in part, focus on key issues and knowledge requirements identified in those programs. Major thrusts in FY 1981 will include (1) innovative process concepts involving advanced catalysts for liquefying and gasifying coal, advanced synthesis gas conversion, upgrading of coal liquids and flash hydropyrolysis; (2) fundamental studies to develop new coal chemistry and better understanding of coal conversion processes, the structure of

coal, and the role of mineral matter in coal on conversion processes; and (3) essential studies on mechanisms, kinetics and the effects of reaction constituents on the catalyst as a function of time and temperature. Such research could lead to the development of combination catalysts for steam-carbon gasification, water-gas shift, and methanation which would enable these reactions to occur simultaneously in the same reactor at reduced overall cost.

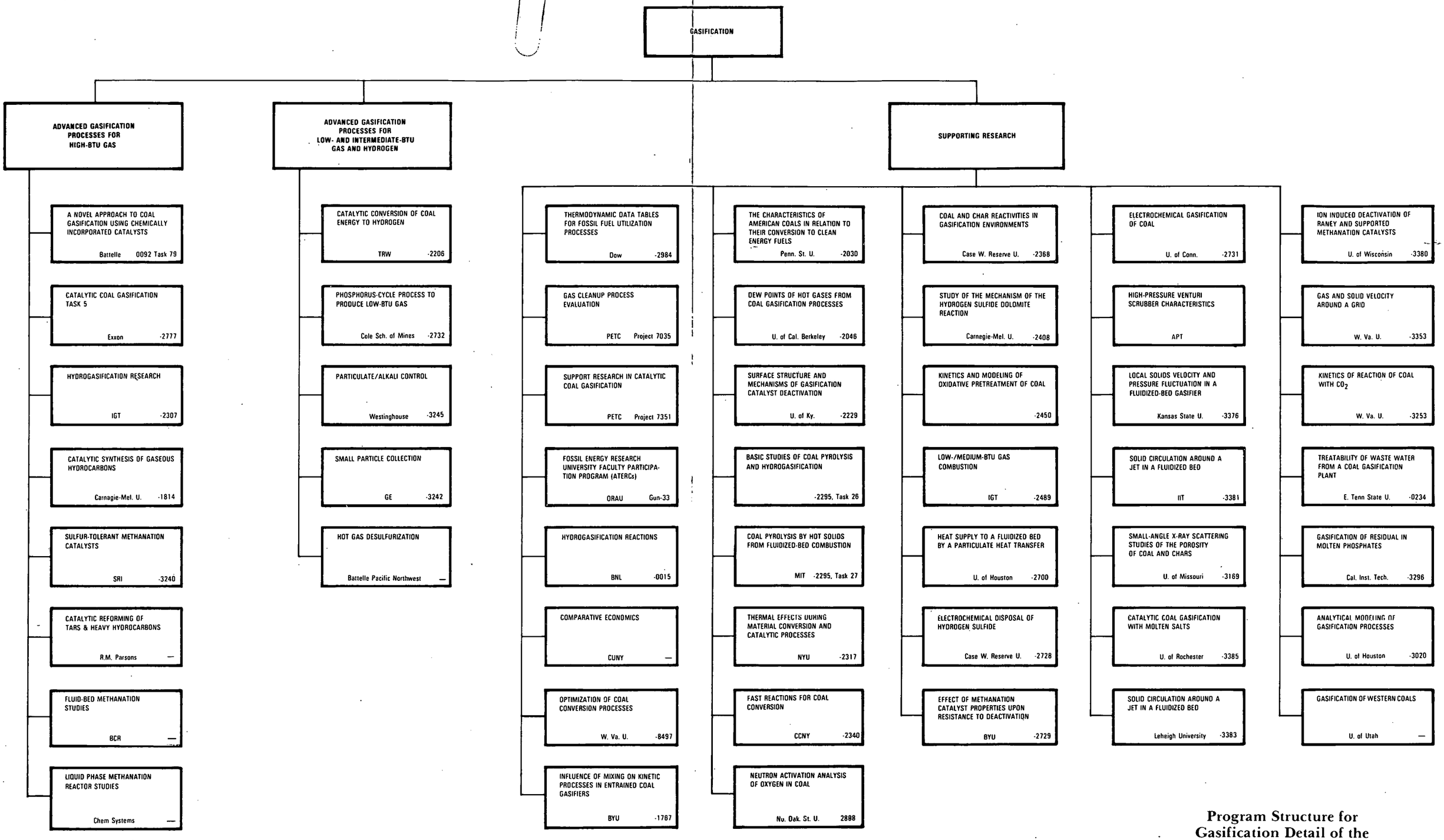
Gasification

Coal gasification processes based on first (commercial) and second generation technology are highly capital intensive; and projected end-product costs are high and very sensitive to conversion efficiency and operability. It is apparent that the current state of the art offers significant room for both technical and economic improvements. These improvements, by providing a better understanding of process fundamentals and an improved data base, can result in identification of advanced processes and an aggressive effort to assess the potential of new, highly innovative concepts. A comprehensive basic and exploratory program is in progress with the objectives of:

- Providing an early assessment of the technical and economic potential of new, novel advanced gasification processes through small bench-scale and early process development studies
- Developing basic chemical and engineering knowledge to facilitate the successful development of current and future generation coal gasification processes and to suggest new approaches to coal gasification
- Conducting supporting research in selected areas such as catalyst development and gas cleanup to provide major improvements.

Major accomplishments in FY 1979 and FY 1980 include:

- Completed bench-scale experiments and preliminary evaluation of the effectiveness of lime and lime/caustic treatments of caking coals for fluid-bed gasification with steam or hydrogen. Data have shown increased reaction rates, increased methane yields and elimination of caking tendencies for a variety of coals
- Initiated program to evaluate advanced gasification concepts, based upon novel chemical and physical processes
- Initiated program to assess the technical feasibility and economic potential of an advanced gas cleanup process removing CO_2, COS and H_2S
- Expanded engineering data bases relating to gas cleanup systems for alkali metal control, and for tar control and utilization via catalytic steam reforming
- Initiated research programs to elucidate kinetic processes associated with catalytic coal gasification



Program Structure for Gasification Detail of the Conversion Processes

- Completed bench-scale evaluation of new methanation catalysts and advanced methanation reactor configurations

- Continued studies to improve the understanding of the process fundamentals associated with all elements of coal gasification.

The Advanced Gasification program contains projects directed at converting coal to synthetic natural gas (SNG), low-Btu gas, and hydrogen. The main program elements are:

- Advanced gasification process for high-Btu gas

  - catalytic gasification
  - catalytic methanation
  - hydrogasification

- Advanced gasification processes for low- and intermediate-Btu gas, synthesis gas, and hydrogen

  - short residence time, rapid rate gasification
  - catalytic conversion of chars to hydrogen via CO_2 acceptor reactions.

- Supporting research

  - alkali metal cleanup, tar control, and acid-gas cleanup
  - reaction kinetics and thermodynamics
  - preliminary engineering and economic assessments

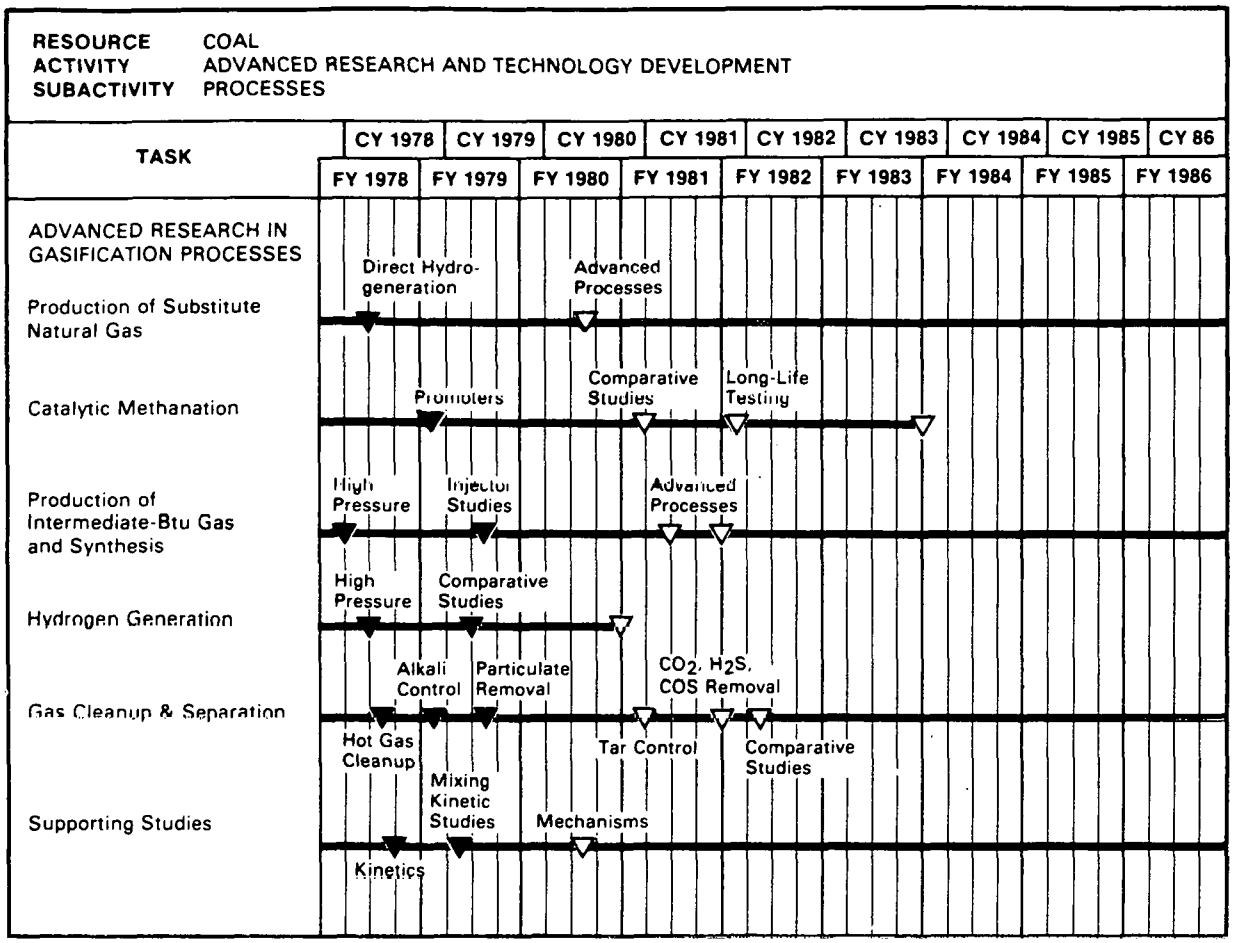
Current research needs include development of a better understanding of the interactions of coal gasification processes in a fluid-bed environment, improvement in the understanding of the interaction of gasification catalysts with the carbon/steam and carbon/hydrogen reactions, development of advanced processes for low-cost synthesis gas, development of lower cost acid-gas cleanup processes, continued efforts to assess advanced cleanup technology for alkali metals, particulates and tars, and a further expansion of the data bases related to process chemistry, kinetics, and thermodynamics.

FY 1981 goals include:

- Improve the engineering data bases related to designing and scaling fluid-bed gasification processes.

- Provide preliminary engineering assessments of advanced gasification processes based on novel chemical and physical phenomena already observed in laboratory studies.

- Continue to expand and improve the understanding and data bases related to the kinetics, chemistry, and thermodynamics of gasification processes.



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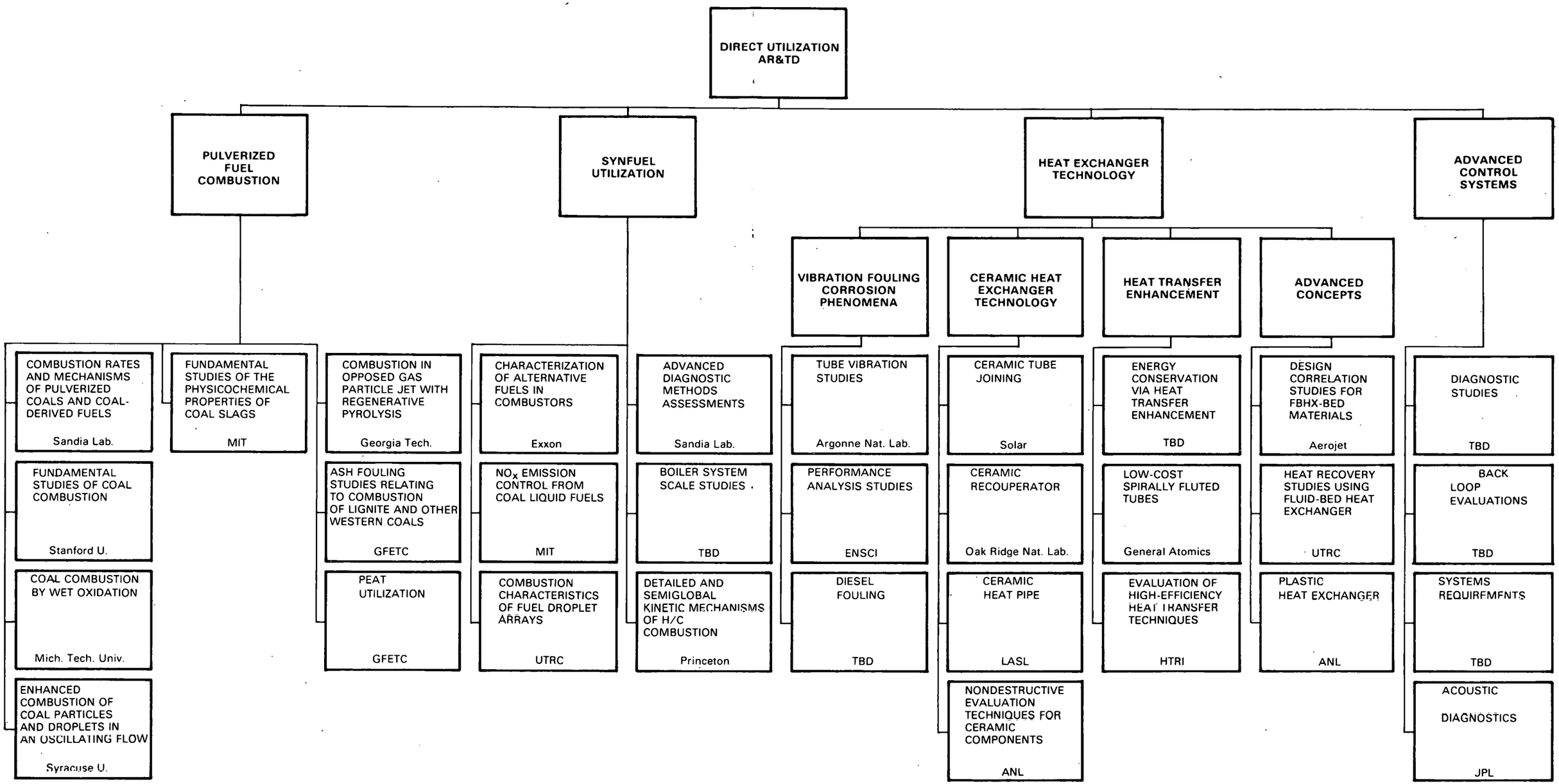
2.0 DIRECT UTILIZATION

Timely substitution of coal and coal-derived fuels (synfuels) by industry requires the solution of a variety of problems related to the end-use system. Techniques to upgrade the raw fuel characteristics, the development of new or modified equipment for more effective and environmentally acceptable combustion, and technologies for more cost-effective treatment of system effluents offer significant potential to improve the competitive position of these fuels and thus accelerate their market penetration. This section describes the activities which have been selected to provide the technologies required for the development of improved coal-fueled systems.



Program Structure for Direct Utilization Subactivity and Related Details

Program emphasis in FY 1980 was changed to reflect that work in the areas of fluid-bed sorbents, coal beneficiation, coal-oil mixtures, and hot-gas cleanup have reached a point of development which allows responsibility to be transferred to the appropriate FE mainline program activity. Major thrusts in FY 1980 focus on:

- Advanced research to relate solid and liquid synfuel composition to combustion characteristics, including fundamental studies on gaseous pollutant formation and particulate agglomeration
- Development of combustion control technologies, including scaling studies for application to industrial-size equipment
- Generic heat exchanger technology to identify and assess promising candidate techniques for improving cost and performance effectiveness in current and advanced systems.

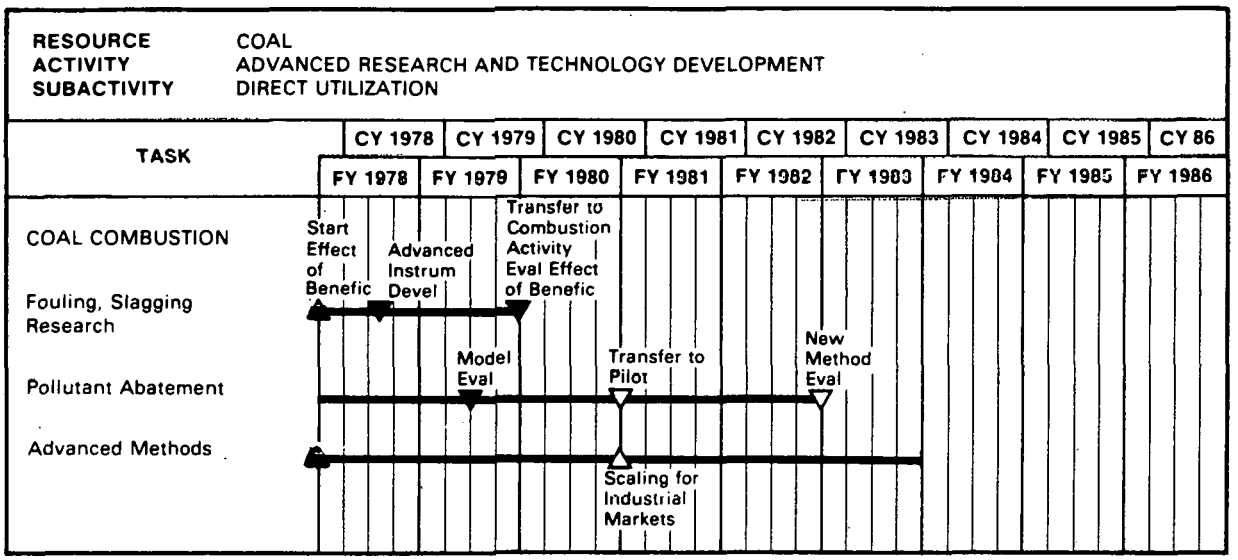
During FY 1981, projects in coal combustion, synfuel utilization, heat exchanger technology, and control system technology will be strengthened. Studies on fundamental mechanisms of combustion and pollutant formation will be expanded and increased emphasis placed on the development of experimentally validated predictive models. These models will form the basis of advanced design tools. Studies on advanced heat exchanger component technology including ceramics for high-temperature applications and fluidized-bed heat exchangers will be continued to develop a technology base for heat exchanger design concepts with improved reliability and effectiveness. In the advanced controls area, results of preliminary studies completed in FY 1980 will be employed to formulate and initiate definitive analytical and experimental projects related to control problems of advanced combustion and power conversion systems.

Pulverized Fuel and Synfuel Combustion

The contribution of this effort to accelerated use of coal-fueled systems is the development of improved combustion components capable of optimizing system performance for different industrial and utility applications.

This is a generic technology project whose goal is to provide the combustion technology base required for optimum substitution of coal into the industrial sector. Significant penetration of this sector presents the equipment designer with the problem of producing reliable combustion equipment for a larger variety of coals and coal chars in a broad range of equipment sizes, and in the face of severe economic and environmental constraints on system performance. The present technology base, which is primarily focused on a narrow range of coal types and equipment sizes, is inadequate to support the timely development of the required equipment. During FY 1979, efforts under this project focused on elucidating fundamental mechanisms for pollutant formation during pulverized-coal combustion.

The FY 1980 effort is based on a coordinated project effort involving participants from industry, universities, and national laboratories as well as energy technology centers. Its objective is application of advanced diagnostics and computational modeling to apply the results of bench-scale studies to full-size pulverized-fuel-burning systems.



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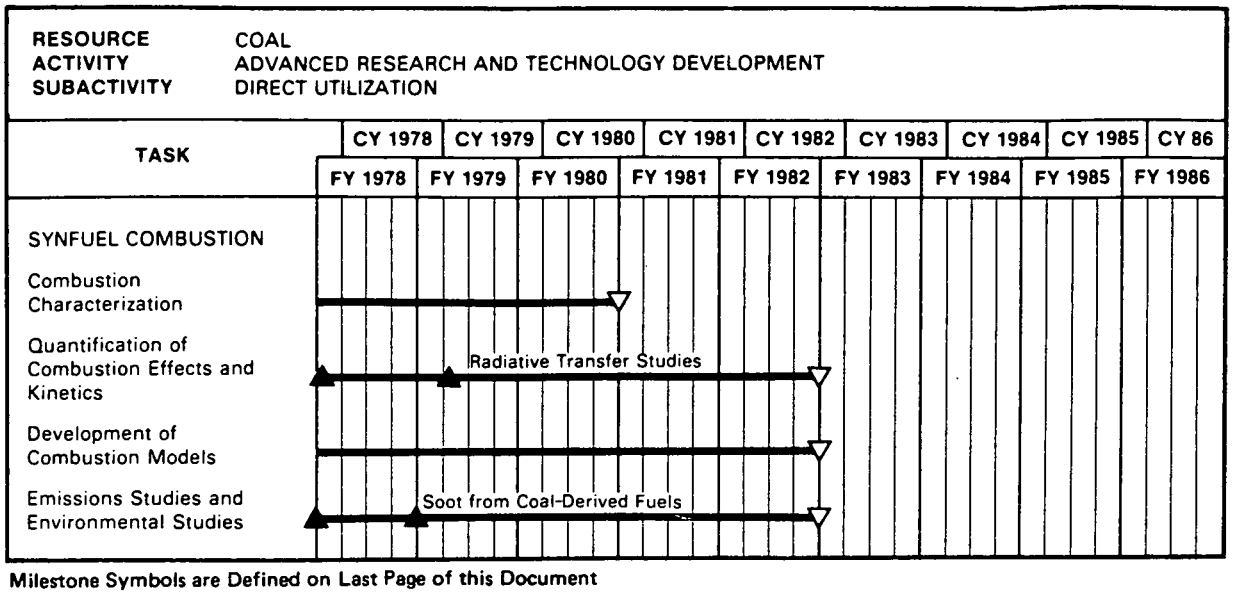
The synfuel technology project will ensure the existence of the technology base required for optimum economic utilization of coal-derived fuels, focusing on coal liquids. The goals of current FE Liquefaction programs are to produce fuels which approach traditional fuel specifications sufficiently to allow utilization in existing combustion equipment designed for petroleum fuels. Cost penalties associated with upgrading raw coal liquids to petroleum fuel specifications have been estimated to be as high as 30 percent, a figure which has an obvious adverse effect on their competitive position. The development of combustion equipment designed specifically for utilization of minimally processed coal liquids offers significant potential to reduce refinery/combustion system costs. This development is severely limited by the inability of the current state of the art to determine those combustion characteristics required by the equipment designer from the elementary fuel composition data available from the various fuel processing investigations. In FY 1979, the project focused on problems associated with utilizing coal liquids in stationary gas turbines.

During FY 1980 the scope of the project was broadened to provide an effective technology base supporting coal-derived fuel utilization in boilers and furnaces.



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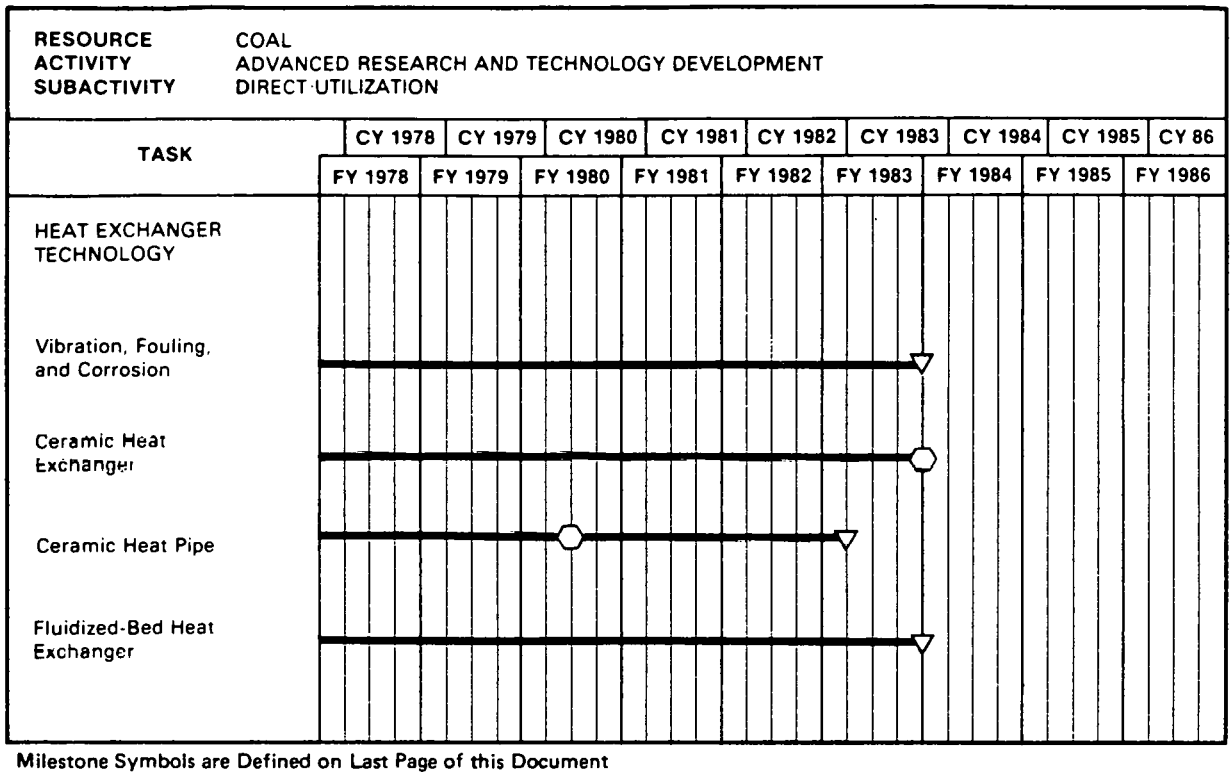
During FY 1981, pulverized fuel and synfuel combustion efforts will include studies on fundamental mechanisms of combustion and pollutant formation will be expanded. Increased emphasis will be placed on the development of experimentally validated predictive models. It is intended that these models will form the basis of advanced design tools for pulverized solid-fuel combustion systems.

Heat Exchanger Technology

This generic technology development project has the goal of improving heat exchanger performance/cost characteristics for application in heat recovery and advanced energy conversion systems.

During FY 1979, some heat exchanger work was performed in the Heat Engines and Heat Recovery Activity. In FY 1980, it was included as part of the AR&TD program. The FY 1980 effort focused on improved understanding of fundamental heat exchanger phenomena, e.g., flow-induced vibration (FIV), fouling, and corrosion, which affect design and cost and evaluation of new concepts that offer the potential of extended temperature capability and higher performance/cost ratios. Specifically, four main program areas will be pursued: (1) development of fluidized-bed heat exchanger (FBHX) design correlations and evaluation of FBHX concepts for heat recovery applications; (2) evaluation of low-cost tubing concepts including plastic heat exchangers; (3) development of ceramic heat pipe and tubular ceramic recuperator concepts; and (4) development of improved joining techniques and NDE/NDT techniques for ceramic heat exchangers.



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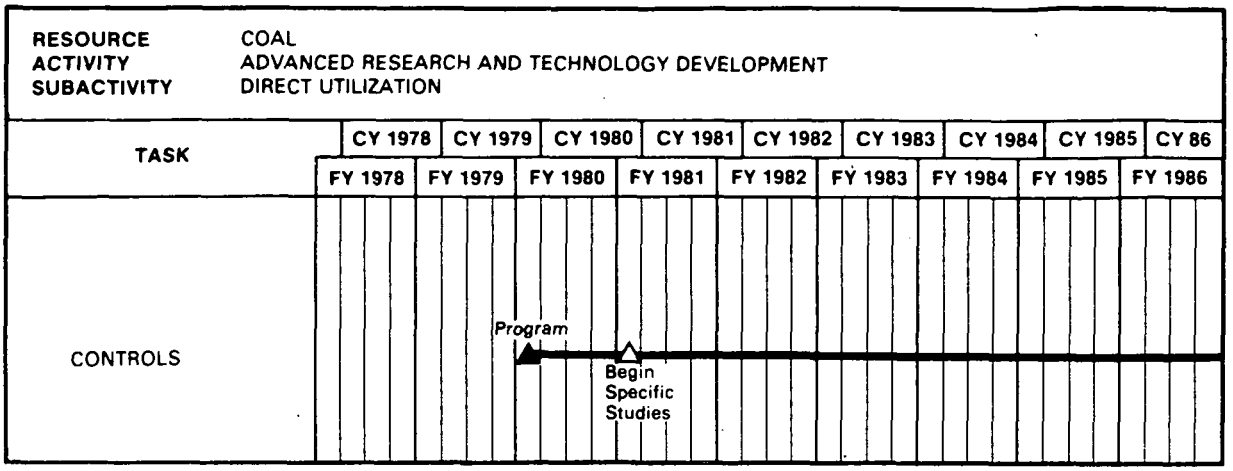
FY 1981 studies will focus on advanced heat exchanger component technology including ceramics for high-temperature applications and fluidized-bed applications. Efforts will be continued to provide a technology base of heat exchanger design concepts with improved reliability and effectiveness.

Advanced Control Systems

The objective of this technology project is to identify and develop new control system concepts required by advanced coal utilization systems now under development. Acceptance of complex and tightly integrated (e.g., combined cycle) systems will require control systems which equal or exceed those systems currently available for gas- or oil-fired systems in terms of safety and reliability.

The variations in grade, rank, and physical preparation of the solid coal can cause perturbations in component performance and power output in a gasified coal-fueled gas turbine combined-cycle which do not occur in conventional systems. Variable properties of the gasified coals can cause problems during startup, shutdown, and/or load following in addition to the recognized variations in gas stream contaminants.

The project for FY 1980 addressed three fundamental areas: studies to identify coal utilization systems which have nonconventional control system requirements; studies to identify promising new control system concepts based on emerging technologies such as laser fiber optics; and studies to develop performance criteria for control systems to meet new coal utilization system requirements.



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In FY 1981 the preliminary studies to identify critical research and development needs for advanced controls, initiated in FY 1980, will be employed to formulate and initiate definitive analytical and experimental projects related to control problems of advanced combustion and power conversion systems.

3.0 MATERIALS AND COMPONENTS

Materials for Coal Conversion

Historically, every developing technology has been keyed to the prior development of critical materials. Efficiency and economy of coal conversion are enhanced at elevated pressures and temperatures; however, erosive and corrosive effects are greater. Successful commercialization requires compatible materials of construction. Accordingly, a broad materials program has been undertaken to meet the specific and unique needs of coal-conversion technology. Elements of this program are:

- Conduct failure analysis of materials now in use in pilot plants, PDUs, and coal-handling applications.
- Conduct research and development on the mechanisms of erosion, corrosion, abrasion, fatigue, and other forms of deterioration as encountered under coal plant operating conditions and environments. Included are metals, special-purpose alloys, ceramics and refractories.
- Select and develop compatible materials for economy of cost and endurance against wear or deterioration. Included are steels, special-purpose alloys, ceramics, and refractory linings.
- Operate one or more materials test facilities as required to obtain realistic material-test data.
- Investigate and identify extra-strong and weldable steels for thick-walled pressure vessels.

- Provide for the timely distribution of materials information by seminars and newsletters.

A significant portion of this program is being investigated at the National Laboratories. Contributing are Ames, Argonne, Oak Ridge, Idaho National Energy Laboratory (INEL), and Lawrence Berkeley.

Significant accomplishments during FY 1979 are:

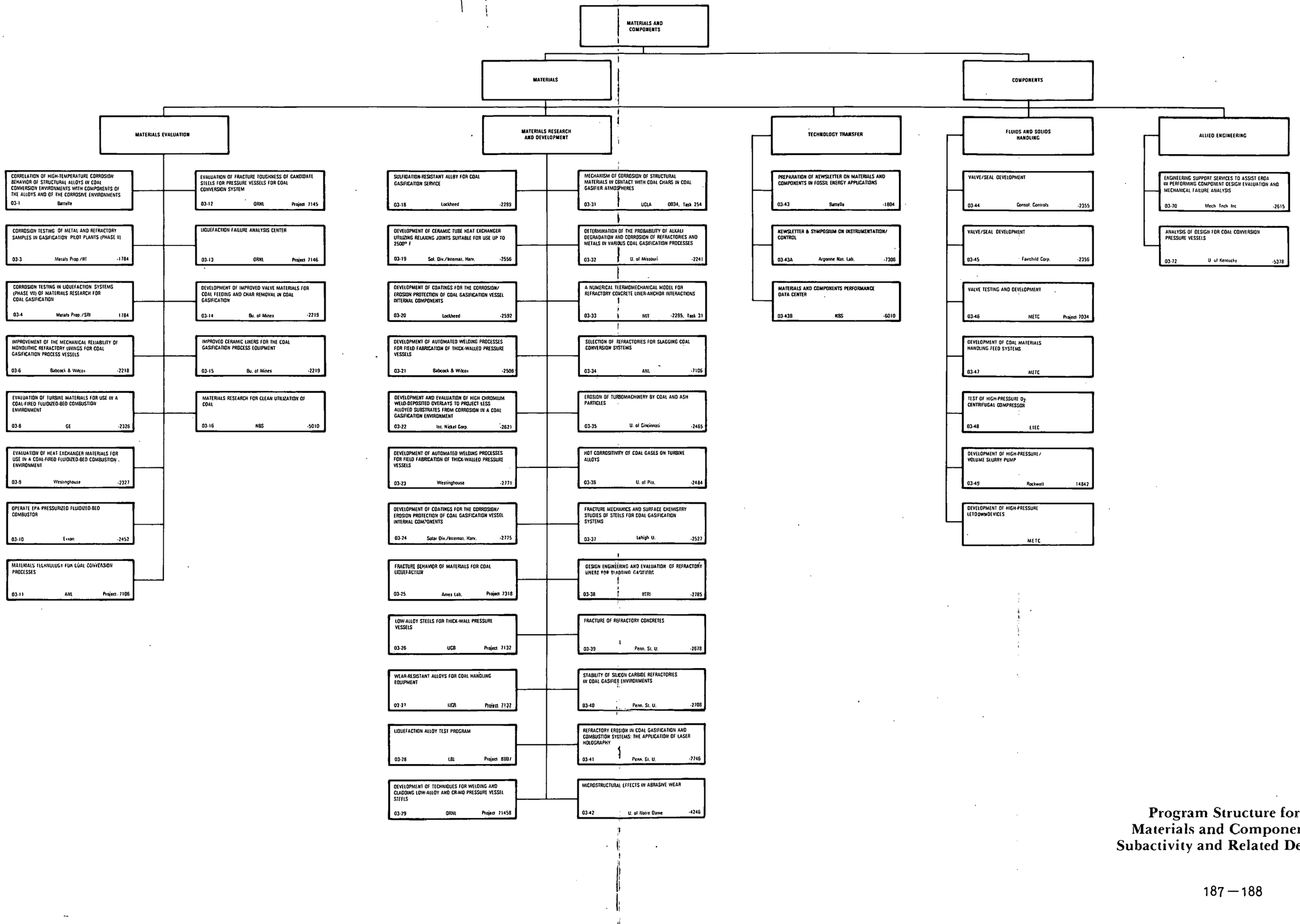
- High-temperature alloys of Fe-Ni-Cr are not resistant to erosion/corrosion in gasifiers over long periods of exposure at 1,000 psi.
- Alloys of Fe-Cr-Al have been fabricated as corrosion-resistant claddings for internal use in gasifiers.
- Construction of a ceramic heat exchanger was completed.
- A program to develop design practices and refractory requirements for slagging gasifiers was initiated.
- A 1,000 hour evaluation of materials for use in heat exchangers and turbines in pressurized fluidized-bed combustors (PFBCs) was completed.

Anticipated accomplishments in FY 1980 include:

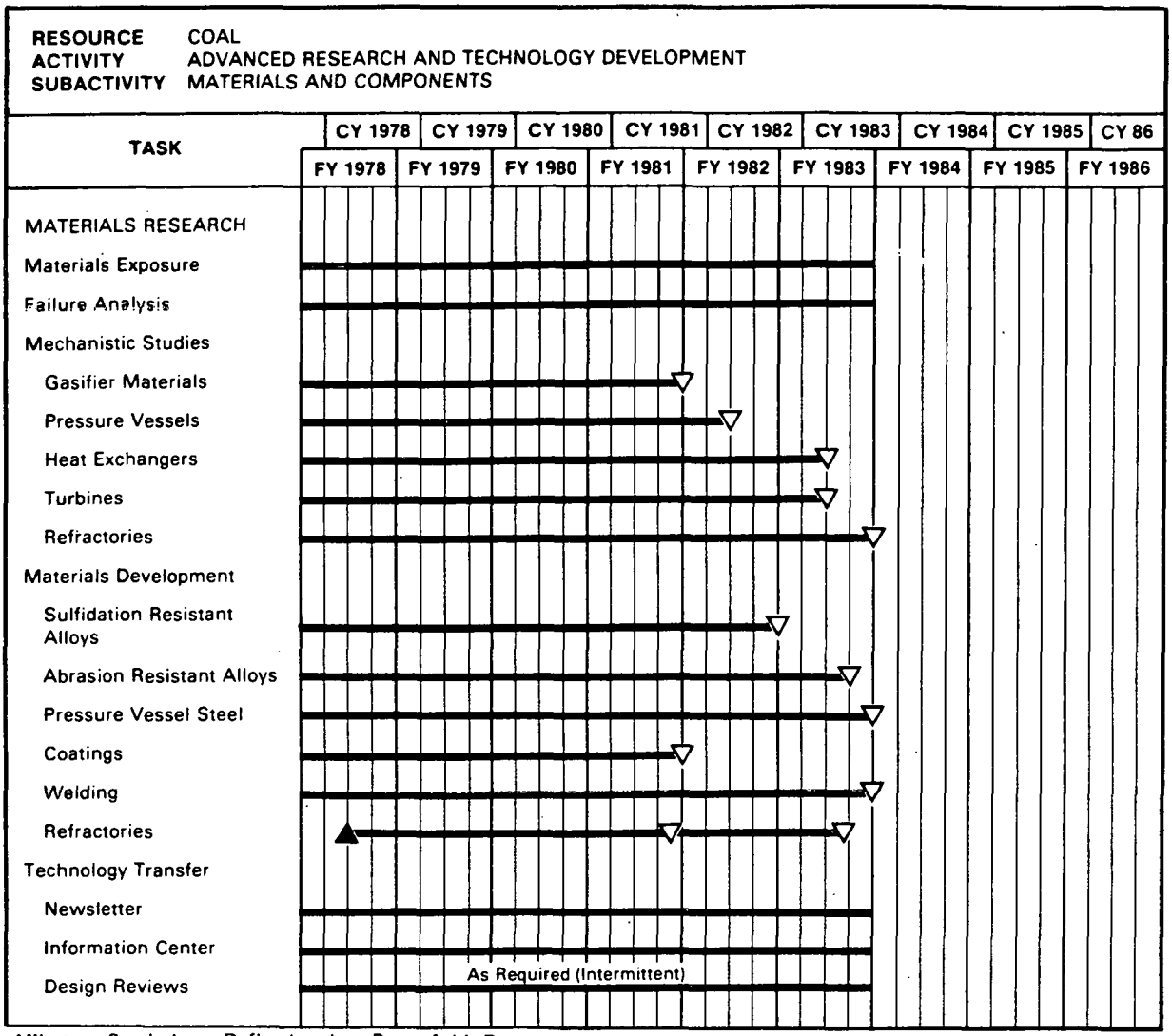
- Complete the selection and/or development of compatible coatings for the internal surfaces of gasifiers.
- Complete a feasibility study to guide development of sulfidation-resistant alloys and metals for use in high-temperature gasifiers.
- Operate a tubular ceramic heat exchanger.
- Determine corrosion species in coal liquefaction processes.

Anticipated accomplishments in FY 1981 include:

- Complete materials testing for second-generation gasifier internals.
- Refine design of a ceramic-tube heat exchanger.
- Operate pilot plant test unit for refractories for slagging gasifiers.
- Issue data book on materials for gasifiers.
- Provide design information on refractories for slagging gasifiers.
- Evaluate effects of deposits on corrosion in fluidized-bed combustors.



Program Structure for Materials and Components Subactivity and Related Details



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The intent of this activity is to provide direct problem definition and early feasibility determinations of selected approaches for specific component problems identified for major coal conversion plants. This primary supporting technology function is in the nature of "seed funding" and early effort to get an expeditious start on problems, thereby allowing a more deliberate and detailed development program to be developed and implemented which is tailored to the specific needs of the affected major coal conversion plants.

Instrumentation and control supporting technology effort in the components area is covered by project funding and is identified earlier in this document under Chapter III, Section C-6.4, Component and Instrumentation Development.

Equipment Subsystems for Major Coal Conversion Plants

A coal conversion plant cannot be more reliable than its support equipment and peripheral subsystems. Many current operating problems and shutdowns in coal conversion pilot plants are directly attributable to the use of commercial components never intended for the higher temperatures and harsh environments of coal conversion plants and in-plant streams. To provide equipment which will endure these environments over extended periods, a vigorous program has been undertaken to adapt, modify, and develop special components, heavy equipment and subsystems compatible with and scaled up to conversion plant needs with proper emphasis on critical plant geometries.

The following subsystems and components are under active investigation and development:

- Advanced techniques for the continuous feeding of coal to pressurized reactors
- Development and testing of lockhopper valves from materials which will perform reliably under adverse and harsh environments
- High-pressure large-capacity and elevated-temperature centrifugal slurry feed pump
- High-pressure large-capacity centrifugal O_2 compressor testing.

Major portions of the above program elements are being implemented by government laboratories.

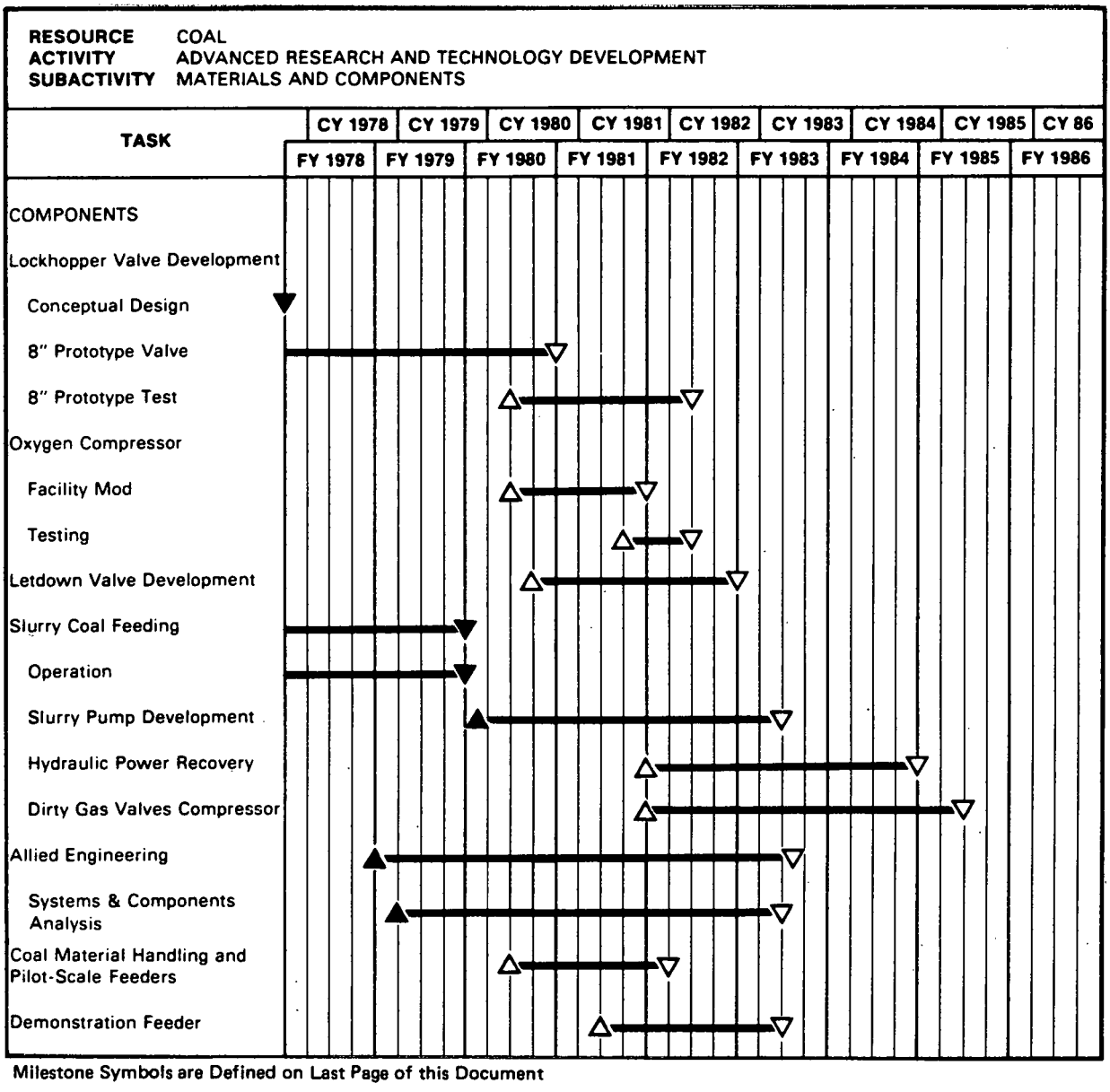
Major accomplishments in FY 1979 include:

- Initiated high-pressure, high-volume centrifugal slurry pump development program
- Conducted shakedown test of hot solids valve test facility
- Received the first lockhopper development valve from the contractor

Expected accomplishments in FY 1980 include:

- Conduct development lockhopper valve testing in the hot solids valve test facility.
- Initiate facility modification for high-pressure, high-volume O_2 compressor at the Engineering Test Evaluation Center (ETEC), Conoga Park, CA.
- Fabricate and assemble development module of high-pressure, high-volume centrifugal slurry pump.

- Initiate high-pressure slurry throttling letdown valve development and test program.
- Complete development of several coal feeding systems at pilot plant scale and initiate operational testing.



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Expected accomplishments in FY 1981 are:

- Continue lockhopper valve testing.
- Start O_2 compressor test.

- Start centrifugal slurry pump test, probably at a DOE pilot plant.
- Conduct slurry throttling letdown valve testing.
- Initiate hydraulic power recovery development based on slurry pump data and equipment.
- Initiate dirty gas valve development and dirty gas compressor development.
- Conduct and consumate procurement on demonstration/commercial-size coal feeding system based on competition between development feeders.

4.0 PROGRAM DEVELOPMENT AND INTEGRATION

The effort in this subactivity supports various FE technologies and projects and is grouped into the following functions:

- Budget and Administration
- Engineering Analysis
- Environmental Activities
- Planning and Policy.

4.1 BUDGET AND ADMINISTRATION

The budget and administration support area provides integrated program plans, budgets, and administrative support for Fossil Energy.

The budget development support area includes formulation and execution of the Fossil Energy budget, development of financial systems, issuance of financial plans, development of integration networks for Fossil Energy program plans and budgets. In addition, the budget support area oversees responsibility for:

- Developing and planning FE resource requirements to carry out R&D programs. This includes coordinating all FE budget estimates, preparing calls and providing guidance and technical assistance to all program divisions and field offices, coordinating analysis and review of the budget; coordinating the preparation of testimony and supporting justification or information; coordinating reprogramming, amendment, and supplemental budget actions; and coordinating responses to internal Office Management and Budget (OMB) and congressional inquiries.
- Coordinating resource requirements of the energy technology centers and national laboratories. This includes providing the field operators with planning and budget guidance, consolidating and analyzing their resource requests, and providing them with approved operating financial plans.

- Ensuring effective utilization of available resources. This includes providing management with up-to-date financial reports; coordinating all contract procurement actions; certifying availability of funds in conjunction with approved procurement and financial plans; maintaining an online data management system to provide timely data to serve management in resource decision-making; and coordinating ETC/NL budget matters with area operation offices.

- Preparing program and planning documents in support of FE efforts. This includes coordinating the preparation of the annual Fossil Energy Program Summary Document (Goldbook), Management Review and Control and the Spring Planning Documents, and assisting in the preparation of other technical documents.

Administration support includes all the usual Federal administrative activities normally serving a technical management organization. These include personnel, records management, correspondence control and travel management.

4.2 ENGINEERING ANALYSIS

The primary mission of the Engineering Analysis function is to provide the Office of the Assistant Secretary for Fossil Energy with an independent resource and capability to analyze and evaluate the technological and economic factors that could affect Fossil Energy policies and plans. This major crosscutting function will emphasize the evaluation and analysis on a common basis of the technological, economic and environmental control aspects of all major Fossil Energy programmatic thrusts.

The major activities are:

- Engineering Societies Commission on Energy (ESCOE)
- Liquefaction Technology Assessment Study (LTAS)
- Performance Assurance System (PAS)
- Advanced System for Process Engineering (ASPEN).

Engineering Societies Commission on Energy

ESCOE was organized by the five major U.S. engineering societies at the request of DOE to provide independent engineering advice and support to Fossil Energy. The technical analyses and advice from this multidisciplinary group of experienced engineers have not only been of use to the Fossil Energy technology program, but also to Policy and Analysis, Energy Research, Resources Applications, Conservation and Solar, and the Under Secretary's Office.

Among the many contributions to DOE's program, ESCOE developed standardized guidelines for making cost estimates for synfuels plants. These guidelines provide a more meaningful and uniform basis for economic comparisons of the numerous synfuel technologies.

Liquefaction Technology Assessment Study

LTAS, underway at ORNL, is a broad-based, consistent technoeconomic evaluation of selected liquefaction processes. Direct and indirect processes will be studied, all at a fixed level of coal input and using representative eastern and western coals. Starting with a reference case having fixed economic ground rules on such items as type of financing, plant life, etc., all plants will be studied as to sensitivity to the basic assumptions.

In a preliminary study of state-of-the-art indirect synthesis of methanol, it was concluded that under present conditions the presently available commercial processes were satisfactory. The first phase of LTAS was comprised of a preliminary screening evaluation of 10 competitive processes ranging from the Mobil MTG process, considered to be nearly commercial now, to the more advanced processes such as zinc chloride hydrocracking and advanced hydrocarbonization.

The second phase, now nearing completion, has addressed an in-depth analysis of methanol production for three different uses: (1) for blending with gasoline; (2) for use as a turbine fuel; and (3) for feedstock to the MTG process. The following phase will make a comparison of alternate gasifiers with regard to overall process performance and comparative economics. The final phase (for FY 1980) will make a comparison of the foregoing systems with a Fischer-Tropsch plant.

It is anticipated that this program will be a continuing procedure of periodic updating of assessments of the various processes.

Performance Assurance System

Reliability, Quality Assurance, and the Fossil Energy Performance Assurance System, incorporating the disciplines of System Safety, are essential to the successful management and development of new energy systems. The Secretary established the DESM 79-2 study group in May 1979, to develop a plan for instituting a strong program involving Reliability, Quality Assurance, and System Safety for application across all elements of the Department of Energy. Prior to the DESM 79-2 study, Fossil Energy began developing the PAS, which has been applied selectively to major Fossil Energy projects with significant benefit.

The implementation of DOE Order 5481.1 "Safety Analysis and Review System (SARS)" on new projects and DOE operations has added still further impetus to the increased application of strong performance assurance (PA) programs. The analyses produced by Quality Assurance, Reliability, and System Safety programs will furnish a major portion of the evidence supporting management certification of the safety of Fossil Energy systems.

PA program requirements are being incorporated in FE RFPs and new contracts. For this purpose, official DOE standards for Reliability, Quality Assurance, and System Safety have been developed and are being coordinated throughout Fossil Energy. These standards define the essential elements of the PA programs to be developed and implemented by contracts, beginning in the early design phase and continuing through construction, operation, and maintenance.

The DOE program managers receive technical support from the FE PAS function for the review and approval of contractors' PA plans and other submittals, which include such documentation as: inspection and test plans and procedures, reliability assessments and predictions, failure mode effect and criticality analyses, hazard analyses and failure reports, and documentation of the investigation and recommendations for resolution of major PA problems affecting project success. Surveillance of contractors is maintained to verify their conformance to established PA program plans, and to provide technical guidance or initiate corrective action when necessary. At key points in the project life cycle, such as design reviews, PA reviews are conducted and documentation analyzed in detail to verify the adequacy and completeness of contractors' controls and technical analyses in response to program requirements.

Advanced System for Process Engineering

ASPEN is a computer-based chemical process simulator which also provides means for developing economic estimates. The model which is under development at MIT will permit Fossil Energy to perform rapid technoeconomic analysis at low cost. This design and evaluation tool, in development for 3 years, has attracted wide interest from industry. Over 25 firms have committed significant resources over the next 2 years to learn about the program and to initiate adaptation to specific usage. This program will provide Fossil Energy a basically uniform basis for design analysis. The final two-year period now underway will continue and increase the successful widespread transfer of the technology to the industrial sector.

4.3 ENVIRONMENTAL ACTIVITIES

The mission of the Environmental Activities function in Fossil Energy is to provide the Office of the Assistant Secretary for Fossil Energy with a comprehensive, dynamic policy framework for ensuring that environmental, safety and health considerations are properly integrated into program activities within Fossil Energy, and that program activities are conducted in timely compliance with ES&H laws and requirements. The activity participates in development of policies and strategies designed to enhance the environmental acceptability of Fossil Energy programs, technologies, and resulting energy products and provides guidance and assistance to Fossil Energy organizations for carrying out their activities in a manner consistent with ES&H mandates.

The implementation of this mission includes the following functions: (1) analyze and understand the impact of potential regulations upon technology development; (2) anticipate future problem areas relative to environment, safety and health, and ensure that information is developed in a timely manner to improve environmental performance of FE technologies; and (3) overview the Fossil Energy program to assure that FE facilities and projects are in compliance with laws and regulations such as the National Environmental Policy Act, Clean Air Act, and Occupational Safety and Health Act.

The major environmental activities of AR&TD include:

- The Independent Safety Analysis and Review System prescribed by DOE Order 5481.1 requires an independent review of safety analysis reports before FE management can authorize proceeding with the construction and operation of a major project. The Division of Plans and Technology Assessment is the appropriate independent organization in FE Headquarters for the review function since it has no technology development program. Fossil Energy programs and projects which have not fulfilled the requirement cannot receive authorization to proceed.

- Policy analysis is being performed to determine the impact of environmental legislation and potential regulations such as the Resource Conservation and Recovery Act, the Toxic Substances Act and the Clean Air Act upon FE technology development. In order to have any meaningful impact upon the regulatory process, FE must have strong data and analysis to support the positions.

- Development and implementation of procedures will be provided. These include: (1) an Environmental Permit Tracking System; (2) an Environmental Impact Statement and Assessment Tracking System; and (3) Industrial and Hygiene guidelines for FE facilities. These procedures provide the capability for Fossil Energy to determine whether critical path environmental compliance activities are on schedule and help prevent unnecessary program delays.

- Environmental studies on FE technology development are being conducted by FE field organizations. For example, PETC is (1) conducting a site selection guideline study which is applicable to all of FE, and (2) conducting studies concerning the disposal of FE wastes from pilot plant facilities. These studies are extremely important because of pending RCRA regulations and because they have implications for all of FE. The siting study enables FE to perform improved site evaluation and selection in a way that will avoid potential environmental problems. The waste disposal study will provide better information regarding waste composition and disposal practices associated with pilot plant facilities. This is particularly important under the RCRA law.

- Assessments of environmental, safety and health R&D are being undertaken. In light of the increasing interest by Congress, environmental groups and other agencies concerned with the environmental acceptability of coal combustion technologies and synthetic fuels, internal and non-FE assessments of ES&H R&D will serve to identify and recommend any additional R&D needed to address environmental uncertainties and to mitigate environmental problems.

- DOE Order 5482, "Environmental Safety and Health Appraisal Program," is being implemented. This order was developed at the request of the Under Secretary to assure that Environmental Safety and Health appraisals are conducted in nonnuclear programs. Line FE program organizations and their field offices have direct

responsibilities in implementing the order by conducting "horizontal" review of management performance across the organization (field facilities, contractors, and subordinate offices) to assure proper balance in Environmental Safety and Health programs.

4.4 PLANNING AND POLICY

The Planning and Policy support area includes many interdepartmental coordination activities and provides the major focal point for interaction with the ASFE staffs. Major activities include: participation in the development of DOE and specific FE policy; translation of policy into programmatic terms; coordination between headquarters, field and FE staffs in developing multiyear energy plans, development of crosscutting fossil energy strategies that relate the FE program to general policy guidance; and market analysis for new technologies. In addition, several critical studies are underway to provide supporting information to the decision process.

Policy and Mission Analysis

This work involves evaluating new and existing energy studies and forecasts that impact FE programs. This includes the Energy Information Agency annual report to Congress as well as more speculative work performed in support of National Energy Plan development. The products of these studies are analyses that interpret this work into FE programmatic terms.

Program Strategy Development

The current focus for this effort is the development of detailed crosscutting strategies for liquid, solid and gaseous fuels. These strategies will be developed in conjunction with headquarters program management and field project management. The activity will use inputs from Policy and Evaluation in developing the strategies and will include sufficient analytical support to insure adequate documentation of programmatic decisions. The effort will identify major goals and their priorities.

Major documents produced by Planning, in addition to specific analysis, include the policy and planning components of DOE's Policy, Programming and Budgeting System (PPBS). Because of its strong analytical capability, the office is frequently called upon to provide special analysis on a quick reaction basis. Finally, the functions provide a broader overview of policy and planning, making it the ideal candidate for coordination of departmental task forces.

Several specific concerns and activities of Planning and Policy are as follows:

- Most Fossil Energy activities are developmental in character, implying a mid- to long-range continuing effort. The PPBS provides the essential management tools of programmatic, technical and fiscal planning for these programs on a five-year basis. The PPBS serves to develop the basic program justification documents.

- The Program Review is a critical, detailed analysis of specific "now-year" activities, both in terms of past performance and projected accomplishments. It is the basis for program evaluation and possible redirection. All Fossil Energy programs undergo periodic review, major programs are reviewed on an annual basis, and other programs at appropriate intervals.

- In addition to the program-specific activities defined above, crosscutting analyses are conducted. It is clear that this country faces a liquid fuels crisis; the President's message clarifies this issue, and establishes goals for additional liquid fuel products from sources such as tertiary recovery, shale and coal. The planned analyses are essential as a management tool for allocating resources among the major programs in this area; they will establish the strategic and tactical framework whereby the President's objectives can be met.

- Two additional strategic crosscutting analyses will be performed, similar to the liquid fuels analysis: coal utilization in the industrial and utility sectors, and gaseous fuels from unconventional sources. Both analyses are directly related to the President's objective of backing out significant quantities of oil from the national economy and substituting more plentiful resources.

- Net Energy Analysis is a method for comparison of the total energy expended in the entire chain of a fuel (or other energy) process versus the energy value of the product. DOE is required by legislation to consider Net Energy Analysis in making programmatic decisions. The current plans include its update in FY 1981.

- A major study will address the questions of regional impact and the implications of emerging and competing technologies to those specific regions. The generic program analyses and reviews have a tendency to be somewhat theoretical. This major effort would insure that the real world, site-specific implications would be included in the development of programs and technologies that could otherwise be insufficiently transferable to the private sector to warrant the massive R&D expenditures involved in their development.

5.0 UNIVERSITY RESEARCH

Under P.L.95-87, the Surface Mining Control and Reclamation Act of 1977 DOE proposed that a number of University Coal Laboratories be instituted with initial funding of $5 million for FY 1980. Congressional appropriation action approved $5 million for coal research to be carried out at universities but specified that the funding was not to be used to establish a system of University Coal Laboratories, as defined in P.L.95-87.

A new program of advanced coal research requires a new approach if it is to be more effective and responsive to the needs of coal-related technologies. In response DOE has developed a focused national and regional program

of university research on coal conversion and utilization that includes research on the following topics:

- Combustion of coal and synthetic fuels
- Coal characterization and specificity as related to liquefaction and gasification processes
- The structure and reactions of coal and analysis of its conversion products
- Multiphase flow phenomena related to coal conversion processes
- Fundamental problems of reactor engineering
- Environmental aspects directly related to coal conversion processes and coal utilization.

Research on other coal-related topics is also being supported if the proposals offer exceptionally pertinent, promising or novel ideas for advancing our knowledge of coal conversion and utilization.

This program was announced to the academic community in December 1979 via a Notice of Program Interest (No. FE-MPI-80-001) that was mailed to more than 2,000 departments of chemistry, chemical engineering, mechanical engineering, and academic vice presidents for research, as well as to many university faculty members at their institutions. The program was also announced in the Federal Register. Unsolicited research proposals in response to this notice were requested to be submitted on or before March 1, 1980. The Pittsburgh Energy Technology Center is assisting the Office of Advanced Research and Technology in the management of this program. It is anticipated that grants for the successful proposals will be awarded on or about July 1, 1980. A similar program is being considered for FY 1981.

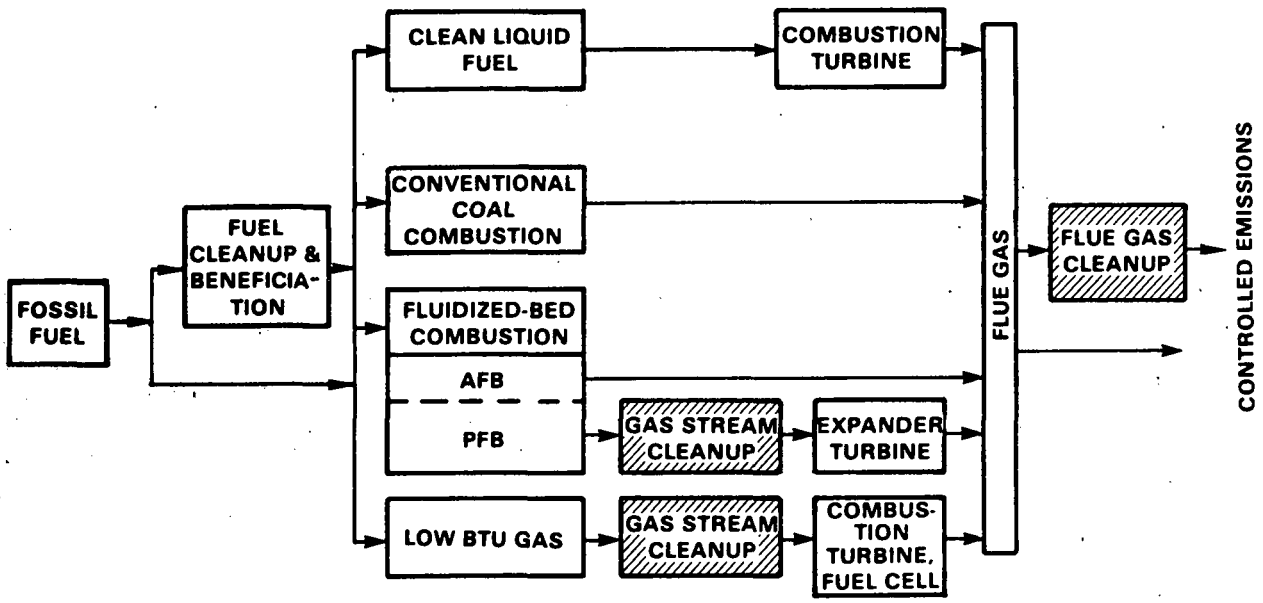
F. ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY

The ultimate goal of the coal strategy is to decrease the Nation's dependence on imported oil through a range of cost-effective uses of coal. Because close to 90 percent of the coal consumed in this country is, and will continue to be, burned directly, a primary objective in achieving this goal is to assure that stationary facilities now burning coal can continue to do so while meeting applicable environmental standards. Coal combustion can, therefore, become an increasingly viable option for new facilities in the utility and industrial sectors during the next decade. Environmental standards pose the greatest constraint on increasing direct coal use. Unless new technologies are available for meeting these standards, many facilities that might use coal will turn to other fuels.

Sulfur, nitrogen, alkali and halogen compounds, and volatile trace metal species are found in varying quantities in coal and are released through gasification and combustion processes. These substances can degrade the performance of energy-producing systems such as turbines and fuel cells and degrade the quality of air and water. The environmental goals set out in the Clean Air Act, the Federal Water Pollution Control Act (FWPCA), the Resource Conservation and Recovery Act (RCRA), and the National Environmental Policy Act are also high national priorities. It is important to achieve both the national energy goal of coal utilization and the environmental goals without endangering the public health, degrading the environment, and with minimum economic impact. The Advanced Environmental Control Technology (AECT) program is a key element in meeting these goals.

The environmental performance required for both utility and industrial coal-burning facilities depends largely on the age and location of the facility. Most existing facilities must meet the emission limitations in the Clean Air Act's State Implementation Plans (SIPS) and, for electric utilities, EPA's previous New Source Performance Standards (NSPS). New electric utilities must comply with the recently revised and stricter NSPS, and industrial boilers will soon be controlled by an industrial NSPS.

Potential solutions to the cleanup problems are illustrated below, showing coal utilization processes in block form. The cleanup problems can be addressed at the front end of the system (coal cleanup), at the back end (flue gas cleanup), or in the process stream during and immediately after combustion (gas stream cleanup). The approach to demonstrating solutions to the cleanup problem is to develop the promising technologies in each of these areas and to provide technical and economic trade-off evaluations to determine which discipline or combination of disciplines most reliably and economically meets the system's requirements for environmental emissions and acceptable equipment operational lifetime.



*Cross hatched areas indicate AECT responsibilities

Cleanup Technology Control Options*

The goals of the Advanced Environmental Control Technology program are to identify, research, develop, refine and demonstrate a range of engineering approaches capable of:

- Removing flue gas pollutants for compliance with emission standards
- Removing undesirable components from coal-derived gas streams produced by gasification and/or combustion processes, thus protecting utilization equipment such as turbines, fuel cells, and heat exchangers.

The program is divided into three major subactivities: Flue Gas Cleanup, Gas Stream Cleanup, and Cleanup Base Technology. The Flue Gas Cleanup subactivity directly addresses the problem of meeting environmental standards when coal is burned in conventional boilers by electric utilities and industrial installations. The very-near-term emphasis will be on improving the performance of conventional lime/limestone scrubbers which will support the new environmental standards for sulfur emissions. Two other efforts will be run in parallel with the conventional flue gas desulfurization (FGD) improvements. Advanced (second-generation) FGD technologies will be developed to improve sulfur removal and increase thermal efficiency and, in particular, to decrease the amount of wet sludge and other wastes discharged by FGD systems. Combined Flue Gas Cleanup technologies will be pursued to provide a more complete system of control for the total spectrum of pollutants. Systems which efficiently remove NO_x, particulates, and trace metals, as well as sulfur compounds, will be developed.

The second subactivity in the program, Gas Stream Cleanup, includes the technology for removal or suppression of contaminants prior to, during, or following the combustion process and before the energy conversion process. Both hardware and environmental protection are key concerns. Primary emphasis will be to develop technologies to clean gas streams produced by coal gasifiers or pressurized fluidized-bed combustors that are used in gas turbines, fuel cells, and heat exchangers. To satisfy the program objectives of cleaning the gas stream to meet environmental requirements and heat engine use will necessitate the removal of contaminants such as sulfur compounds, particulates, alkali metals, tars, ammonia, etc. In parallel, innovative modifications to the combustion process to reduce emissions will be pursued. Approaches include techniques for removing ash and slag from the gas stream within the combustor and modifying combustion parameters for reducing NO_x.

The final subactivity, Cleanup Base Technology, will provide the systems engineering and economic comparisons to ensure that AECT technologies will not only meet cleanup needs, but provide practical technology for energy systems, i.e., solutions meeting environmental and hardware requirements with acceptable costs. Flue gas and gas stream waste management, instrumentation, and process controls will be developed in this category. Applied research common to both flue gas and gas stream cleanup will be conducted, as well as examination and preliminary development of innovative concepts not directly attributable to the other categories.

The role of the Advanced Environmental Control Technology Activity is to develop cleanup systems which can be optimally integrated into process and power systems. The final goal is to demonstrate that the technology works and is economically, technically, and environmentally acceptable. The mechanism for achieving commercialization includes advancement of the technology through bench-scale process development units (PDU), use in pilot plants, and evaluation in full-scale existing plants. As the technology matures, private industry will be asked to cost-share development with the government. Information on progress will be disseminated via reports, symposia, plant visitations, demonstrations, and workshops.

The Advanced Environmental Control Technology Activity is a new effort in DOE which was initiated in FY 1979. Certain related efforts, however, have been conducted in previous years within the DOE Fossil Energy Combustion Systems and Advanced Research and Technology Development Activities. In FY 1980, these efforts were integrated into this program and are also included as part of this budget request. Primary emphasis in FY 1979 was directed at developing detailed program and project plans to enable a smooth and organized transition into FY 1980, at which point the program attained sufficient resources necessary to make significant strides in meeting its goals. These detailed plans utilized the input and review of the many organizations deeply involved and necessary to the success of this program (EPA, EPRI, utilities, private industry, TVA, Government laboratories and technology centers, universities, etc.).

Major activities planned for FY 1981 include:

- A full-scale demonstration of a lime/limestone scrubber utilizing chemical additives to enhance performance will be initiated in cooperation with EPA.
- Two operational utility lime/limestone scrubbers will be fully characterized (coordinated with EPRI's efforts).
- Support of TVA's 10-MW experimental scrubbers at Shawnee will be continued.
- Major dry-scrubbing efforts for both low- and high-sulfur coal applications will be continued.
- An advanced FGD system will be selected for a full-scale, cost-shared utility demonstration.
- Performance tests of electrostatic precipitators (ESPs) and baghouses will be conducted for full-scale utility applications using western coals.
- Pilot-scale evaluations of advanced combined NO_x/SO_x scrubber processes will be initiated.
- Bench- and subpilot-scale testing for the PFB hot-gas cleanup Program Research and Development Announcement (PRDA) initiated in FY 1979 will be continued.
- Cleanup requirements development for the molten carbonate fuel cell will be completed.
- A major effort in the characterization of fossil energy waste streams will be completed.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Flue Gas Cleanup	2,700	20,050	21,000
Gas Stream Cleanup	2,400	10,400	13,000
Cleanup Base Technology	1,900	7,000	8,000
Capital Equipment	0	800	500
TOTAL	7,000	38,250	42,500

1.0 FLUE GAS CLEANUP

Flue Gas Cleanup (FGC) addresses the removal of gaseous and particulate pollution-causing contaminants from the stack gases of combustion units. The justification for the effort is as follows:

- Conventional combustion is the most available utility-scale approach in the near term, through 1990.
- FGC is required in most combustion applications (new construction) to meet EPA regulations.
- Stricter New Source Performance Standards are already in force for utilities, and standards are in preparation for industry.
- RCRA may inhibit the use of current lime/limestone systems due to sludge disposal problems.
- Environmental standards are a moving target which must be matched through improved capability of control technologies.
- Poor scrubber performance, sludge disposal problems, or high cost are court-accepted reasons for exemptions to burn oil or exemptions from oil-to-coal conversions.
- Poor scrubber availability results in plant shutdowns with subsequently increased usage of oil and gas in turbines and possible power shortages.

The technical objectives are stated in terms of meeting the following performance standards:

- Particulates — 99% removal - 0.03 lbs/MMBtu
- Sulfur (SO_x) — 90% removal - 0.6 to 1.2 lbs/MMBtu; 70% removal - below 0.6 lbs/MMBtu
- Nitrogen Oxides (NO_x) (function of type) — 0.5 lbs/MMBtu - Subbituminous; 0.6 lbs/MMBtu - Anthracite, bituminous, lignite; 0.8 lbs/MMBtu - Specified lignite
- Continuous control; no bypass
- State control of sludge handling and storage
- EPA regulation of hazardous waste handling, storage, and disposal.

Flue gas cleanup technology is still at an early stage of development. While first-generation FGD technology (lime/limestone scrubbing) is now in limited commercial operation, performance of such systems has been below acceptable levels when used with high-sulfur coals. Other major problems are

the generation of sludges requiring containment and disposal, high operating costs, and efficiency losses.

Scrubber systems are characterized by chemical plant rather than power plant operation, requiring large equipment and maintenance labor (up to 50-man crews), redundant units, etc. The units typically do not adapt to changes in coal supplies, sorbent grades, or load variations; are damaged on shutdown; and are difficult to "chemically" control.

Resultant sludge disposal problems are severe. Fixative agents are required to make the sludge harden; it cannot be allowed to seep into ground or runoff water; it has excessive space requirements for sludge ponds; and it has problems peculiar to humid areas.

Particulate removal from flue gas streams has progressed substantially with electrostatic precipitators and baghouse filters presently considered as adequate removal systems. The capital and operating costs are still high and, under some operating conditions, problems occur with collection efficiency and by-product removal. The particulate (fly ash) disposal problem is receiving new attention as research identifies potentially harmful fly-ash components. Further, the adequacy of fine particulate control is now being questioned as a result of recent information regarding health-related problems and current EPA interests in control of respirable or fine particulates.

The Flue Gas Cleanup subactivity is divided into three projects:

- Lime/Limestone Scrubbers
- Advanced Flue Gas Desulfurization
- Combined Flue Gas Cleanup.

1.1 LIME/LIMESTONE SCRUBBERS

The objective of this project is to demonstrate process modifications on full-scale utility boiler scrubbers which improve conventional scrubber performance and economy, and mitigate associated waste management problems. This will make possible the effective use of available scrubber technology to facilitate the use of coal in new near-term electrical utility power plants.

The strategy is to collect, correlate, and evaluate detailed experience and then conduct parallel experimental programs using eastern and western coals. After technology development, final demonstrations will be conducted at a minimum size of 100 MW in facilities which already have controlled emissions. Thus, temporary inconvenience will not adversely affect the plant output. The results will be increasingly reliable "base case" modes, with off-base conditions explored and limits identified. A key to success will be utility industry participation.

The project will address economic issues and will provide utilities with technical support through the development of design, operational, and maintenance manuals. The project will supplement the current EPRI lime data book project.

Some specific process improvement efforts are already under advanced development and will be demonstrated and evaluated in the FY 1980-1983 time frame. These include:

- Additive methods for improved SO_2 removal efficiency
- Forced oxidation of scrubber sludge for improved dewatering characteristics
- Prescrubbing the flue gas to minimize chloride corrosion of scrubber components
- Maintenance guides to improve scrubber performance and availability
- Performance improvement teams
- Continuous SO_2 monitoring equipment evaluation.

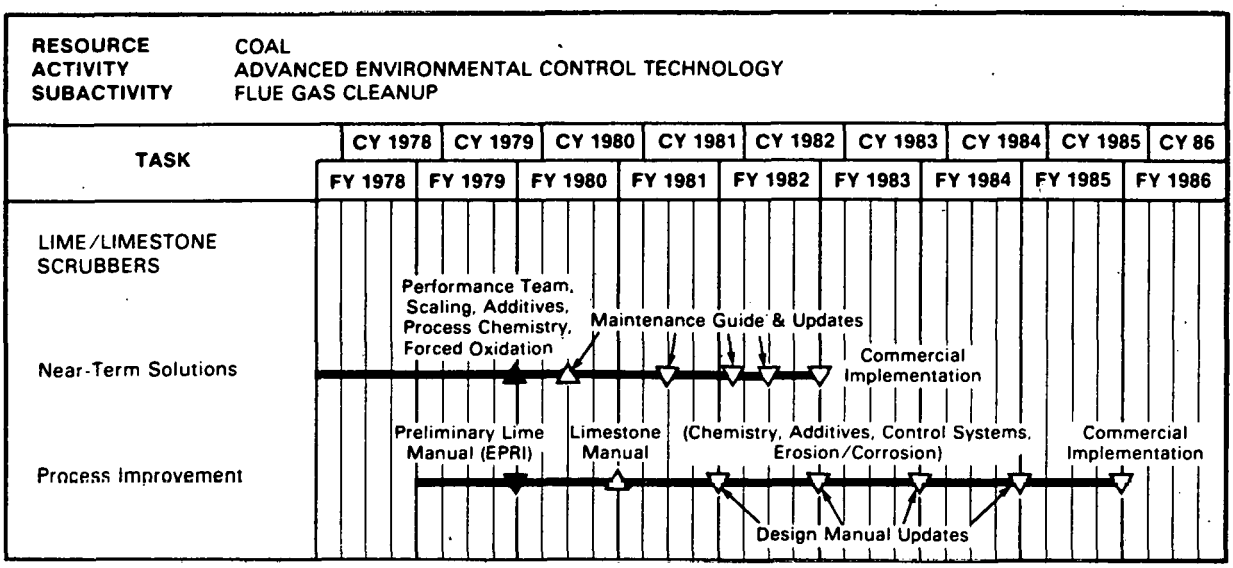
In parallel with these near-term efforts, DOE will undertake a systematic and thorough process design and control improvement effort to control the oxidation and precipitation of sulfur compounds to appropriate points in the process to minimize plugging and scaling and to maximize gypsum production in the waste sludge, and to reliably control SO_2 removal efficiencies. This will require improvement of existing process control of sulfur, calcium, contaminant, and additive process chemistry, developed and validated in part by characterization of the performance of full-scale scrubber systems by DOE Performance Improvement Teams. This effort will be coordinated with ongoing EPRI full-scale scrubber-performance site studies. It will also require the modification or development of instrumentation and sampling procedures for adequate process control. This development, demonstration, and evaluation effort will provide many of the following process improvements in the FY 1983-1986 time frame:

- Process control for improved long-term SO_2 removal efficiencies using buffering and catalytic additives
- Design modifications to mitigate chemical depositions through oxidation and precipitation control using additives
- Oxidation and precipitation control of sludge dewatering properties
- Prescrubber optimization for closed-loop operations
- Component materials selection criteria for cost-effective corrosion mitigation
- Automatic process monitoring and control for short- and long-term performance reliability, particularly for closed-loop operation
- Reheater evaluation for reduction of flue gas reheat requirements and other energy losses

- Evaluation and control of environmental consequences of FGD
- Scrubber redesign for improved waste control
- Scrubber redesign for pressure drop minimization.

Project Status

The FY 1980 efforts in the Lime/Limestone Scrubber project included both near-term improvements and the systematic and thorough process design and control advancements. Specific near-term efforts initiated were a full-scale forced oxidation demonstration for improved dewatering characteristics, control of chlorides buildup in closed-loop operation, establishment of the performance improvement teams, and instrumentation for scrubber process control. DOE also provided the funds to EPA to continue the utilization of the 10 MW pilot scrubber facilities located at TVA's Shawnee plant and which are operated by TVA personnel. Specific process design and control improvement efforts consisted of process chemistry effects of additives for mitigating chemical depositions, a scrubber failure mode analysis, scrubber design manuals supplementing EPRI's efforts, and the sponsoring of both FGD modeling and FGD instrumentation workshops.



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In FY 1981, DOE will participate in the EPRI-sponsored FGD characterization tests. Data from these tests will provide a basis for the maintenance guide and design manual efforts which will be pursued in parallel with the characterization program. Preliminary manuals will be prepared in late FY 1981 and updated periodically as information becomes available through FY 1984. A large-scale test of either an organic or inorganic additive for improved reliability and SO_2 capture will be performed in cooperation with EPA. One attractive prospect is adipic acid which has been demonstrated in pilot-scale scrubbers and has the advantage of retrofit applications. Operation of the 10 MW spray tower and turbulent contact absorber scrubbers at TVA's Shawnee plant will be continued for improved

performance and SO_2 removal efficiencies. Selected commercial FGD systems will be monitored in cooperation with industry to obtain the operability and maintenance data required in pinpointing problem areas for concentrated applied effort. An important effort will be the demonstration of forced oxidation as a means of converting calcium sulfite to the sulfate form in scrubber sludge, greatly reducing dewatering problems, waste volume, and disposal problems. Improved methods for sampling, instrumentation, and control of FGD systems are key problems that were identified and evaluated during FYs 1979 and 1980 and for which hardware development and testing will begin in FY 1981.

1.2 ADVANCED FLUE GAS DESULFURIZATION

Conventional lime/limestone systems (wet, nonregenerable processes) essentially trade air pollution for solid waste pollution. The amount of solid waste resulting from the expanded use of coal will present disposal problems before the end of the century. Further, the goal of limiting the increasing cost of energy to the consumer would be inhibited by the rising cost of solid-waste disposal. Therefore, smaller, cheaper, less energy consuming FGD systems that minimize solid waste will be developed under this task. Advanced FGD concepts are in various stages of development and some have been operating on a small scale. But, there are currently no large-scale systems (on the order of 400 MW) with any U.S. operating history. Some have been operating in Japan on oil-fired units and many have been tested to some extent at the bench and in small-scale applications. Over 160 industrial boiler installations of various sizes have FGD systems under construction or in operation. They represent several different processes that will be evaluated to establish the state of the art, additional research needed, the possibility of removing particulates and SO_2 in a single unit, and the minimum size of coal combustion systems for which it is economically feasible to install FGD systems. Available data indicate that per kW, FGD capital costs increase significantly for small units. The processes are grouped as follows:

Nonregenerable Processes

Wet Processes. The three systems in this category that are currently considered the most promising are: the dual alkali (sodium base with lime regeneration), the DOWA dual alkali (alkalized aluminum sulfate with limestone regeneration), and the Chiyoda 121. The first two are the most advanced dual-alkali systems. A clear liquid is used for SO_2 removal which minimizes plugging and fouling problems. The Chiyoda process is a proprietary limestone scrubbing system that uses a single vessel to remove SO_2 and to oxidize the calcium sulfite to gypsum.

Dry Processes. These dry scrubbing processes operate without flue gas reheat and produce dry solid wastes with no sludge disposal problems. Dry limestone boiler injection systems were tested in the 1960s with conventional methods of fly ash and calcium sulfate removal from the flue gas. The extent of calcium utilization was found to be poor in these systems. Nevertheless, the potential simplicity and reliability of flue gas alkali injection systems are attractive, and baghouse dust collectors may be used for ash and spent reagent removal. An additional incentive relates to the revised NSPS that for plants emitting less than 0.6 lbs/million Btu input, 70 percent sulfur

removal is required. If sufficient alkali utilization can be attained, the NSPS requirements can be met directly by the dry systems. Some low-rank western and Gulf Coast coals of sufficient calcium and sodium content provide an alkaline fly ash suitable for capturing SO_2 in a bag filter. Other candidate sorbents include nahcolite ($NaHCO_3$) and trona (Na_2CO_3). These materials, when used, supplement the SO_2 capture of the fly ash. The Advanced FGD project will reassess the candidate sorbents for this application. Acceptable disposal methods for the soluble residues will also be addressed.

Systems based on dry injection and spray drying of dissolved or suspended solids such as trona, lime, nahcolite and high-alkali fly ash are adequate for low-sulfur coals and no flue gas reheat is required. The hot flue gas serves as the source of evaporative heat. Transfer of this technology to high-sulfur, midwest coals may prove feasible. However, the large physical size of spray driers can create some problems in retrofitting.

Regenerable Processes

These minimize solid-waste pollution, conserve natural resources, and generate potentially marketable products. The large quantities of waste materials generated by throwaway control systems and potential environmental problems with treatment and disposal necessitate a continued examination of processes which create little or no waste but produce a potentially salable product. This product may be SO_2, elemental sulfur, or sulfuric acid. Both wet and dry processes are in various stages of development. Wet processes are more mature and will be emphasized.

Wet Processes. Wet regenerable processes use alkaline reagents other than calcium oxide (the stabiliity of calcium sulfate is so great that it is not worth regenerating from wet sludge). The alkaline material can be magnesia, sodium hydroxide, carbonate or sulfite, with or without buffering agents such as citrate or phosphate ions, ammonia, or basic aluminum sulfate.

The sulfur compounds are regenerated and the concentrated SO_2 is converted to elemental sulfur, sulfuric acid, or liquefied SO_2. These processes can operate in a closed-loop manner. In many processes, natural gas is used as a purge reductant. Reduction using coal gases and through the EPRI-funded RESOX process are primary approaches for alternate reductants. EPA initiated an evaluation of the Rockwell International Aqueous Carbonate System now underway at Niagara Mohawk Power Company. This wet regenerative process is being cost shared with the Empire State Electric Energy Research Corporation (ESEERCO), EPRI, and the New York State ERDA.

Three additional systems, the magnesium oxide scrubbing with regeneration, the Wellman Lord system, and the St. Joe Minerals citrate unit have been installed for demonstration testing. All systems need additional development and long-term operation before they are accepted as commercially available.

Dry Processes. Dry regenerable processes use a metal oxide (copper or manganese are leading contenders but many others have been proposed) to form sulfates, or solid catalytic material (char or carbon) to generate sulfuric acid from SO_2. The details of decomposing the metal sulfate or desorbing the

H_2SO_4 from the reusable carriers depend on the specific processes. Several of the dry-type processes are of interest in connection with combined SO_2-NO_x abatement.

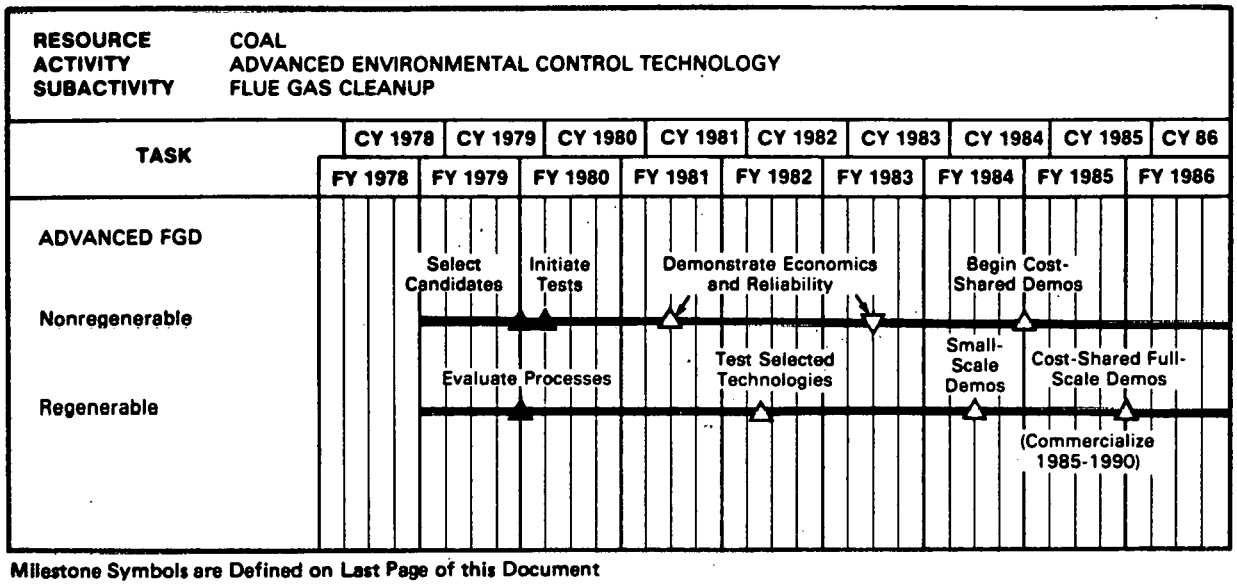
Evaluation shall be made of new processes for technical feasibility and site specific, regional, or specific use application where commercial- or demonstration-level techniques cannot meet environmental or NEP economic constraints. Some evaluations of advanced systems are already underway by DOE. Additional candidates may be identified as new concepts are proposed.

Project Status

FY 1980 efforts in Advanced Flue Gas Desulfurization included a continuation of the FY 1979 support of the testing and evaluation of the Rockwell International Aqueous Carbonate Demonstration. The construction and operation of this plant are being funded by EPA, ESEERCO, EPRI, Rockwell International, and the New York State ERDA. This will be the largest near-term demonstration of an industry-supported regenerative system. Three additional efforts in cooperation with EPA included pilot plant testing of spray dryer technology for scrubbing high-sulfur eastern coals, the monitoring and evaluation of dry scrubbing at a full-scale western utility for a period of at least one year, and evaluation of full-scale dual alkali scrubbers at two utility sites. An effort to provide technical support for the application of first-generation FGD processes to low-rank coals, to improve efficiency and reliability and to reduce energy, water, and reagent requirements was initiated at Grand Forks Energy Technology Center (GFETC). Chemical additives were tested at GFETC and in the field for enhancing SO_2 removal in ash-alkali scrubbers, additional sources of fly ash were surveyed, sulfate areosol measurements made on commercial units, and a process for regenerating dry sorbents was investigated. Three activities were initiated at the Pittsburgh Energy Technology Center (PETC); the evaluation of the effectiveness and economics of removing SO_2 from the flue gas of boilers fired with high-sulfur coals by injecting various alkali materials into the flue gas as solutions or slurries (spray drying), the generation of the data necessary to develop a simplified one-step process to reduce SO_2 directly to elemental sulfur using bituminous coal, and the generation of the equilibrium data for the absorption/steam stripping process which may lead to less energy-consuming methods for producing sulfur from SO_2 when combined with processes such as RESOX.

Specific accomplishments planned for FY 1981 include completion of the funding requirements for the test and evaluation plan for the Aqueous Carbonate regenerative scrubber demonstration, continuation of the monitoring and evaluation of a full-scale dry scrubber at a western utility, continued operation of the dry scrubber pilot plant for high-sulfur eastern coals initiated in FY 1980, and evaluation of a full-scale utility dual alkali scrubber. The survey of low-rank coal fly-ash suitability for ash-alkali scrubbing, the measurement of sulfate aerosols, and the evaluation of full-scale spray dryer FGD systems will be completed by GFETC. At PETC, the tests for SO_x and particulate removal with a spray dryer/baghouse system, the process design and construction of a PDU for the direct reduction of SO_2 to elemental sulfur, and the SO_2 absorption/steam stripping equilibria data correlation with the model will be completed. An advanced scrubber system, such as DOWA, Chiyoda 121, dual alkali, or magnesium oxide, will be selected

for a full-scale, cost-shared demonstration at a utility site. Special emphasis will be placed on developing or modifying technologies for industrial applications including calcium-based sorbents and dry scrubbing. A cost-shared demonstration of these technologies will be initiated.



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1.3 COMBINED FLUE GAS CLEANUP

The presence of SO_x may cause undesirable synergistic effects on NO_x, particulate, and trace metal removal from coal combustion. This project extends coal flue gas technology beyond sulfur removal to NO_x, particulate, and trace metals in anticipation of possible impacts caused by the increasingly extensive use of coal. The target is a more complete control of the total spectrum of pollutants with technology to become available in the mid-term (late 1980) period.

Efforts in this project are grouped into four areas: NO_x control, particulates (including trace metal and organics control), integrated and advanced systems, and engine exhaust control.

To determine the most cost-effective route for NO_x control in coal combustion, a state-of-the-art assessment of existing methods for NO_x abatement will be carried out to weigh the relative merits of decomposition by NH_3 injection, retrofit modification of FGD systems, and dedicated NO_x removal procedures. Dedicated NO_x cleanup can consist of decomposition methods in the flue gas or tail-end stand-alone techniques. NH_3 injection may function as such a method, and efforts in that area will focus on NO_x removal efficiency and the environmental effects of escaping NH_3. In addition, innovative concepts for tail-end NO_x control will be evaluated for retrofit capability on installations which include other cleanup systems. Since this activity will require an understanding of NO_x solution chemistry, backup technical support efforts will be carried out for process feasibility evaluation.

Coal combustion results in the emission of large amounts of particulate matter. Particulate cleanup devices include advanced centrifuges, electrostatic precipitators and fabric filters (baghouse filters). Primary needs are to improve filtering efficiency, especially for particles of less than 2 microns in size, and improving the ability to operate at higher temperature. In order to accurately evaluate the performance of new particulate control devices in coal-fired boiler flue gases, novel and advanced sampling and analysis methods will have to be developed and validated for size- and composition-resolved particulate characterization. Because respirable particulates may be controlled in the near future, new or modified particle removal techniques may be necessary. The economics, fine particle removal efficiencies, retrofit capabilities, energy penalties, and compatibility with other cleanup systems will be evaluated. Promising techniques will be tested at an industrial boiler and also at prototype or full-scale utility boilers.

In addition, field evaluations of new or modified particulate removal concepts will be carried out on industrial sources with peculiar particulate emission characteristics, on utility boilers which utilize low-rank western coals, on high-ash or high-sulfur coals, on coal-fired burners which employ advanced coal utilization technologies such as AFBC and on post-FGD scrubber flue gases from utility boilers. Field evaluations of fabric filters (baghouses) and ESPs will be performed to assess their suitability for these applications.

Development efforts to combine NO_x removal with FGD for SO_2 control will be evaluated. The feasibility of retrofit modifications of lime/limestone FGD scrubbers for simultaneous NO_x removal, either by additive selection or by hardware design changes, will be examined. In addition, new process concepts which effect simultaneous SO_2/NO_x removal will be tested. The Shell/UOP copper oxide SO_x removal process, for example, operates at a suitable temperature for NH_3 injection and has been able to demonstrate 60 percent removal of NO_x. Other new concepts may be in the offing. Combined processes must have the potential of being more cost effective and require less energy than separate NO_x and SO_x control systems.

A continuing activity in advanced concepts will be maintained to ensure that promising technology and ideas can be evaluated. Several concepts under study propose the use of irradiation techniques using electron beams, lasers, or plasma-jets.

This project will also include studies of stationary engine (turbines, diesels, etc.) exhaust controls when fueled by high-sulfur residual oils, coal liquids, or coal-derived solids. The market for such engines will be surveyed and evaluated. The environmental impact from such sources, if uncontrolled, will be determined to define the need for future work in this area.

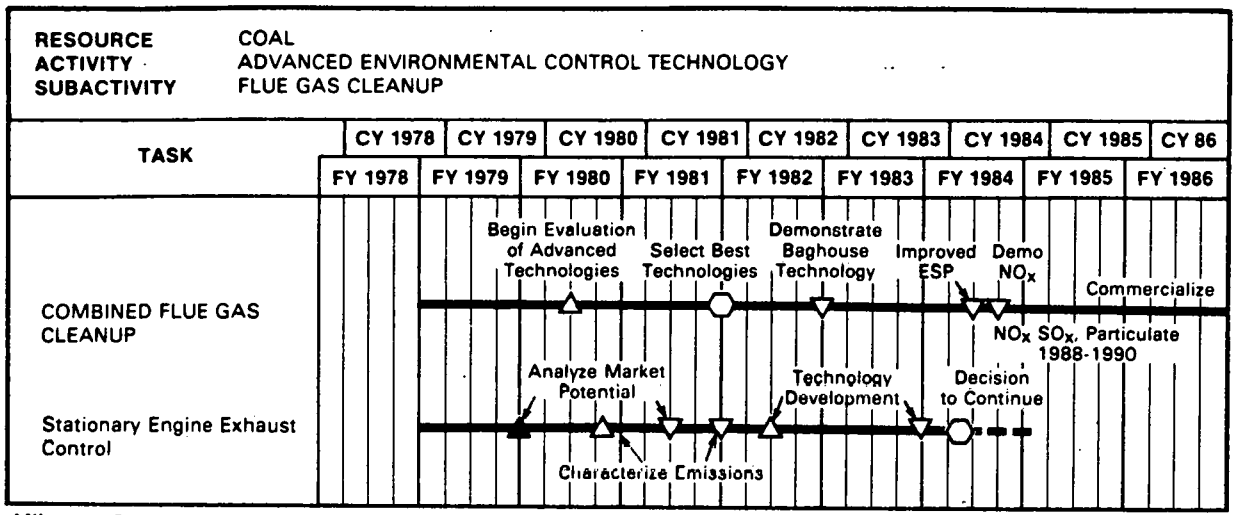
Project Status

A significant number of efforts in Combined Flue Gas Cleanup were conducted in FY 1980 including three in cooperation with EPA. Specific efforts in the flue gas treatment for NO_x control included the extension of the Hitochi-Zosen and Shell/UOP pilot programs and the initiation of a

project to monitor full-scale NO_x and NO_x/SO_x control technologies in California; both were in cooperation with EPA. An evaluation was initiated to review the performance data, identify R&D requirements, and perform process cost analysis for selected NO_x control techniques. Two previous Advanced Research and Technology Development (AR&TD) efforts investigating the formation of NO_x and decomposition of NO_x in combustion processes were continued. In FY 1981, the monitoring of NO_x control technologies in California will be continued and a decision to demonstrate flue gas treatment at full-scale will be made on the basis of the pilot program results and the technical and economic assessments.

In the area of particulate control, FY 1980 efforts included the start of long-term monitoring of a western utility baghouse application (pass through of EPA funds), the modeling and analysis of high-temperature ESP phenomena, evaluation of electrofluidized-bed and granular and electro-granular-bed filters, and staged ESP development. Because the combustion of low-rank western coals produces fly ash with high electrical resistivity, GFETC expanded its activities to develop advanced techniques for sampling, characterizing, and controlling these difficult particulates in stack gases. In addition, an assessment will be conducted of the capabilities and costs of fabric filtration and electrostatic precipitation to control various levels of respirable and fine particulates. The FY 1981 activities will include the continuation of the long-term monitoring of a western utility baghouse application, completion of a pilot plant evaluation of ESP conditioning agents for western coals at GFETC, and initiation of efforts to evaluate, construct, and test online sensors for fine particle and organics control in conventional combustors and for sorbent and burnup cell control for fluidized-bed combustors. Based on evaluations of currently proposed enhanced ESP devices, DOE will cost share in the design, construction and testing of a full-scale system. This improved technology has the potential of reducing the cost of electrostatic precipitators for the control of fly ash from low-sulfur coals by a factor of 2 to 5.

In the area of combined NO_x and SO_x control, FY 1980 efforts included the completion of sub-PDU testing of the SULF-X process and at PETC, the initiation of PDU tests of a fluidized-bed process utilizing a copper-impregnated substrate. In FY 1981, PETC will complete testing using varied substrates and also complete the economic analysis. Sufficient data should be available at this time to determine which combined NO_x/SO_x process is suitable for pilot-scale testing.



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2.0 GAS STREAM CLEANUP

Combined-cycle systems for power generation are an attractive energy option from the thermal efficiency standpoint. Low-Btu gas from a coal gasifier can be used to power gas turbine-steam or fuel cell-steam cycles. The gas turbine-steam cycle can also be driven by the exhaust stream from a coal-fired, pressurized fluidized-bed combustor. These gas streams range up to 2400°F in temperature and 500 psi in pressure. These hot gas streams, however, contain contaminants that, if not removed, will cause failure of the conversion-cycle equipment and violate environmental emission standards.

The purpose of the Gas Stream Cleanup subactivity is to develop and demonstrate systems for removing particulate matter, sulfur compounds, alkali metals and other substances that may prevent the direct use of coal gases; and to demonstrate technology to limit emissions of SO_x, NO_x, and other pollutants via process stream cleanup.

Pressurized fluidized-bed combustion (PFBC) removes sulfur in the bed and produces low NO_x emissions. Heavy duty industrial type gas turbines are used in PFB cycles to generate shaft power from the hot pressurized combustion products. These turbines may be subject to erosive attack from the particles entrained in the gas at loading levels below those expected to be provided by a two-stage cyclone particle-removal system and are subject to alkali-related corrosion and deposition dependent on the PFB operating temperature. Removal of these contaminants at or near bed temperature is advantageous for most efficient cycle operation. Hot cleanup of particulates and alkalis is a difficult problem, the solution to which will contribute substantially to large-scale integrated demonstration of PFB combined-cycle technology.

Low- or medium-Btu gasification provides a fuel which can be used in a combustion turbine or fuel cell to generate electricity, with a steam bottoming cycle to use rejected heat. The raw product gas from a gasifier will generally contain sulfur, nitrogen, alkali, and trace metal compounds and particulates. Some gasifiers produce tars or other hydrocarbons. Coal gasification processes may be air or oxygen-blown, and are usually classified

as fixed, fluidized bed, or entrained flow. Alkalis and particles must be removed to protect gas turbines, while sulfur, halogens, and particles will damage molten carbonate fuel cells.

Commercialization of reliable, cost-effective cycles will be dependent upon the successful development of equipment that can remove the contaminants from the gas stream down to a level that can be tolerated by the utilization equipment and does not violate environmental emissions standards. Furthermore, successful optimization and integration of the gas stream cleanup equipment with the gasifier or PFBC and the utilization equipment must also be accomplished.

In addition to the contaminant removal prior to or following combustion, it is also possible to suppress contaminant formation during the combustion process. This may be accomplished through the use of innovative combustion techniques, combustor design modifications or the introduction of additives.

The strategy taken in the Gas Stream Cleanup subactivity is to address the technology needs on a systems basis separately for turbines and fuel cells while pursuing the combustion-related effort as generic "process modification" technology.

2.1 TURBINE CLEANUP SYSTEMS

Hot-gas inlet "cleanup" requirement specifications for turbines from a hardware standpoint are presently speculative at best. The objective of this task is to quantify the limits of particulate and gaseous corrodants/erodants for acceptable gas turbine service life, to define the limits of operation of economically practical gas cleanup systems, and to develop the technology to provide reliable systems. Both low-Btu gasifier/gas turbine and PFBC/gas turbine systems will be studied.

Coal gasification produces primarily carbon monoxide and hydrogen and smaller quantities of hydrocarbons, carbon dioxide, and water. Existing coal-bound sulfur, nitrogen, alkalis, halogens, and volatile trace metals produce compounds which are toxins, erodants, corrodants, and catalyst poisons. For example, trace quantities of sodium and/or potassium sulfates can corrode conventional turbine blades at temperatures of 1250° to 1450°F, and alkali metals, independently, can cause corrosion above 1500°F. Particulates entrained in the gas and condensed metal vapors can cause hardware erosion and cause visible emissions problems.

The PFBC products, unlike a gasifier, are completely oxidized. Sulfur generally is removed but the process increases the particulates and still produces some sulfur and alkali contaminant particles. Otherwise, PFB systems have the same problems as low-Btu gasifiers.

Project Status

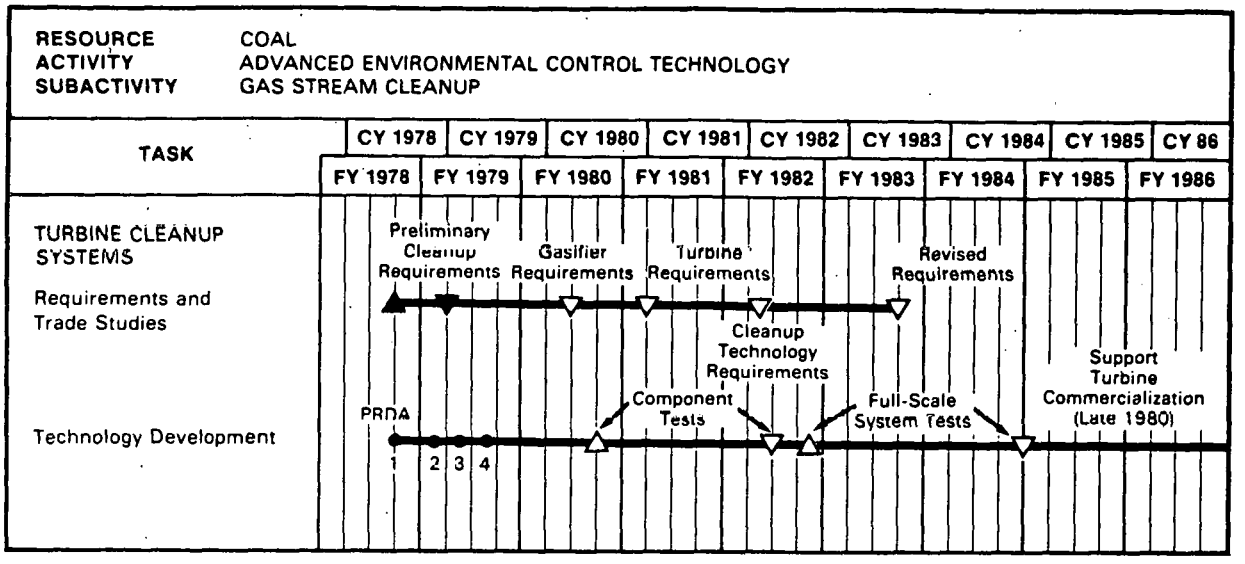
Emphasis to date has been on particulate cleanup to mitigate turbine blade erosion effects. Cold flow testing of a combined cyclone-centrifuge has been completed. Results indicate that a particulate removal efficiency greater than 99 percent for particles down to 2.5 microns, can be achieved as compared to 90 percent for particles down to 10 microns for a conventional

cyclone. Experiments using molten glass to entrain particulates are also being conducted for application to high-temperature gasifiers (<1800°F). Results to date show a collection efficiency in the range of 92 to 98 percent.

Laboratory-scale work was initiated in FY 1980 on a number of particle and alkali removal concepts identified as a result of a PRDA. These include magnetic and electrostatic granular-bed filtration, ceramic membranes filtration, acoustic agglomeration and dry plate scrubbing. Bench- scale efforts are scheduled for completion in FY 1982 at which time the most promising concepts will be moved forward to the pilot-scale evaluation phase.

Additional efforts being conducted under this project include:

- Evaluation of recuperators for heat recovery in conjunction with commercial low-temperature cleanup processes
- Trade-off studies of costs to achieve a given level of cleanup vs. periodic turbine reblading costs necessitated by erosion corrosion considerations
- Evaluation of catalysts for ammonia decomposition to suppress NO_x formation in gasifier turbine combined-cycle systems.



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FY 1981 efforts will focus on continuation of bench-scale development of innovative particulate and alkali removal concepts and completion of the recuperator evaluation, turbine reblading study, and ammonia decomposition investigation.

2.2 MOLTEN CARBONATE FUEL CELL (MCFC) CLEANUP SYSTEMS

Hot gas inlet "cleanup" requirements specifications for MCFC Cleanup Systems are presently unavailable. The objective of this task is to quantify the limits of particulates and gaseous pollutants acceptable for operation in

a MCFC, define the limits of operation of economically practical gas cleanup systems, and develop the technology to provide reliable systems.

The fuel supply is derived from hot, low-Btu gasifiers. The MCFC problems using this source of fuel differ from turbine systems. The aerodynamics/materials problems linked to the high-speed turbomachinery do not exist with the fuel cell. However, the MCFC is susceptible to catalyst poisoning, electrode deterioration, and electrolyte contamination. DOE has outlined an accelerated development strategy for the MCFC program leading to tests of prototype 0.5 MW stacks by 1983.

Tests with small-scale cells on bottled gas mixtures have shown the need to reduce fuel gas H_2S content to 1 ppm or below, although it is unclear whether this limit is due to direct anode poisoning or due to a known tendency for SO_2 from the anode to be absorbed into the electrolyte as sulfate. COS, CS_2 and other sulfurous gases are also expected to be harmful. Other expected, but not yet demonstrated, contaminant sensitivities include particulates, which would plug porous electrodes, and chlorine, which might react with the anode to poison it. Sensitivities to other trace elements and compounds have not been studied. Since nickel is also used as a methanation catalyst in the synthetic natural gas development program, review of methanation experience with contaminants is expected to be useful for MCFC sensitivity studies.

Commercial cold (wet) methods will probably remove particles, sulfur, chlorine, and trace elements to levels suitable for MCFC. The sulfur requirement is quite stringent and can probably be achieved by carefully designed, staged wet sulfur scrubbers, more expensive than the usual acid gas removers, followed by ZnO or activated-carbon "guard" reactors. Selective sorber regeneration may be possible to produce CO_2 needed for the cathode. Integrated cleanup trains to accomplish this requirement have not been demonstrated on coal gasifiers. Such an integrated system will be developed in time for MCFC 0.5 MW stack tests at a yet to be selected gasifier site.

In addition to cold cleanup, elevated-temperature techniques for desulfurization are also under evaluation for longer term application. Since the cell operates at a temperature of 1200°F, efficiency improvement can be obtained by cleaning the fuel gas above this temperature.

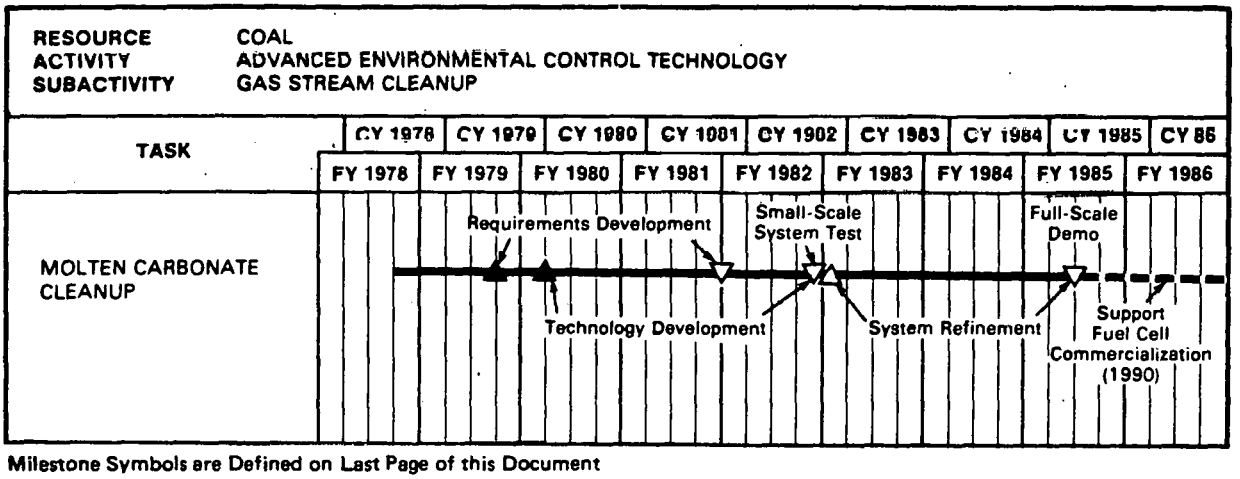
Project Status

Efforts to date have centered on the determination of fuel cell tolerance to contaminants. Preliminary small-scale tests indicate that the fuel gas hydrogen sulfide content must be kept down to 1 ppm or less. Concurrently, a number of evaluations have been initiated:

- Trade-off study of cell life as a function of fuel gas contaminant loading
- Selection of gasification process for fuel cell applications

- Evaluation of commercial desulfurization processes
- Evaluation of elevated-temperature cleanup vs. cold cleanup with heat recovery.

FY 1981 efforts on this project will primarily concentrate on the completion of these evaluations in support of the definition of an integrated cleanup system in FY 1982, which will be tested with a 0.5 MW molten carbonate fuel cell stack in FY 1983.



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2.3 PROCESS MODIFICATION TECHNOLOGY

A possible alternative to add-on procedures for flue gas and gas stream cleanup is the development and application of process modifications to control the production and emission of deleterious contaminants. In addition to meeting the needs of turbines and fuel cells, gas stream cleanup by process modification technology may provide a cost-effective means of meeting environmental and combustion requirements. This project brings together systems to control process streams through innovative combustion techniques, in order to demonstrate technology to limit NO_x, SO_x, fly ash, alkali and/or trace pollutants in gas streams by 1985. Specifically, this project will investigate and improve technology involving sorbent injection, ash/slag retention, and combustion modification.

- Sorbent injection: Traditionally, efforts in the control of SO_2 emission during combustion, instead of by tail-end FGD, have focused on limestone fed into the boiler, but results to date have been generally disappointing. Dry alkali injection may prove more successful, and field tests of retrofit application to utility boilers will be made.
- Combustion modification: Several techniques for NO_x control by combustor modification have been studied under projects supported by EPA and EPRI. However, results have shown that interactions between requirements for high firing temperatures versus NO_x

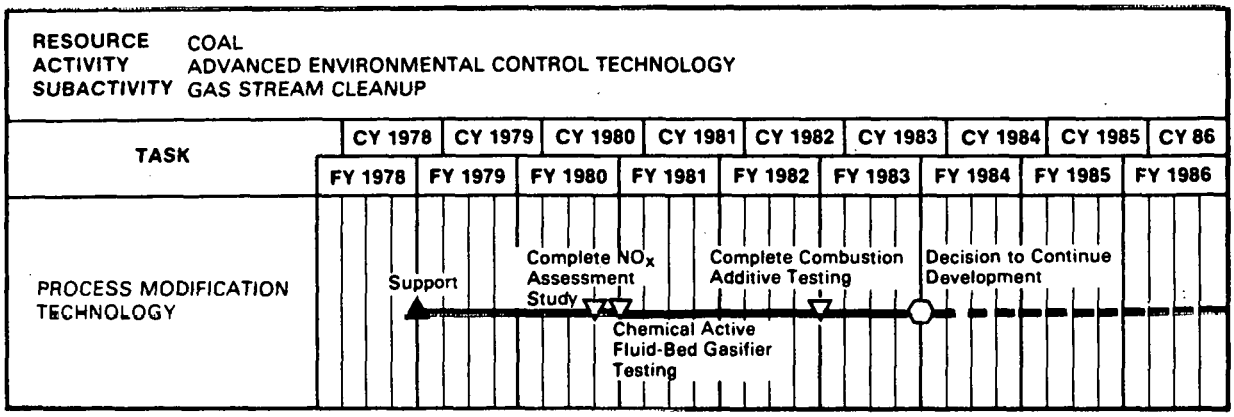
quenching efficiency are not sufficiently understood for definition of the best firing practices. Trade-off studies of the various approaches will be made.

Project Status

Primary effort to date has focused on supporting EPA's Chemically Active Fluidized-Bed (CAFB) process that allows coal to be burned with existing gas- or oil-fired boilers while meeting the NSPS with respect to NO_x, SO_x, and particulates. Pilot plant tests have shown that the NSPS can be complied with. A 10 MW_e demonstration unit has been constructed. Testing is underway using Texas lignite, with test completion scheduled to occur by the end of FY 1980.

Dry sorbent injection into the combustor for SO_x control is being considered as a low-cost alternative to FGD for relatively low-sulfur coals. The primary application would be for retrofit in the utility and industrial sectors and perhaps some potential application in new industrial boilers. A number of sorbents are being evaluated including trona, limestone, calcium silicate, and nahcolite. Laboratory studies are underway and will be followed by pilot plant tests and field demonstration tests.

A technology evaluation of NO_x suppression and reduction will be completed by the end of FY 1980 that will provide outyear guidance to this technology area. Concurrently, a number of pertinent research efforts were initiated covering such areas as chemical kinetics of pollutant formation in combustion process, staged combustion, and catalytic oxidation.



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FY 1981 efforts will concentrate on completion of the pilot-scale work on the pollutant control via dry sorbent injection into the combustor and definition of a demonstration program contingent upon the results. Laboratory-scale work on the multiple segmented air addition staged combustion concept will be completed and a decision reached as to advancement to pilot-scale evaluation. Research on catalytic oxidation for suppression of pollutant formation will be continued and completed in FY 1982.

3.0 CLEANUP BASE TECHNOLOGY

The Cleanup Base Technology subactivity will develop the "crosscutting" technologies in areas such as waste management, instrumentation and process controls, and systems and economic comparisons which are common to both flue gas and gas stream technology requirements. In addition, innovative concepts will be pursued within this area.

3.1 WASTE MANAGEMENT

The goal of the Waste Management project is to seek understanding of and sound technological solutions to problems and activities related to fossil residue streams. Pursuit of this objective can enhance the desirability and success of a variety of control technologies as well as support the objective of greater national use of coal by providing improved methods of waste characterization and handling, advances in resource recovery and reutilization techniques, and sound management and/or disposal of combustion and other fossil wastes in compliance with environmental regulations such as RCRA and TSCA.

Implementing cleanup technology will involve a combination of coal cleaning, flue gas, gas stream, and combustion stream cleanup processes all of which will generate large amounts of liquid or solid wastes potentially hazardous to the environment. Proper disposal of these wastes is becoming a major problem associated with lime/limestone scrubbers. Disposal will continue to be a problem with the other cleanup technologies as they are incorporated. DOE will initiate and continue development in the following areas:

- Coal Ash Wastes: The composition of the large volume of coal ash being produced presents opportunities for the economic recovery of mineral by-products. DOE will identify and develop those recovery processes which offer economic potential. Given the proper economic incentives and market conditions, waste-coal fly ash could be processed to produce aluminum and iron depending upon the recovery efficiency. In addition, other properties of coal fly ash have demonstrated good potential for use in concrete materials, building block, soil amendment, road base stabilization, and neutralization of hazardous properties of certain types of industrial chemical wastes.

- FGD Waste: FGD sludge disposal costs represent a major part (up to 20 percent) of the capital and operating costs of an FGD system, and if these sludges are declared hazardous under proposed RCRA regulations, FGD disposal costs can be expected to increase significantly above current levels. These costs can be drastically reduced by improved sorbent (e.g., limestone) utilization, controlled solids quality, and by improved sludge dewatering equipment. Currently under study are techniques to develop sulfite solids and forced oxidation processes to produce gypsum.

Various forms of waste disposal must be considered, and a selection depends on the environmental and economical acceptability. Because of environmental concerns related to disposal of FGD wastes, which are influenced by the characteristics of the waste, topography, hydrology, climate, geology, and availability of, as well as proximity to, disposal site, numerous alternatives, including variations within each, must be studied and evaluated.

- FBC Waste: The FBC process produces a spent-bed residue which is recovered in dry condition. DOE has initiated a program to evaluate whether this spent residue can be used commercially. Plans for field demonstrations include the use of the alkaline FBC residue as an SO_2 sorbent, a stabilizing medium for scrubber sludge, a neutralizer of acid-mine drainage discharge, and a component of a stabilized road-base pavement system in a highway construction project. Agricultural uses of FBC wastes are possible since they contain large amounts of nutrients necessary for plant growth. The major concern, however, is the possibility of contamination with biotoxic elements, such as lead, cadmium, and chromium. DOE and USDA are now investigating all aspects in a comprehensive program which includes extensive greenhouse, growth chamber, and field studies and will culminate in animal feeding trials and analyses.

3.2 INSTRUMENTATION

Both the operation and evaluation of cleanup equipment are dependent on reliable, accurate instrumentation to provide performance information in real time. Instrumentation capable of measuring all process variables during process operation is necessary. Flow rates, pH, chemical species, pressures, and temperature must be measured at multiple locations within reaction vessels. Instrumentation is vital to both process evaluations and for the development of automatic control systems. Similarly, instrumentation is necessary to measure constituent elements at all stages of the process gas stream flow. Key constituents necessary to be monitored include sulfur, nitrogen, alkali metals, halogens, heavy metals, mineral particulates, and hydrocarbons. Instrumentation that is accurate and precise and capable of functioning at temperature and pressure and within the process stream will continue to be the critical requirement. Improved continuous SO_2 monitoring systems are a very-high-priority need.

The development and improvement of instrumentation capable of providing this information is the objective of this project. Results of this effort will accelerate the development of the systems described in the preceding project areas and will be published in design handbooks. Widespread dissemination of such basic information will help minimize government involvement in demonstration by reducing technical risk and allowing broad competition between vendors.

3.3 APPLIED RESEARCH

The objective of the AECT applied research project is to provide the scientific bases for development of flue gas and gas stream cleanup technologies. Results of this task element will enhance the development of

the control systems described in the preceding subactivities. Efforts will include:

- Systems and Materials

  Tests on synthetic or conditioned representative gasification and combustion streams will identify deleterious species levels, and possible synergisms that can limit the useful process life of turbine, fuel cell, synthesis catalyst, and heat exchanger components. The gasification and combustion stream degradation signatures under various loadings and cleanup requirements versus effective life will be characterized.

  Long-term materials testing will be conducted on a variety of materials in the presence of the large variety of chemical compounds found in flue gas cleanup.

- Chemical/Physical Effects

  This effort will address those key scientific areas necessary to allow an understanding of the basic phenomena that control gas cleanup processes. This includes physical dynamics of particulate matter in centrifuges and cyclones, electrodynamics of electrostatic precipitators, and chemistry and thermodynamics in wet and dry sulfur removal concepts.

  Specific efforts will include the determination of corrodant formation control parameters in coal gasification and combustion, development of hydrodynamic and reactions models of contaminant composition in gasifiers and pressurized fluidized-bed combustor gas streams, measurement of thermodynamic parameters and kinetic data for contaminant reaction with gasification and combustion species, analysis of rates of liquid and solid particle formation and conglomeration under process stream conditions, and the measurement of thermodynamics and kinetics parameters for advanced sorbents for organic or alkali removal techniques.

3.4 SYSTEMS AND ECONOMIC COMPARISONS

The AECT program goal of solving the fossil fuel problems of air pollution and power system component contamination and damage requires more than the development of hardware components. Only an integrated systems approach trading off various energy generation and cleanup alternatives, will result in successful coal utilization. The objective of the Systems and Economic Comparisons project is to ensure that the optimum system combinations are provided for coal utilization. The following tasks are being pursued in this project:

- Economic/Technical Trade-Off Analyses

  A comprehensive continuing analysis effort is underway to determine the trade-offs among various control technology options and between control technologies, power systems components, and other coal processing system components. This project includes development

and verification of a control technology data base and simplified system models and process components. Performance and costs of flue gas and gas stream cleanup systems will be evaluated in terms of environmental requirements, siting factors, and fuel use requirements. In the case of a high-sulfur coal combustion/steam turbine system, for example, environmental standards could conceivably be met by coal cleaning, fluidized- bed combustion, conventional coal combustion with high efficiency FGD, or combinations of these approaches. An analysis of the economics of the options and comparisons with other systems (PFB, gas turbine closed-cycle, fuel cell, etc.) containing multiple options will be conducted.

- Systems Integration and Control

  Increased system efficiency and cost minimization require integration of the cleanup system into the overall power plant. For example, scrubber water flows can be integrated with other system water flows. This subtask will consider these factors and their impact on maximizing total system reliability and cost savings.

- Planning

  The requirements of existing and anticipated environmental regulations and fuel regulations and their impacts on coal utilization systems will continue to be incorporated with the outputs of the trade-off analyses and systems integration efforts in the ongoing planning of the AECT program.

3.5 CLEANUP BASE TECHNOLOGY STATUS

Waste management efforts began in FY 1977 in both the AR&TD and Combustion Activities and included studies in coal waste utilization, regenerable fluidized-bed sorbents, aluminum from fly ash, chemical properties of coal slags, and utilization of FBC spent-bed materials. These activities were incorporated into AECT in FY 1980. A collaborative testing program was begun in FY 1978 with the Fossil Energy Technology Centers and the American Society for Testing and Materials (ASTM) to evaluate EPA and ASTM proposed testing procedures for characterizing the properties of solid waste materials. Phase II of that program was initiated in FY 1979 primarily to collect metals data on leachates from a wide variety of fossil fuel waste materials with a secondary objective of determining the scientific quality of the test extraction methodologies themselves. Limited support of the National Bureau of Standards (NBS) was given to this effort. Property characterization of fossil waste properties is essential to development of sound waste management or disposal techniques such as will be required under proposed regulations of the RCRA. Also initiated in FY 1979 was an effort to evaluate the impacts of RCRA on coal-fired electric generating facilities and the implications to Fossil Energy programmatic objectives.

Efforts initiated in FY 1980 included investigation of gasifier tar disposal waste water cleanup techniques, FBC residue regeneration, and waste control associated with western coals. Increased support was given to a

promising activity begun in 1976 to recover aluminum and iron from fly ash through a high-temperature chlorination process being developed at Ames Laboratory. Work begun in FY 1979 was expanded into a major effort in FY 1980 to comprehensively assess, through case studies and waste sampling, the impacts of proposed RCRA regulations and other Federal/Environmental regulations (TSCA, CWA, NPDES Permitting, etc.) on utility and industrial sector fossil fuel-fired facilities. Paralleling this activity, an extensive fossil technology waste sampling and characterization project was initiated to develop a definitive and authoritative body of data on the characteristics of fossil residues from a variety of combustion and conversion systems using the most advanced science currently available. Data generated will be essential to development of technically and economically acceptable environmental management of waste streams from coal combustion and fossil energy conversion processes. This pilot project will be a multifaceted interlaboratory activity involving major support by the NBS in conjunction with the Fossil Energy Technology Centers. Participation by ASTM independent voluntary laboratories and several national laboratories is expected early in the project. Phase II and supplemental work conducted under the DOE/ASTM collaborative testing program is expected to be completed and a final report issued.

Specific FY 1981 efforts in waste management will include the continuation of control technology development for disposal of waste materials from lime/limestone scrubbers to satisfy RCRA requirements, continuation of an effort with the Department of Agriculture to evaluate the use of fluidized-bed spent-bed material as a lime replacement for eastern United States crops, the evaluation of spent-bed material and ash as a construction material, the development and testing of methods for regeneration of FBC sulfur sorbents to increase overall sorbent utilization and reduce waste outputs, the initiation of studies for treatment, utilization and disposal options for wastes associated with advanced flue gas cleanup processes. Final results on the process for recovery of aluminum (and iron) from coal fly ash are expected. The comprehensive assessment of the impacts from proposed RCRA and other Federal regulations on utility and industrial coal burning sectors as well as the companion interlaboratory activity on fossil technology waste sampling and characterization will be completed.

The Instrumentation effort initiated in FY 1979 to identify the critical lime/limestone scrubber, advanced flue gas cleaning and gas stream cleanup instrumentation needs will continue with subprojects initiated during FY 1980 to develop instrumentation hardware unique to AECT requirements. By FY 1981, additional instrumentation requirements will be identified for which funding will be required. Specific efforts conducted in FY 1980 include in situ determination of particles in combustion streams, an investigation of the control of organic emissions from fluidized-bed combustors, and the monitoring of particulates and gases in AFB combustion streams. Instrumentation developments to be tested and demonstrated in FY 1981 are expected to include online sulfur and ash meters, pH monitors and sensors, and reliable particulate monitoring devices, especially for minus 2-micron respirable particles. Efforts to measure trace element emissions will also be initiated.

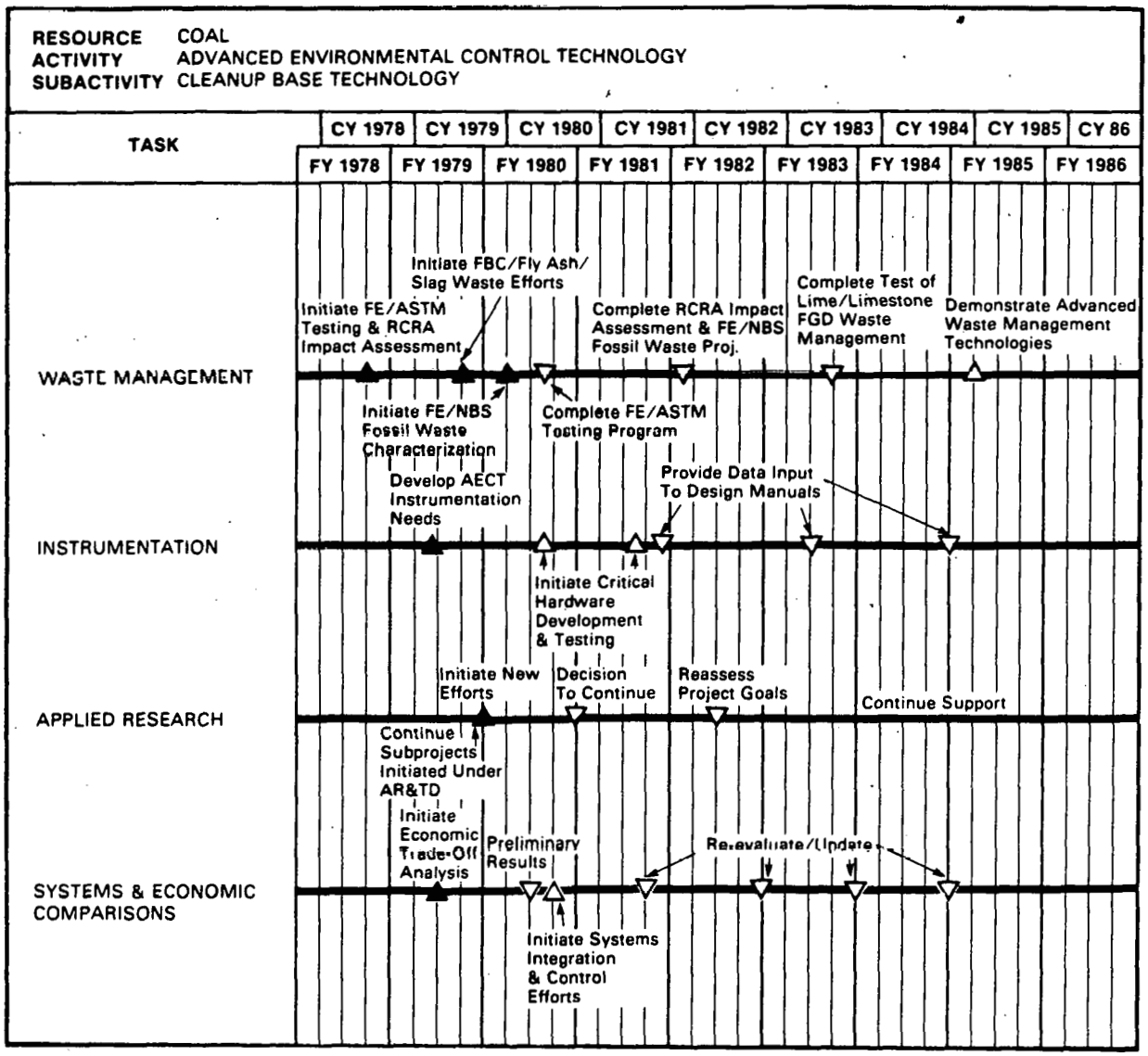
Applied Research projects started in FYs 1978 and 1979 in the AR&TD Activity will be continued. Specific efforts in FY 1981 will include the determination of corrodant formation control parameters in coal gasification and combustion, development of hydrodynamic and reaction models of contaminant composition in gasifiers and pressurized fluidized-bed combustor gas streams, measurement of thermodynamic parameters and kinetic data for contaminant reaction with gasification and combustion species, analysis of rates of liquid and solid particulate formation and conglomeration under process stream conditions, and the measurement of thermodynamics and kinetics parameters for advanced sorbents for organic or alkali removal techniques.

During FY 1981, a number of the projects initiated under the AR&TD program will culminate in useful modeling tools developed from applying theory and experimentation. For example, considerable knowledge will be developed on the relation between coal organic structure and the products of thermal decomposition. The subsequent model will be used to predict the amount of volatile fuel nitrogen and sulfur evolved in pyrolysis which is essential in estimating the conversion to NO_x and SO_x. Other work will result in the development of kinetic data on key combustion and exhaust flow reactions of bound nitrogen. These and other projects are part of the applied research effort that is designed to determine and model the mechanism of conversion of fuel-bound nitrogen to NO_x and other fixed nitrogen species during the combustion of coal and other solid-phase fuels. The result will provide useful tools for combustion modification and new burner design practices for the purpose of minimizing the formation of polluting, fouling, and slagging species and improving burner flexibility and boiler availability.

In the Systems and Economic Comparisons project, a net energy analysis has been completed of various approaches for the clean use of coal. Coal cleaning, FGD, gasification, liquefaction, and fluidized-bed combustion were considered. A number of studies previously initiated will be continued and completed by the end of FY 1981:

- Evaluation of advanced FGD system economics for regional use
- Economics of techniques for fine particle control
- Comparative assessment of industrial boiler options to meet air emission regulations
- Evaluation of elevated-temperature cleanup vs. cold cleanup with heat recovery for gasifier-turbine combined cycles
- Trade-off study of coal cleaning vs. FGD to determine the optimum combinations, in terms of economics, to meet air emission regulations.

In FY 1981, modeling of integrated cleanup systems for optimization purposes and the initial development of a cleanup technology data base will be conducted with a scheduled completion date of FY 1982.



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Capital equipment funds will be required at the energy technology centers and national laboratories to provide onstream analyzers to measure flue gas composition and scrubber performance; to provide necessary instrumentation for online monitoring of particle size distribution and organics in flue gas streams; and to procure necessary laboratory equipment for online alkali and particulate measurements of gas streams from gasifiers and PFB combustors.

G. HEAT ENGINES & HEAT RECOVERY

The Heat Engines and Heat Recovery Activity is directed toward: advancing the state of the art of heat engine systems to provide a capability for the economical and environmentally acceptable use of coal and coal- or shale-derived fuels, and the development of heat recovery systems that can displace oil and gas fuel by converting residual energy to useful purposes.

There are three subactivities within the Heat Engines and Heat Recovery Activity, for which funds are identified in the annual budget request.

- Central Power Systems[1]
- Dispersed Power Systems[2]
- Heat Recovery Component Technology

Advanced energy conversion technologies which are being developed with the funds made available under these line items are intended to penetrate the stationary power market of the utility, industrial, and residential/commercial sectors. Opportunities for improved technology in this tri-market sector are shown in the following figure, which illustrates both the interrelation between the Quads of fossil fuel consumption (Q_f) in each market, the useful electric energy produced (Q_e), and the associated Quads of heat rejection (Q_r).

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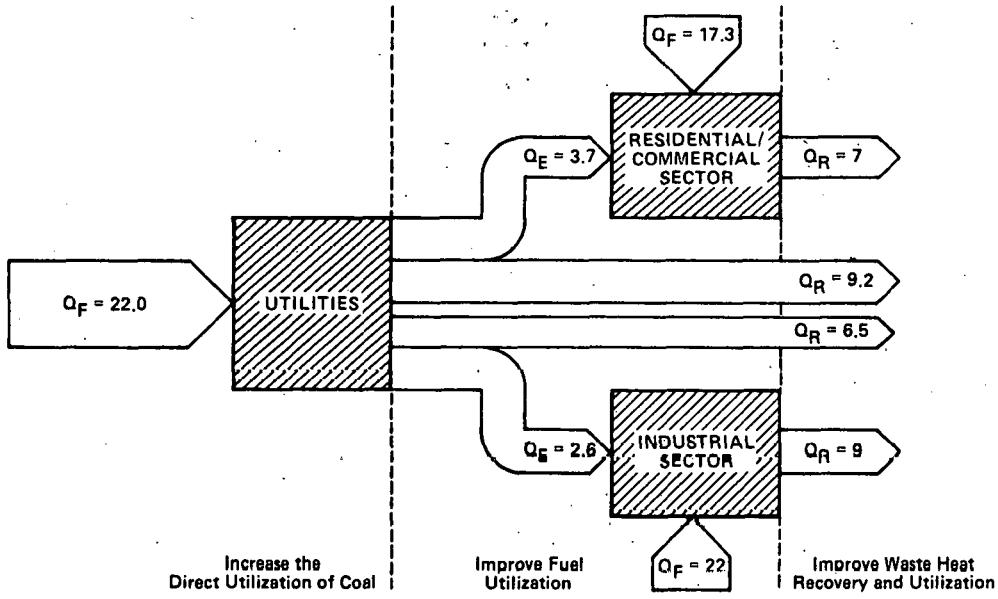
[1]Identified in previous budget years as "Integrated Coal Conversion and Utilization Systems."

[2]Identified in previous budget years as "Advanced Cogeneration Systems."



Opportunities for Heat Engines and Heat Recovery Technology

As shown, the utilities currently consume over 22 Quads of fuel energy to produce a little over 6 Quads of electrical energy. This electrical energy is distributed to customers in the residential/commercial and industrial sectors, while two-thirds of the fuel consumed by the utilities is rejected as waste heat. Meanwhile, the industrial sector consumes around 22 Quads of fossil fuels in order to produce heat for various process needs. The residential/commercial sector consumes a significant quantity of fuel energy (Q_f = 17.3) for space heating, hot water, etc. A substantial portion of that energy consumption is also rejected without extracting any useful work. The opportunities for improving this wasteful tri-market energy pattern are the focus of the subactivities within the Heat Engines and Heat Recovery Activity, as shown in the following figure.

The Central Power Systems subactivity addresses R&D for increasing the direct use of coal by central station electric utility power generation. For electrical generation by utilities, the integrated high-temperature turbine gasification combined-cycle system offers potential for improved economics, higher efficiency and the low emission levels. The advanced systems under development can produce electricity at a lower cost than conventional steam with flue gas desulfurization (scrubbers). Their successful development and commercialization would permit the utilities to increase the utilization of our abundant coal resources, thereby releasing critical oil and gas for use in other domestic markets.

The R&D efforts under the Dispersed Power Systems subactivity are directed toward development of industrial size or small utility size stationary heat engine systems capable of using coal and coal- or shale-derived fuels in an environmentally acceptable and reliable manner. Utilization of these coal-fueled power plants on site in advanced cogeneration systems has been shown to be one of the most efficient means of improving fuel utilization by the residential/commercial and industrial

SUBACTIVITIES	OVERALL OBJECTIVE	APPLICATION
Central Power Systems	Increase Direct Utilization of Coal	Central Station Utility Power Plants • Base Load • Intermediate
Dispersed Power Systems	Improve Fuel Utilization	Small Municipal Utility & Cogeneration Power Plants • Industrial Cogeneration • Residential/Commercial Total Energy • Small Utilities Power Generation
Heat Recovery Component Technology	Improve Waste Heat Recovery and Utilization	• Utility • Residential/Commercial • Industrial

Focus of the Heat Engines and Heat Recovery Activity

sectors. The concept of simultaneously producing both electricity and process heat on the industrial or residential/commercial site is known as cogeneration. Examples of residential/commercial cogeneration are small, dispersed total energy systems for multifamily buildings, or larger integrated energy systems for communities that can efficiently supply both the electrical and heating needs of residential/commercial complexes. The waste heat recovered from the electrical generation process in these total energy systems can supply space heating hot water and even cooling by combining absorption air conditioning which operates directly from low-grade waste heat. Cogeneration in industrial plants can supply their electrical needs and heat for the various processes. Industrial processes generally require higher temperature heat than residential/commercial applications, so the equipment for the two applications differ in their overall size as well as in the temperature of the heat produced.

Studies have shown that the best coal-derived liquid fuel cogeneration options are stationary diesels for residential/commercial total energy systems and stationary gas turbines for industrial cogeneration. The heat engine systems offering the greatest fuel flexibility and economic attractiveness for solid coal use in cogeneration are those based upon the atmospheric fluidized-bed coal combustors (AFBC). Specifically, the AFBC/steam turbine system can satisfy a significant portion of industrial heat and power requirements. Expanding the AFBC option to include AFBC/gas turbine (both open- and closed-cycle) can more than double the market development for advanced coal cogeneration. The AFB/gas turbine system is presently being tested at the pilot scale under the Combustion program AFB TTU subactivity.

Heat recovery component technology can provide a means to effectively recover waste heat and convert it to useful purposes, thus offsetting fuel now burned to produce that equivalent work. Considering the current total 52 Quads of fuel energy usage by the tri-market sector, it is estimated that approximately 28 Quads are rejected to the atmosphere and rivers in the form of waste heat. Effective recovery and utilization of even a fraction of this reject heat could reduce dependence on foreign energy imports, alleviate the associated balance of payments problem, and help reduce the cost of energy to the American public. The technology related to improved waste heat recovery and utilization would have important applications in all three market sectors. Residual energy applications of the heat currently being rejected by the coal-fueled DOE-owned gaseous diffusion plants and nuclear weapons processing facility have been shown to be the most efficient and expedient way for the government to demonstrate utilization of reject heat for rapid transfer to the private sector.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

HEAT ENGINES AND HEAT RECOVERY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Central Power Systems	20,700	24,800	22,200
Dispersed Power Systems	14,920	13,000	16,900
Heat Recovery Component Technology	16,180	12,500	4,300
Capital Equipment	300	200	0
TOTAL	52,100	50,500	43,400

1.0 CENTRAL POWER SYSTEMS

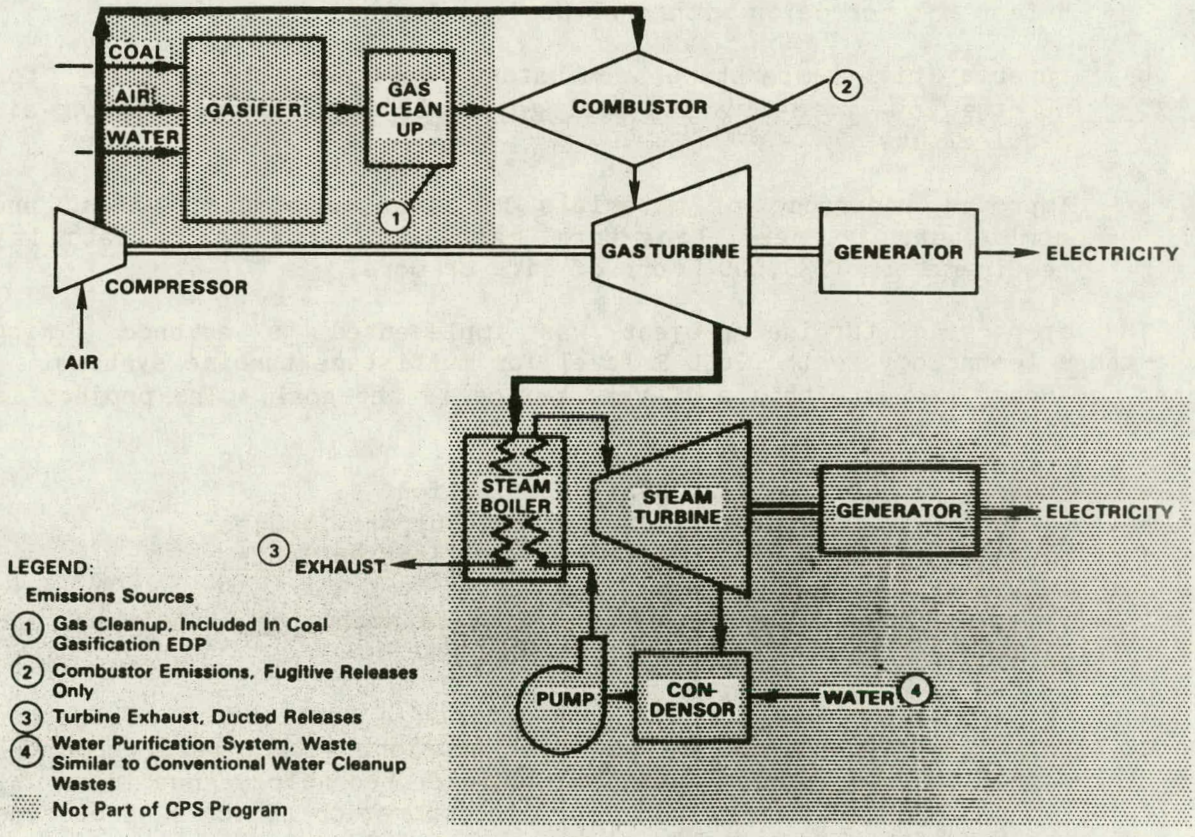
The Central Power Systems R&D efforts are arranged in two tasks, discussed herein: (1) Open-Cycle Gas Turbine, and (2) Closed-Cycle Power Systems. They are aimed toward providing technology for increasing the utilization of our abundant coal fuel resources in order to offset the use of critical oil and gas in the utility market.

Integrated coal conversion and utilization systems have been shown to be a most promising option for efficiently using coal in an economic and environmentally acceptable manner. Specifically, the integrated high-temperature gas turbine/low-Btu coal gasification combined-cycle system employing high-temperature (2600° to 3000°F) open-cycle turbine holds promise for achieving the high efficiency needed to offset energy losses in gasifying and cleaning the coal. Electricity can therefore be produced at a lower cost and with significantly less emissions than conventional coal-fired steam systems using flue gas desulfurization.

Closed-cycle power systems integrated with a fluidized-bed combustor represent another environmentally promising approach for utilizing coal directly in utility base-load service. Closed-cycle systems have found widespread use in Europe, particularly in municipal central station cogeneration applications where waste heat is recovered and hot water distributed to residential/commercial customers, a concept known as district heating. If the cycle temperature could be increased, advanced closed-cycle power systems could have the potential for efficiency and cost of electricity comparable to gasification combined-cycle, but feasible in smaller sizes to meet the needs of smaller utilities. The major technical problem related to achieving that performance is the operating temperature of the coal-fired primary heater.

1.1 OPEN-CYCLE GAS TURBINE SYSTEMS

The concept of this advanced system is to burn gasified coal fuels in air to produce high-temperature combustion products (at 2600°F or higher) before expanding it through the turbine to produce electricity. After expansion, remaining hot gases can be used to generate steam in conventional steam bottoming plants to produce additional electricity. Such a supplemental power-producing stage is called a bottoming cycle. The open-cycle gas turbine (OCGT)/steam system forms a combined-cycle power plant with significantly greater efficiency than today's standard steam plant.



Open-Cycle Gas Turbine/Steam Turbine System

With this system, crushed coal, water, and compressed air are fed into the gasifier. Hot gases are passed through a cleanup system for removal of particulates, sulfur compounds, and other chemical contaminants, and are burned in a combustor prior to driving the gas-turbine electric generator. From the turbine, the expanded gases are routed through a steam generator, relinquish some of their remaining heat, and are exhausted to the atmosphere. Steam thus generated is expanded through a steam turbine driving an electric power generator. Exhausted steam is condensed, and a pump arrangement feeds the fluid back to the steam generator.

Project Status

The OCGT technology base is quite advanced with clean fuels such as oil and natural gas. Industrial units with clean fuels are presently in wide use for utility peaking service, as are clean-fuel-fired gas turbine/steam turbine combined-cycles for intermediate-duty service. The general state-of-the-art firing temperatures for all these stationary clean fuel turbines is about 2000°F.

Adaptation of new gas turbine technology for use with coal and coal-derived fuels will require development of three key capabilities:

- Practical turbine cooling methods to withstand higher turbine inlet temperature, while achieving low metal operating temperatures to defeat hot corrosion with coal-derived fuels

- Durable high-temperature combustors designed specifically for burning low- to medium-Btu coal gas fuels with minimum cooling-air requirements

- Improved endurance of materials for turbine blades, vanes, and combustors to meet long-term base-load service reliability requirements of 30,000 hours of life or more.

The open-cycle turbine project was implemented to advance firing temperature technology to the 2600°F level for multistage turbine systems. A technology-ready status within a 10-year period is the goal. The project is divided into three phases:

- Phase I: Project and System Definition
- Phase II: Technology Test and Test Support Studies
- Phase III: Technology Readiness Verification Tests.

Successful completion of these phases will provide technology readiness, and commercial demonstration is expected to follow.

Turbine component durability is dependent on a combination of factors such as stress, temperature and hot corrosion/erosion. The strategy for the open-cycle gas turbine project is to achieve technology readiness by developing key high-risk components for incorporation into a prototype advanced high-temperature gas turbine. The major effort of this project concerns development of advanced cooling concepts, such as air film and transpiration cooling and water/steam cooling of turbine blades and nozzles, along with development of material alternatives (superalloy metals and

ceramics) for combustor liners, transition sections, and appropriate hot section parts. An assessment of ceramics for key high-temperature, open-cycle turbine components is included as a project element since impurities present in coal-derived fuels may seriously degrade the metals and coatings conventionally used in gas turbines.

An additional, significant project element is the development of advanced low- and medium-Btu gas combustor designs to ensure that the gas temperature profile is carefully controlled to prevent uneven temperature distribution or "hot spots" on turbine components and to ensure that the exhaust meets emission standards. Also, with coal gas as fuel, there is less cooling air available for cooling the combustor walls, and hot wall technology possibly involving ceramics must be developed. Design data for combustors using coal-derived gases have been generated to date. Two specific approaches aimed at the "temperature profile" goals were evaluated to improve combustion control by premixing of fuel and air in a separate upstream section of the burner, and to use catalytic combustion. Approximately 1,100 hours of testing is planned through FY 1980. The status of each project is shown below.

Project	Status
High-Temperature Turbine Technology - Phases I, II	Complete
High-Temperature Turbine Technology - Phase III	Initiate in early FY 1981
Catalytic Combustor Technology - Phase I	Complete
Ceramic Technology Assessment - Phase I	Complete
Durable High-Temperature Low-/Medium-Btu Combustor Technology	Initiate in late FY 1980
Materials Testing - Component Testing	1,800 Hours

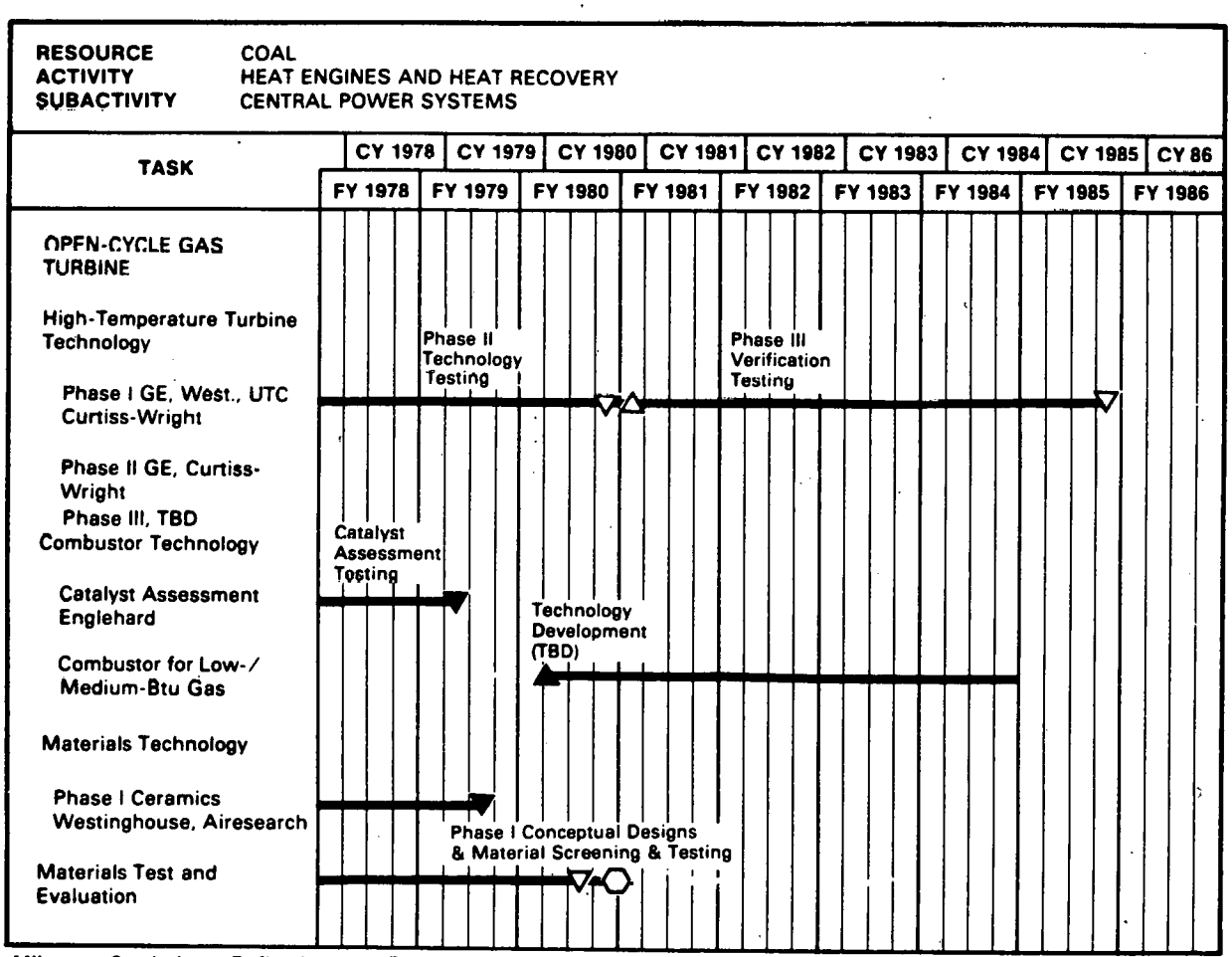
The following accomplishments are expected in the Open-Cycle Turbine Technology task in the FY 1980 and FY 1981 period:

- Phase II testing of the transpiration-cooled turbine blading for the large-utility high-temperature gas turbine gasification combined-cycle system could indicate during FY 1980 that operation with coal-gas fuel up to 3000°F firing temperatures is feasible with air transpiration cooling of the turbine hot section. Over 3,000 hours of testing under current contracts is to be completed during FY 1980 prior to planned initiation of Phase III in early FY 1981.

- Phase II testing of the water-cooled blading for the large-utility high-temperature gas turbine gasification combined-cycle system could indicate that operation with coal-gas fuel at over 2600°F can be readily achieved with water cooling of the turbine hot section. Over 3,000 hours of testing under current contracts is to be completed during FY 1980 prior to planned initiation of Phase III in early FY 1981.

- Phase I testing of advanced bench-scale catalytic combustion techniques for turbine combustor applications where low- and medium-Btu coal-derived gases would be predominant fuels proved encouraging to the extent that an effort to evaluate full-scale combustor concepts is deemed to be warranted starting in late FY 1980. Over 2,000 hours of testing various catalytic combustor techniques is expected to be accumulated under current contract efforts.

- The test program for screening advanced metallic and ceramic materials that could be applied to high-temperature turbine gasification combined-cycles is expected to accumulate around 8,000 hours of testing. Promising materials are to be chosen for further evaluation in future tests with a view toward stationary component applications such as combustor walls and transition ducts.



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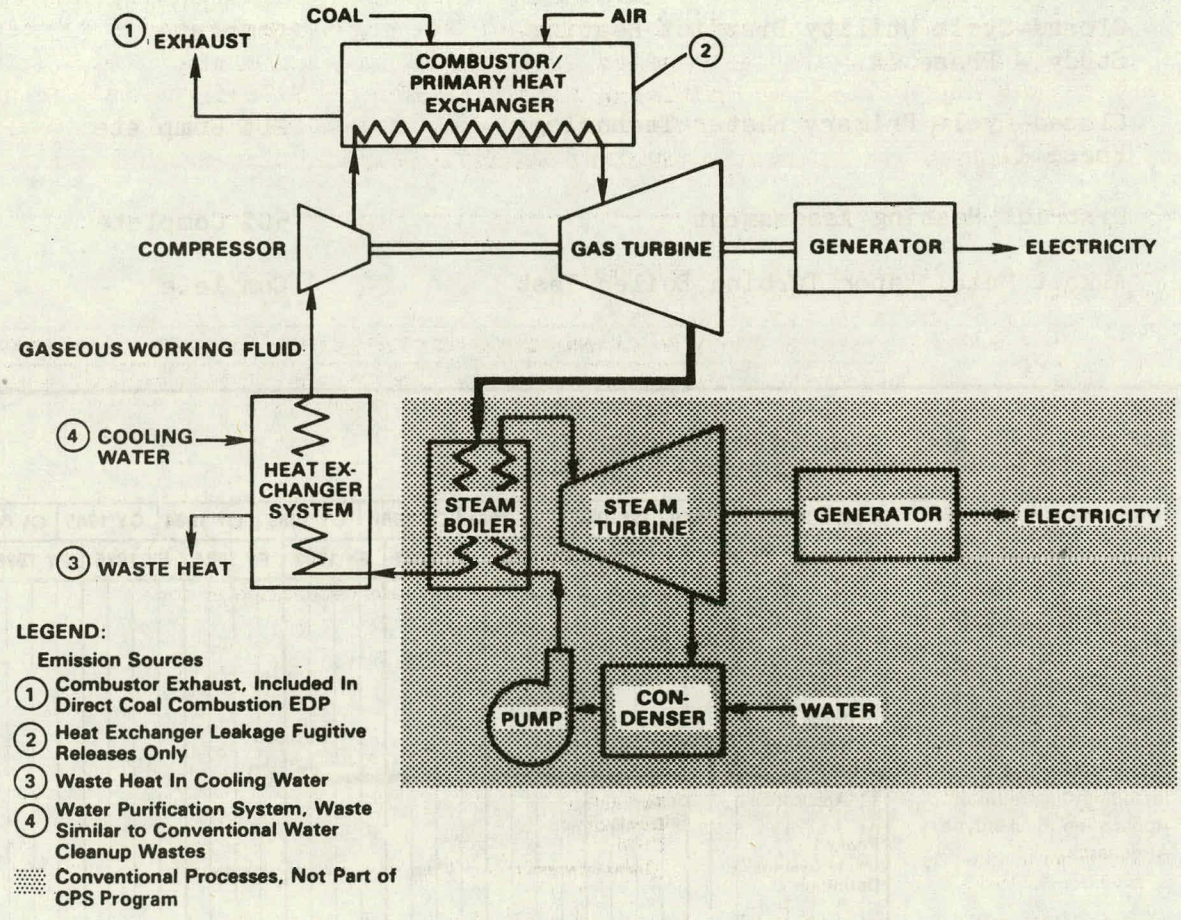
- Testing of high-temperature diagnostic measuring devices for analyzing the corrosive containment content in the high-temperature combustor subsystem of a gasification combined-cycle turbine continued. Approximately 1,000 hours of test time will have been achieved.

1.2 CLOSED-CYCLE POWER SYSTEMS

As in the open-cycle gas turbine system, the closed-cycle system can burn coal or coal-derived fuels. Because the working fluid is contained within a sealed system and is recirculated with negligible loss, working fluids such as helium, nitrogen, carbon dioxide, and air can be used. Since these are relatively noncorrosive or inert working fluids, the gas turbine can operate at higher temperatures (above 1550°F) than a standard steam system.



Combined Closed-Cycle Gas Turbine/Steam Turbine System

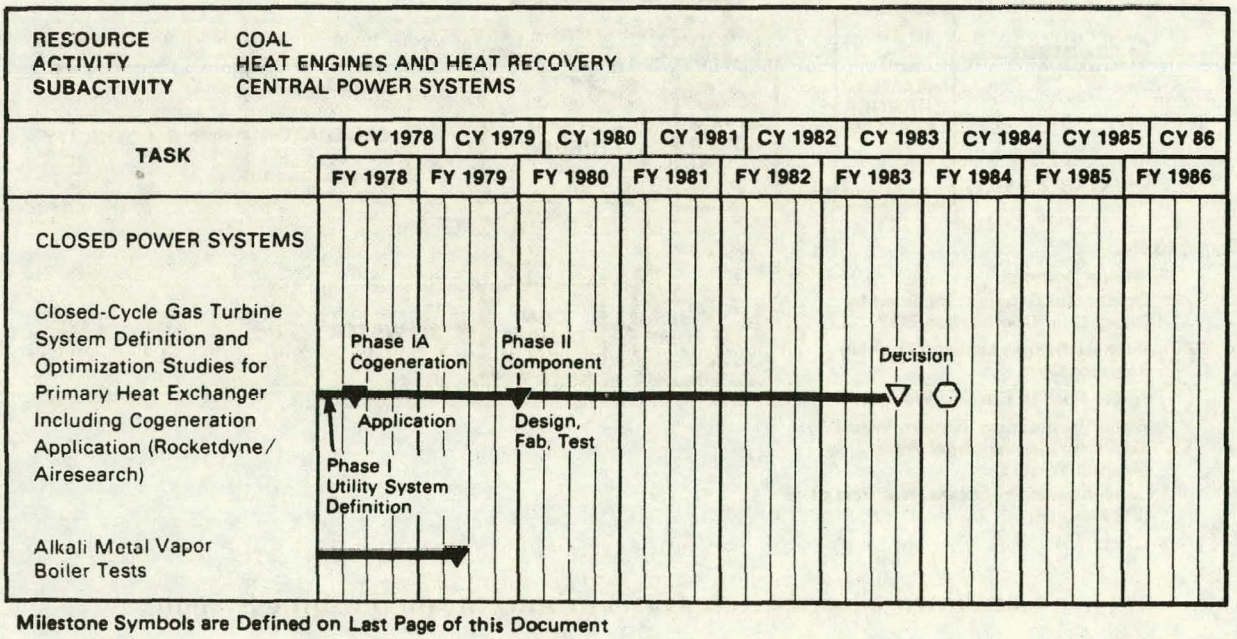
The gaseous working fluid is compressed and then heated by the primary heat exchanger. It is then expanded through the gas turbine driving an electric power generator. After expansion through the turbine, remaining

heat can be used in a conventional steam bottoming cycle or in a lower temperature bottoming cycle with an organic working fluid. The expanded gas then rejects heat to the heat rejection heat exchanger, and the fluid is then recycled through the system by being recompressed. Steam thus generated is expanded through a steam turbine driving an electric power generator, the exhausted steam is condensed, and a pump arrangement feeds the fluid back to the steam generator.

Project Status

The closed-cycle gas turbine system (primary heater) is continuing into Phase II. The status of each project is shown below.

Project	Status
Closed-Cycle Utility Electric Generation Study - Phase I	Complete
Closed-Cycle Utility District Heating Study - Phase IA	Complete
Closed-Cycle Primary Heater Technology - Phase II	20% Complete
District Heating Assessment	50% Complete
Alkali Metal Vapor Turbine Boiler Test	Complete



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In the FY 1980 and FY 1981 period the following major accomplishment is expected:

- Effort will continue on Phase II of the Closed Power Systems program initiated in FY 1979, which focuses on the development of advanced coal-fired primary heater technology. It is anticipated that during FY 1980 around 250 hours of testing will be completed.

No further work will be conducted on the alkali metal vapor systems.

2.0 DISPERSED POWER SYSTEMS

The technology for the use of coal and coal-derived liquids to displace imported fossil fuels in stationary power plants outside the domain of large central utility plants is under development in the Dispersed Power Systems (DPS) subactivity. Applications for these technologies where significant displacement could occur include the industrial and commercial/residential sectors. Both industrial and residential/commercial consumers of this group now generally purchase electricity and separately fire fuels in boilers for process heat or space heating. Their electrical needs are generally provided by the utilities, many of which are municipal or rural systems that generate electricity from oil and gas in small (less than 100 MW) units. They generally have few options for converting to coal with currently available technology. These sectors currently consume substantially more petroleum and natural gas than do large central utilities, and large portions of these fuels are light distillate petroleum, a fuel which could be directly used in home heating if it were displaced by coal-derived fuels.

The simultaneous generation of both electricity and process heat by recovery of waste heat from the prime mover exhaust is known as cogeneration. Compared to purchased electricity and fired onsite boilers, cogeneration systems use substantially less fuel and can generate much lower emissions per unit of useful output because they convert about twice as much of their fuel energy into electricity and useful thermal energy as do noncogenerated systems. The use of coal-based fuels in such systems can therefore be a highly acceptable form of increasing the use of coal in these petroleum- and natural-gas-intensive sectors.

The small utilities are also seen as an important market for advanced dispersed power systems because they represent a significant generating capacity that uses predominately light distillate or natural gas. The unavailability of coal-fired equipment in appropriate smaller sizes poses enormous problems for conversion to coal with currently available technology.

The primary thrust of the DPS work, therefore, focuses on the development of decentralized power systems for efficient onsite applications such as industrial cogeneration and small utilities. A major emphasis here is on stationary engine diesel and gas turbine technology permitting the environmentally acceptable use of lower grade petroleum fuels and alternate liquid fuels derived from coal or shale oil. The development of advanced industrial-sized engines capable of being fired with coal or coal-derived fuels would enhance industrial cogeneration and provide both municipal and

rural utilities the capabilities of using coal in power producing units previously considered too small to be economically fired with fuels other than distillate oil and natural gas.

2.1 DIRECTLY FIRED HEAT CYCLES

The major thrust of the Directly Fired Heat Cycles task is to help industry provide the engine technology for promoting a smooth transition from today's clean, light distillate fuels to future minimally processed coal-derived liquid fuels.

This effort has considerable near-term emphasis. It is focused on technology improvements for directly fired diesel and small- to medium-sized gas turbines to facilitate retrofit of these present long-life engines that now require distillate or natural gas fuels. The R&D is directed toward permitting durable and low-emission operation on minimally processed, more economical coal-derived liquids. These liquids are expected to be more like today's residual oils with respect to corrosive agents and emission sources than the more highly processed and expensive coal liquids that have these items removed by processing techniques involving extensive hydrogenation. In addition to the economies of being able to operate on the residual-type oils from coal, it is expected that there may be more of this type of fuel from a barrel of coal oil than there is from a barrel of crude oil. Shown below is a comparison of the fuel characteristics of concern between light distillates, residual oils, and future coal-derived minimally processed liquids for gas turbines and diesels and the R&D which is judged to be common for the use of both.

CHARACTERISTICS OF CONCERN	TODAY'S FUEL CLEAN NO. 2 OIL	NEAR TERM RESIDUAL OIL	FUTURE COAL-DERIVED LIQUIDS	PROBLEM IN TURBINES & DIESELS	R&D COMMON TO RESIDUAL AND COAL-DERIVED LIQUIDS
Fuel Bound Nitrogen	Low	High	Higher	Environmental	Combustor Design, Fuel Cleaning
Hydrogen/Carbon Ratio	High	Low	Lower	Luminous Flame	Combustor Cooling, Coatings and Material
Alkali Metal Content	Low	High	High	Corrosion	Component Cooling, Coatings and Material
Viscosity	Low	High	High	Pumping & Atomization	Fuel Handling, Cleaning, Additives, Fuel Injection and Combustor Design
Ash	Low	High	High	Erosion/ Deposition	Fuel Cleaning, Additives, Coatings, and Materials

Future Fuels and Engine Problems

Project Status

The Reliable Advanced Liquid Fuel Turbine Engine project is planned as a cooperative DOE/EPRI R&D effort. It is envisioned as a 6-year joint program leading to commercialization of engines with current or moderately increased firing temperatures along with their associated efficiencies becoming compatible with coal gases and minimally processed coal-derived liquid fuels. The technology advances in coatings, cooling, combustors, and engine components are planned to be incorporated into a dual fuel reference engine design. The results of these cofunded efforts are being directed toward a joint DOE/EPRI decision-point target in late FY 1981. At that time the need for a new engine development program will be determined.

At the decision-point milestone an assessment of the best means of incorporating this technology will also be thoroughly investigated by DOE/EPRI and engine manufacturers. It is envisioned that it would prove more effective to pursue "dash" engines, or modified versions of today's engines which incorporate this new technology for improved efficiency and fuel flexibility, in lieu of a new engine development. Either the new engine development program or a development program involving modified "dash" engines would be structured to best support the needs of both industrial and utility gas turbine users, where liquid fuels are predominant.

Gas turbine technology now undergoing component development for improved performance and the capability to operate reliably and cleanly on coal-derived fuels includes: (1) ceramic coatings for hot-part protection from alkali metals; (2) low NO_x combustor development for burning fuels high in fuel-bound nitrogen without exceeding federal or state NO_x emission standards; (3) advanced solid-surface convectively cooled turbine airfoils which can provide enhanced cooling while mitigating the clogging problem with ash-bearing, coal-derived fuels; and (4) advanced compressor technology for higher efficiency, lower wheel speeds, and up to 50 percent fewer parts for greater reliability and reduced manufacturing costs. The key technologies in the compressor for both industrial and utility sizes will be tested for the first time in FY 1980, and during FY 1980 this compressor concept will be used in the EPRI new center-line design.

An experimental evaluation of a promising convectively cooled airfoil design was completed in FY 1978 where the highest known cooling effectiveness for a convectively cooled airfoil was demonstrated in heat transfer cascade tests. This airfoil concept is now undergoing coal-derived fuel tests by EPRI. A focused effort to screen promising concepts in ceramic coatings and low NO_x combustors through design, fabrication, and hot tests was initiated in late FY 1978 and will complete the Phase I screening effort in mid-FY 1980. The next phase for the coatings and the combustor program will be ready for procurement initiation in late FY 1980 with the objective of starting engine testing with full-scale hardware by FY 1983. Both technologies have been incorporated into the EPRI reliable new engine design/retrofit program at 2150°-2300°F firing temperature.

The second effort in Directly Fired Heat Engines is the stationary diesel program which is comprised of two major elements. The first was initiated in FY 1978 and has the objective of defining the capability of

current diesel operation, with minimum modifications, on fuels from coal, principally coal-derived liquids. This effort continued in FY 1979 along with selected efforts in low-wear materials for high ash-bearing fuels. The engine test program which was competitively awarded in FY 1979 emphasizes large-, medium-, and small-sized stationary diesel engine capabilities to ignite on low-cetane-number fuel, wear and corrosion due to ash and alkali metal content and emission of NO_x. It is anticipated that this coal-derived fuel evaluation in diesels will be completed in FY 1980 permitting initiation of the second phase late in FY 1980 or early FY 1981.

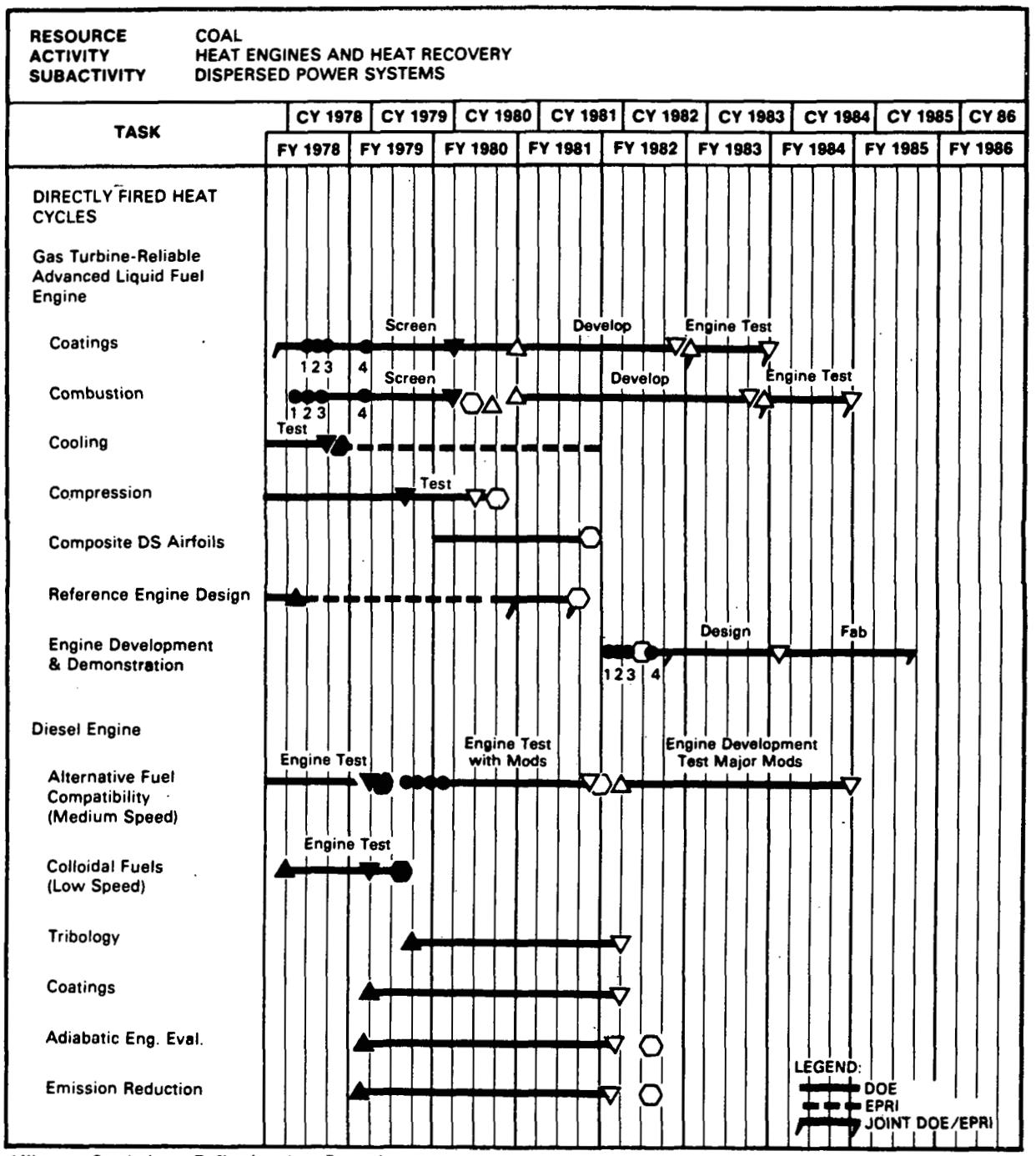
The second phase of the medium-speed diesel engine/alternative fuel compatibility program involves proceeding with the engine and fuel handling modifications which will be defined in the Phase I test program. Emission reduction, in particular NO_x, will be an important part of this new effort. The overall objective of this Phase II work will be to enable existing and current production diesel engines to operate efficiently, durably and in an environmentally acceptable manner with coal-derived liquid fuels and shale oil fuels such that these engines will be capable of switching from petroleum and natural gas at the earliest time.

A test program with the low-speed, two-stroke diesel engine has been completed with Sulzer Brothers, Ltd. Sulzer operated its single-cylinder research engine on COED, SRC-II and coal-oil slurries (colloidal fuels). The results with the highly refined COED fuel were interpreted by Sulzer as indicating that COED fuel can be directly substituted for diesel fuel in low-speed diesels. The SRC-II fuel had a very low cetane number which results in ignition lag and required pilot injection of petroleum fuel for ignition. Satisfactory operation was initially obtained with a 20 percent addition of light petroleum distillate to SRC-II without pilot injection. Ultimately, Sulzer obtained successful operation with pilot injections of 4 percent distillate petroleum while firing 96 percent SRC-II (minimally processed grade). Use of coal-oil slurries required improved fuel injection systems for erosion/corrosion problems. Also, severe wear was noted on piston ring-cylinder wall interfaces after a few hours operation. SRC-II and coal slurry fuels were also provided to Burmeister & Wain for test in its low-speed, two-stroke, valved diesel engine. Burmeister & Wain operated at full power satisfactorily with a 15 percent light distillate addition to the SRC-II. Severe wear problems were also encountered with coal-oil slurry fuel.

There are three supporting R&D projects that will provide technology for Phase II of the diesel/alternative fuel compatibility program. Current and candidate diesel materials are currently undergoing tribological tests. Norwegian coatings that have demonstrated exhaust valve-life improvements of a factor of 2 to 3 while operating on residual fuels are being evaluated by the Naval Research Laboratory (NRL) for mechanical properties and by Eaton in its laboratory valve testing equipment. Also, these coatings are being engine tested by DeLaval. Cummins is operating its adiabatic diesel, which uses monolithic ceramics and ceramic coatings for insulation, on coal-derived fuels to determine emission and efficiency advantages operating with about a 700°F increase in combustion zone temperatures.

The following accomplishments are expected in the Directly Fired Heat Cycles task during the FY 1980 and FY 1981 period:

- Technology developments in the area of low-NO_x turbine combustors and ceramic coatings for compatibility with coal-derived fuels are expected to successfully complete the Phase I concept screening. Full-scale evaluations under Phase II are being initiated in late FY 1980.



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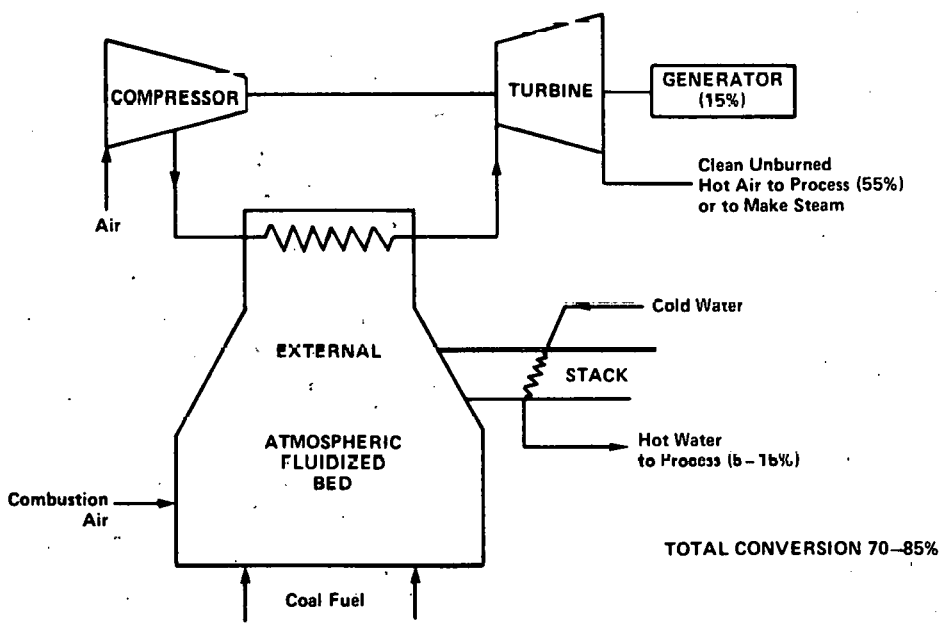
- A test program evaluating coal-derived liquids in medium-speed diesel engines for small utilities and commercial/residential cogeneration is anticipated to be successfully completed in late FY 1980. Major emphasis is on defining emissions and operating problems; the next phase involving engine modifications is planned to commence in FY 1981.

2.2 EXTERNALLY FIRED HEAT CYCLES

The Externally Fired Heat Cycle task has three primary thrusts: (1) the development of small steam turbines of high efficiency; (2) the development of an externally fired Brayton engine for industrial cogeneration; and (3) evaluation for potential development of a large Stirling engine for commercial/residential cogeneration applications. These are in support of the overall objective of providing heat engine technology for the direct use of coal in power systems sized for the industrial and commercial cogeneration markets.

The following figure illustrates a total energy (cogeneration) system with an externally fired open-cycle gas turbine. The engine extracts heat from an atmospheric fluidized-bed coal combustor via an externally mounted heat exchanger which takes the place of the conventional gas turbine combustor. The rotating machinery drives a generator as in conventional gas turbine practice, but the engine exhaust air unlike conventional gas turbines is totally clean and becomes an outstanding source of clean heat for many cogeneration applications.



Externally Fired Brayton Cycle

Few externally fired Brayton cycle engines are in use because of the limit in turbine inlet temperature which is a result of metal temperature limits in the heat exchanger. This effects a relatively low efficiency in cases where the only output is electrical power. Using the exhaust air directly in a cogeneration installation, however, can boost the overall fuel utilization from 15 to over 80 percent and make this cycle particularly viable as a means of substituting coal in industrial processes normally burning light distillate or natural gas.

Project Status

Two contracts include design, fabrication and testing of several efficient and cost-effective small steam turbines which were in place and ongoing by early FY 1979. They address the low efficiency and high cost of today's state-of-the-art small steam turbines now available for dispersed cogeneration power units. The specific objective is to raise current efficiency levels of approximately 10 to 30 percent above the 75 percent level while reducing specific costs so that small steam turbines can be efficient and economically competitive as a prime mover component in small coal-fired dispersed power systems. The range of horsepower to be addressed is from 500 to 6,000 hp. During FY 1979 the design efforts were near completion. In FY 1980, fabrication will be initiated and completed, including one turbine which will be configured as an extraction turbine for a cogeneration application. Factory testing will be completed in FY 1981.

One of the key cycles under investigation for advanced coal-fired cogeneration systems in the Cogeneration Technology Alternatives Study (CTAS) is the externally fired Brayton engine. While the applications and sizes for this cycle are pending in the CTAS program, certain critical technologies have been identified for early hardware investigation which began in FY 1978. A contract has been let to modify the combustor of an existing small turboshaft gas turbine to make it externally fired. This effort includes investigation of power modulation controls, startup and shutdown, and will use steam injection as a means of varying the ratio of thermal to electrical power, an essential parameter when considering the thermal and electrical power requirements of an industrial plant. The system was fabricated and successfully run for the first time in late FY 1979 for several short periods. Additional testing for further controls investigation will be accomplished in FY 1980. A pilot-scale AFB combustor firing an open-cycle Brayton engine (AFB TTU) is being fabricated and tested under the Combustion Systems Activity.

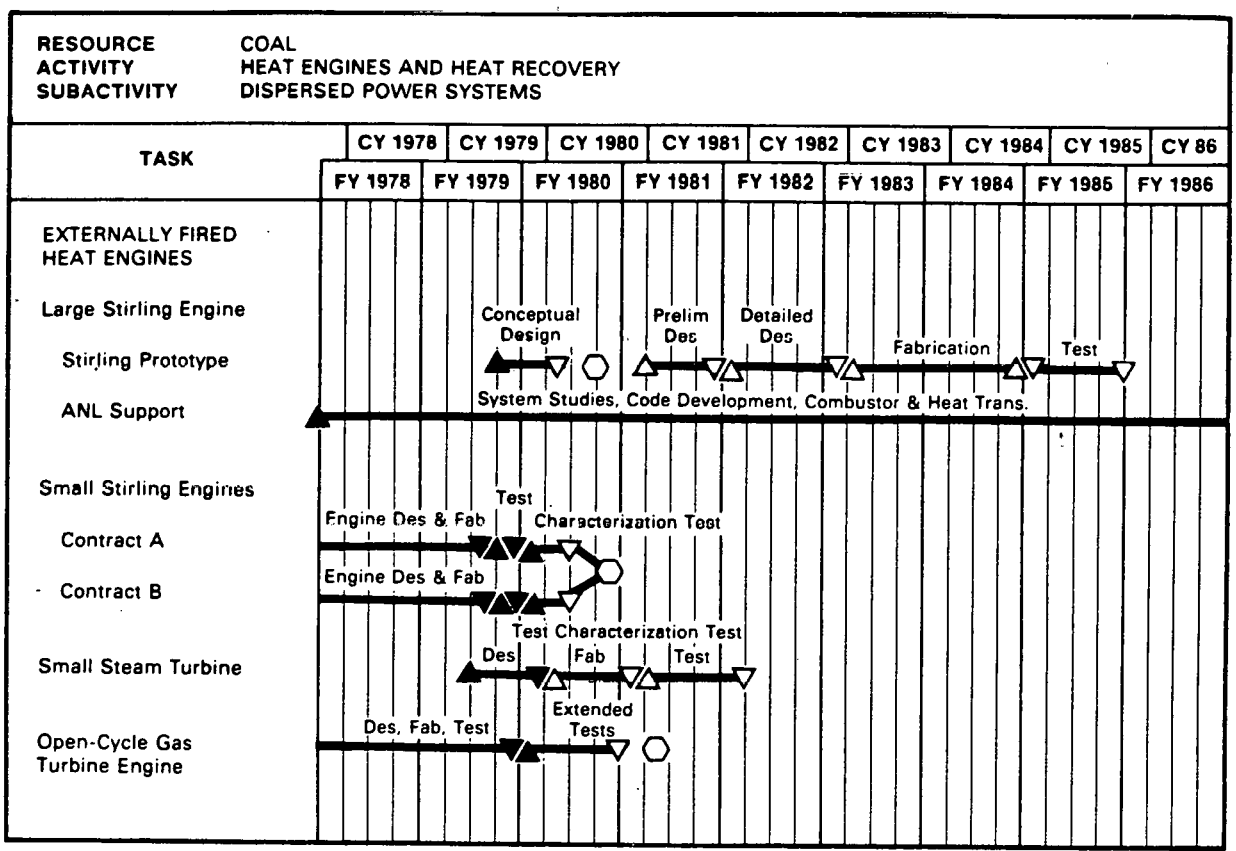
In FY 1979, fabrication of two small Stirling engines was completed and testing was begun by early FY 1980. Due to the limited nature of the testing, additional endurance time of several hundred hours each will be attempted in FYs 1979 and 1980. The test results will be used as a data source for the industrial teams selected, if Phase II of the large Stirling engine is initiated in FY 1981.

The large Stirling engine program is seen as three competitive phases: Phase I, Conceptual Design; Phase II, Preliminary and Detailed Design; and Phase III, Engine Fabrication and Test. Contracts for Phase I were initiated with several competitive team awards in FY 1979. This effort will be complete in FY 1980 with major emphasis in this study to determine probable

manufacturing costs in the range of 500 to 3,000 hp. While the technical attractiveness of the large Stirling, namely high thermal efficiency on direct coal and quiet operation, make it an excellent competitor for the diesel and the fuel cell in identical markets, the impact that its manufacturing costs could have upon market penetration will have a major bearing upon the Phase II decision in FY 1980.

Major accomplishments expected in the FY 1980 and FY 1981 period for the Externally Fired Heat Engines include:

- Additional operating time will be obtained to evaluate starting, power modulation, and response characteristics of an externally fired steam-injected open-cycle gas turbine for future, larger scale development of these systems in industrial process heat cogeneration applications.
- The conceptual design of a large 500 to 3,000 hp stationary Stirling engine is expected to be completed along with experimental results obtained from testing two small stationary Stirling engines featuring two different output drive configurations.
- Fabrication will be completed on improved efficiency small steam turbines for industrial cogeneration applications; they are being readied for test in FY 1981.



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2.3 PROTOTYPE SYSTEMS ASSESSMENT

This task is to assess the capability of dispersed power systems to meet the near- and far-term power requirements of the industrial and commercial/residential sectors. Various types of heat engine systems utilizing coal and coal-derived fuels are competed technically, environmentally, and economically for the purpose of steering engine development activities towards market application where they can optimally displace scarce fossil fuels. Cogeneration of heat and power in these two sectors is viewed as a primary market because of the potential 20 to 40 percent reduction in emissions and potentially attractive operating costs. The initial function of this task is, therefore, to perform such studies as are required in order to determine which engines and which fuels from coal offer the most competitive penetration against the conventional option (i.e., large central utilities for power generation and onsite boilers for process heat).

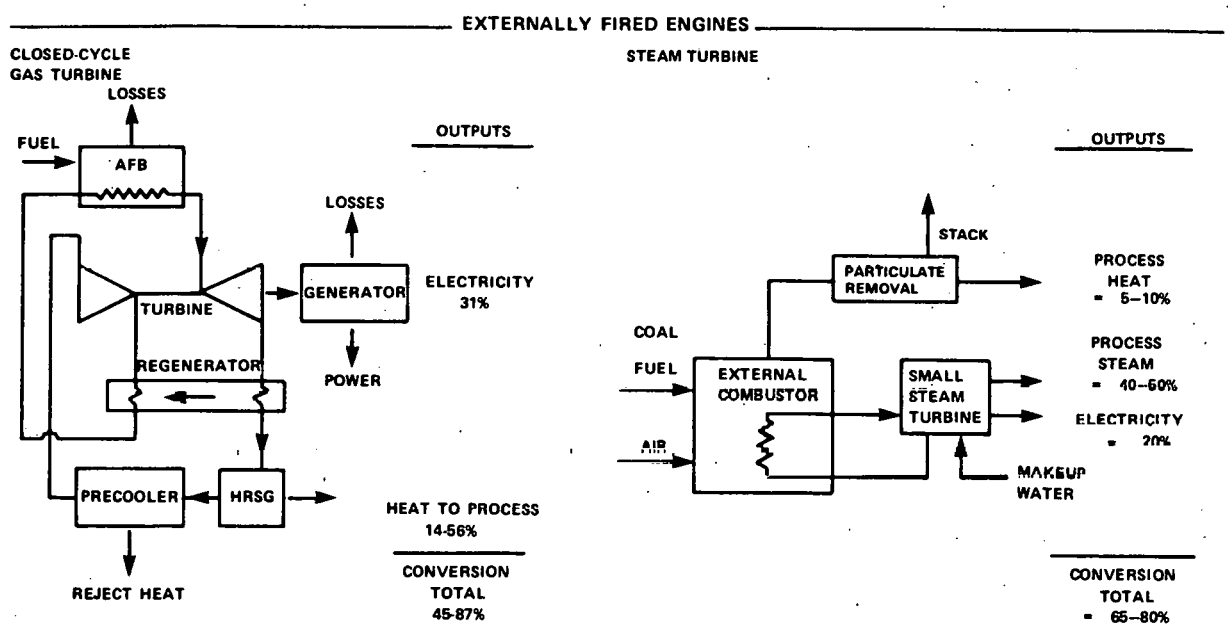
Since dispersed power systems also include engine types of interest to small utilities, the capability of these systems for efficient coal power generation in sizes appropriate to this class of utilities is also being examined. Like the industrial and commercial/residential sectors, small utilities almost exclusively use scarce fossil fuels.

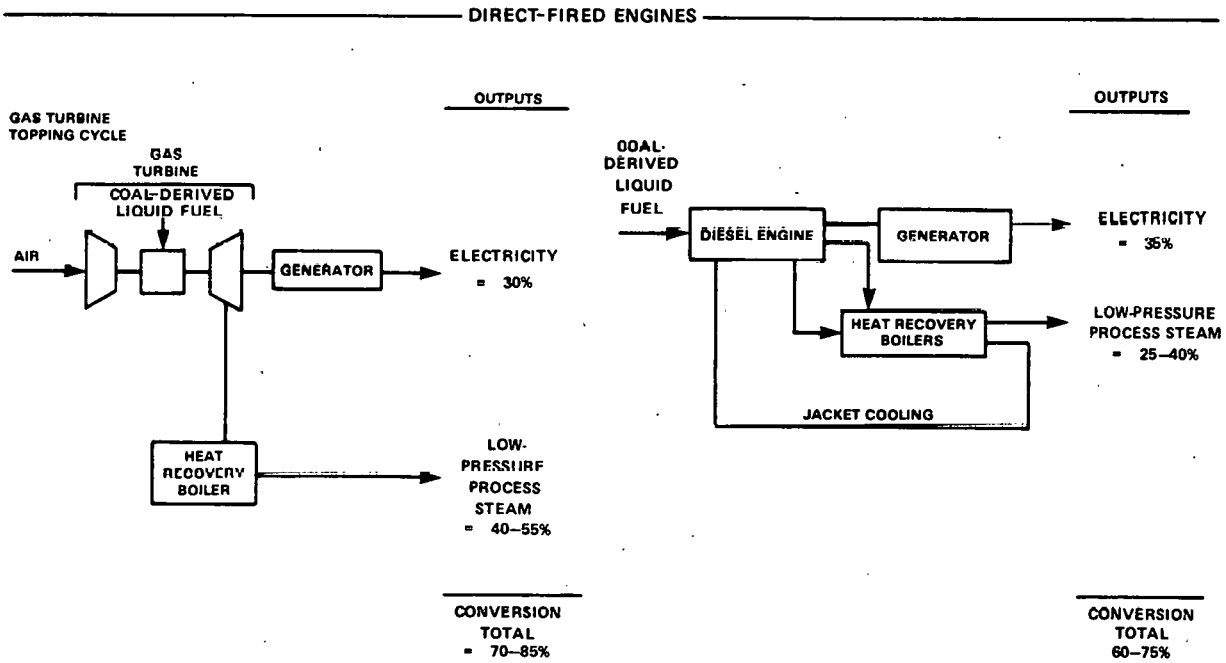
In the cogeneration work, the two stationary markets being examined are the industrial and the commercial/residential sectors. Two major studies began in FY 1977-1978 to perform this analysis. The industrial effort is the Cogeneration Technology Alternatives Study, and the commercial/residential effort is the Total Energy Technology Assessment Study (TETAS). These first-generation studies are to define the optimum matches between engine types and process heat and electrical requirements for the 1985-2000 time frame and will be completed in FY 1980. The next step will be to examine the best systems in more detail to determine the site-specific feasibility of cogeneration on coal using the heat engine technology under development in the Dispersed Power Systems subactivity.

Project Status

In the industrial sector, the Cogeneration Technology Alternatives Study was completed in mid-FY 1979, a public briefing was given in July 1979, and final reports will be published during the first quarter of FY 1980. The study focused on defining advanced coal-burning cogeneration systems for the six major industries that currently consume over 80 percent of the Nation's industrial process heat. CTAS was done by two major contractors and their industry teams. Factors that the CTAS emphasized included emission reductions for coal-burning cogeneration systems, return on investment, fuel savings, industry specific economics, including incremental costs to install cogeneration, and R&D requirements.

Based upon return on investment, the best systems for solid coal were the steam and gas turbines with fluidized-bed coal combustors and gasifiers. Gas turbines were clearly the best cogeneration for coal liquids. Subsequent market penetration analyses in the industrial sector were initiated in FY





Examples of Cogeneration Concepts

1980. Preliminary results from these analyses in early FY 1980 suggest that 16,000 MW of cogenerated installed power can occur between 1985 and 2000, using the advanced technologies offered by dispersed power systems, almost 90 percent of which can be on solid coal. Key component technologies to accomplish this are fluidized beds, gasifiers, closed-cycle gas turbines and advanced open-cycle gas turbines in the 2300°F-firing-temperature range. Market surveys will continue into FY 1980 for additional confirmation of these analyses.

At this time it is concluded that industrial coal cogeneration on a national basis is sufficiently feasible from an economic, technical, and environmental viewpoint to warrant site-specific investigation and definition of a demonstration program to prove the most promising of these emerging coal cogeneration systems. In FY 1980 a competitive program will be structured and awarded to initiate the detail planning for this effort.

TETAS was initiated in late FY 1977 to define the most promising advanced total energy systems for commercialization in the commercial/residential sector and will be completed in FY 1980. In late FY 1979 preliminary results compared the cogeneration capabilities of gas turbines, diesels, steam turbines and Stirling engines for a range of commercial/residential energy requirements. In early FY 1980, market penetration analysis of these initial results started and will continue through 1980. For conservatism in the assessments, the systems were assumed to be competing with relatively low electricity costs from the grid (3.5¢/kWh) and liquid fuel costs of approximately $4.00/MBtu. Despite this some of the TETAS engine systems reflected return on investment levels over 20 percent, even on solid coal. The leading systems, from an energy consumption and economic basis, appear to be the closed-cycle gas turbine with an atmospheric fluidized-bed for solid coal use and the diesel for liquid coal fuels. Market penetration analysis done for the diesel in total energy type systems in early FY 1980 indicated that about 5,000 MW of installed power could be achieved by the year 2000 on coal-based fuels. Similar projections will be conducted for the Stirling, but will be deferred until the manufacturing costs are more properly assessed in the Phase I conceptual design program discussed under Externally Fired Heat Cycles.

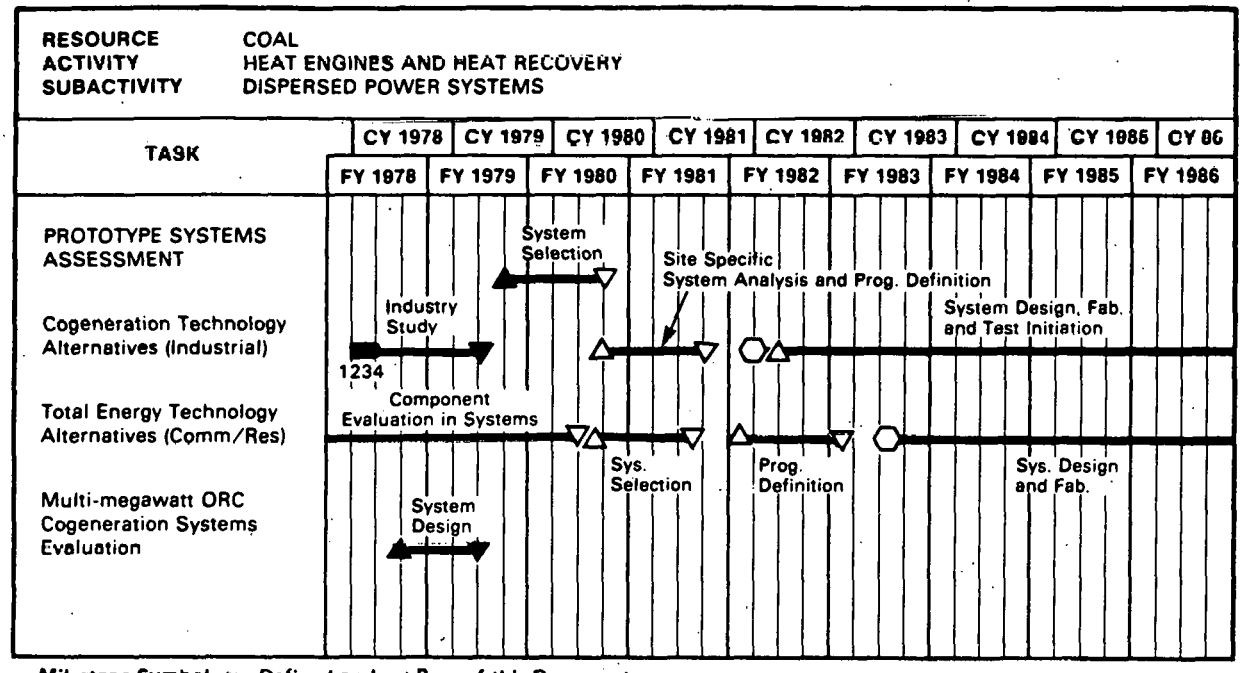
In early FY 1980, the TETAS program also conducted a comparison of various total energy systems for the heat and power requirements of a DOE Energy Technology Center. This center is in an environment where the local utility was desirous of purchasing excess power for the grid during off-business hours. In this situation, the small steam turbine using an AFB and fired by coal and municipal waste was found economical enough to be considered for this facility. As a result of this analysis, the steam turbine under development in the externally fired heat cycles task could be dedicated to this site for demonstration in 1981.

The multimegawatt Organic Rankine Cycle (ORC) system evaluation which was cofunded with the Office of Industrial Programs in Conservation was successfully completed. Conservation is currently evaluating the results for potential application to the cement industry.

The major accomplishments expected in the Prototype Systems Assessment task during the FY 1980 and FY 1981 period are as follows:

- Competitively awarded site-specific coal-burning industrial cogeneration studies that focus on gas turbine fluidized-bed coal combustor systems which were identified in the CTAS as one of the most viable industrial cogeneration options.

- The TETAS will be completed.



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3.0 HEAT RECOVERY COMPONENT TECHNOLOGY

The goal of the Heat Recovery Component Technology subactivity is to develop the required technology base and to demonstrate the technological feasibility of cost-effective components and systems for the recovery and utilization of waste heat. Widespread use of waste heat as an equivalent fuel source is, at present, limited by the availability of cost effective recovery and utilization systems and the lack of sufficient technological options. Technology development is organized into two tasks: (1) Low- Grade Heat Recovery, and (2) High-Grade Heat Recovery. The dividing line between low- and high-grade heat has been defined as 200°F. A breakout into these two broad areas was made because the types of utilization systems and the associated technological problems are quite different for each. These two tasks are now known as the Residual Energy Applications Program (REAP).

Low-grade heat energy currently rejected in the process cooling streams at the three DOE gaseous diffusion plants and the Savannah River weapons plant is in excess of 6,000 MW, all of it being most often below 150°F. The useful residual energy that is rejected to the atmosphere at all DOE Federal

facilities is approximately 12.8 x 10^9 Btu/hr or the equivalent of 20 million barrels of oil per year. Studies to date show that technology for the cost-effective recovery and utilization of this waste heat is lacking. Thus, a continued technology development effort and a federal effort to implement heat recovery at these facilities is judged to be the most effective means of eventually utilizing this reject heat.

With regard to higher grade heat, the major technology need is to provide capabilities that do not exist. In the area from 200° to 1000°F, encompassing the exhaust temperature range of stationary diesels and gas turbines as well as many industrial processes, the efficiency of power recovery cycles using steam as a working fluid drops off sharply. Cycles using organic working fluids are being developed for application in this regime.

3.1 LOW-GRADE HEAT RECOVERY

Low-grade heat recovery technology is being developed for application to heat sources with temperatures generally at 200°F or less. This effort is directed at utilizing the very abundant energy from low-temperature sources such as waste heat from industrial processes and power production.

In the program entitled "Use of Energy Rejected from Federal Facilities," feasibility evaluations to determine the technical, economic, and institutional viability of utilizing energy currently being rejected by DOE-owned facilities have been completed. The efforts are directed to the three uranium enrichment gaseous diffusion plants located in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio; and the Savannah River facility in South Carolina. Because of institutional barriers predicted for possible applications, direct use applications such as agriculture and aquaculture will not comprise the total solution. It is apparent that complex and innovative definition and full-scale central energy management systems must be successfully developed to ultimately exploit this energy source.

The 200°F range of waste heat is a relatively uncharted area in terms of productive heat utilization. The REAP activity is designed to determine the feasibility of developing heat recovery systems which can economically convert the thermal energy available at these temperatures to productive use.

A major project effort is currently devoted to determining the requirements necessary to utilize this energy and to identify opportunities for applying the low-temperature heat utilization systems.

Project Status

In FY 1978, a low-temperature technology development program was initiated to address the evaluation and conceptual design aspects of candidate heat recovery devices. This effort continued through FY 1980 with major emphasis on advanced heat pump concepts for upgrading low-grade heat and advanced adsorption cooling technology.

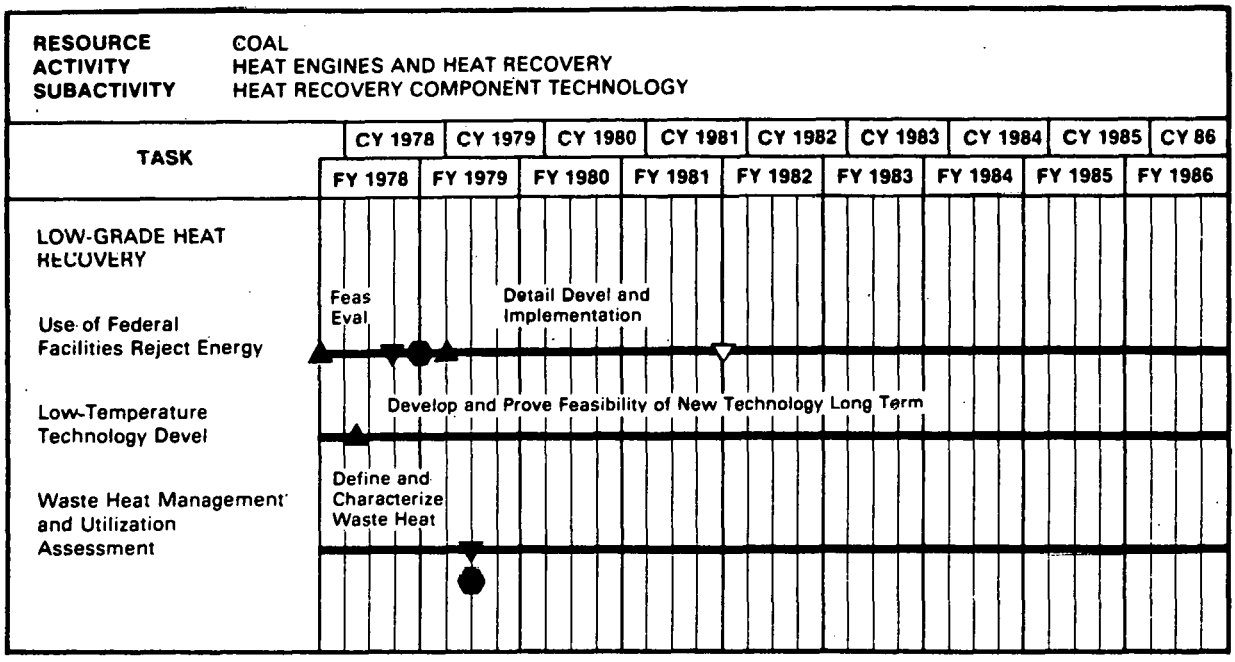
The feasibility evaluation phase of the Federal facilities program was completed in FY 1979. Program planning activities for follow-on implementation in FY 1980 are being conducted. It is expected that this effort

will lead to facility design activities in FY 1981 at Portsmouth for feasibility experiments and the design of the Energy Applied Systems Test Facility at Savannah River for central energy management systems. Major objectives of this program are to stimulate institutional and organizational change with industrial participation that allows implementation and utilization of residual heat energy technology, the conduct of application feasibility experiments in a "real world" environment, and the conduct of ongoing technology development and systems R&D activities that focus on cost-effective central energy management systems applied to available residual heat recovery. REAP will involve significant technology development, screening and verification as well as facility construction activities by a number of industrial, utility, and government entities in numerous locations.

During FYs 1980 and 1981 the following accomplishments are expected in the Low-Grade Heat Recovery task:

- Low-grade heat recovery technology projects initiated in FY 1979 in the area of thermally activated cooling, heat pumps and low-temperature heat engines are to continue.

- A program to implement the recovery of low-grade waste heat from the three DOE gaseous diffusion plants and the Savannah River weapons plant will be initiated.



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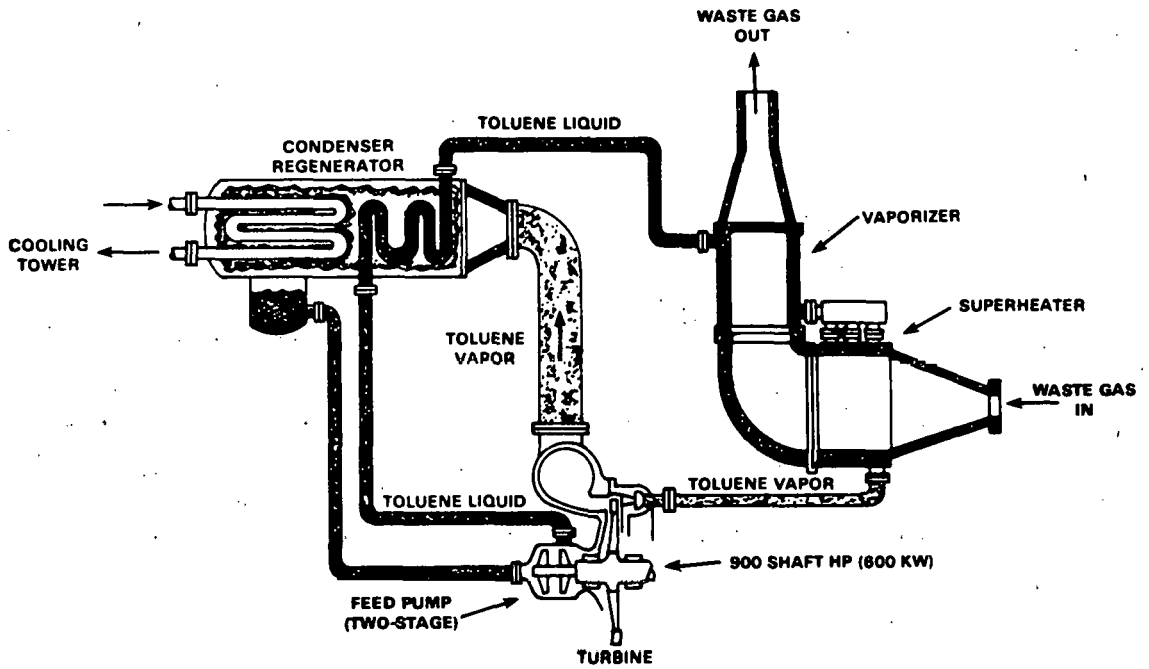
3.2 HIGH-GRADE HEAT RECOVERY

High-grade heat recovery technology is being developed for application to heat sources available at temperatures generally well above 200°F. This effort is directed toward recovery and utilization of energy rejected by

movers such as diesel engines and gas turbines and energy expended in large central station power plants and industrial process heat streams.

In FY 1976, a 6-month technology assessment, the Industrial Applications Study, was performed to develop a profile of energy consumption and waste heat availability for all Standard Industrial Code (SIC) two-digit industries. Because of the success of this effort, a follow-on study, to extend the data bank to SIC four-digit industries, was initiated late in FY 1977. This is a major undertaking which, when completed, will provide the most complete and detailed data bank of waste heat resources to date for the planning of future energy conservation efforts. The effort is expected to take approximately 1.5 years. It is planned to use the results as a basis for the determination of additional high payoff areas of the higher grade waste heat utilization.

The Bottoming Cycle Systems program covers technology suitable for application to waste heat streams with temperatures between 200° and 1000°F. This temperature range includes most existing industrial and commercial waste heat sources. The program is directed towards the near-term utilization of these sources through the development of waste heat recovery systems. Efforts have been initiated to design, develop, and field test three competing Rankine-cycle-based systems suitable for operation with public and municipal utility diesel power plants and industrial process waste heat streams.



Organic Rankine Bottoming Cycle

Illustrated is a typical bottoming system that employs an organic working fluid. The waste heat stream is passed through a heat exchanger (vaporizer) to vaporize the organic fluid; this vapor is expanded through a turbine to produce a shaft work output; the vapor at lower temperature and pressure is condensed back to a liquid state, compressed, and revaporized. In general, higher availability and recoverability are provided by using organic working fluids rather than for steam in this temperature regime.

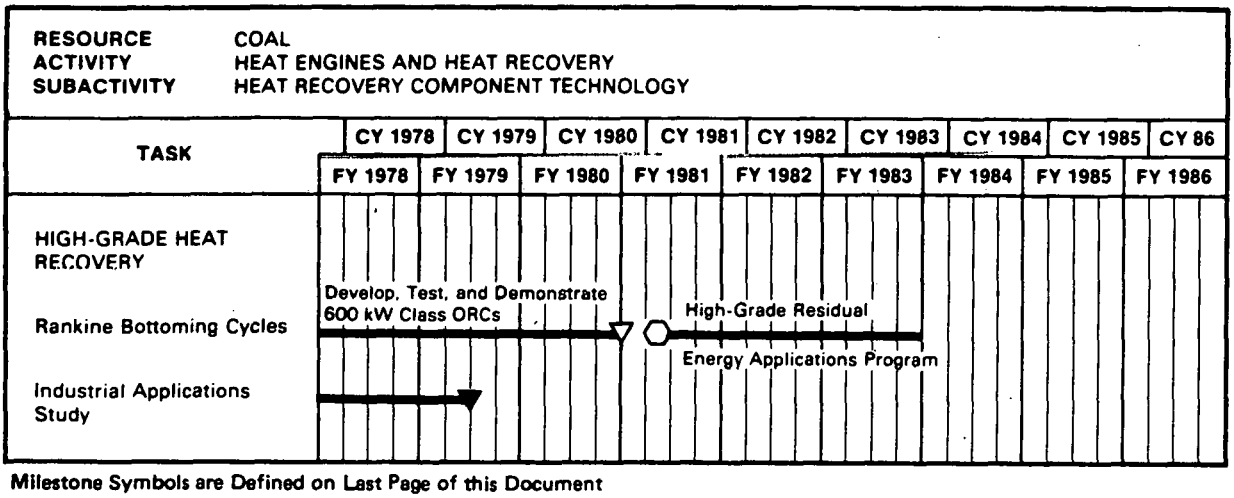
Project Status

The Organic Rankine Bottoming Cycle program has been underway since FY 1976. The major thrust has been the development of systems in the 500-600 kW output range for application to waste heat utilization from stationary power-generating diesels and industrial process waste heat streams. Through FY 1980, six field test demonstration systems will be delivered, installed, and brought on stream. The fuel savings attributable to these field demonstration units alone is in excess of 40,000 barrels of oil annually.

The ongoing FY 1980 through FY 1981 effort is to develop technology for the utilization of waste heat in the temperature range of 200° to 1000°F in the industrial and utility sectors. The bottoming cycle projects initiated in FY 1976 will be continued. Specifically, tests and evaluations will be performed at the six demonstration sites completed in FY 1980, and development of a program to advance these systems for future broader based applications will be initiated.

The major accomplishments expected in the High-Grade Heat Recovery task in FYs 1980 and 1981 will include:

- Field testing of the three organic heat recovery systems, one at a municipal utility and two at industrial sites.



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H. COMBUSTION SYSTEMS

Combustion is involved in over 90 percent of the fuel utilization processes in this country and, even under the most optimistic predictions for alternatives, will continue to dominate our energy usage. Our most abundant resource, coal, accounts for less than 20 percent of our current fuel utilization. The tasks under the Combustion Systems Activity are selected on the basis of their potential for burning coal cleanly and more efficiently and for reducing oil and natural gas consumption by developing the technology required for substitution of coal and coal-derived fuels for oil and gas.

Even though coal is the Nation's most abundant domestic fuel, it represents less than 55 percent of the fossil fuel consumed by steam-electric utilities. National emission standards for stationary coal-fired steam generators presently limit sulfur dioxide (SO_2) emissions to 1.2 lb/MMBtu, and nitrogen oxides (NO_x) to 0.6 lb/MMBtu. Revised emission standards for coal-fired utility plants are based on the 1977 Clean Air Act amendments requiring Best Available Control Technology (BACT). These standards require that 70 to 90 percent of the fuel sulfur be removed prior to emission of the combustion products. The high cost of removing SO_2 from large volumes of stack gases has restricted the use of high-sulfur coals. In fluidized-bed combustion (FBC) boilers, atmospheric and pressurized, most of the SO_2 is absorbed in the combustion process and considerably less NO_x is produced than in conventional coal-fired boilers. This technology should enable increased coal utilization in an environmentally acceptable manner (i.e., reduce SO_2 and NO_x to acceptable levels). The particulates emitted from the combustion zone of FBCs can be controlled to acceptable levels with existing technology. An environmental concern with FBCs is the disposal of the large quantities of solid wastes produced from the fly ash and the spent bed itself. Programs are presently underway to study the characteristics of these materials and to demonstrate their possible uses.

The objectives of the Combustion Systems Activity are to:

- Develop fluidized-bed combustion systems capable of directly burning high-sulfur and other coals of all ranks and quality in an environmentally acceptable manner.

- Develop technology to substitute coal for a substantial portion of oil in combustors capable of firing coal-oil or other coal-based mixtures.

To realize these objectives, research efforts are being directed toward development of environmentally acceptable methods of combustion and improved technology for the use of coal. The total effort has been integrated into subactivities, as shown in the following table that summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

COMBUSTION SYSTEMS	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Atmospheric Fluidized Beds (AFB)	23,600	25,900	22,800
Pressurized Fluidized Beds (PFB)	14,234	15,000	21,400
Advanced Combustion Technology	7,342	4,950	2,000
Alternative Fuel Utilization	9,400	2,500	22,000
Combustion Systems Demonstration Plants	0	2,500	0
Prior Year Funds	−3,000	0	0
Capital Equipment	573	0	300
TOTAL	57,149	50,850	68,500

Specific areas of research and development include:

- Development of fluidized-bed combustion (atmospheric and pressurized) with particular attention to achieving high combustion efficiency, acceptable component durability, minimum emission of particulates and sulfur and nitrogen oxides, and reliable operation of combined-cycle systems

- Determination of combustion and heat transfer characteristics of chars, coal-oil mixtures (COMs), solvent refined coal, and coal-derived liquid fuels when burned in conventional equipment and the application of such data to improved combustion component design

- Determination of causes of adherent slag and ash deposits, and development of methods for minimizing these reliability and efficiency degrading problems

- Identification and control of toxic elements evolved during the direct combustion of coal.

The application of these objectives has resulted in the following:

The 30 MW_e atmospheric fluidized-bed (AFB) boiler project, located at the Monongahela Power Company plant at Rivesville, West Virginia, had an improved coal-feed system installed in early 1978, and was in steady operation delivering superheated steam under utility-controlled conditions of temperature and pressure on several occasions, including runs of 50, 25, and 24 hours. Preliminary analysis of the data obtained during 1,054 hours of operation in 1978 shows the SO_2 adsorption to be in agreement with the design basis of the unit. The Rivesville facility will be phased out of operation in FY 1981, and its functions of utility AFB support will be initiated by the Component Test and Integration Unit (CTIU).

The AFB CTIU at Morgantown, West Virginia, has proceeded to the stage where the building has been completed, and the research boiler and other facility components are in the process of being installed in the CTIU.

The 100,000 lb/hr saturated steam AFB boiler for Georgetown University began startup in July 1979. In the following 5-month period total accumulated run time exceeded 1,000 hours. Stringent District of Columbia environmental emissions standards were met for SO_2, NO_x and particulate. A data processing program was designed and implemented to disseminate operating and maintenance data to boiler manufacturers and industrial users. System characterization and EPA-sponsored programs were conducted with eventual assimilation of the facility into the University's steam supply system.

Construction of the 50,000 lb/hr AFB boiler at Great Lakes, Illinois started in early 1979. The system is scheduled to be ready for startup in October 1980. Other fluidized-bed boilers and heaters were in varying stages of final design for project evaluation. Detail design was completed on two AFB boilers to burn anthracite culm/anthracite and a third boiler design awaited site selection.

Accomplishments in the pressurized fluidized-bed (PFB) program include the operation of the small gas turbine (SGT) rig to test the PFB pilot plant combustor design and to obtain data on PFB combustor and gas turbine blade material life and corrosive attack mechanisms, and progress towards completion of the design of the PFB pilot plant such that, subject to confirmative data on materials behavior, construction may be started in early 1980. The International Energy Agency (IEA) PFB test facility will be completed in 1980 and will commence combustion testing with a (stationary) turbine blade cascade. A "Long-Term Materials Development" program was initiated in FY 1980 to further address the gas-turbine materials problem. The IEA PFB facility scope of work was expanded to include a stationary gas-turbine blade cascade with tertiary particulate removal and a design study to determine the merits of adding a (rotating) gas turbine to the combustor exhaust gas path.

The coal-oil mixture program progressed with the operation of the 700 hp COM test facility and COM preparation laboratory at the Pittsburgh Energy Technology Center (PETC). Construction of the demonstration projects has started. An AFB-boiler materials test apparatus was contracted to have a facility in which to perform long-term materials testing. Programs to demonstrate utilization of AFB spent-bed materials as highway road-base aggregate, agronomic soil nutrient, and as a source of lime for neutralizing acid soils and as a scrubber reagent produced encouraging initial results.

In addition to these projects, laboratory studies, engineering studies, and economic analyses are underway in support of the development programs.

1.0 ATMOSPHERIC FLUIDIZED BEDS

Systems currently being investigated and tested include:

- AFB Boiler, 30 MW_e
- AFB Industrial Applications
- Atmospheric Fluidized-Bed Coal-Combustion Closed-Cycle Gas-Turbine Technology Test Unit (TTU)

- Atmospheric Fluidized-Bed Component Test and Integration Unit (AFB/CTIU)

- AFB Anthracite Applications.

Coal-fired fluidized-bed boilers are more attractive for commercial use than conventional coal-fired boilers with stack-gas scrubbers. They show potential for improving net power generation efficiency and heat transfer rates while lowering emissions of sulfur oxides, nitrogen oxides and trace metals, and eliminating problems associated with ash slagging and fouling. The capital cost of such systems is expected to be less than that of conventional systems with stack-gas scrubbers.

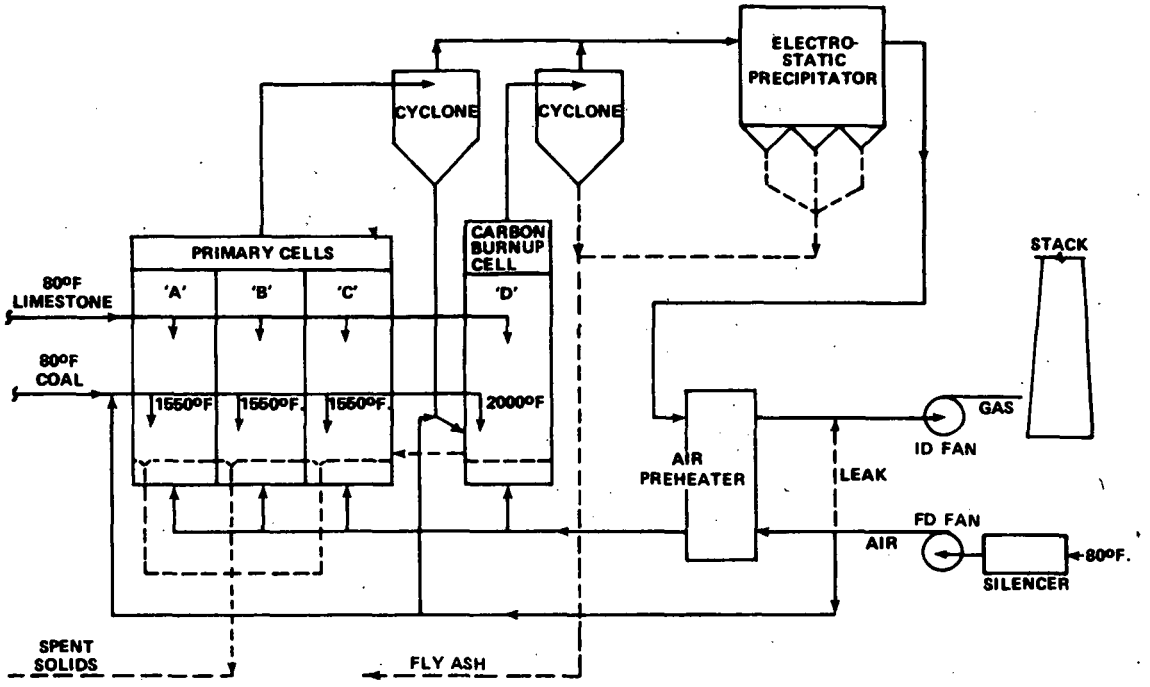
Emission control of SO_2 and NO_x for fluidized-bed boilers is centered in the combustion zone. Sized coal is burned in a fluidized-bed of inert ash and limestone or dolomite. The limestone or dolomite calcines then react with SO_2 in the presence of oxygen to form a solid sulfate material that can be utilized or disposed of with the ash as an inert granular landfill. Fluidized-bed boilers operate at combustion temperatures appreciably lower than conventional boilers, thus inhibiting formation of nitrogen oxides. An atmospheric pressure coal-fired fluidized-bed boiler having a capacity of 5,000 lb/hr of steam has been operating successfully at furnace temperatures of approximately 1600°F since 1967. It has demonstrated that all of coal, char, coal wastes, and other low-grade combustible materials can be burned in an environmentally acceptable manner.

An investigation is currently being conducted concerning utilization of FBC solid waste material for use in agriculture, for neutralization of acid mine spoils, and for subsoil stabilization and aggregate for highway construction use. Building blocks have been produced using only FBC waste and conventional fly ash as ingredients. Wastes from currently operating fluidized-bed combustors are being disposed of as landfill in an environmentally safe manner.

1.1 AFB BOILER, 30 MW_e

The objective of the current DOE Fossil Energy 30 MW_e AFB boiler task is to design, construct, test, and evaluate a 300,000-lb/hr-capacity multicell fluidized-bed (MFB) boiler as a pollution-free method of burning high-sulfur content or slagging coals in a practical manner under actual electrical utility conditions. Steam pressure, temperature, and circuitry of the boiler, therefore, were designed to meet requirements of the selected Monongahela Power Company (Allegheny Power System), Rivesville, West Virginia, power station.

Successful development of the atmospheric fluidized-bed boiler is seen as a necessary first step toward the better use of high-sulfur and slagging coals. Based on the successful performance of this first 30 MW_e unit and a subsequent demonstration plant (being funded by the Tennessee Valley Authority and supported by DOE), it is expected that several electric utilities will commit to the installation of atmospheric fluidized-bed boilers in the 200 to 800 MW_e capacity range.



Fluidized-Bed Boiler, 30 MW_e

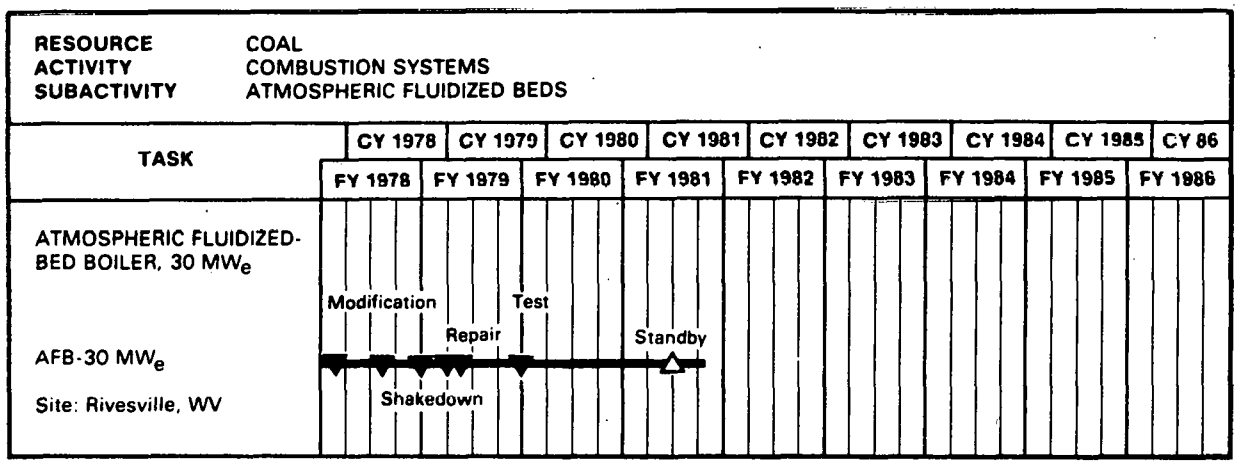
Project Status

Since 1965 Pope, Evans and Robbins, Inc., has been investigating atmospheric fluidized-bed combustors in the DOE laboratory facility in Alexandria, VA. A 0.5 MW_e AFB Process Development Unit (PDU) has been operated in Alexandria to support the pilot plant design, construction, and operation. Construction of a 30-MW_e-size MFB pilot plant was completed in 1976 at the Monongahela Power Company's plant at Rivesville, West Virginia, by Pope, Evans and Robbins, Inc. Initial light-off of the boiler with coal was successfully accomplished on December 7, 1976. Operation and testing of the pilot plant to demonstrate the applicability of the MFB for steam-electric power generation has been carried out since 1977 and is continuing. On September 30, 1977, the unit achieved its full nameplate rating. In the fall of 1977, it produced steam for use in commercial power generation on several occasions. Modifications of the coal feed system were made in 1978 to improve the system reliability. Instrumentation was also added.

Between April 12, 1978 and August 9, 1978, 1,054 hours of test operation were obtained. This included five periods of commercial power generation operation, including periods of 50, 25, and 24 hours continuous operation supplying superheated steam within the narrow control band required for utility operation. Preliminary data show that the SO_2 removal verifies the design basics of the unit. The air preheater, induced draft fan, and associated duct work were damaged beyond repair and, together with water damaged equipment, have been replaced. The unit was put back in service in early 1979 and post-repair shakedown and test operations have continued

during the year. In 1980 the unit will be operated on a minimum test plan to produce needed data points for the AFB program and be placed on standby in FY 1981.

The Rivesville facility is the first major step toward commercial-size central-station power generation.



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1.2 AFB INDUSTRIAL APPLICATIONS

These projects consist of development and demonstration of AFB boilers and heaters for industrial applications, using the atmospheric fluidized-bed concept, and operation of prototypes on industrial sites for such purposes as steam raising, process heat, and cogeneration. Objectives are to:

- Design, build, operate, test, and demonstrate prototype boilers and heaters to establish the practicality of burning high-sulfur coals and other fuels for industrial applications.
- Obtain sufficient data from prototype operations to enable the industry to design, construct, and operate full-sized units in industrial plants.

Although industrial boiler and process heater needs are quite diverse, a relatively small number of equipment configurations define the majority of applications. Thus, key components will be constructed on an industrial scale to determine applicability of fluidized-bed combustors to industrial units.

Three areas of industrial applications are being investigated:

- Saturated Steam Boiler: capable of producing steam of the quality and quantity suitable for process heating and space heating requirements of industrial or institutional facilities. The individual boiler capacity is predicated on the intended application.

- Superheated Steam Generator: capable of producing steam of the quality and quantity for both cogeneration via back-pressure turbines and industrial process and heating requirements.

- Indirect-Fired Process Heater: utilizing tubes or other heat-exchange devices in the combustor to heat process liquids or gases.

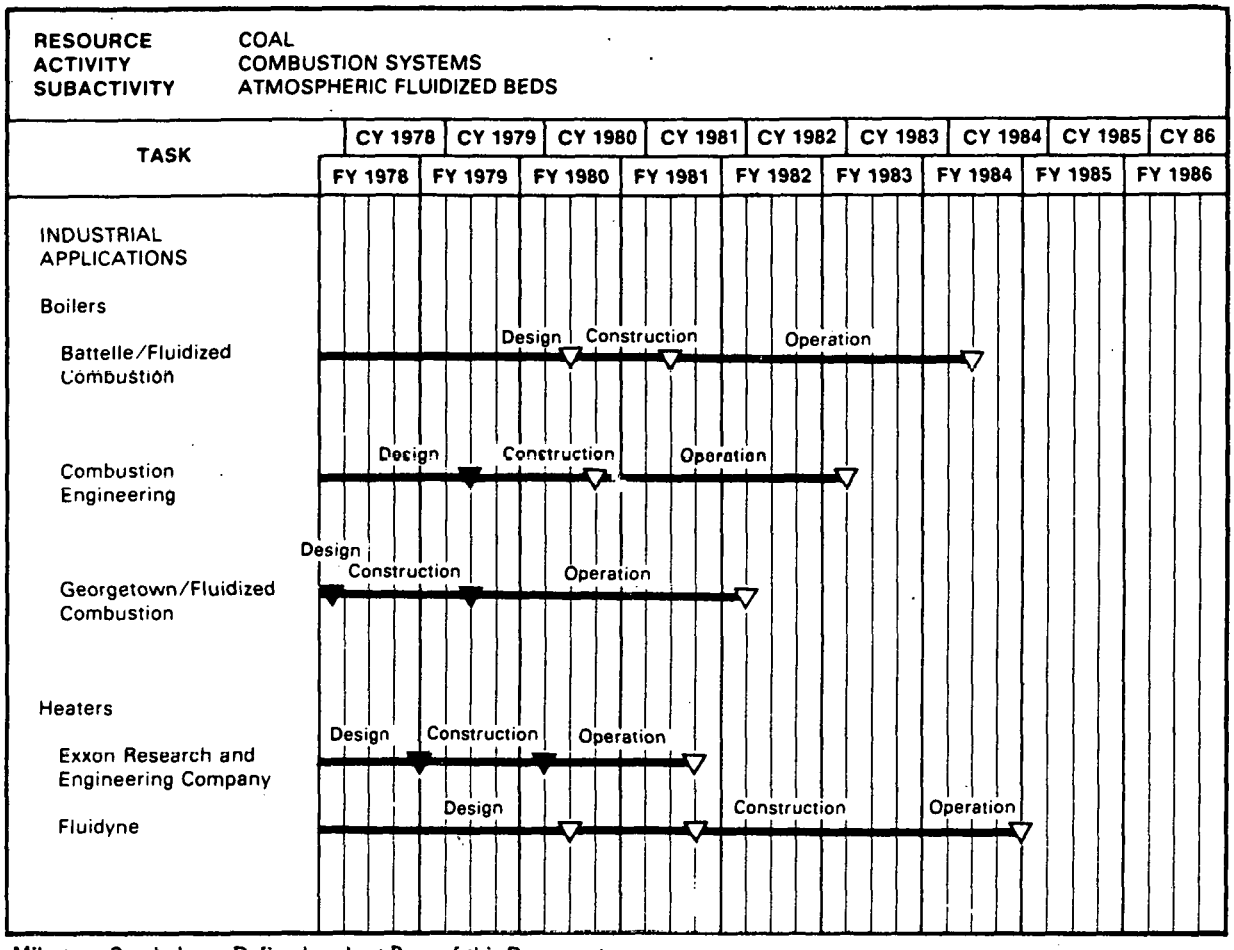
Project Status

Five contractors (or groups) were selected to design, construct, and test industrial boilers or industrial heaters using atmospheric fluidized-bed combustors:

	Steam Rate	Coal Rate
Georgetown University/Fluidized Combustion Co. Washington, D.C.	100,000 lb/hr saturated steam	5 tons/hr
Combustion Engineering Great Lakes Naval Training Center, Illinois	50,000 lb/hr superheated steam	2.5 tons/hr
Battelle/Fluidized Combustion Co., Columbus, Ohio	25,000 lb/hr saturated steam	1 ton/hr
Fluidyne Engineering Minneapolis, Minnesota	Heated Air/Metal Working, 780°F 28 MMBtu/hr	1.5 tons/hr
Exxon Research & Engineering Co., Linden, New Jersey	Petroleum Crude Heater, 15 MMBtu/hr	.75 ton/hr

In 1981, operation of the Georgetown University 100,000 lb/hr steam boiler will continue. Operating and maintenance data will be collected, processed and disseminated. The operation site will continue to be available for meetings and visits. Construction of the 50,000 lb/hr steam boiler by Combustion Engineering at Great Lakes, Illinois, will be completed. Startup will occur, the boiler will begin operation, and data reporting and site visitation will be initiated. The Exxon activity will depend on the results of pilot plant data evaluation in 1980. If plant operation is justified, the demonstration facility will be sited, started and operated.

Evaluations of the Fluidyne and Battelle designs will be conducted in FY 1980, and demonstration plant construction will begin in early FY 1981 if the designs are found to be acceptable and within budget constraints.



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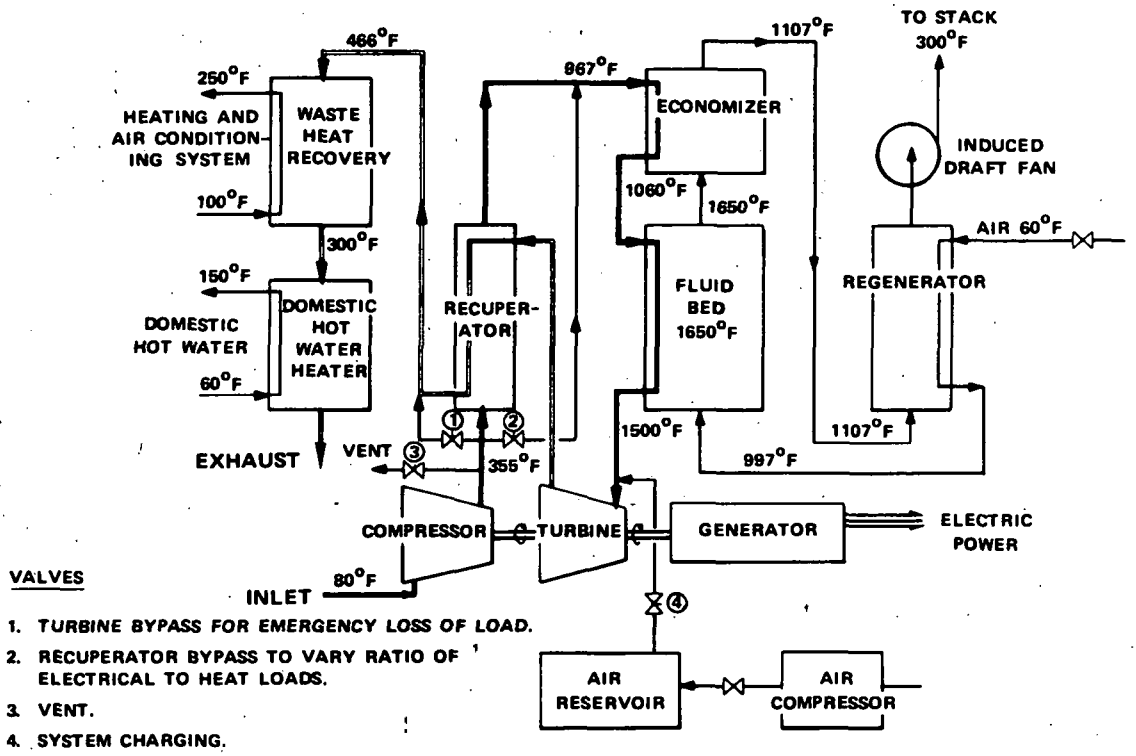
1.3 AFB TURBINE TEST UNIT (TTU)

The development of an Atmospheric Fluidized-Bed Coal Combustion for Cogeneration (CCC) Hot-Air Gas Turbine Technology Test Unit was initiated in FY 1977. This effort was originally a part of the Housing and Urban Development (HUD) Modular Integrated Utility Systems (MIUS) program. Oak Ridge National Laboratory (ORNL), under the technical direction of DOE, has conducted several technology studies, engineering analyses and economic analyses and concluded that a coal-fueled AFB coupled to a hot air turbine (externally fired) is the most promising system for residential/commercial cogeneration applications. Also, the recently concluded Cogeneration Technology Alternatives Study arrived at similar conclusions for industrial applications.

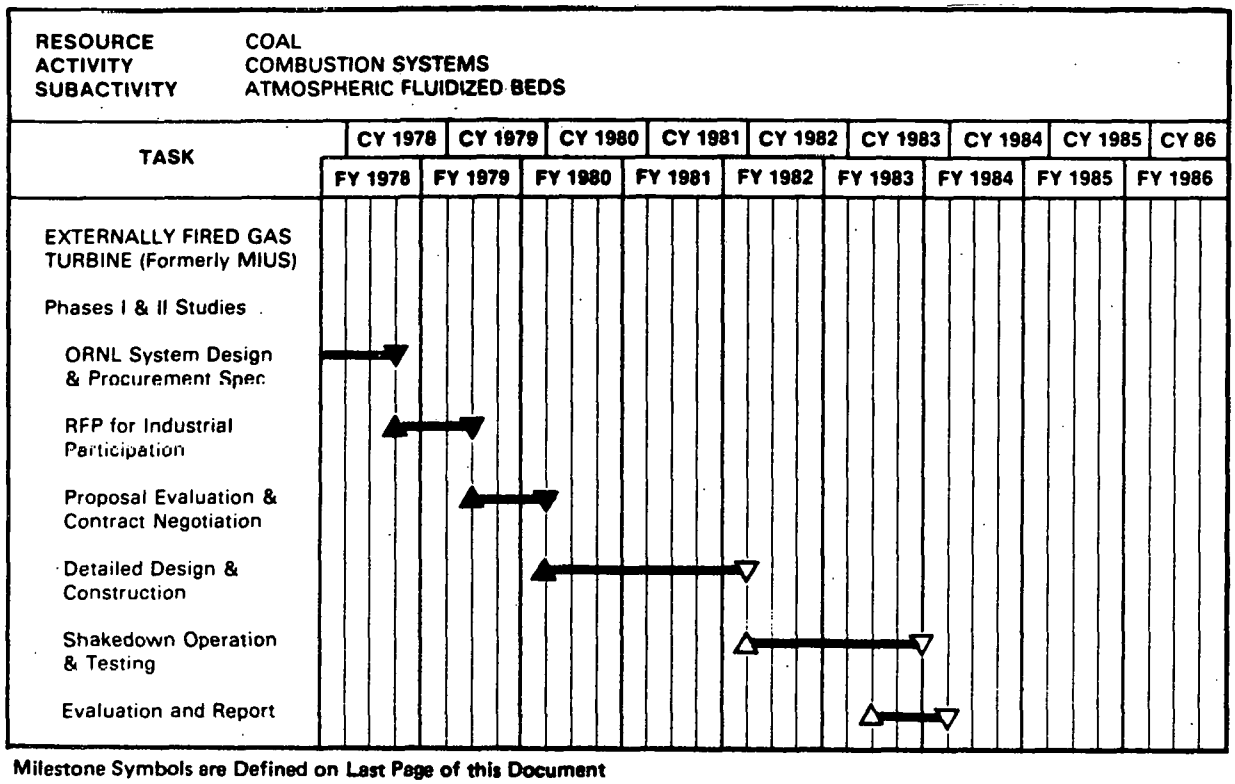
The CCC will consist of a coal-burning atmospheric FBC system coupled to an externally fired hot-air gas-turbine generator. This test unit will have basic electrical capability from 300 to 500 kW plus approximately 2.5 x 10^6 Btu/hr of recoverable waste heat. This size test unit will provide credible scaleup data to the 5 to 50 MW range for commercial application in the industrial/institutional sector for cogeneration applications.



Atmospheric Fluidized-Bed Coal Combustion
Externally Fired Gas Turbine Technology Test Unit

Project Status

The AFB combustor and gas turbine integration is being contracted with an industrial team rather than having the combustor built to government design. In this manner, upon successful completion of the program, an industrial team is expected to be in a position to supply such combustors for cogeneration commercially, as the design and fabrication method will be a result of its effort. In this regard, the team of Westinghouse-Babcock & Wilcox-Stone & Webster has been selected (from eight competing teams) to design and construct the test unit at Oak Ridge, TN, and to participate in operation and test of the unit. In FYs 1980 and 1981 the unit will undergo design and construction with shakedown scheduled for early FY 1982.



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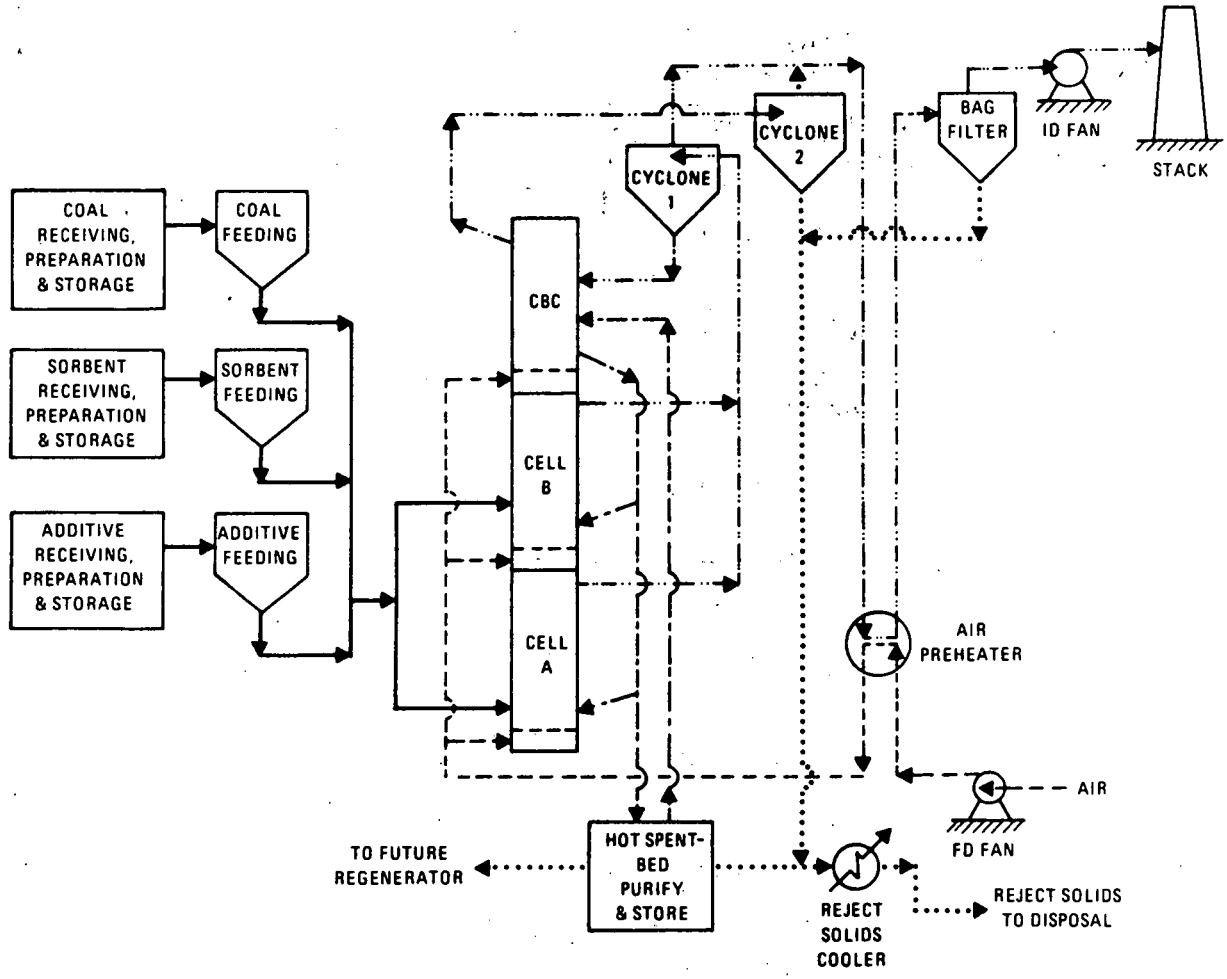
1.4 AFB COMPONENT TEST AND INTEGRATION UNIT

The AFB/CTIU is a flexible, instrumented research and development facility at the smallest scale at which data apply to full-size systems. It consists of a stacked, three cell, fluidized-bed combustor with its heat recovery system; ash removal from flue gases will be in cyclone separators with reinjection for carbon burnup in a separate CBC or within either coal burning cell; final gas cleaning will be effected by bag filter collectors. Provision is made for coal, limestone, and additive receiving, preparation, and feeding into the combustor cells. The spent-bed material is removed, purified by size classification and magnetic separation, and stored hot for reinjection into any of the combustor cells. Air for fluidization and injection is provided by primary and auxiliary forced-draft fans. An induced-draft fan moves the flue gases through the dust removal system and vents to the stack. The complete system is designed with sophisticated analytical instrumentation, computerized data acquisition, and electronic control systems so that the maximum amount of useful data can be obtained in the operation of the unit.

Operation of the CTIU will provide vital data to the TVA AFB Demonstration program, particularly in the areas of multiple-bed control and coal feed and ash handling.

Project Status

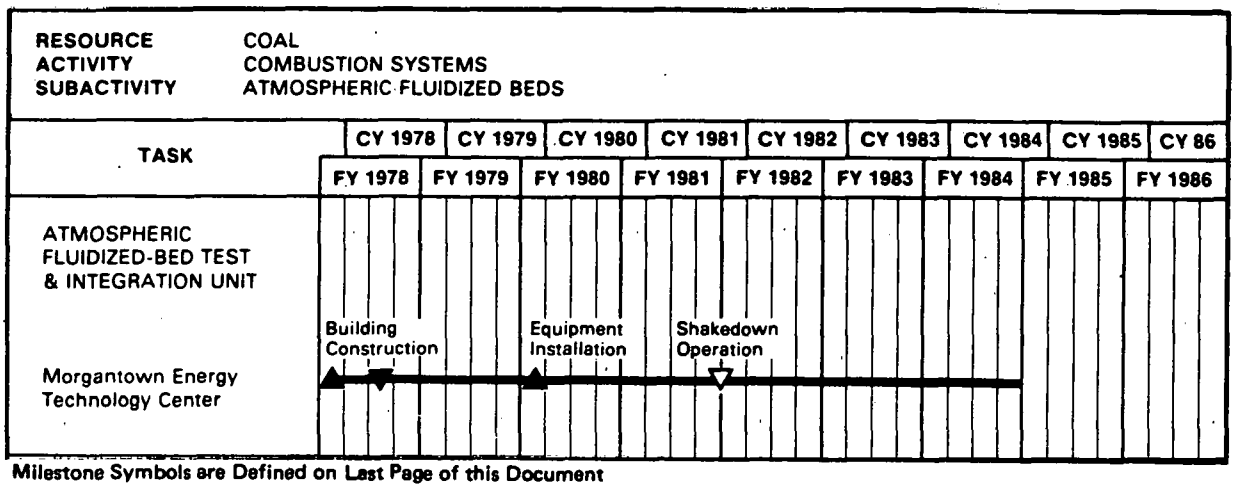
This component test and integration unit is located in Morgantown, West Virginia. It will obtain data on bed fluidization, combustion, emissions, sorbent performance and will test new atmospheric fluidized-bed combustion



Atmospheric Fluidized-Bed Component Test and Integration Unit (AFB/CTIU)

systems and components at an intermediate-size scale and will act as an investigative facility for problems developed in the 30 MW_e boiler test project. Design of the CTIU started in FY 1976. Fabrication and field erection started in FY 1978, and construction will be completed in FY 1982. The CTIU will test improved solids-handling systems, develop technology for vertical stacking of multiple beds, and serve as a boiler development laboratory to test tube bundle geometries and materials in operating fluidized-bed combustors. During 1978 the boiler contract was let, boiler detailed design begun, and the building shell closed in.

Construction will continue through FYs 1980 and 1981, with light-off scheduled for early FY 1982.



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1.5 AFB ANTHRACITE APPLICATIONS

The waste material, or culm, resulting from the mining and cleaning of anthracite coal (principally in northeastern Pennsylvania) contains a substantial amount of fuel value, which can be recovered in fluidized-bed or other direct combustion boilers/combustors in an environmentally acceptable manner.

This effort is designed to investigate the combustion of anthracite culm in fluidized beds and other direct culm-burning processes in industrial/utility boilers and heaters.

In the anthracite mining region, culm is piled in a densely populated, geographically small area of about 480 square miles. It is estimated by the U.S. Bureau of Mines that 800 banks containing 900 million cubic yards of refuse can be found within the anthracite mining fields. These spoil banks contribute to acid drainage and other environmental problems. The recovery of the fuel value of coal remaining in them while converting the remaining minerals to inert material provides a needed environmental service while obtaining useful energy from waste material.

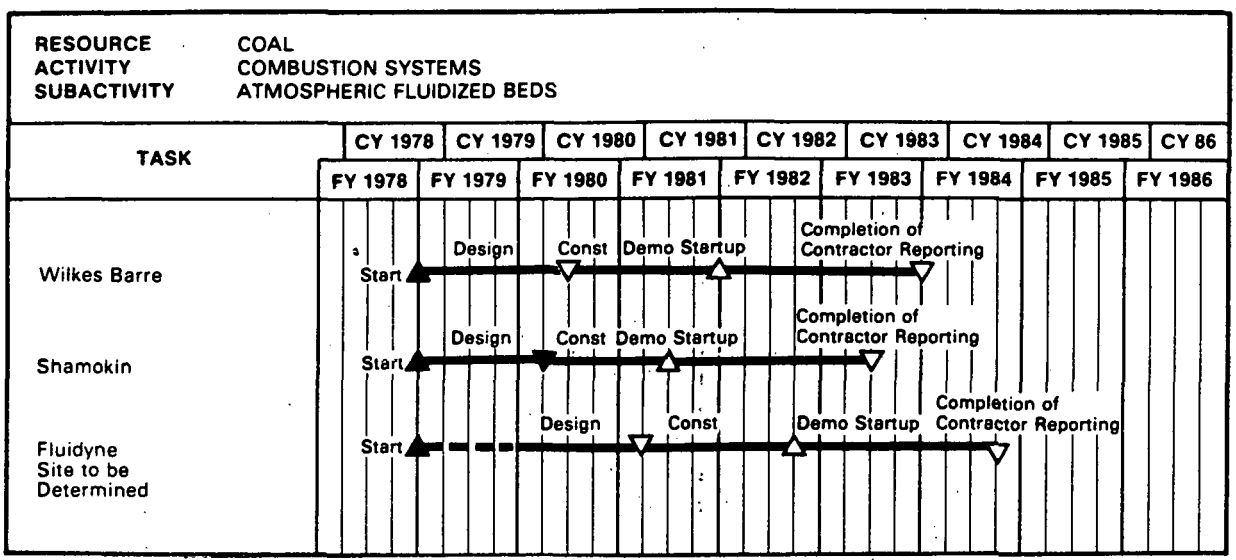
DOE has begun a program of extending the combustion characteristics of these refuse materials by fluidized-bed combustion. The value of this refuse as a fuel is important in the anthracite region because of the decline in mining in the area, which has led to a growing dependence on oil and gas.

Project Status

A PON was released in the second quarter of FY 1977. The major activity in FY 1977 was the evaluation of proposals. The effort during FY 1978 was the selection of contractors and contracting negotiations, which will proceed to prototype equipment development.

	Steam Rate	Feed Rate
Wilkes-Barre, PA/Pope Evans & Robbins/Foster Wheeler	100,000 lb/hr	14.5 tons/hr
Shamokin, PA/Curtiss-Wright/ Dorr-Oliver/Reeler Boiler	20,000 lb/hr	4 tons/hr
Site tbd/Fluidyne	20,000 - 30,000 lb/hr	5 tons/hr

In FY 1980 the demonstration unit design was completed for both the Shamokin and Wilkes-Barre anthracite culm projects. Plant construction has started and will carry into FY 1981. The Shamokin project startup will occur in the latter portion of the year. Wilkes-Barre construction will continue to the end of FY 1981. The Fluidyne project will be in final stages of design and early construction in FY 1981 if site evaluation, process application, and budget constraints in FY 1981 justify continuation.



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2.0 PRESSURIZED FLUIDIZED BEDS

Projects currently underway in this area include:

- Pressurized Fluidized-Bed Combined-Cycle Pilot Plant, 13 MW_e
- PFB combustor and component development
- International Energy Agency
- PFB utility EDS plant.

Pressurization of the fluidized-bed combustor is a means of reducing emissions of SO_2, NO_x, CO, and hydrocarbons while simultaneously effecting an

increase in power generation efficiency with the possibility of reducing the cost of power generation.

The basic technology requires that the coal and sorbent be fed into a pressurized combustion chamber where it burns in a fluidized bed with the off-gas going to a gas turbine. The plant is operated as a combined cycle, gas turbine, steam turbine system. The pressurized system further reduces the size of the combustor and thus the capital cost. The use of combined-cycle systems increases overall plant efficiency.

Objectives for the pressurized program are similar to the atmospheric, except that developmental problems are greater and more complex, and the first commercial units are expected to be operational at an appreciably later date. Limited tests of American coal have been performed at 5 atmospheres in a test unit at Leatherhead, England, and have shown that this approach is technically feasible, that NO_x emissions are reduced below the level of AFB systems, and that greater SO_2 removal is possible than with AFB systems. Additional work is required and is being performed to accomplish cleanup of the hot gases produced from pressurized FBC. This work is necessary to produce the high turbine reliability and long life required for practical power-generation application and control of emissions to the atmosphere. The use of gas turbines at low turbine blade temperatures (1200° to $1300^{\circ}F$) avoids the hot corrosion problems associated with the higher temperatures. The use of protective coatings is also being investigated.

In the same respect as atmospheric fluidized-bed boilers, the utilization of solid waste material is being considered in agriculture and highway programs.

2.1 PFB COMBINED-CYCLE PILOT PLANT

The combination of pressurized fluidized-bed combustor (PFBC) technology with the gas turbine, steam turbine, combined-cycle power system offers the unique opportunity for the production of clean, cost competitive electric power from the combustion of high-sulfur coal.

The Curtiss-Wright Corporation is designing, constructing, operating, and evaluating a coal-fired gas-turbine pilot electric power plant. The pilot plant, which will produce an equivalent of 13 MW_e, will address a number of key technical issues associated with PFB development. Environmental considerations, maintenance, reliability, and durability of the air-cooled PFB combustor and turbine will be evaluated. The program will provide design data to verify scaleup of the gas turbine and PFBC units to commercial plant size for the utilities industry.

The project objective is to conduct a pilot plant test program to obtain data on gas-turbine operation on coal combustion products and to evaluate the validity of the commercial plant design concept. The test program will identify and seek solutions for design or component deficiencies, establish operating characteristics under normal and off-design conditions, and provide a firm engineering base for full-scale plant development decisions.

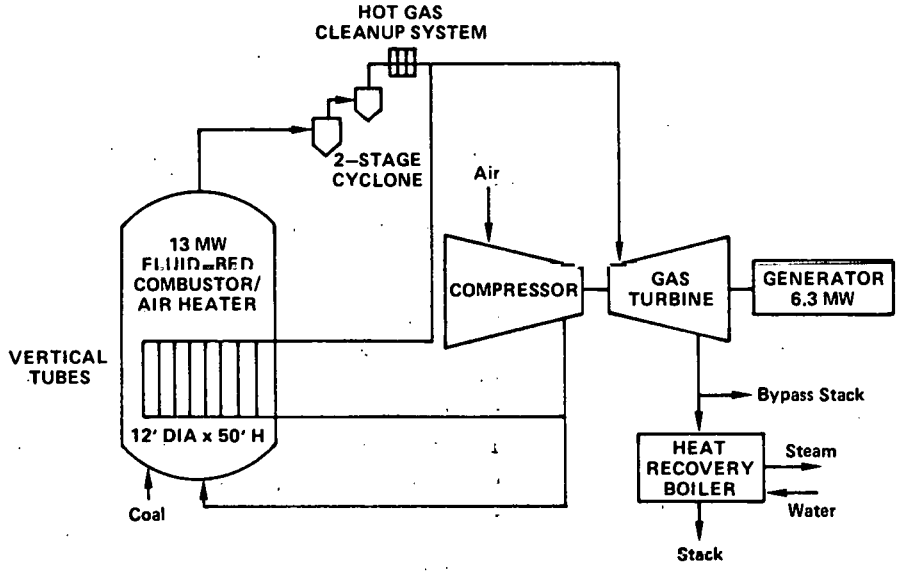
The pilot plant program is a 5-year, multiphase, cost shared effort. Phase I is a 14-month program to provide the following:

- Conceptual commercial design of a coal-fired 300 to 500 MW_e combined-cycle generating station using the PFB combustion technique
- Pilot plant design that is representative of the commercial concept
- Site and environmental assessment study
- Technology support programs that resolve technical issues and provide data on the performance of the selected PFB design.

Phase II is an 8-month effort to complete the detail design drawings and specifications of the pilot plant, prepare a construction bid package, and obtain and evaluate bids.

Phase III is a 20-month construction period for the manufacturing, buildup, and installation of the pilot plant.

Phase IV is a 24-month effort to operate and evaluate the pilot plant operating parameters and durability on several coal types. At the conclusion of this phase, a reassessment of the commercial plant conceptual design will be completed.



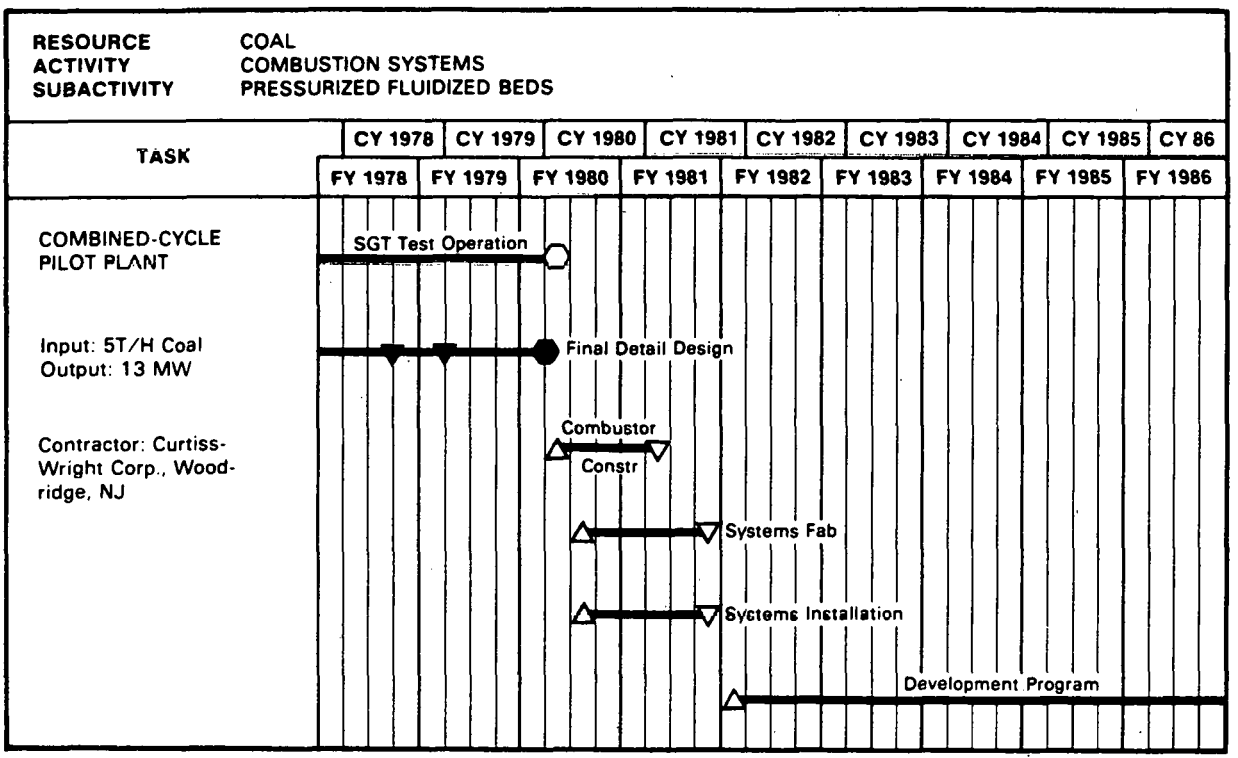
Pressurized Fluidized-Bed Combined-Cycle Pilot Plant, 13 MW

The pressurized fluidized-bed combustion process concept used is briefly described as follows: air is compressed to approximately 7 atm and fed into the PFBC where combustion takes place at 1650°F. The gases are passed through a gas turbine, which drives an electric power generator. From the

gas turbine, the gases pass through a heat recovery boiler, generating steam which in turn drives a steam-turbine electric generator. The pilot plant does not include the steam turbine cycle, which is available technology. Its gas-turbine electric generator will produce 7.15 MW_e. Six MW of waste heat is also recovered in the form of 49,000-pph 175-Psig steam for in-plant use, as a total energy system.

Project Status

This project includes design, construction, and operation of a 13 MW coal fired, pressurized fluidized-bed combined-cycle pilot plant to be located at the Curtiss-Wright Corporation, Wood-Ridge, New Jersey facility. This prototype module is to be designed as a basic element of a central station power plant so that operating, engineering, and economic data can be fully evaluated. An existing oil fired, combined-cycle electrical power generating station is planned for conversion to a PFBC system. The pilot plant facilities will include a 12-ft-diameter by 50-ft-high pressurized fluidized-bed combustor, the CW 6515 gas turbine, and a waste heat boiler capable of generating 175-psig/377°F steam. The basic module will be about one-fifth the scale of commercial plant components. Phase I is a study of comparative commercial systems and a preliminary design of the pilot plant.



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Phase I also includes the operation of a small gas-turbine test rig, which is a 3-ft-diameter section of the full combustor, together with a turbine materials test program. Data are being obtained on the corrosion and erosion of turbine materials and the protection offered by transpired air. Phase I testing with the 3-ft-diameter rig has continued through 1979. Phase II, the detailed design of the pilot plant, is complete. Phase III, construction of the pilot plant, will start in FY 1980, and shakedown testing will occur in FY 1982. Phase IV, operational testing and evaluation, will be performed in FYs 1982 and 1983.

2.2 PFB SUPPORT/INTERNATIONAL ENERGY AGENCY

PFB Combustor and Component Development

The PFB program is based on the marriage of fluidized-bed combustion at pressures of 6 to 16 atm, and gas-turbine combined-cycle plant operation. In order that commercial plants be rapidly forthcoming, the development of improved components and their proof in integrated operation is needed. Component development is being carried out at the various existing PFBC facilities, namely the Curtiss-Wright SGT rig, the Coal Utilization Research Laboratory (CURL) facility at Leatherhead, England, and the IEA facility in construction at Grimethorpe, England, and to allocate the systems integration mission of the PFB/CTIU to the PFBC pilot plant and the Engineering Development System (EDS) plant. The EDS is the first complete integration of a PFB combustor/boiler and a gas turbine. With such a reallocation of mission, greater emphasis can be placed on developing and improving hot-gas cleanup equipment, solids handling (feed, removal and bed-level control) controls, gas-turbine materials evaluation and further analytic and experimental evaluation of the pressurized boiler-power recovery turbine PFB system configuration. Had DOE proceeded with the PFB/CTIU, the work on components development necessarily would have been slowed and the whole program would have suffered delays. The PFB/CTIU mission has been apportioned as follows:

- Small Gas Turbine rig
  - Instrumentation test bed
  - Hot-gas cleanup test bed
  - Gas-turbine blade cascade testing
  - Transpiration air-film blade protection testing
  - PFB combustor materials testing
- CURL
  - PFB boiler configuration development
  - Hot-gas cleanup test bed
  - PFB combustor/boiler configuration development
  - Gas turbine cascade testing
- PFBC Pilot Plant
  - Design testing of the PFBC plant system for operation in an uncoupled gas turbine mode

- Testing of plant control
- Testing of gas turbine on cleaned and diluted combustion products
- Testing of air-cooled vertical tube PFB combustor configuration

- IEA Facility
  - Combustion characteristics and profiles in a steam-cooled bed of substantial size (2m x 2m)
  - Testing of commercial-scale solids-handling systems
  - Testing of gas turbine on undiluted PFB combustion products
  - Obtaining data on gas-turbine materials over a range of blade temperatures

- Engineering Development System
  - Integration of PFB boiler/combustor with coupled steam turbine and coupled power recovery gas turbine

- PFBC gas-turbine materials long-term test apparatus
  - Dedicated materials test rig.

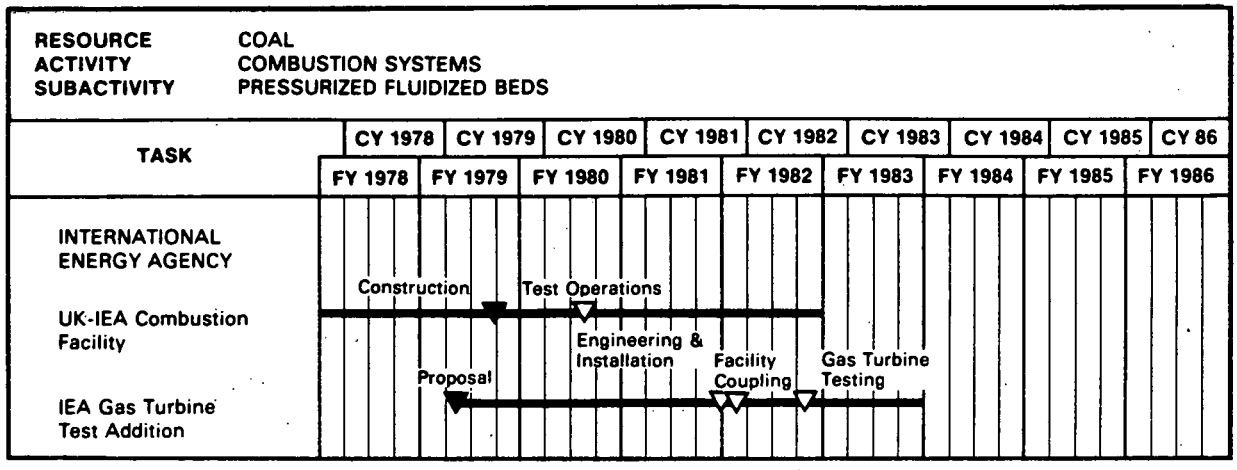
DOE has terminated further work on the PFB/CTIU with the Title I design being completed. The project is otherwise ready to begin construction.

During FYs 1980 and 1981, the PFB Combustor and Component Development task will test improved combustors and gas-turbine blade cascades in Leatherhead, test improved particulate and alkali measurement instrumentation in several facilities, and perform materials evaluation. During FYs 1980 and 1981 such component development work will continue with testing of hot-gas cleanup alternative and continuation of the combustor testing and instrumentation development.

International Energy Agency

As part of the activities of the International Energy Agency, consisting of a joint effort by the United Kingdom, the Federal Republic of Germany, and the United States, a combustion test facility for the development of the pressurized fluidized-bed combustor is being constructed in Grimethorpe, Yorkshire, England. As shown in the following milestone chart, the facility was started in FY 1977 and will be completed by FY 1980. (See Chapter X for further details). In FY 1981, the unit will be used to obtain detailed data on the PFB combustion process in equipment sufficiently large to apply to utility systems. Such data will include profiles of fluidization, bed mixing, coal injection, combustion and sorbent kinetics, particle and alkali elutriation, and associated information necessary to engineer reliable utility systems. The plant will be expanded by adding a gas-turbine test rig

with a tertiary cleanup that will allow data to be produced on gas-turbine performance for a range of blade temperatures and a variety of blade materials.



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2.3 PFB UTILITY ENGINEERING DEVELOPMENT SYSTEM (EDS) PLANT

The Engineering Development System will allow integration of the boiler-steam turbine plant components with the PFB combustor-gas turbine PFB system elements to proceed. Such a plant will have a PFB combustor/boiler supplying steam to a utility steam turbine and will be operated with compressed air supplied by the power recovery gas turbine. The unit will be designed for startup and operation without any auxiliary boiler and will be capable of stand-alone operation.

In FYs 1980 and 1981, the EDS will be designed in cooperation with industry and the utilities.

3.0 ADVANCED COMBUSTION TECHNOLOGY

Tasks under this subactivity are:

- Engine Combustion Technology
- Improved Oil and Gas Burners
- Coal Combustion Support and Engineering Evaluations.

The present generation of production engines evolved during a period of relatively inexpensive petroleum-derived fuels when performance and cost rather than efficiency or emission constraints governed their development. As a result, neither the engines themselves nor the design techniques by which they have been incrementally improved are readily adapted to emerging requirements in terms of efficiency, emissions, and broadened fuel tolerance. While there have been advances in the past few years with the introduction of stratified charge and lean-burn engines, only a fraction of the 20 to 30 percent efficiency improvements inherent in these concepts have been obtained. In cooperation with industry, investigations are currently being

conducted on prototype design concepts for a generation of engines specifically tailored for realizing these potentials in different engine classes.

Present industrial design practices for furnaces and boilers are based on experience with specific business situations which traditionally stressed low cost rather than high efficiency. This R&D effort is concerned with the evaluation and the development of combustion technology and equipment for boilers and furnaces in residential, commercial, and industrial use. Such technology development should improve the efficiencies, controls, and heat transfer and fuel utilization properties of boilers and furnaces. This activity was started in the Increased Conversion Efficiency (ICE) program in ERDA and was transferred to the Fossil Energy Program in DOE. The improved boiler and furnace program will be transferred to an appropriate group in DOE to handle the improvement of oil- and gas-burning equipment.

Laboratory and design studies now in progress support the direct coal combustion development projects. These studies are designed to promote optimum coal utilization by supplying data essential for application of direct combustion units to public utility and industrial systems. Key components of the total system, including processing, handling, and transport equipment, will be considered in the context of operability and design optimization. Component corrosion and fouling studies will be made and methods will be developed for minimizing these problems.

3.1 ENGINE COMBUSTION TECHNOLOGY

This task supports the development of advanced combustion technology necessary to increase fuel efficiency, control emissions, and broaden the range of usable fuels for automotive engines. The approach is to apply the advanced research capabilities of the DOE multipurpose laboratories, the universities, and selected private R&D laboratories to the solution of critical problems in engine systems under advanced development in industry. The effort is directed primarily toward three engine classes: (1) direct-injected stratified-charge (DISC), (2) lean-burn homogeneous charge, and (3) diesel. The subtasks complement traditional engineering research in industry and involve major industry participation. Relevance and technology transfer to the manufacturers' development laboratories are accomplished by their direct involvement in program definition, execution and review. Research results from this task have immediate impact on industry design commitments for their near-term developments and will accelerate the energy savings to be achieved with these engine design concepts.

Project Status

Programmatic Accomplishments include:

- Initiated cooperative research program in DISC engines involving Sandia, LLL, LASL, Princeton University, and General Motors Research Laboratories. Generated noncombusting model of DISC engine aerodynamics

- Demonstrated stratified-charge diagnostic systems using combustion bomb facility loaned to Sandia by Volkswagen Research as part of international cooperative program

- Received cooperative financial support from MVMA for engine combustion technology program and thus formulated MVMA engine combustion research review committee representing all of the auto industry

- Organized joint engine research program, through IEA, with U.S., U.K., and Sweden participation. Staff exchange has occurred between Sandia (U.S.) and Harwell (U.K.) Laboratories to accelerate technology sharing

- Initiated major cooperative research program in direct combustion aimed at identifying and controlling particulate formation, noise, and carcinogenic aromatic hydrocarbon emissions.

Specific technical accomplishments include:

- Turbulent flame propagation in a combustion chamber has been qualitatively reproduced with a 2-dimensional computer model for swirling flows with and without fuel injection.

- Two-chamber stratified charge combustion has been simulated with a reacting Eulerian-Lagrangian finite difference formulation and illustrates the strong momentum coupling between main chamber and prechamber.

- Grid-free turbulence simulations using a vortex dynamics approach have been successfully applied to predict nonaxisymmetric turbulent flow in various engine geometries.

- Fluid motion, spray formation and combustion processes have been coupled into a preliminary system model for an operating direct-injection stratified-charge engine.

The application of advanced experimental methods has provided new capabilities for measuring turbulence, velocity fields, fuel-air distribution, and temperature within the combustion chambers of operating engines. Specifically:

- Turbulence levels and velocity fields have been measured in engines by means of hot-wire anemometry and laser Doppler velocimetry.

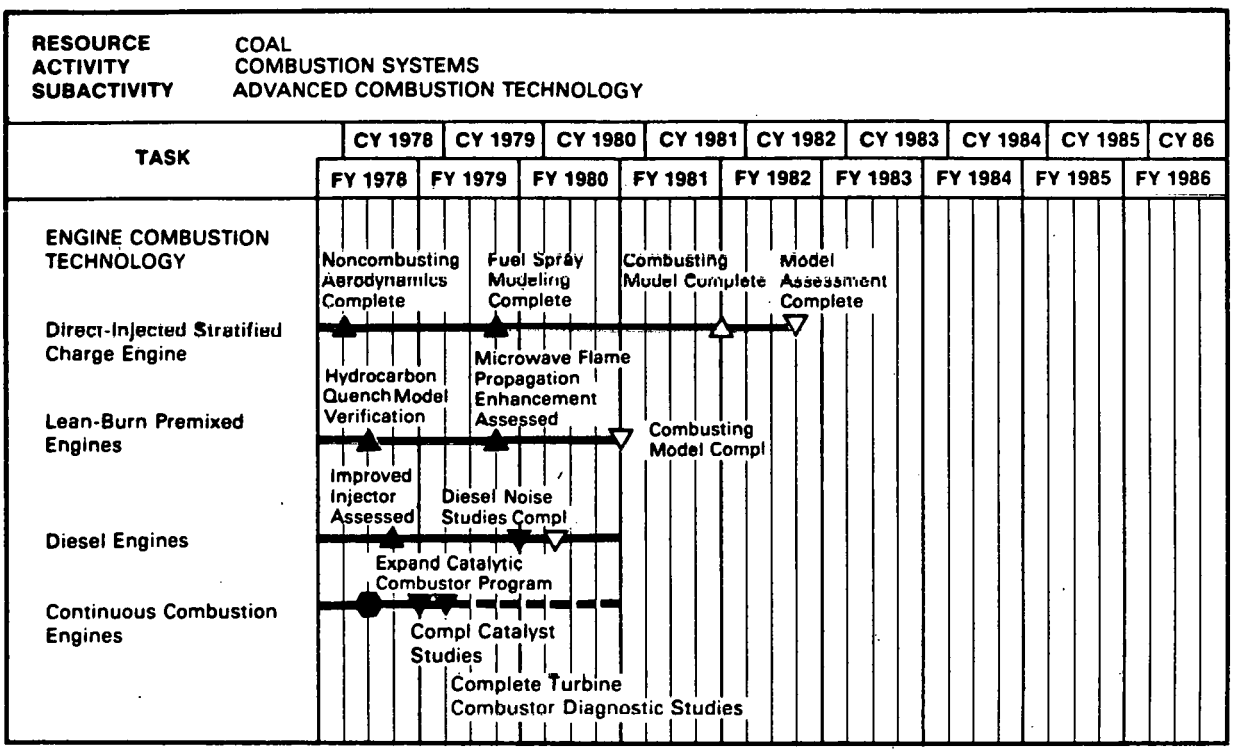
- Temperatures, fuel-air distributions, and density fluctuations have been measured in an operating engine by means of laser Raman spectroscopy.

Expected accomplishments in FY 1980 include:

- Develop a 2-dimensional, noncombusting working model of DISC engine operation capable of providing simple engineering design trade-off calculations.

- Demonstrate enhanced combustion in lean-burn homogeneous charge engines.

- Initiate cooperative research program in diesel engines involving SL, LASL, Chrysler, Cummins and Systems Science and Software, Inc.
- Complete catalytic combustion characterization for continuous combustion systems.



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Expected accomplishments in FY 1981 include:

- Application of in-cylinder time-resolved diesel particulate measurements techniques to allow development of particulate control strategies
- Application of hydrocarbon quench concepts to allow improved hydrocarbon emission control
- Complete development and verification of methods for analysis of intake, fuel preparation, and exhaust processes.

The management of this program will be assumed by the Assistant Secretary for Solar/Conservation in FYs 1980 and 1981.

3.2 IMPROVED OIL AND GAS BURNERS

The overall objective of this project is to improve the utilization of gas and oil by modification (including retrofit) of the combustion equipment and processes. Of particular importance is the ability to provide means for

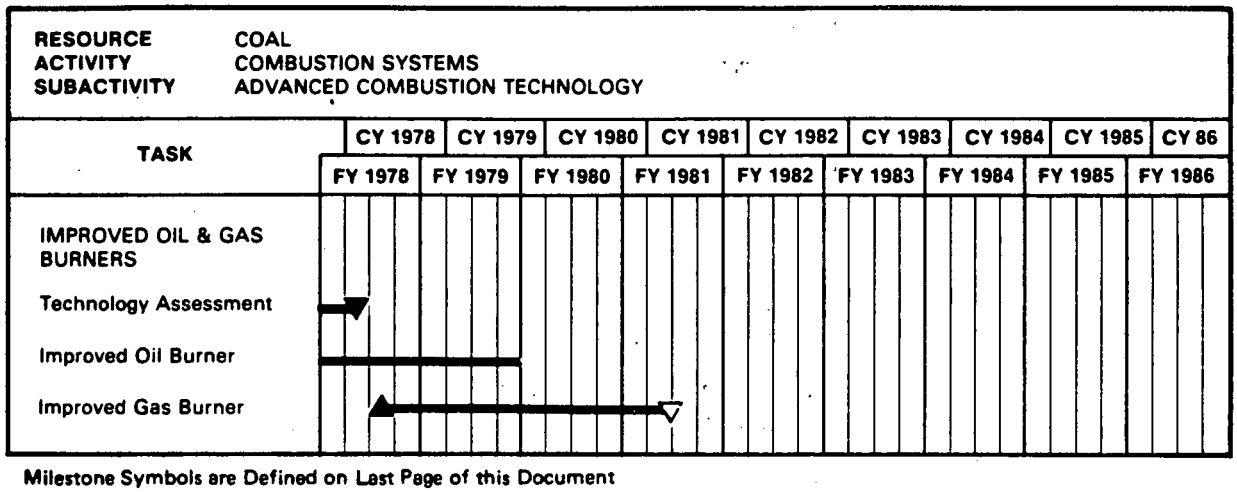
switching to more readily available fuels (e.g., low-Btu gases for natural gas), and to improve the efficiency of boilers and furnaces burning low-grade residual oils so that they will be capable of cleanly and efficiently burning the synthetic fuels of the future.

Project Status

This project was started in the second quarter of FY 1977. The following efforts were initiated in FY 1979 and continued into FY 1980:

- Pulse-combustor designs, offering great promise for residential and industrial heating (but currently unacceptable for that purpose), will be improved.
- Scaling criteria for oil and gas furnaces, leading to more confident transfer of information from small scale to boiler design, will be evaluated.
- The design of boiler components (e.g., atomizers) will be evaluated with the goal of achieving minimum excess air operation consistent with clean exhaust requirements.

The presently planned effort will be completed in mid-FY 1981.



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3.3 COAL COMBUSTION SUPPORT AND ENGINEERING EVALUATIONS

Laboratory and design studies now in progress which support the combustion systems development projects are designed to promote optimum coal utilization by supplying data essential for application of direct combustion units to public utility and industrial systems. These efforts are being integrated into the projects which they support in FY 1980 and will be continued in FY 1981 under the direct funding of the applicable program.

4.0 ALTERNATIVE FUEL UTILIZATION

Tasks currently underway in this subactivity are:

- Coal-oil mixtures combustion
- Principal alternative fuel combustion.

The combustion of coal-oil mixtures in combustors traditionally fired with oil offer a near-term opportunity for extending fuel oil resources. The goal of the Alternative Fuel Utilization task is to provide the fuels technology to assist the timely switching from premium fuel (petroleum and natural gas) to alternatives. This will be accomplished by developing the combustion technology for fuel specification and combustion equipment design and operation. Two groups of fuels are being addressed: (1) agricultural and forest residues and industrial wastes; and (2) principal alternative fuels (PAF) derived from coal and shale. (Municipal and urban wastes utilization are excluded since they are covered by other DOE divisions.)

4.1 COAL-OIL MIXTURES

The objectives of this task are to modify or retrofit, operate, and test existing boilers, heaters and furnaces to demonstrate combustion technology and practicability of burning coal-oil mixtures. Combustion of COM in existing oil-fired combustors will be investigated to determine the extent to which this retrofit technology can be implemented practically. The goal is to substitute coal for an appreciable fraction of oil in appropriate industrial and utility combustors within the near term.

Project Status

Two contractors were selected to apply COM combustion technology to modified/retrofit existing equipment beginning in early FY 1977. The selected contractors and their project completion dates are:

New England Power Co. Salem, Massachusetts	Coal-Oil Mixture Combustion, Utility Steam Generator, 80 MW, Originally Designed for Coal and Converted to Oil--Late FY 1980 Completion
Interlake, Inc. Chicago, Illinois	Coal-Oil Mixture Combustion, Blast Furnace--Late FY 1980 Completion

In addition to the above two demonstrations, a program opportunity notice (PON) was issued on November 14, 1979, to solicit two additional utility and industrial demonstrations. The award of contracts is anticipated for mid-FY 1980. The specific categories sited in the PON are:

- Category I. Existing utility boiler, originally designed to fire oil, 100 MW_e minimum capacity

- Category II. Existing utility boiler, designed to fire oil with intended potential conversion to coal, but has never fired coal, 100 MW_e minimum capacity. (This category may be supported in part by foreign governments under joint agreement with DOE.)

- Category III. Existing industrial boiler designed to fire oil, greater than 100 million Btu/hr energy input.

- Category IV. New industrial boiler designed to fire COM as the primary fuel, greater than 100 million Btu/hr energy input.

Additionally, COM fuel for these demonstrations will be purchased under contract by the selected offeror from a COM fuel supplier(s) who is expected to construct (if necessary) and operate the COM preparation plant at its own expense. A portion of the price for the COM fuel, however, shall be reimbursable under the Cooperative Agreement between the DOE and the successful offeror.

A 700 hp combustion test facility using coal-oil mixture for combustion has been completed at PETC. Preliminary COM information has been and is presently being obtained from this unit. The objectives of the PETC projects are to develop in-house technical capability in COM combustion technology and to supply direct technical support to the total COM combustion program.

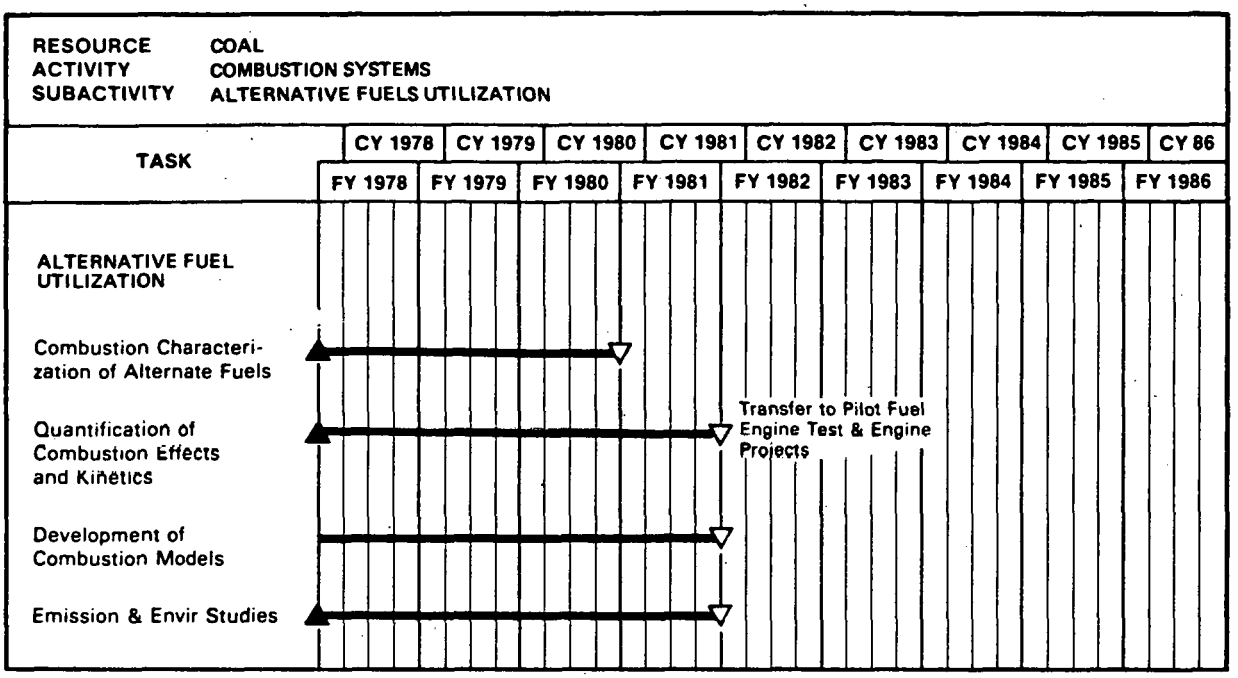
4.2 ALTERNATIVE FUEL COMBUSTION

Principal Alternate Fuels

The expanded use of minimally processed, heavier petroleum fractions offers an energy efficient strategy to significantly extend oil reserves while coal-derived liquids are leading candidates to furnish the bulk of our liquid fuel requirements after the mid-1990s. Also, the pending availability of ethracoal, methacoal, peat, biomass, and similar fuel options in commercially desirable quantities dictates a need to investigate the viable mix options that will produce an environmentally and economically sound liquid fuel product for existing oil-fired facilities. These fuel stocks have notably different characteristics than their straight petroleum analogs and require some energy consumption in processing prior to use in existing combustion equipment. The goal of this subtask is to provide the fuel combustion technology base required for the application of these fuels with a minimum of energy intensive processing, and thus allow an energy optimization of the fuel/combustion system. The overall approach is to determine the relationship between the fundamental fuel composition and those combustion characteristics which are the necessary data for equipment modification. The primary areas of definition addressed by this subtask are economic, environmental, and technical.

Project Status

This subtask was initiated in late FY 1977. Seven projects are currently underway, six in the area of combustion characterization and one in NO_x emissions control techniques. In FY 1980 these activities will be conducted under the direct utilization portion of the AR&TD effort.



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5.0 COMBUSTION SYSTEMS DEMONSTRATION PLANTS

Only one demonstration plant in fluidized-bed technology has been authorized to date.

AFB Utility Demonstration Plant

The demonstration of a coal-fired fluidized-bed combustion boiler at a near-commercial size will be required to implement commercial adoption by the utilities. Congress authorized a direct combustion demonstration plant in FY 1976. The initial plant is expected to be an atmospheric pressure unit. The unit is to be a nominal 200 MW size and will provide high-pressure steam for utility power generation.

The planning level power plant conceptual design contracts for AFB power plants that were awarded to Stone & Webster and Burns & Roe were completed in FY 1978. Plant designs used preliminary boiler designs funded by DOE. This work was accomplished by three major utility boiler manufacturers and was completed in FY 1978. Sensitivity analyses were conducted to determine the effects of the EPA's revisions of the New Source Performance Standards based on the BACT section of the 1977 Clean Air Act amendments, which in preliminary form require 85 percent sulfur removal.

Preprocurement activity for the AFBC utility demonstration plant has been suspended until the technology base is more fully developed.

Technology Support objectives in FYs 1980 and 1981 are to obtain engineering data on boiler materials testing and fuel facilities to assist making decisions, technical and economic, on utility fluidized-bed demonstration plants.

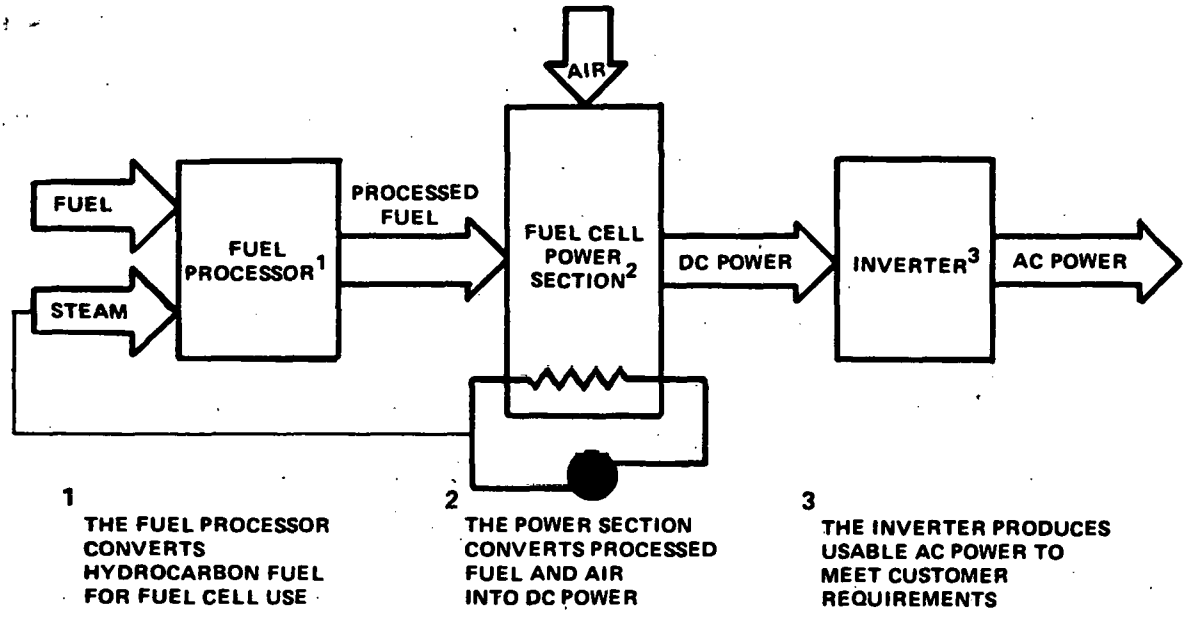
I. FUEL CELLS

A fuel cell is a device that electrochemically converts potential energy of a fuel to electricity in a highly efficient and environmentally acceptable manner. Fuel cell power plants can be factory built and then located close to the point of electricity demand, thereby avoiding energy losses presently associated with power transmission and distribution. Effective use of waste heat can also be incorporated in the plant design. The modular construction of fuel cell generators provides a size flexibility from kilowatt to megawatt capacities. The essentially nonpolluting, practically noiseless operation permits location in large load centers in urban, rural, and residential areas. Measured emissions from an experimental fuel cell power plant were orders of magnitude lower than the Environmental Protection Agency (EPA) standards for modern conventional fossil-fueled central station generators.

A fuel cell power plant is comprised of three sections: the fuel processor, the power section, and the inverter. The fuel processor converts hydrocarbon fuel into a gaseous mixture of hydrogen and carbon dioxide and/or carbon monoxide. If the product gas is to be used in first-generation phosphoric acid fuel cells, the carbon monoxide is reacted with steam recovered from the power section to generate hydrogen and carbon dioxide. If the product gas (such as gasified coal) is to be used in second-generation molten carbonate fuel cells, both hydrogen and carbon monoxide are used directly as fuel by the power section.

The fuel cell power section consists of many individual cells in which the hydrogen or hydrogen/carbon monoxide gas mixture and oxygen from the air are electrochemically reacted to produce direct current (dc) electricity. Because the conversion of fuel chemical energy to electricity is an electrochemical process, the conversion efficiency is very high and is achievable for any plant size and at part load. The high conversion efficiency of fuel cell power plants has the potential for using more expensive coal-derived and unconventional fuels providing usable electricity and heat at reasonable costs. With minor modifications, presently available fuel processors designed to handle conventional fuels could be made to handle coal-derived gases (high-, medium-, and low-Btu), methanol from coal, and other coal-derived liquids.

The last subsystem of the fuel cell power plant is an inverter that converts the dc output to alternating current (ac). The inverter produces a waveform compatible with conventional electrical supplies generated by rotating machinery.



Major Sections of a Fuel Cell Power Plant

Phosphoric acid fuel cell systems being sought within the next three to seven years which could use hydrocarbon waste, coal-derived, and other unconventional fuels are aimed towards a wide spectrum of applications including:

- Industrial cogeneration where advantage is taken of the high electrical and thermal efficiencies
- Onsite/integrated energy systems (OS/IES) for small industrial, residential and commercial buildings providing electricity and space heating and cooling
- Electric generation for peaking and intermediate-cycling loads; small dispersed base-load; spinning reserve; small utilities (10 MW_e); and replacement of old, inefficient units.

Second-generation, molten carbonate fuel-cell systems, being sought within the next 6 to 10 years, which operate on coal and coal-derived and unconventional fuels are aimed towards the following applications:

- Large (200 to 1,000 MW_e) base-load electric utility power plants operating on coal
- Dispersed small and medium base-load (10 to 50 MW_e) electric utility power plants operating on coal-derived and unconventional fuels
- Medium- and small-size cogeneration power plants for industrial applications.

In addition to the above energy-saving applications, the foreign market potential for phosphoric acid fuel cells and potentially molten carbonate systems is quite large, including:

- Developed countries where environmental considerations are important
- Developing nations because of the small unit size and ability to run fully automated without operating personnel
- Countries that are shifting to an alcohol-fuel-based (derived from biomass or coal resources) economy.

The objective of the DOE Fossil Energy Fuel Cells Activity is to establish the commercial feasibility of fuel cell power plants for electric utility applications, industrial cogeneration, onsite total energy systems in the near term, and to develop advanced, higher efficiency, economically competitive, fuel cell technologies for all end-use applications in the longer term. The Fuel Cell Activity is assisting, over the next three to seven years, the development of a fuel cell industry with its associated significant national benefits. Specifically, the Fuel Cells Activity has accomplished the following:

- Selected Consolidated Edison of New York City as the host utility in the demonstration of a 4.8 MW fuel cell power plant on a utility grid. The power plant, manufactured as a result of a three-way, cost-shared contract, is to be delivered in the fall of 1980. It is significant that this plant is being sited on Manhatten island, a nonattainment area
- Completed a market analysis and formulated a commercialization strategy for phosphoric acid OS/IES in residential and commercial buildings
- Successfully completed on schedule and within projected cost a cost-shared development of a 40 kW fuel cell power plant for OS/IES
- Accomplished satisfactory progress on schedule and within projected cost, on two cost-shared projects with potential competitive manufacturers of phosphoric acid fuel cell systems. These projects are providing significant alternative technology options and system performance capabilities
- Successfully tested integrated phosphoric acid fuel cell stacks. The new cell and stack technology has higher power density and life expectancy with major impact on system economics and reliability improvements
- Completed four industrial cogeneration application studies, resulting in the realization of a large potential for near-term applications

- Initiated a 3-1/2-year electric utility, phosphoric acid power plant technology development program, with cost sharing from EPRI and electric utilities. This program will lead to the development of a commercial power plant configuration (10 MW_e)

- Demonstrated feasibility of thermally cycling molten carbonate fuel cells successfully; previously believed to be a limiting technical problem

- Identified and established feasibility of a potentially cost-effective, internally manifolded molten carbonate stack design. Successfully tested cells for this design of approximately 1 ft^2 area (previously tested cells were 2" x 2")

- Established feasibility of a simple, externally manifolded molten carbonate stack design with cell components manufactured by methods suitable to mass production, and successfully tested such components

- Established a 33-month mission-oriented program to qualify both internally and externally manifolded carbonate stack designs for testing at individual stack-scale commensurate with full-scale power plants

- Developed a non-carbonyl method of synthesizing powder precursors to porous metal electrodes. Method is flexible and adaptable to mass production potentially ameliorating a large cost item

- Identified two alternatives to conventional molten carbonate electrolyte tiles and initiated testing. This could radically enhance both power density and life expectancy of cells and stacks

- Identified and demonstrated feasible solutions to cathode-current collecter (In_2O_3) spallation problem in solid oxide fuel cells, a third-generation advanced technology

- Demonstrated that the combustion stage of an advanced fuel processor (autothermal reformer) can be operated without the formation of soot in the reactor under significantly more severe conditions than had previously been found possible. This processor was fueled with No. 2 fuel oil similar in behavior to coal-derived liquids.

In order to achieve the overall DOE Fossil Energy Fuel Cells objective, the Activity is divided into four subactivities. Each of these areas has a specific objective as follows:

- 4.8 MW Electric Utility Power Plant Demonstration: On a utility grid, test the operational feasibility and full-scale system integration of early design (1976) electric utility fuel cells.

- Phosphoric Acid Systems Development: Develop fuel cell systems for OS/IES applications and provide technology to lower cost and increase reliability of phosphoric acid fuel cell systems for both electric utility service and OS/IES applications.

- Molten Carbonate Systems Development: Advance the state of the art of molten carbonate fuel cells to achieve the earliest possible commercialization of coal-fueled power plants in electric utility base load and industrial cogeneration applications.

- Fuel Cell Advanced Systems: Support emerging systems with a sufficient technology base, examine advanced fuel cell systems thermionics, and broaden the spectrum of acceptable fuels.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

FUEL CELLS	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
4.8 MW Electric Utility Power Plant Development	5,500	0	0
Phosphoric Acid Systems Development	14,000	14,000	11,000
Molten Carbonate Systems Development	17,000	12,000	11,000
Advanced Concepts	4,000	0	3,000
Capital Equipment	552	500	0
TOTAL	41,052	26,500	25,000

1.0 4.8 MW ELECTRIC UTILITY POWER PLANT DEVELOPMENT

This subactivity consists of design and fabrication of a 4.8 MW fuel cell power plant with subsequent integration of the hardware into a utility grid for testing. The system is being constructed at United Technologies Corporation (UTC). The project is cost shared by DOE, the Electric Power Research Institute (EPRI), and UTC. Consolidated Edison has been selected as the host utility, and the power plant is to be installed and tested in New York City. The overall objective of the project is to establish the operational feasibility of a full-scale fuel cell power plant and to provide an opportunity for the utility sector to evaluate the attributes of this technology for the first time.

The 4.8 MW fuel cell power plant is a modularly constructed, truck-transportable, power plant consisting of fuel processor, power section, power conditioner, and ancillary equipment to maintain appropriate process balance. Because of its modularity, as well as the virtual absence of plant-generated pollution, it has almost unlimited application for the production of electric power. The plant offers spectacular siting flexibility because of its

operating characteristics. It can serve as a component of central station generation, with particular application for intermediate and peaking loads, and as a dispersed generator for utilities, industries, and community systems. When sited near load centers, cogeneration becomes an available option. The operating temperature of the system (375°F), allows cogeneration of process steam and low-grade heat for space conditioning.

Prior to the 4.8 MW_e demonstration, the technological feasibility of the phosphoric acid fuel cell for producing electric power had been demonstrated in systems up to 1 MW in size. The 4.8 MW module is the basic building block for a utility power plant with meaningful capacity.

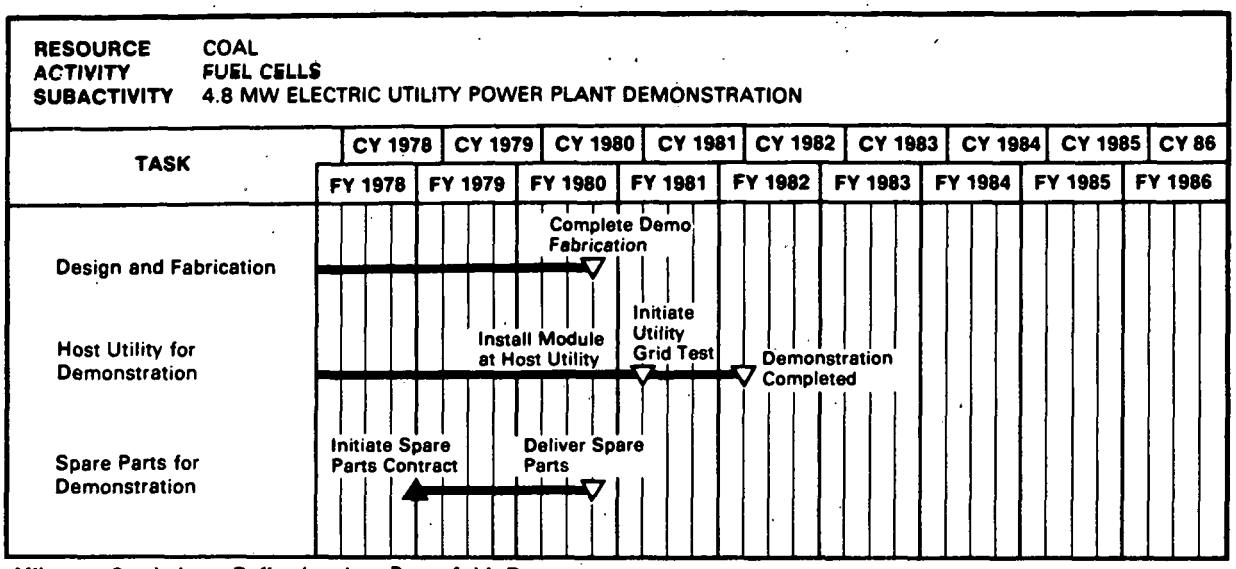
4.8 MW Fuel Cell Power Plant

Project Status

The design and design confirmation phases of the program have been completed, and projected performance, meeting specification goals, has been substantiated through subsystem testing and system performance modeling. The power plant will be sited in lower Manhattan, and site approval by the New York City Board of Standards and Appeals has been received. The power plant delivery has slipped to late FY 1980, principally due to the implementation

f special fabrication, inspection and test requirements desired by the New ork City Fire Department to permit the 4.8 MW demonstration to be sited. No ajor technical problems are expected.

The following chart includes accomplishments expected in FYs 1980 and 981.



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2.0 PHOSPHORIC ACID SYSTEMS DEVELOPMENT

The phosphoric acid fuel cell utility plant is in the preprototype stage of development. The 4.8 MW system requires improved performance, longer life and an extension of range of application. Furthermore, additional industrial suppliers of phosphoric acid fuel cells are required in order to provide a competitive environment. The 40 kW OS/IES power plant (described below) is also in the preprototype stage of development. Needed technology improvements must be sought in the areas of cost reductions, endurance extensions, and improvements in reliability and performance.

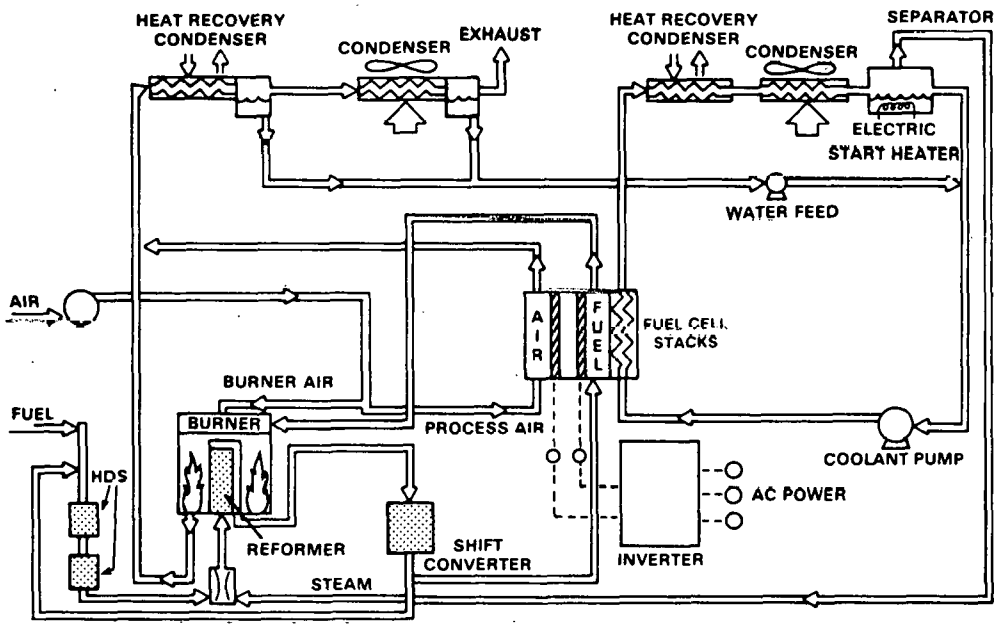
Potential applications of the OS/IES power plants include fuel cell powered total energy systems (providing electricity, space heating and cooling) for residential, commercial and industrial applications. In order to meet these technology development objectives, the subactivity is divided into two areas: OS/IES power plant development and phosphoric acid technology development for both electric utility and OS/IES applications. A description of each of these areas and the associated program strategy follow.

Onsite/integrated energy systems, in which the plant meets both the electrical and thermal energy demands of the user, have the potential of saving over 20 percent of the present fuel requirements of conventional systems. The power plants could meet all of the thermal and electrical demands of residential building complexes using the same or less fuel than is presently used for heating alone. This is made possible because of the availability of waste heat at the application site, the plant's high

conversion efficiency, and the reduction in distribution and transmission losses. The plant is favorable for system application because of its modularity, flexibility, and minimum impact on the environment. The integrated energy systems have application in residential and commercial buildings and industrial plants. The power plant performance specifications are different for those applications (from those for utility applications); however, the advantages of the fuel utilization efficiency is equally applicable. The primary limitations historically associated with conventionally powered total energy systems have been reliability and siting flexibility. Fuel cell systems provide an opportunity for overcoming these limitations. Fuel cell powered total energy systems would replace natural gas- and oil-burning systems which provide space and process heat. They could also replace conventional grid-supplied electrical power. These fuel cell systems could be operated on new fuel supplies such as coal-derived or unconventional fuels. The OS/IES research and development effort has been structured emphasizing competition.

The achievement of significant cost-reductions for electric utility and OS/IES power plants via technology is receiving major emphasis. Specific efforts involve: (1) improving cell endurance; (2) developing an integral cooler for lower cost and greater durability; (3) developing a design which eliminates the need for nitrogen inert pressurization; (4) improving performance via higher operating temperature and pressure; and (5) developing a new, low-cost, integral cell stack concept.

Determining system and technology requirements for electric utility and OS/IES applications is vital to the effort. Requirements involving electrical efficiency, heat quality, size, operational characteristics, cost, and fuel availability and compatibility are some of the items being addressed. System studies provide a focus for the technology effort and assess the range of applications that the technology serves.



Typical Phosphoric Acid Power Plant Schematic Design

Project Status

In the OS/IES area, the 40 kW engineering and development effort is in the most advanced stage. The 40 kW pilot power plant (PC 18), pictured schematically above, was originally developed under gas utility and UTC sponsorship and was the starting point for this development effort. This pilot power plant has operated for over 15,000 hours. The current effort, cost shared with the Gas Research Institute (GRI), is directed toward cost, reliability, endurance, and performance improvements of the pilot power plant design in order to develop a preprototype, properly functioning 40 kW field test power plant. Effort in this area also involves the work of several manufacturers to foster competition and design options for continued development of the OS/IES concept. In FY 1980, a number of 40 kW OS/IES power plants will be procured for testing in the field in cooperation with GRI and host utilities. This is covered by $9.5 million appropriated in FY 1980 in the Conservation and Solar Applications budget.

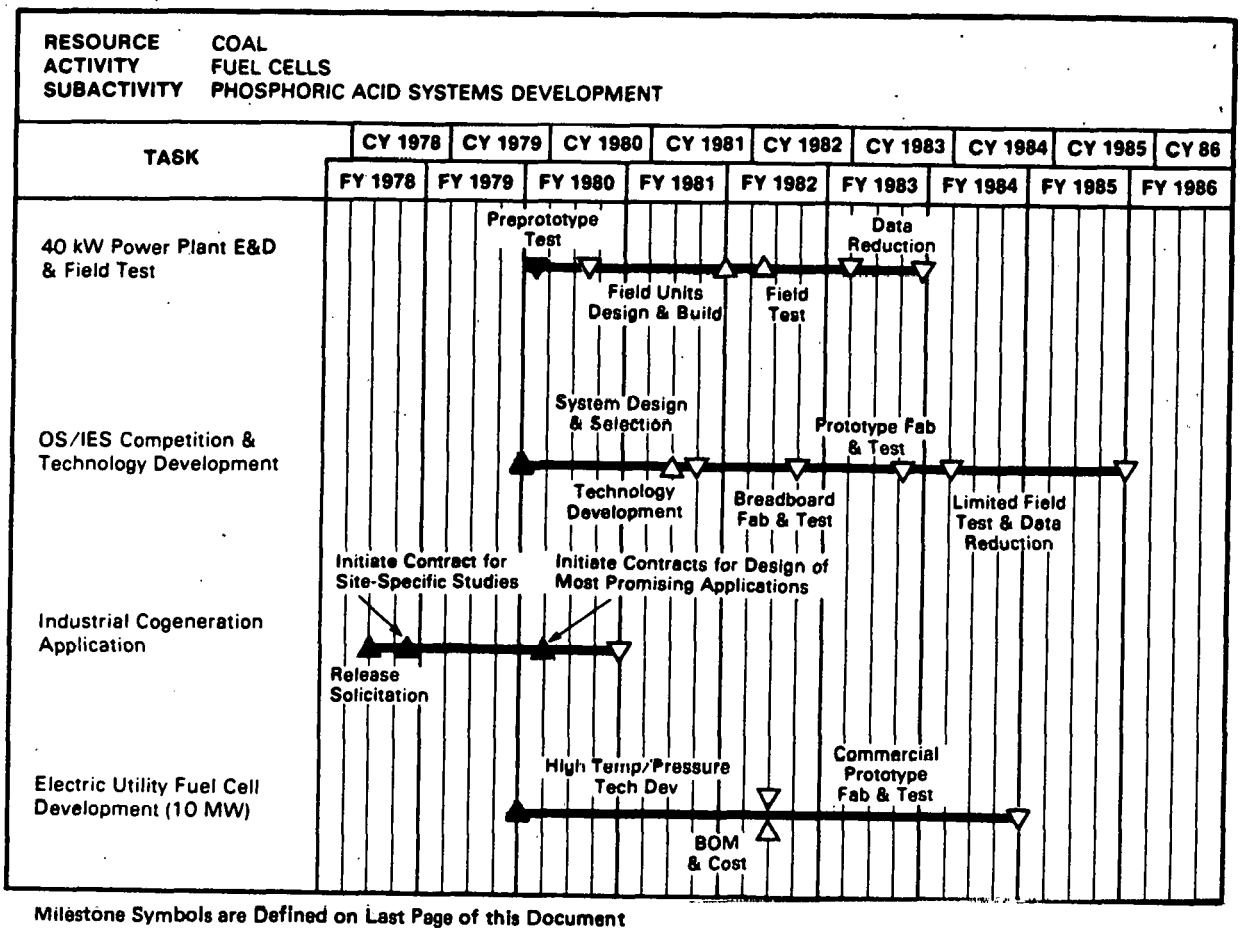
An OS/IES technology program (initiated in FY 1980) is being conducted in parallel with and is deriving input from the 40 kW field test, which will continue through FY 1983.

Two major cost reduction tasks were initiated in FY 1978 and are continuing through FY 1980. The first, platinum catalyst activity enhancement, represents an alternative to higher temperature and pressure for increasing performance. This effort focuses primarily on the cathode. The success of this task will have an important impact upon phosphoric acid fuel cell systems being developed for OS/IES applications. The second effort involves the development of a low-cost, integral cell stack concept to be incorporated into the 40 kW power plants under development for field testing.

Several systems studies were completed during FY 1979, identifying market and regulatory restraints, capital requirements, quantified benefits, and associated costs. Four industrial cogeneration studies for fuel cell power plants were completed in FY 1979. These feasibility studies were conducted to define requirements, potential benefits, costs and schedule for the construction, installation and operation of a 4.8 MW fuel cell power plant in industrial cogeneration applications. During FY 1980 further effort will be initiated involving the most promising applications chosen from the four studies, which could lead to field demonstrations. Consideration is being given to utilizing an 8 to 10 MW fuel cell power plant for these cogeneration applications.

In FY 1980, a 3-1/2-year electric utility, phosphoric acid power plant technology development program is being initiated, with cost sharing from EPRI and individual electric utilities. This program will move the electric utility power plant toward commercial readiness by improving and verifying its performance, endurance and costs consistent with the requirements for utility applications. The main elements of this program are to complete development of the power plant, verify the design for initial production units, define modifications needed to utilize coal-derived fuels, and define the production cost and market for the power plant.

Efforts discussed above will be continued in FY 1981 and subsequently, as shown in the following milestone chart.



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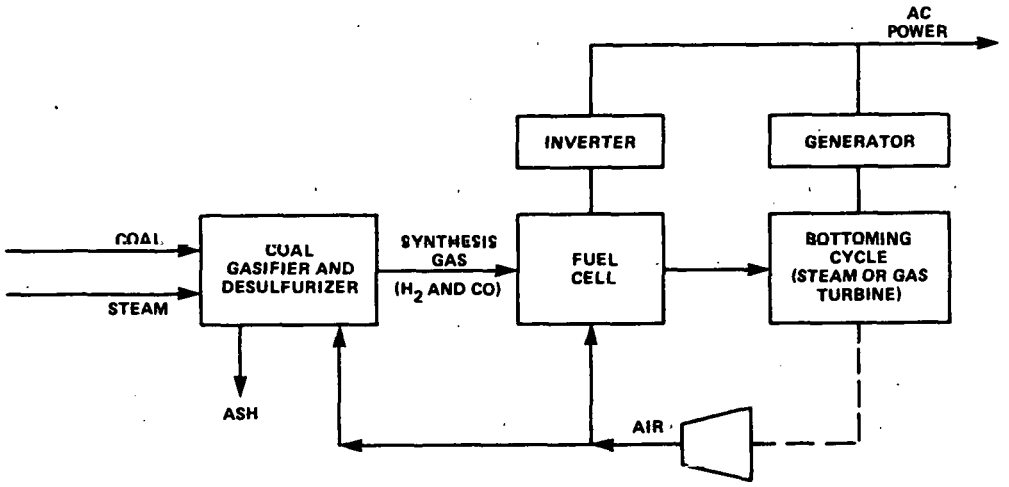
3.0 MOLTEN CARBONATE SYSTEMS DEVELOPMENT

The objective of the Molten Carbonate Systems Development subactivity is to bring about the earliest feasible commercial use of molten carbonate fuel cell systems, so that the environmental and resource conservation benefits of these clean, efficient, coal-fueled systems can be realized. Replacement of gas and oil with the minimum amount of coal is facilitated by high system efficiency. Sulfur is removed to low levels from the fuel stream, and because the fuel is oxidized electrochemically rather than by combustion, NO_x emissions are very low. The environmental impact of this type of coal-fueled generator is, therefore, rather small.

The primary application of molten carbonate fuel cell generators is for base-load electrical generation and industrial cogeneration. The program leading to this product is well defined. With appropriate liquid fuels, such as coal-derived hydrocarbons, it would be possible to meet intermediate and peaking demand as well with similar benefits. The fuel cell technology development required for this application is essentially the same as for base-load power plants.

In a molten carbonate fuel cell, which would be thermally integrated with a coal gasifier, coal is gasified with steam and air or oxygen to form a fuel gas stream rich in CO and H_2. The gas stream is purified of particulate and sulfur in the cleanup section, then fed to the fuel cell where it is combined electrochemically with air to form CO_2 and H_2O. This process produces dc electric power, which is transformed to ac in the inverter and stepped up to transmission-line voltage levels. Sensible heat from the gasifier and the fuel cell outlet gas stream is recovered by raising steam which is used in a steam turbine generator. About two-thirds of the power plant electric output comes from the fuel cell and one-third from the steam turbine. Where plant sizes smaller than about 500 MW are needed, a gas turbine can be used instead of the steam system with 2 to 5 percent reduction in plant efficiency. If volatile fuels, such as SNG, methanol, or unconventional natural gas, are available, small (<100 MW) plants could be built which could be suitable in environmentally limited areas, and which would have efficiencies approaching 60 percent. The sensible heat in this system is at a sufficient temperature (600°C) to be used directly in many industrial processes to replace gas or oil furnaces. A schematic of this system appears below.

The strategy for implementation is the same for all above applications. The approach is to conduct parallel interactive efforts in system definition and component development. The system definition task provides guidance and direction to the development work. Similarly, the results of the component development work are fed back into the system/subsystem definition effort. For the next few years, the paramount effort will be in cell and stack development since they are the least developed part of the system.



Second-Generation Molten Carbonate Fuel Cell Power Plant

Project Status

In order to meet the requirements of an electric utility base-load system, the following goals were established for the molten carbonate fuel cell stacks:

- Life of 40,000 hours to meet low maintenance-cost requirements
- Current density of 150 A/ft^2 at 0.8 V, 75 percent fuel utilization
- First cost (stack material only) of $60/kW at the current density and endurance design points.

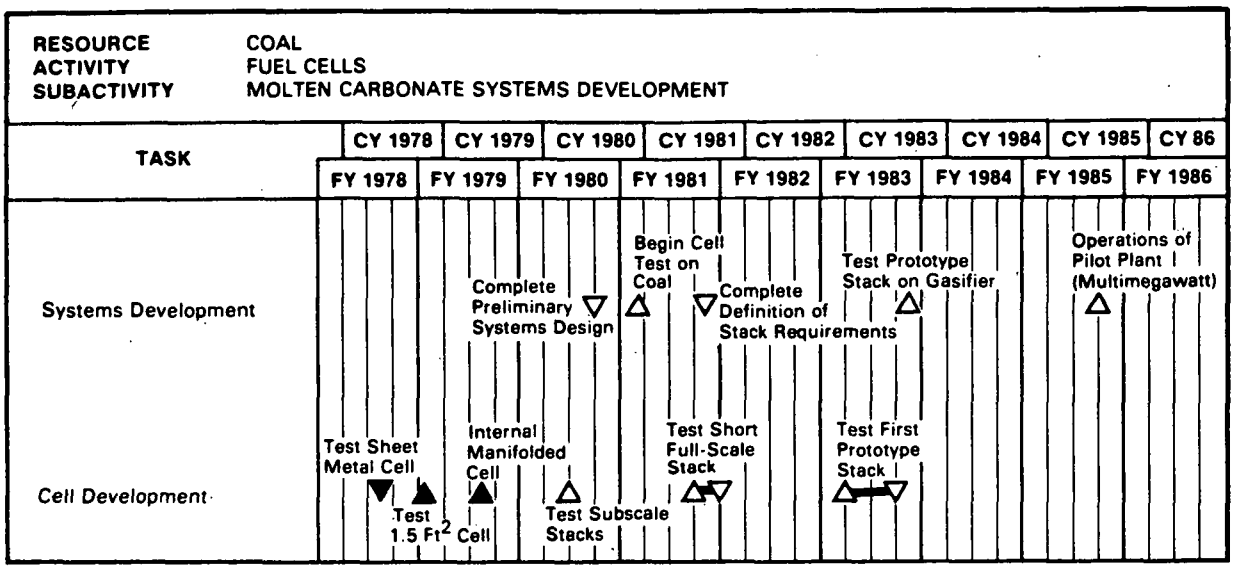
Successful achievement of these goals will allow for a system design of 50 percent overall conversion efficiency (coal pile to busbar) at a competitive capital cost.

Cell performance is rapidly approaching the specified goal and may well exceed that level before other goals are met. The present current density at 0.8 V is 140 A/ft^2. This specification must be met under system operating conditions of temperature (923° K), pressure (<10 atm), and CO_2 recycle (currently by burner), and in-cell fuel utilization.

The best cell life to date is 16,000 hours. Obviously, the cell was built with what is now 3-year-old technology. Satisfactory solutions to the wet seal corrosion problem (believed to be the primary cause of failure) have been subsequently devised. The next hurdle appears to be electrolyte management. The advanced cell designs currently under development address this issue through (1) provision for electrolyte storage and (2) elimination of electrolyte sinks within the cell. Ten-thousand-hour tests on cells with projected 40,000 hour capability are scheduled in the present 33-month contracts with General Electric and United Technologies.

Capital cost is of fundamental concern in all aspects of component development. Three manufacturing cost-related areas are of special concern: scaleup; use of sheet metal cell hardware; and electrolyte production methods. Critical cell components were scaled up to 2.75 ft^2 in FY 1978 and further scaleup is in progress. The first true sheet metal cells were successfully operated in FY 1978. Work in FY 1979 developed and tested two independent advanced designs for both internally and externally manifolded cells having minimal number and complexity of cell parts. These cells are the first of a commercializable type. They will be tested in subscale stacks beginning in FY 1981. Electrolyte stability and $LiAlO_2$ synthesis studies at the Argonne National Laboratory identified α-$LiAlO_2$ as the support material of choice and two acceptable synthesis routes for it. Electrolyte structures made by methods suitable to low-cost mass production are beginning to be tested. An anode material of improved surface area having no discernible loss of area for at least 3,000 hours has been developed, together with a synthesis process for the material, which allows wide control of alloy composition and electrode area, and which does not involve toxic carbonyl compounds. The electrolyte manufacturing advances initiated in FY 1977 were further developed, and it appears that both electrolyte synthesis and tile manufacturing will be amenable to mass production.

The cleanup technology required to allow molten carbonate fuel cell stacks to operate on gasified coal is being developed under the Advanced Environmental Control Technology Activity. Also, the low-Btu gasifier development efforts were carried out under the coal gasification activity and are closely coordinated at a system level with the Fuel Cell program.



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4.0 ADVANCED CONCEPTS

This subactivity has the objective to continue identification, research, development, and demonstration of new direct conversion technology aimed at significant advancement in the state of the art. Solid oxide fuel cells and thermionic energy conversion are presently being investigated as possible systems that may warrant development and demonstration.

Solid Oxide Systems Development

The high-temperature, solid oxide electrolyte fuel cell (SOFC) is an alternative technology to the molten carbonate fuel cell (MCFC). The two technologies have a similar wide range of potential applications including especially base-load electric generation from coal, as well as industrial cogeneration from coal or logistic fuels, and intermediate (cycling) electric generation from coal liquid or logistic fuels. The SOFC program objective is the same as the MCFC objective: the earliest feasible use of clean, coal-fueled, cost-effective power plants.

As shown in the illustration below, present contracts are scheduled to allow an intermediate decision point in April 1980 concerning continuation of the SOFC program and concomitant progress from a primarily basic-research phase into an applied research phase. This intermediate point will be primarily based on assessment of concept feasibility. Preliminary systems studies and hardware evaluations will contribute to cost/benefit aspects of the 1980 decision.

Given a favorable decision, the next two years' effort will be primarily directed to developing manufacturing capability for and to testing of 3 meter, 50 W stack tubes and kilowatt-sized arrays thereof. This work will be carried out under more realistic conditions than are presently used, and the effects of contaminants, pressure, thermal cycles, etc., will be investigated in greater depth. Systems studies and technology cost/benefit comparisons will be carried out preparatory to a 1982 decision concerning entering the exploratory development phase.

Thermionic Energy Conversion System Development

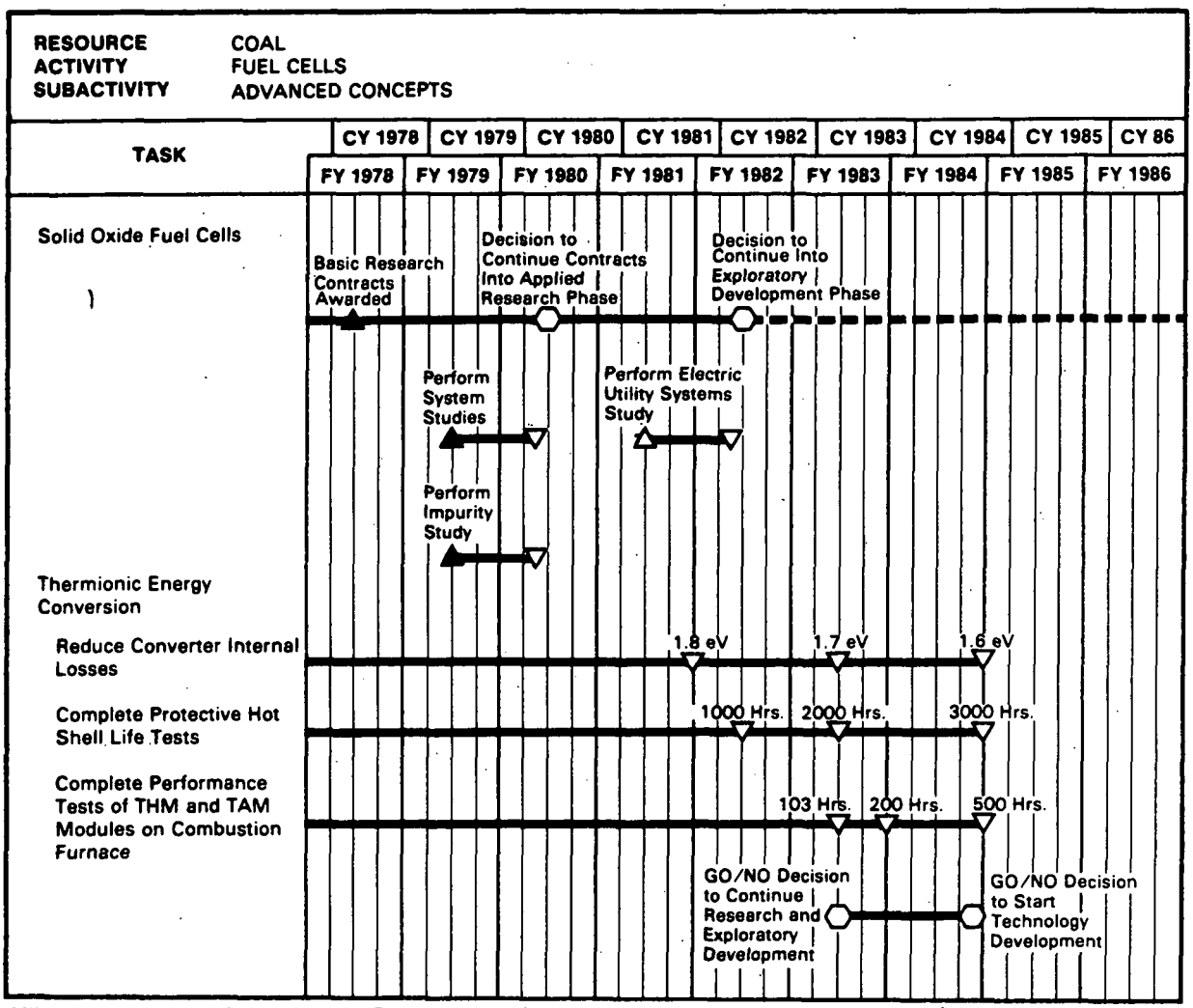
The objective of Thermionic Energy Conversion System Development is to develop thermionic electrical power generation technology permitting economical and environmentally acceptable utilization of oil, natural gas, coal, and coal-derived fuels. Application targets for this technology are utility power generation and industrial and commercial cogeneration.

Present steam-electric power plants utilize only about one-third of their fuel's energy in the generation of electricity. This is because the steam cycle operates only over the lower portion of the available temperature range, i.e., from 1000° to 100°F, whereas combustion temperatures of 4500°F and higher are available. Improvement of 25 percent or higher in overall plant efficiency is projected by the direct conversion of this high-temperature thermal energy to electricity by the use of the thermionic topping cycle. For this application, current emphasis is on the development of a technology base with operating temperatures of about 2000°F. Operation at this temperature requires (1) R&D to improve the performance of thermionic converters, (2) development of protective coatings or "hot shells" to preserve the integrity and performance of the converters in the combustion furnace environment, and (3) the development of preprototypical thermionic modules which will be tested in a simulated furnace environment.

Both theoretical and experimental R&D will be conducted on methods to reduce (1) the plasma arc drop, and (2) the collector work function, first in laboratory devices and next in operating converters. Close correlation will be made between theoretical predictions and experimental results. Successive goals of 1.8 eV, 1.7 eV, and 1.6 eV have been established for converter internal losses in an operating converter.

The emitter side of the thermionic converter (in one concept), or heat pipes which transmit heat to the emitter (in another concept), will be exposed to the harsh combustion furnace environment. The development of silicon carbide (SiC) or superalloys as protective coatings to preserve the integrity and performance of the thermionic converters (or heat pipes) over extended periods is the objective of the hot shell development task.

Bridging the gap between laboratory applied research and engineering development and demonstration requires the application of technology from the former to the engineering hardware of the latter. The objective of the performance tests is to develop and test, in a simulated or actual combustion furnace environment, thermionic modules, consisting of several thermionic converters connected in series, to demonstrate acceptable module performance in an operational environment.



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J. MAGNETOHYDRODYNAMICS (MHD)

Commercialization is the ultimate goal of MHD power development. This follows the national drive to use coal more effectively as a replacement for oil in the generation of electric power. The potential efficiency advantages of MHD, if realized, would accomplish this at less cost and environmental intrusion, and with less coal use than any other directly coal-fired system.

The immediate objective of the MHD program is to facilitate the commercialization of MHD electric power plants through the design, construction, and operation of a 500 MW_t commercial prototype MHD power plant, designated as the Engineering Test Facility (ETF). Operation of this plant would demonstrate the commercial readiness of MHD as a future source of low-cost, coal-fired central-station electric power. Its principal advantages are that it burns coal directly to produce electricity; it can be coupled to a steam electric generator to improve the overall efficiency of a base-load plant; and environmentally, it offers the advantage that sulfur is removed as an inherent part of the process, thus reducing the need for extensive subsidiary cleanup equipment (e.g., flue gas desulfurization). Recent experiments further indicate that NO_x formation can be effectively suppressed. Another environmental advantage is that, because at least 50 percent more power is produced from a given quantity of coal, less heat is thrown away, less cooling water required, and less coal must be mined, transported, and processed. Studies indicate that a mature, coal-burning, base-load, MHD/steam power plant could:

- Achieve overall coal-to-busbar energy conversion efficiencies in the 50 percent range.
- Meet all existing or proposed Federal standards for SO_x and NO_x and particulate emissions with reduced thermal pollution.
- Achieve a cost of electricity lower than potential alternative power systems.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

MAGNETOHYDRODYNAMICS	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Open-Cycle Plasma Systems	78,500	73,000	69,500
Closed-Cycle Systems	1,000	2,000	2,000
Capital Equipment	500	0	500
TOTAL	80,000	75,000	72,000

1.0 OPEN-CYCLE PLASMA SYSTEMS

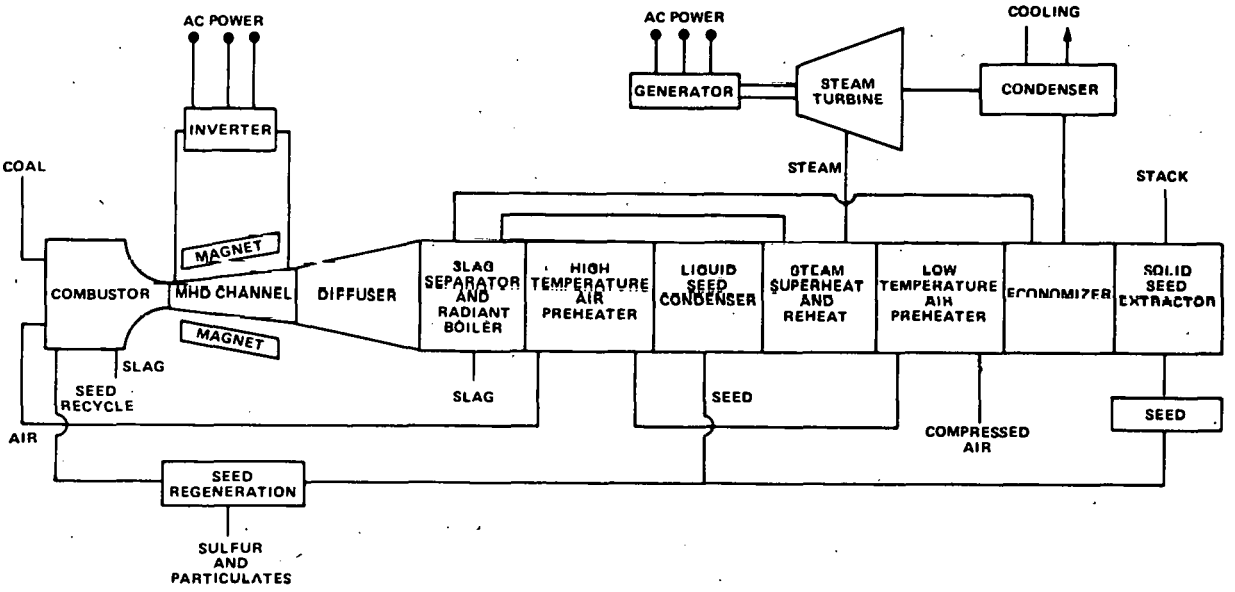
The MHD Process

MHD power generation is based on the direct conversion of heat to electricity by passing a high-temperature, high-velocity, electrically conducting fluid through a magnetic field. The principle is similar to a conventional turbine generator system, but differs in that the rotating conductors of a turbogenerator are replaced in open-cycle MHD by a partially ionized combustion gas which is accelerated to near sonic velocity, and then interacts with the magnetic field. The interaction of the high-velocity conducting fluid with the transverse magnetic field induces an electric field within the fluid. If electrodes are present to collect the current, then electric power can be supplied through an inverter to a utility power grid. The high temperatures of the conducting fluid, compared to the temperatures in a conventional steam turbogenerator system, increase the available energy which accounts for the efficiency advantage obtained with MHD.

Potassium seed is injected into the combustor in the form of potassium carbonate to achieve adequate levels of electrical conductivity in the combustion products at the temperature involved. This requirement provides a unique built-in capability for removing sulfur pollutants produced during the combustion of high-sulfur-bearing coals. The ionized potassium seed recombines preferentially with the sulfur downstream of the MHD generator, and the products are then removed from the system in the form of potassium sulfate, which is then regenerated to potassium carbonate to recover the seed and separate the sulfur.

The combustion products leaving the MHD generator are no longer appreciably conductive electrically, but still have a temperature in the range of 3000°F. The remaining large amounts of available thermal energy downstream of the generator are used to generate additional power by using

a bottoming steam-turbine power plant. A schematic of a typical MHD/steam power plant is shown in the accompanying figure.



Open-Cycle Coal-Fired MHD System

The concentration of NO_x products in the exhaust gas is minimized by a combination of two-stage combustion and controlled gas stream cooling. High-temperature combustion (which virtually eliminates all of the fuel-bound nitrogen) can be initially "fuel rich" to minimize NO_x formation and can then be completed at lower temperatures. Additionally, by controlling the cooling rate of the gas stream (above the NO_x "freezing" point), the NO_x products can be allowed to decompose to the equilibrium values of nitrogen and oxygen.

The Open-Cycle Program

A new strategy for the open-cycle baseline program plan pursues a two-step approach to commercialization rather than the old three-step approach. The first step, Phase I, lays the engineering groundwork for the design of an MHD commercial prototype plant, termed the Engineering Test Facility. Commercialization is then facilitated, in Phase II, by the construction and operation of the ETF. The ETF utilizing an innovative oxygen enrichment approach will be a fully integrated, combined-cycle MHD/steam system operating at a power level of approximately 500 MW_t. This power level is considered to be the minimum level needed to demonstrate the commercial readiness of an open-cycle MHD power plant.

Specific engineering requirements are being established through analyses of cost and performance criteria for an early commercial plant. Research and

development work focuses on these requirements. Component and subsystem designs are being developed for validation by "milestone" qualification testing.

Phase I primarily focuses on the development of engineering components and subsystems, generally at up to a 20 MW_t size, by industrial contractors. Engineering development progress in Phase I is monitored through a succession of critical 50 to 100 MW_t tests in the Component Development and Integration Facility (CDIF) and 20 MW_t tests in the Coal-Fired Flow Facility (CFFF). Enhancement of the CDIF will allow testing at the 100 MW_t range.

Successively improved component and subsystems designs are selected from the 20 MW_t development work, scaled up, and integrated in these qualification tests. This progression culminates in the determination of an ETF design, leading to Phase II. At this stage, construction and operation of the ETF is undertaken by an industrial contractor team (under the direction of a systems manager). Under this plan, commercialization is facilitated in a conservative manner, i.e., development progress at 20 MW_t is validated at up to 50 to 100 MW_t and, when appropriate, translated to the ETF at 500 MW_t.

Through an innovative oxygen enrichment approach utilizing available air separation plants, the need for developmental activity in separately fired air heaters has been eliminated. This innovation allows the two-phase approach to proceed with a high technical confidence level that was not previously available to the MHD program.

Since the early 1970s, MHD development emphasis has progressively shifted from studies of a fundamental nature to its present large-scale engineering focus. In that time period, progress has exceeded expectations. Impressive gains have been achieved in demonstrating generator efficiency, channel durability, and superconducting magnet performance. In addition, substantial progress has been made in development of coal combustors, air heaters, and heat and seed recovery subsystems. Major accomplishments in the MHD program include:

- Generator: completed scheduled 500-hour generator endurance tests under electrical and thermal conditions simulating commercial services and achieving order-of-magnitude improvement in electrode corrosion/erosion resistance.

- Generator: initiated generator testing at 250 MW_t in the Arnold Engineering and Development Center (AEDC). Long-duration U.S. generator testing will shortly be initiated at the U.S.S.R. U-25 Pilot Plant.

- Generator: initiated subsonic generator testing at a high magnetic field (5 tesla) using the U.S.S.R. U-25B test facility.

- Generator: confirmed capability of extracting energy from the MHD generator at high efficiency (15 percent enthalpy extraction).

- Magnets: superconducting magnet-design principles confirmed for large superconducting magnets by continued operation of a 40-ton, 5-tesla magnet at design conditions. Final designs have been completed for larger size magnets.

- Combustor: slag rejection in excess of 90 percent with carbon conversion of 97 percent achieved in 20 MW_t prototype of a two-stage combustor for MHD application.

- Environmental: achievement of 95 percent sulfur removal from high-sulfur coal as well as NO_x reduction to 20 ppm in small systems.

- Air Heaters: achieved 1,000-hour cumulative testing at 2700°F on a direct-fired regenerative air preheater element under heat transfer, fluidynamic, and seed/slag conditions simulating MHD service; 100-hour continuous run on a complete subscale, separately fired heater at 3000°F using simulated coal firing with ash carryover into the heater matrix.

Major anticipated accomplishments for FY 1980 include:

- CDIF facility activation and initial component testing at the CDIF

- Initiation of design of a Heat Recovery and Seed Recovery (HRSR) Subsystem

- Initiation of testing at the CFFF

- Initiation of testing of a 250 MW_t U.S. generator in the U.S.S.R. U-25 MHD Pilot Plant

- Continued testing at the AEDC 250 MW facility.

The potential offered by open-cycle MHD is supported by data obtained from the Energy Conversion Alternatives Study (ECAS). This study, jointly sponsored by ERDA, NASA, and the National Science Foundation, showed that MHD promised the highest efficiency of all the base-load power systems considered. ECAS predicted that a combined-cycle MHD/steam power plant could achieve a coal-to-busbar efficiency approaching 50 percent at a cost of electricity of approximately 32 mils per kWh, as compared to a 1975 cost of approximately 37 mils per kWh for a conventional coal-fired power plant. Furthermore, sulfur and NO_x emission levels below 0.55 pounds per million Btu and 0.3 pounds per million Btu, respectively, were predicted without requiring significant pre-processing of coal or stack gas cleanup. These levels compare favorably with the existing EPA New Source Performance Standards (NSPS) of 1.2 pounds per million Btu and 0.5 pounds per million Btu, respectively for sulfur and NO_x. More recent experimental and analytical evidence indicates the promise of reducing NO_x and SO_x emissions well below the NSPS.

The ECAS study, performed by industry for the Federal Government, was directed mainly to base-load power system concepts. The potential benefits of cogeneration in the energy-intensive industries, retrofit of existing

plants, and application to peak loading were not considered. Each of these benefits is postulated to be very significant in special circumstances.

Two additional studies, Operational Analysis of MHD and Comparative Study and Evaluation of Advanced Cycle Systems, have recently been performed for the Electric Power Research Institute by major industrial contractors. The results of these studies further support the technical conclusions of ECAS and also indicate strong potential market penetration for MHD.

The program requires the development of a strong technology base to support the large-scale integrated engineering needed to facilitate commercialization of MHD electric power plants. The main concerns in the current, initial phase are to establish basic engineering design data, to apply these data to the engineering development of components, and, finally, through progressively stringent test screening, to select specific designs for integrated subsystem tests. Guided by environmental and economic requirements, various design choices and operating modes will be tested and refined to provide the technical specifications necessary to meet commercial cost and performance criteria. These experimental activities will be backed up by comprehensive and continuing systems analyses to establish realistic technical requirements and cost data. Trade-off studies are required to direct the overall system concept towards the most advantageous designs. Such realistic system studies are essential to focus the experimental work on commercially valid goals.

MHD Program Implementation

The program utilizes numerous facilities at various locations in 15 states. Two major government test facilities are also being completed to accommodate key development and integrated engineering tests at larger scales than are available elsewhere in the United States.

The first major government test facility, the CDIF, is located in Butte, Montana. This facility will be the principal facility within the MHD program for continuous testing of engineering-scale power trains. Initial testing at the CDIF will be at the 50 MW_t level, with later enhancement to a scale of about 100 MW_t. The CDIF is the largest coal-fired MHD facility in the United States capable of continuous operation. It will be a highly flexible test facility for MHD component and integrated power train testing. The purposes of the CDIF are to:

- Evaluate the performance of MHD components and systems and compare the performance of different designs.
- Provide the critical engineering design base to scale MHD system designs to commercial prototype sizes.

It is expected that a major portion of the data for the ETF design will be validated through CDIF testing. The facility is to be equipped with both superconducting and conventional iron-core magnets. The coal processing and feed system is designed to handle both eastern and western coals. Additionally, the facility can accommodate multistage coal combustors that may have a

slag rejection of up to 90 percent. The CDIF facility is to be activated in FY 1980. Major components are now being installed; completed support systems are being checked out.

The second facility is the CFFF and is located adjacent to the University of Tennessee Space Institute near Tullahoma, Tennessee. It will be capable of continuous operation at a nominal input of 20 MW_t and short-duration testing at higher levels. The mission of the CFFF is development testing of components simulating the complete MHD/steam system, in particular, under conditions of 100 percent slag carryover from the coal combustor. In addition, the CFFF will be used for development testing of the heat recovery and seed recovery system now being developed by the Department of Energy. User testing can also be accommodated to provide a test capability for contractors who may not have access to a facility of this type. The CFFF will be equipped with both superconducting and conventional iron-core magnets. Presently, the CFFF construction is over 95 percent complete, and the facility will be activated in FY 1980.

Two other key projects are directly related to the orderly development of MHD. One of these, at the U.S. Air Force AEDC, is directed toward the quantification of scaling effects. Data generated through these tests will provide a firm basis for translating successful generator designs to the scale of the ETF. In addition, operational data, which are being made available through the testing of the U.S.-built components of pilot scale in the U.S.S.R. Pilot Plant under the U.S./U.S.S.R. Cooperative Program, are expected to further strengthen engineering design confidence in scaling to the ETF size.

2.0 CLOSED-CYCLE SYSTEMS

Closed-cycle is differentiated from open-cycle MHD in that for closed-cycle the working fluid operates in a closed loop rather than being exhausted to the atmosphere. In this approach, a noble gas (argon) is seeded with cesium to enhance its electrical conductivity, cycled through the MHD flow-train and steam system and then recompressed and recirculated through the system. Because of "nonequilibrium ionization," the cesium-seeded argon plasma attains useful electrical conductivity at temperatures of about 3000°F, a relatively low temperature for an MHD process. To maintain the required system conductivity, the argon flow must be kept free from contamination by combustion products. The contaminant carryover into the argon occurs in the heat exchanger process of heating the compressed argon to 3000°F prior to its passage through the closed-cycle MHD generator. Typically, a ceramic regenerative heat exchanger is used to transfer the coal-generated heat energy to the argon gas. Successful design and development of this heat exchanger has been identified as the pacing technology for closed-cycle MHD.

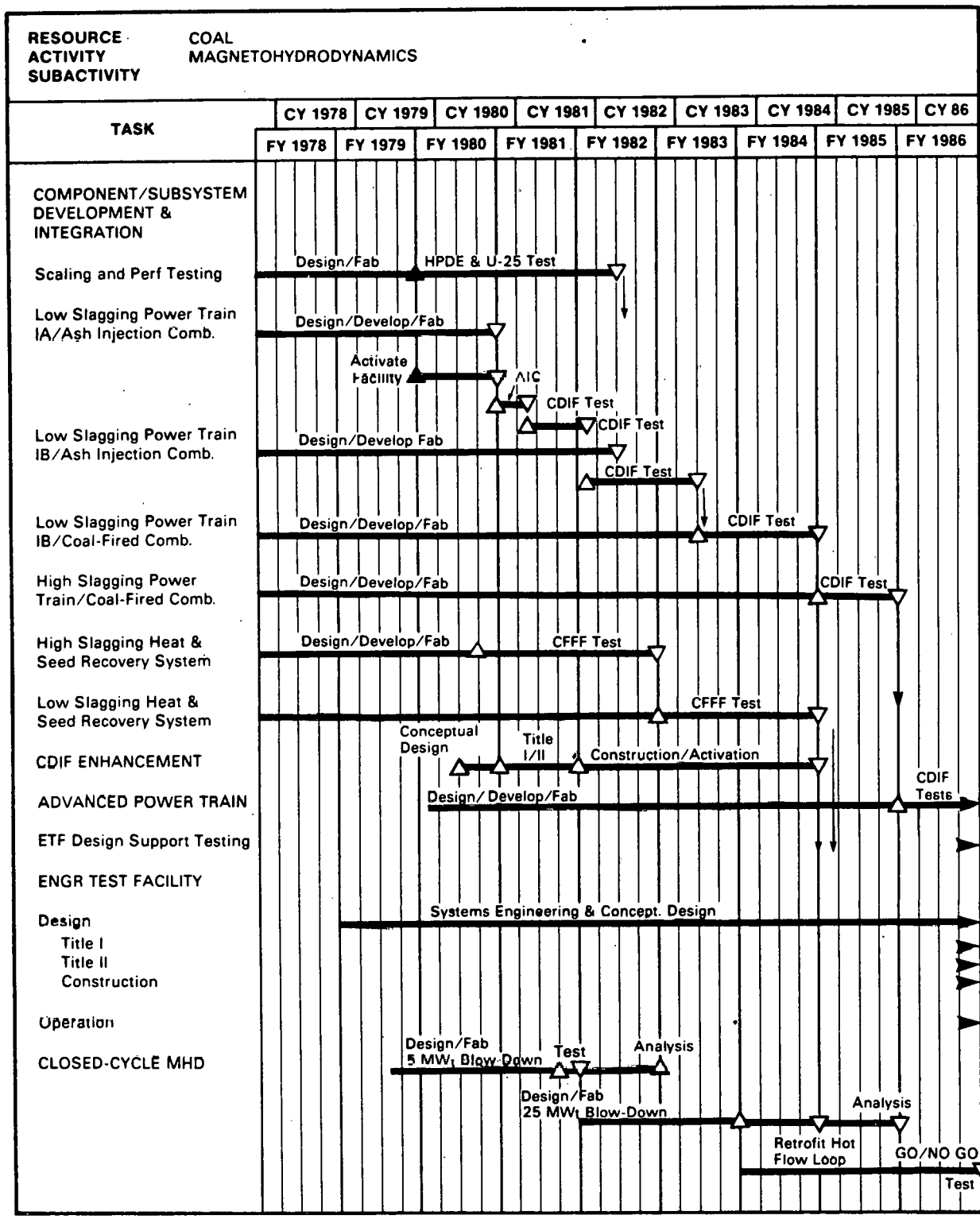
Current work in closed cycle focuses on three main activities:

- Systems engineering studies which will provide an assessment of closed-cycle MHD power plants and associated technology requirements

- Experimental studies of the compatibility of a coal-fired combustor with a regenerative heat exchanger

- Design of a major blow-down experiment of a 25 MW_t input.

Under a recently signed cooperative agreement with the Netherlands, the U.S. will design and fabricate a channel to be tested in the 5 MW_t blow-down facility at the Technical University of Eindhoven, the Netherlands. The 5 MW_t data will contribute significantly to the larger scale of the U.S. blow-down experiment.



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IV. ACTIVITY DESCRIPTION — PETROLEUM

PETROLEUM RESOURCE OVERVIEW

Petroleum will continue to be one of the Nation's major energy sources for many years with domestic petroleum demand expected to be about 18 million barrels a day (18 MMbbl/d) in 1980. The Fossil Energy mission supports the goal of developing the science and technology necessary to increase U.S. reliance on domestic energy. Activities supported through the Fossil Energy Petroleum Program include developing more efficient techniques for recovering petroleum and developing more effective methods for extracting petroleum from unconventional petroleum resources.

The effort in this Resource Program is divided into the four research and development areas discussed below.

Enhanced Oil Recovery

The goal of the EOR Activity is to develop the technology necessary to increase the Nation's recovery of domestic petroleum. This program can increase domestic petroleum production by developing more efficient recovery technologies, by enlarging the resource target for enhanced recovery, and by accelerating the development of improved technologies and making all related information readily available to small independent producers. In addition, unit costs of oil production can be reduced, and the new technologies are potentially exportable to such areas as Venezuela, where large oil deposits requiring enhanced techniques exist.

With decontrol of heavy oil prices and the recent amendments to the ERA pricing regulations, the FY 1981 EOR program will continue with the same general philosophy as in FY 1980. Emphasis will be placed on collection and analysis of data from ongoing field tests (both directly funded and through the ERA regulation) to better understand process behavior. Research will continue to develop new and improved recovery techniques, and small field experiments will be conducted as new techniques are developed to identify problem areas where further research is necessary. The program has been restructured from a technology orientation (steam flooding, carbon dioxide flooding, etc.) to a resource-oriented structure (light oil, heavy oil, tar sands). This allows an expanded investigation into the optimum recovery techniques for each resource. One new area that has emerged from this is the beginning of investigations in FY 1980 into the mining of heavy oil and tar sands.

The main thrusts of the Light Oil subactivity in FY 1981 will be collection and analysis of field test data and continued research on improved micellar-polymer and carbon dioxide flooding processes. The Heavy Oil subactivity will emphasize research and a small field test of methods which use additives to improve the sweep efficiency of steam drive. Also,

prototype downhole steam generators are scheduled to be constructed and begin field testing during FY 1981. The first tar sand steam-drive field experiment will be completed and evaluated during FY 1981, leading to a second field experiment later in the year using a process to be determined based on the results of the first steam experiment. Extensive efforts will also continue to define and evaluate the domestic tar sand resource.

Oil Shale

The Nation's oil shale resources constitute the most promising alternative source of petroleum fuels to crude oil. Although coal, tar sands, and other resources are additional alternative resources for petroleum-based fuels, cost estimates consistently indicate that shale oil is the next higher cost alternative to natural petroleum.

Two basic recovery and processing techniques for oil shale are (1) conventional mining plus surface retorting, and (2) in situ recovery. Surface retorting technology for the higher grade oil shales is generally considered to be ready for commercial scaleup and demonstration. DOE is sponsoring cost-shared engineering design studies.

In situ technologies, however, are still developmental and receive the major amount of government-sponsored research and development support. This support involves true and modified in situ recovery, where the latter requires that an initial fraction be removed by mining prior to in situ recovery. Government-sponsored research and development projects include true and modified in situ technologies for the recovery of shale oil.

The potential advantages of in situ versus surface retorting technologies are lower production costs and fewer environmental impacts. Lower production costs may eventually make it possible to economically process lower grade shales.

Drilling and Offshore Technology

The most promising areas for major discoveries and production of conventional petroleum and natural gas lie in the offshore areas and in the deeper onshore zones. One of the factors inhibiting activities in these areas is the need for improved and more efficient drilling technologies. Government-sponsored research and development activities are involved in the development of these advanced drilling technologies, increasing the productivity of conventional drilling technologies, and in mitigating the environmental impacts of new drilling and production technologies.

Included in the FY 1981 program will be systems analysis of conventional drilling techniques, development of geotechnical measuring instruments, and data analysis of geotechnical parameters affecting offshore drilling and production operations.

Advanced Process Technology

The Advanced Process Technology subactivity is oriented toward exploratory research in advanced process technologies, petroleum product characterization and utilization, and refining processes for shale oil.

The Advanced Exploratory Research effort will pursue two major thrusts: basic technology development and new process concepts. Basic technology development includes developments in rock mechanics and fragmentation, in situ heat transfer, and mass transfer with fluid flow (hydrology). Rock mechanics and fragmentation (the development of enhanced permeability in the rock matrix) is a controlling factor in virtually all in situ processes and is thus applicable to oil shale retorting, enhanced oil recovery, unconventional gas recovery, and in situ coal gasification. Hydrology (the flow and composition of formation water) also has an impact on the success or failure of in situ processes involving EOR by micellar and surfactant flooding, unconventional gas recovery, oil shale retorting, and in situ coal gasification. New process concepts includes new approaches to oil shale retorting and improved recovery of conventional hydrocarbons.

The Product Characterization and Utilization element focuses on the analysis and characterization of crude oil, heavy oil, and tar sands, including analysis of asphalt as a function of road life.

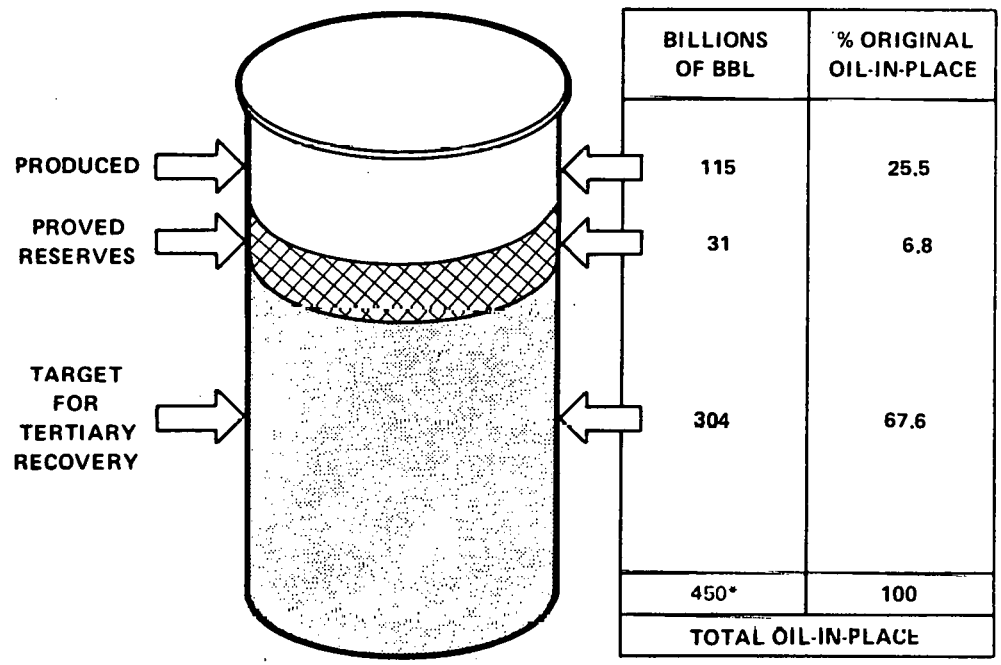
The goals of the Shale Oil Refining Research program are to continue the state-of-the-art shale oil refining studies, develop processes related to the refining of heavy crude oil, determine the nature of stability and performance of shale oil fuel products, and develop technology to remove nitrogen with minimum hydrogen consumption.

The following table summarizes the funding levels by Activity for the FY 1979 to FY 1981 period.

PETROLEUM RESOURCE	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
ACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Enhanced Oil Recovery	46,872	23,100	19,400
Oil Shale	48,600	28,200	36,048
Drilling and Offshore Technology	2,600	3,000	2,370
Advanced Process Technology	2,200	6,000	5,000
Program Direction	582	781	940
TOTAL	100,854	61,081	63,758

A. ENHANCED OIL RECOVERY

Over two-thirds of the oil discovered in the United States remains unrecoverable by conventional (primary and secondary) production technology. This amounts to over 300 billion barrels left in the ground. Additional recovery of even a small portion of this oil by improving the technology of oil recovery could greatly reduce the Nation's dependence on imports. Producing some portion of this remaining oil is the purpose of enhanced oil recovery (EOR), the application of advanced technology to crude oil production. EOR methods can also be implemented as primary or secondary techniques in certain reservoirs, resulting in lower recovery costs and higher ultimate oil recovery.



Production, Reserves, and Residual Oil-in-Place — Total United States, Including Offshore and Alaska

Ultimately, wide-scale application of EOR technology in the Nation's oil fields will be carried out by the petroleum industry. Important questions remain, however, concerning the directions and levels of industry's EOR activity and whether public research and development can stimulate additional activity.

Major Resource Types

As of January 1, 1978, the API data base shows the following potential EOR targets.

	BILLION BARRELS		
	LIGHT OIL	HEAVY OIL	TAR SANDS
Original Oil In Place	350	100	30
Recovered to Date (by conventional means)	90	25	–
Remaining Proved Plus Indicated Reserves (by conventional means)	30	1	–
EOR Target	230	74	30

The resource base is further delineated by a variety of geological and geographical criteria that influence the most appropriate type of recovery technology. For example, offshore applications place logistical limitations on the most appropriate enhanced oil recovery technology. The basic lithology, sandstone versus carbonates, influences the type of injection material that would be selected. The depth of the reservoir and its associated pressure and temperature relationship influence the technical efficiency of the selected EOR injection material. The gravity of the crude may determine the method of recovery.

Potential Benefits

The primary benefits from undertaking R&D in enhanced oil recovery are:

- A more efficient technology that would recover a larger fraction of the remaining oil. The recovery efficiencies of some existing EOR processes may be improved by as much as 50 percent by advanced second-generation recovery technology.

- An enlarged resource target for EOR by expanding the applicability (e.g., technical limits) of the enhanced recovery techniques to more reservoir and oil types.

- An accelerated pace of EOR technology development, including broader access to this technology by independent producers; years of testing by industry have yielded only one enhanced recovery process, steam drive for shallow, heavy oil reservoirs, that approaches conventional application; intensive research and a pooling of industry/government expertise toward key problems could accelerate the pace of technology and innovation.

- Lower unit costs of oil production would help hold down inflationary pressures stemming from higher oil prices; analysis shows that improved EOR technology could lower production costs by about $3.00 per barrel.

- A potentially exportable technology. A considerable portion of the world's oil resource is not recoverable by conventional techniques. Advanced technology could provide the U.S. with continued access to overseas oil and increase the competitiveness of the domestic petroleum industry.

Program Direction

The EOR Activity was significantly redirected in FY 1980 as a result of the amended ERA pricing regulations. The amendment will allow oil producers to sell oil currently under price controls at market prices, with the incremental profit being applied to an approved EOR project. The upper limits on this rule are 75 percent of the project expenses, up to $20 million. It is expected that as many as 100 EOR projects may be stimulated by this rule, so that direct funding of new EOR pilots and demonstrations can be limited. However, the responsibility for monitoring these projects and analyzing and disseminating the data still lies within the EOR program, although funding for this responsibility has not been provided.

As a result of this redirection, the EOR budget was significantly reduced in FY 1980 from that of FY 1979. This reduced budget represents the elimination of direct funding for new field pilots and demonstrations and does not provide for monitoring field tests under the incentive program. The remaining program will place a strong emphasis on analyzing the results of ongoing projects (both direct funded and from the ERA regulation) with the purpose of developing an understanding of the technical and economic factors of each project. A high priority will continue on research for new or improved recovery processes, and small field experiments will be conducted as advanced processes become available, to identify problems and areas where additional research is needed. Some direct funding for pilot tests may again become necessary in future years, as it is questionable if the ERA regulation or decontrol will be sufficient to stimulate pilot tests of advanced, untested processes.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

ENHANCED OIL RECOVERY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Heavy Oil	20,329	7,250	7,900
Light Oil	23,819	10,550	5,000
Tar Sands	2,024	4,800	5,900
Capital Equipment	700	500	600
TOTAL	46,872	23,100	19,400

The EOR Activity underwent two shifts in organizational structure during FY 1980. First, the internal structure was revised from a technology-oriented (micellar polymer, thermal, etc.) to a resource-oriented structure (heavy oil, light oil, tar sands). Within each resource, the existing gaps in the technology are identified and a program is laid out to develop the necessary technology for optimum development of each resource.

Second, implementation of the EOR Activity has been decentralized from headquarters to the field. Headquarters retains responsibility for overseeing the entire program, and providing policy and budget guidance. Headquarters and the field work together formulating the program, which is then implemented by the field. The Bartlesville Energy Technology Center (BETC) has been designated as the lead center for petroleum recovery (light and heavy oils), and the Laramie Energy Technology Center (LETC) has been designated as the lead center for tar sands recovery. Reporting through BETC, the San Francisco Operations Office is responsible for the heavy oil program, and the Morgantown Energy Technology Center (METC) conducts the carbon dioxide flooding portion of the Light Oil subactivity. A special activity, Project Deepsteam, is conducted through a management agreement with Sandia Labs, Albuquerque.

The Main FY 1981 thrusts for each subactivity are as follows.

Heavy Oil

- Continue resource assessment and reservoir characterization efforts.
- Continue development of downhole steam generators and thermally efficient well completions (Project Deepsteam).
- Continue development of improved sand control methods.

- Continue R&D efforts for additives to improve the sweep efficiency of steam drive.
- Continue to monitor heavy oil field tests.
- Conduct field experiment of improved steam drive process with additives.

Light Oil

- Continue to monitor and analyze the ongoing field projects, within budget limits.
- Continue in-house micellar-polymer research program.
- Continue in-house and university research on carbon dioxide flooding, including phase behavior and mobility control studies.
- Continue examining potential carbon dioxide and chemical supply sources.
- Continue environmental risk analysis.

Tar Sands

- Begin cost-shared field experiment of in situ recovery process resulting from an FY 1980 program opportunity notice (PON).
- Continue expanded resource assessment activities begun in FY 1980.
- Continue studies on sand control and permeability enhancement.
- Continue laboratory and field experiments of thermal processes in tar sands.
- Continue evaluation of alternate extraction techniques.
- Continue characterization of lab and field products and begin bitumen upgrading studies.
- Continue environmental investigations and monitoring.

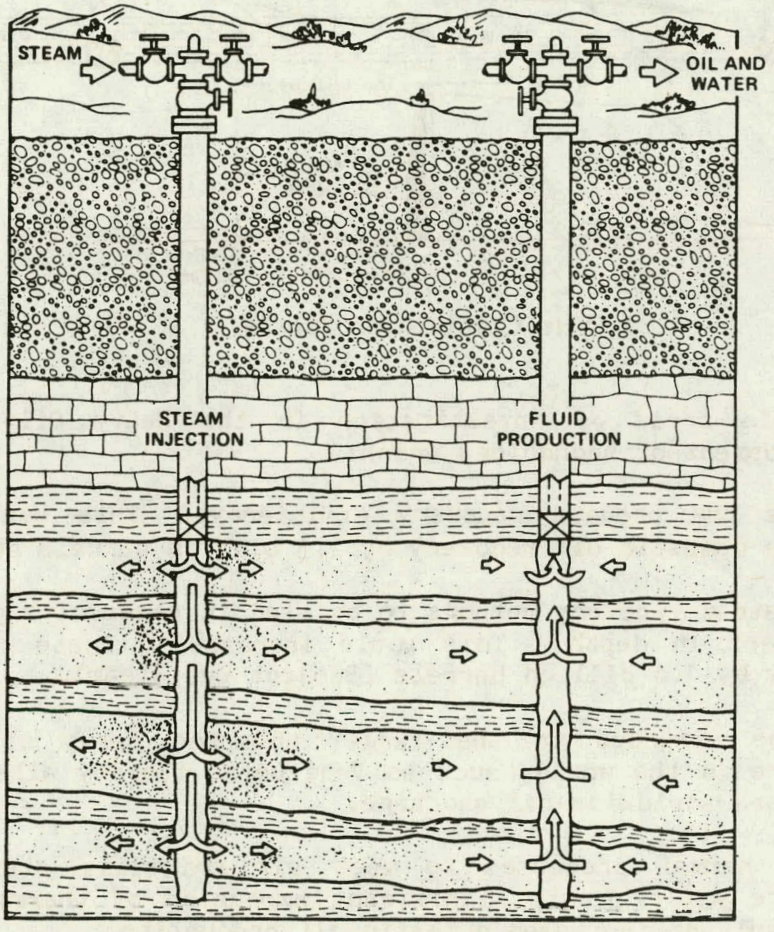
1.0 HEAVY OIL

The recovery of heavy oils by thermal methods developed during the 1960s, primarily in California. Many of the major heavy oil fields were discovered early in the century but did not realize significant production for 50 years. The neglect was due to heavy oil production problems, light oil availability and the lower refining yield of heavy crudes. Success with cyclic steam injection, or huff and puff, led to rapid production increases in the mid- and late-1960s. The 1973-74 embargo and subsequent price rises spurred new production in the mid-1970s. However, the recent implementation of strict environmental controls for ambient air quality have made further increases difficult. Additionally, market conditions, related to the lower

quality of heavy crudes and lack of required refining capacity, have further constrained heavy oil production. The new ERA price incentives and the President's decontrol of heavy oil prices seem to be increasing heavy oil recovery activity.

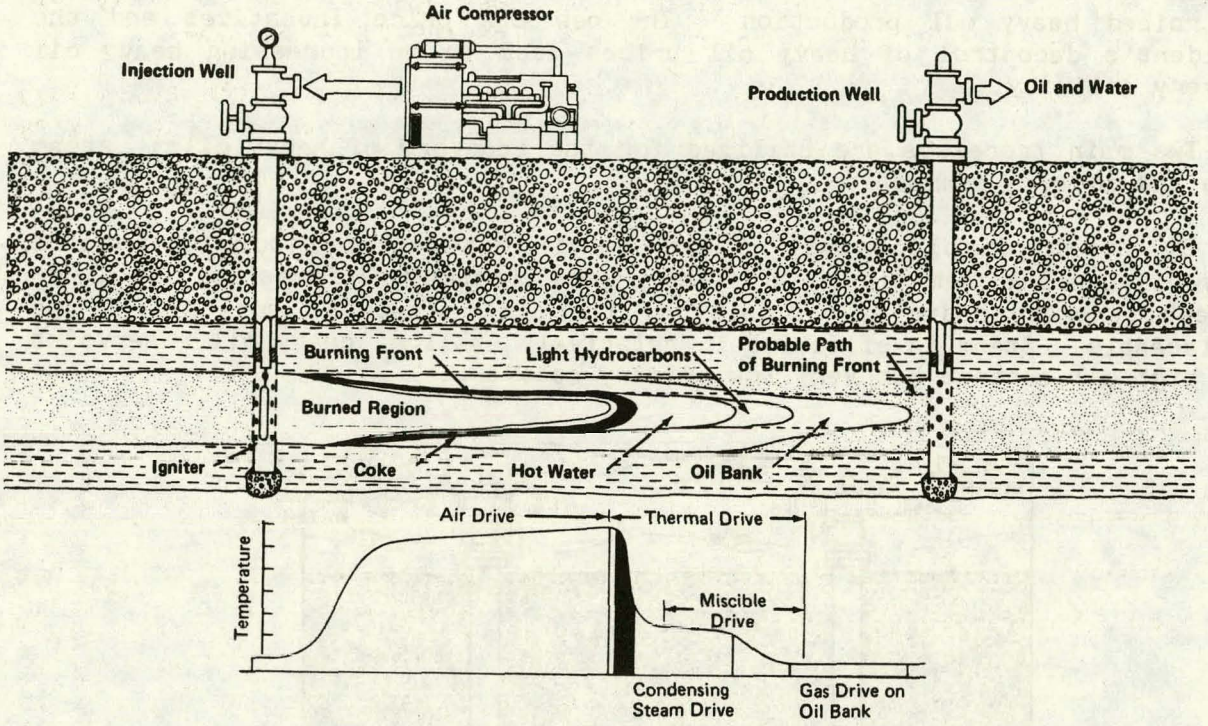
Two main processes are utilized for the recovery of heavy oils: steam drive and in situ combustion.

In steam displacement, steam is injected continuously into a heavy-oil-bearing formation. As steam passes through the formation, it gives up heat, thereby reducing viscosity of the oil to make it more mobile and displaceable. Steam is effective in relatively shallow, heavy oil reservoirs with high oil content but very low primary recovery.



Steam Displacement Process

In situ combustion (forward or reverse, dry or wet) is a process involving high-temperature oxidation in the reservoir itself by continuous injection of air or air and water. During the process, part of the oil is converted to coke which is then consumed to produce more heat. The water is turned to steam that, in turn, distills some of the oil ahead, making it more mobile and causing it to move more readily to the producing wells.



In Situ Combustion Process

The four main areas of investigation in the Heavy Oil subactivity include the development of technology which:

- Improves the process recovery efficiency. This could increase ultimate domestic oil recovery by 2.3 billion barrels or more.
- Allows steam recovery methods to be used in reservoirs greater than 2,500 feet in depth. This would increase ultimate domestic oil recovery by 1.6 billion barrels (Project Deepsteam).
- Could be extended to the large, untapped heavy oil resources elsewhere in the world, such as Venezuela, thereby alleviating the forecasted worldwide oil shortage.
- Allows thermal processes to meet air emissions standards, and therefore would permit significant expansion of thermal processes with resultant increased domestic oil production.

Of these, the greatest emphasis is placed on research to improve the sweep efficiency and on the reduction of heat losses (Project Deepsteam).

Resource Assessment and Planning

This activity is composed of three tasks: planning; resource characterization; and reservoir evaluation. The planning effort involves preparing the necessary program plans, and working with other DOE elements

to evaluate and attempt to alleviate nonprocess constraints on heavy oil production, such as environmental, market, and refinery limitations.

The resource characterization effort emphasizes an active technology transfer program and an analysis of heavy oil fields, aimed at prioritizing candidate reservoirs for the application of EOR techniques. This study was begun in FY 1979 and will be completed during FY 1980.

The reservoir evaluation effort primarily involves support of the residual oil determination program being conducted at BETC (described in subsection 2, Light Oil).

Reservoir Access

This activity is primarily composed of Project Deepsteam, with additional activity in the areas of sand control, fracturing, and mining of heavy oil.

A major problem associated with steam recovery is the heat lost through the wellbore to the surrounding formations. This loss has basically limited steam operations in the U.S. to reservoirs less than 2,500 feet in depth. The purpose of Project Deepsteam is to develop the technology necessary to overcome these heat losses. One technique for accomplishing this is to insulate the well string. Sandia Labs, through a contract with General Electric, is conducting comparative tests of commercially available well string insulations and high-temperature packers to determine whether existing products can withstand the severe conditions or whether further development is necessary. These tests were completed in early FY 1980, and limited development work on high-temperature packers is expected to continue into FY 1981.

A second method is to generate the steam at the bottom of the hole, thus eliminating all heat losses through the well string. Two alternate designs are being developed by Rockwell and Foster Miller. One involves low-pressure combustion with the combustion gases being vented to the surface. The other design involves high-temperature combustion with the combustion gases being injected into the formation with the steam. Modeling efforts have shown a potentially significant improvement in the process performance with combustion gases added, primarily due to the effects of the carbon dioxide. In early FY 1980, a two-well field experiment was begun with the cooperation of Chevron to try to confirm these predictions and also to determine if injection of the combustion gases would eliminate or reduce the environmental constraints. The development of the downhole generators began late in FY 1977. Prototypes are currently undergoing testing in the laboratory, with construction of prototypes and field testing scheduled for FY 1981.

The activities in mining and sand control will involve low levels of research into new or improved methods evolving from basic assessment studies begun in FY 1980.

Recovery

Because of the high displacement efficiency of steam wherever it reaches into the reservoir, the main R&D emphasis in the recovery area is in efforts to increase the volumetric sweep of the steam. A good steam drive in a favorable reservoir may only recover 40 to 50 percent of the original oil in place.

The principal technological factor that impedes achieving higher recovery of the crude oil is the gravitational instability of the steam with respect to other reservoir fluids. It rises to the top of the formation and overrides the oil column. Oil is displaced by the pressure gradient which exists in the steam zone. As oil is displaced the steam zone grows in a vertical direction. As a result of the greater cross-sectional area available for steam flow, the pressure gradient decreases and, accordingly, so does the displacement of the oil at the interface between the steam zone and the oil column. A similar situation occurs in in situ combustion with the hot gases rising to the top of the formation and overriding the oil column. In consolidated formations, some relief from the bypassing of the steam or combustion gases can be achieved by sealing off the top of the producing interval with cement and repeating this as the vapor zone is progressively displaced downwards. In unconsolidated formations, it is impossible to perform adequate sealing operations because of the liners and gravel packs that are customarily used in such formations.

Schemes that have been proposed for effecting this plugging have been the injection of particulate suspensions or solutions that would precipitate solids within the porous media. Such approaches have not been successful in the past. A contributing reason is that plugging must occur in-depth within the formation; otherwise steam will rise into the upper depleted zone beyond the plugging radius. An alternate scheme recently proposed is the injection of foams into the depleted interval. However, this has not been adequately tested in the field. The ability of foams to reduce the permeability, and even plug permeable sands, is attributed to the work required to deform the extensive stabilized, interfacial area of the foam.

The EOR Activity has been sponsoring research at Stanford and USC for the development of high-temperature foams and surfactants that can penetrate into the formation and stabilize the front. The Stanford process is expected to be ready for field testing in FY 1981, and the USC process in late FY 1981 or FY 1982. Two contracts were signed at the end of FY 1979 for a series of field experiments using commercially available chemicals at several different fields to determine their effectiveness as blocking agents. These tests will continue into FY 1981.

Other research areas in the recovery activity include improving the displacement efficiency in the hot water swept zone, investigations into combination systems, such as carbon dioxide/steam, caustic/steam, etc., evaluation of novel concepts such as ultrasonic or microwave, and lab tests of surface recovery processes from mined material.

Preparation

This is a low level of effort program basically comprised of a continuation of work begun in FY 1979 to analyze produced fluid emulsions and develop emulsion breaking techniques. Also included is the continuation of studies, scheduled to begin in FY 1980, on analyzing the upgrading requirements for heavy oil.

Environment

This is an ongoing effort involving monitoring and compliance for field tests, and preparation of environmental plans and permits. Several studies were initiated in FY 1979, reviewing the impact of environmental controls on thermal EOR, and reviewing thermal EOR steam generator scrubbing systems. These studies will be completed during FY 1980.

Description of Heavy Oil Field Tests

Husky Oil Company, Paris Valley Field, California (In Situ Combustion): The Husky Oil Company field tested the combination thermal drive method of enhanced oil recovery aided by steam stimulation of producing wells in the Paris Valley oil field, Monterey County, California. The formation was ignited and air was injected for several months. Due to channeling of the heat front, poor injectivity in the Upper Lobe, bottom water entry and other causes, most of the producers did not respond to the burn and the project has been terminated. Some response to air-steam cyclic stimulation was obtained, but generally the stimulations were not economic.

Cities Service Oil Company, Bellevue Field, Louisiana (In Situ Combustion): The Cities Service Oil Company is field testing improved oil recovery by in situ combustion in the Bellevue Field, Louisiana. All facilities were completed and in production on schedule. In situ combustion has been initiated in all five air injection wells, and several-fold increases in production have been obtained. A combination of air and water is being injected. The project is on schedule. Several new patterns are in operation as part of full field development.

Getty Oil Company, Cat Canyon Field, California (Steam Flooding): Getty Oil Company has conducted a steam drive project in Cat Canyon Field, California. Four inverted 5-spot patterns encompassing 20 acres are involved. All producing wells were cyclically steam-stimulated to improve the oil mobility until steam from the injectors breaks through. The estimated recovery from the project is 850,000 barrels of oil, and steam injection has been underway for two years.

Santa Fe Energy Company-Chanslor Western Midway Sunset Field, California (Steam Flooding): This project is to demonstrate the operational and economic aspects of steam flooding a typical, low-pressure, flat, heavy oil reservoir that had an unfavorable response to cyclic steam stimulation. Encouraging incremental oil production has been obtained from the pilot test area, although later than predicted. Expansion of the pilot area to 14 patterns has been presented to Santa Fe Energy Company's management for consideration.

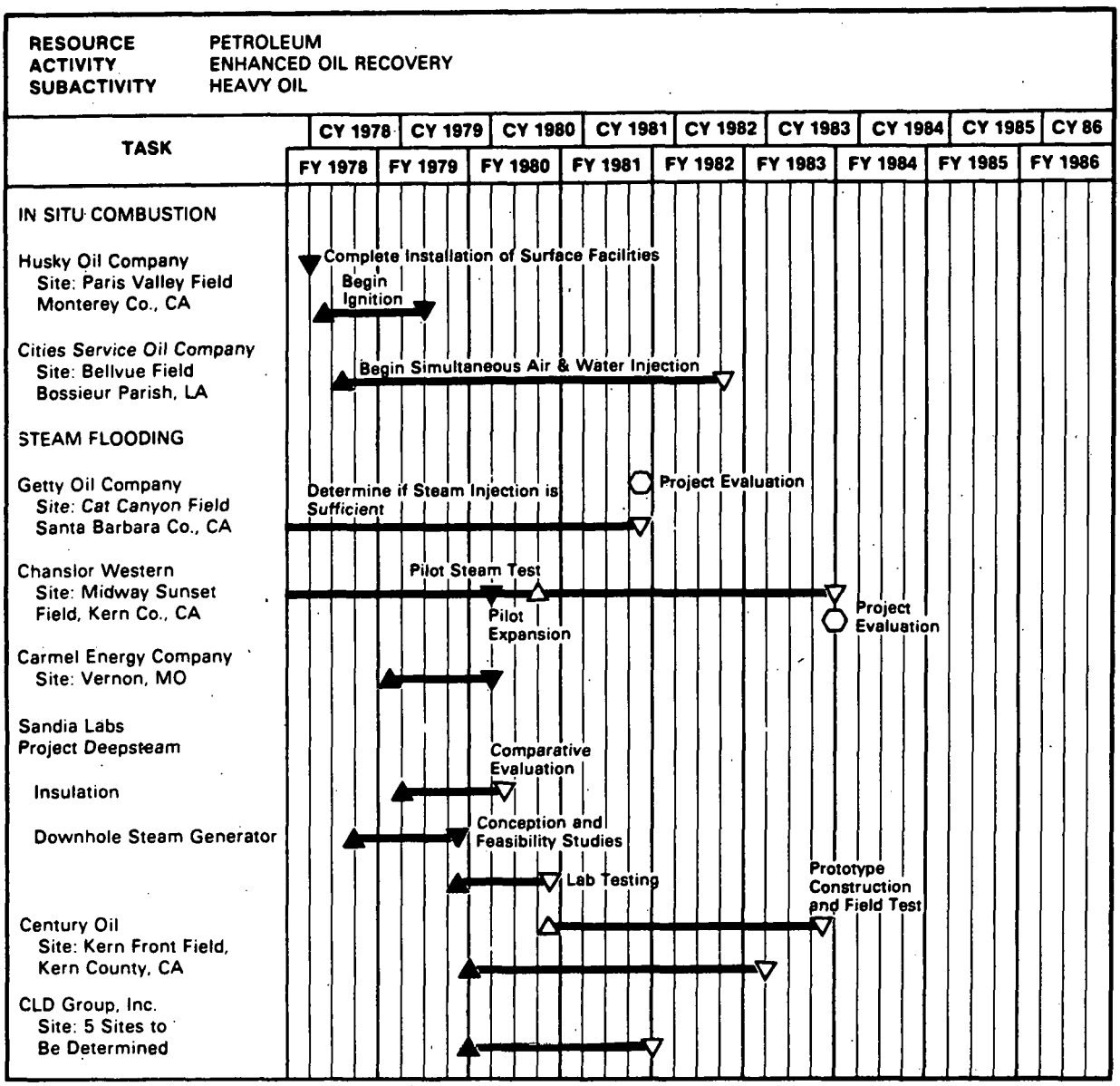
Century Oil Co., Kern Front Field, California: The primary goals of this project are to design, construct, test and evaluate processes to improve the oil displacement efficiency of the steam drive process. Based on previous laboratory and field experience with ancillary materials, a site has been selected to permit a side-by-side demonstration of the efficiency of ancillary materials in a conventional steam drive field project. Specifically, additives to the steam will be evaluated to determine the technical and economic merits of using ancillary materials to improve sweep efficiency. The four permeability alteration schemes that will be used to improve the vertical sweep efficiency are:

- Sequential injection of steam-foam
- Continuous injection of steam-foam
- Steam-foam-polymer combination
- Lignosulfonates as channel-plugging agents.

The contract for this project was signed in September of 1979.

CLD Group, Inc., Five Fields to be Determined: The purpose of this project is to field test the potential of channel blocking foams to increase the efficiency of steam drive operations, particularly in the shallow, heavy oil reservoirs of California. The project will consist of 5 tests using 5-acre, 5-spot patterns. To provide testing under a variety of conditions the pilot tests will be conducted in different reservoirs and under differing process adaptations. Laboratory tests, temperature logs and scaled physical-model runs will be used to support the tests and analyze results. Briefly, a slug of surfactant will be injected, followed by steam injection. The amount of chemical injected will be sufficient to achieve some minimum concentration in the liquid contents of the reservoir. The injection of steam and water will then be followed by noncondensible gas, either air or nitrogen, which will develop and stabilize the foam. This process may be repeated several times depending on the volume of the reservoir and the duration of the test. The contract to conduct this project was signed in September of 1979.

Project Deepsteam: The objectives of Project Deepsteam are to examine modified well completions for surface injection into deep reservoirs, develop economic downhole steam generators, and examine existing reservoir models for modifications required for steam injection into deep heavy-oil reservoirs. The project is designed to make deep steam drive a conventionally applied technique for producing low-gravity reservoirs. The downhole steam generators are currently undergoing laboratory testing, with prototype construction and field testing planned for FY 1981.



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2.0 LIGHT OIL

Waterflooding has been the dominant secondary means used for increasing the recovery efficiency of light oil reservoirs. Because water does not displace all oil from the pores as it moves through the reservoir rock, waterflooding has two major problems that impede its efficiency:

- Bypassing due to geological heterogeneity, which may be exacerbated by an unfavorable mobility ratio (water more mobile or effectively more viscous than the oil)
- A positive interfacial tension (a measure of the fact that water and oil do not mix) which results in some oil being dispersed into nonmobile residuals.

Altogether, 30 to 70 percent of the original oil-in-place remains after waterflooding, with the smaller residuals being found in well-sorted, clean reservoir sands with good continuity and crudes of low viscosity.

Early attempts to increase the viscosity of the injected water used natural gums which were subject to rapid hydrolytic and bacterial decomposition. About ten years ago, the hydrolyzed polyacrylamides were introduced as stable, water-soluble polymers for increasing the viscosity of water. Somewhat more recently, polysaccharides have also been offered on the market. Both additives exhibit the desired properties in the laboratory; they "thicken" the water so less bypassing and fingering occur.

Substantial quantities of oil are trapped by capillary action in the porous rock medium of the reservoir. (Capillary trapping is the resistance of a nonwetting fluid, oil, to flow through a microscopic pore or constriction which is wetted by a second fluid, water.) The original concept for using surfactants is to overcome the capillary forces, mainly by reducing the interfacial tension between the two fluids.

Very large decreases in the interfacial tension, however, are required at ordinary pressure gradients to release or prevent the trapping of residual oil by capillary action. Values of 10^{-4} dynes per centimeter, compared to the ordinary level of 30 dynes per centimeter between oil and water, are required to effect any significant reduction in the amount of oil held by capillary action. Early attempts to achieve these low values encountered problems with adsorption of the surfactants, particularly on delays.

More recent activity in this field has involved the preparation of highly concentrated slugs of surfactants. The surfactant slugs may initially be miscible with the oil and displace it over a significant length of the reservoir. However, adsorption, redistribution of chemicals, ion exchange, and thermal instability result in a loss of effectiveness of the chemical slug. The interfacial tension rises and displacement must continue under immiscible conditions.

Careful formulation has resulted in systems in which, under laboratory conditions, adsorption can be reduced and other damaging effects mitigated. Excellent results have been obtained with a number of proprietary systems.

Field results, however, have shown much poorer performance than would have been anticipated based on the laboratory studies. It may be that the actual reservoir and its configuration of oil and water have not been sufficiently well recreated in the laboratory, or that the process is vitiated by factors which have not been taken into account in assessing the results of laboratory studies.

Degradation of the polymer and surfactant effectiveness can be traced to salinity, temperature, and adsorption effects which are impossible to reproduce in the short systems used in laboratory studies. Of even greater suspected effect is the inability of the surfactant/polymer systems under reservoir conditions to initiate the buildup of the oil bank vital to the propagation of an effective process through the formation. The distribution of residual oil and water around an injection well, after the injection of large quantities of water under high-pressure gradients, also may not be

reproducible in the laboratory. As a result, the laboratory buildup of an oil bank occurs much more readily. Without the initiation of the oil bank, the process will behave more like the unstable injection of a surfactant solution alone, where the oil is produced by entrainment (emulsification) in the following surfactant stream. Many results of field pilots have suggested this to be the prevailing production mechanism.

The surfactants used in this process are generally mixtures of petroleum sulfonates and other chemicals (alcohols and salts) in aqueous solutions or as a microemulsion dispersed in oil (the micellar formulation). A variation is the in situ formulation of similar substances that results from the injection of caustic into reservoirs with oil containing specific (acidic) components. The displacement agent is driven through the reservoir by a polymer solution to maintain mobility control.

As of the end of 1977, enhanced recovery technologies being applied to light oils contributed about 120,000 bbl/d to domestic production. However, the bulk of this is due to hydrocarbon miscible gas injection (20,000 bbl/d), inert gas (45,000 bbl/d) and the SACROC CO_2 project (37,000 bbl/d). Moreover, due to the recent increases in natural gas prices, few major new efforts will rely on hydrocarbon miscible flooding, and carbon dioxide and inert gas flooding must fill the void.

The current status of enhanced recovery of light oils is as follows:

- Carbon dioxide miscible flooding projects have not produced sufficient data to evaluate this technique's true potential. Some limits on its applicability have begun to appear.

- Chemical processes have not fared well in the transition from laboratory to field pilot operation. Surfactant, polymer and caustic applications are the least predictable and the farthest from conventional application.

- Although steam drive is approaching conventional application in the shallow, high-saturation heavy oil reservoirs in which it has been applied, its potential for increasing the recovery of light oils remains to be proven.

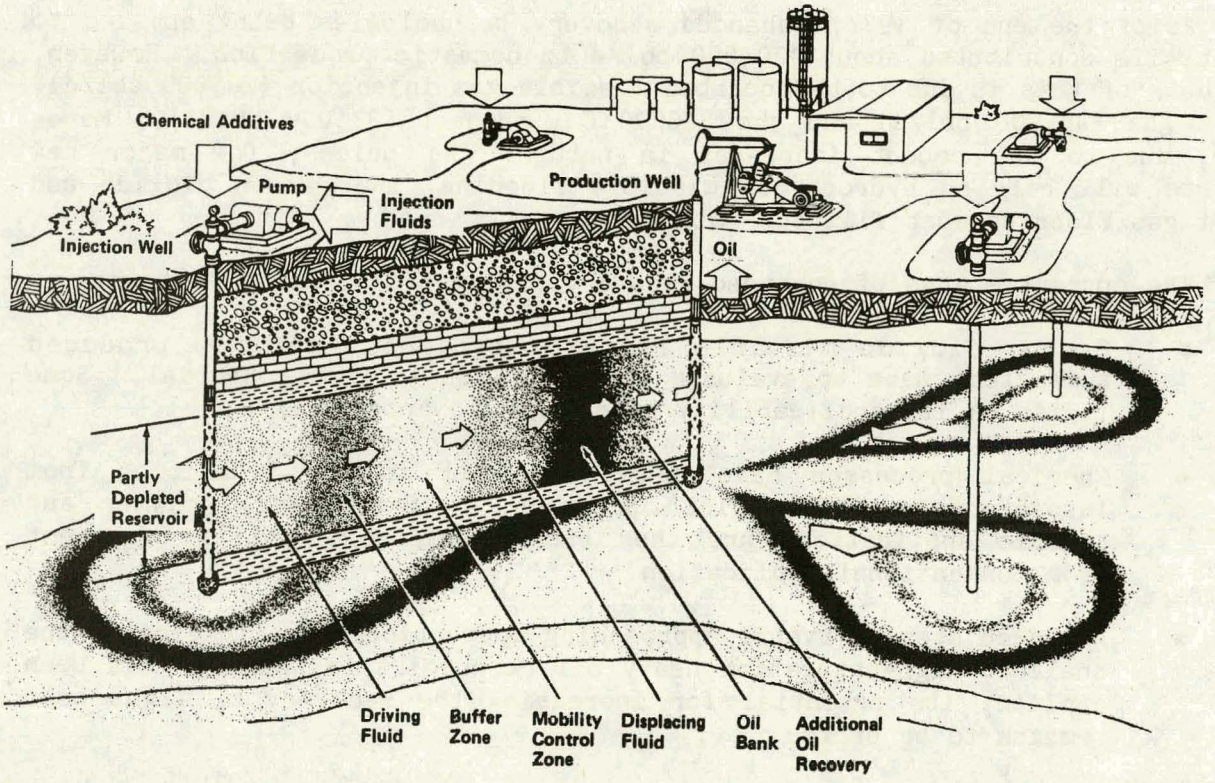
- Major difficulties with many techniques have been encountered in extrapolating from laboratory results to field tests. Demonstrations of effectiveness in the laboratory have not been replicated in the field. This argues that substantial basic research, both in the laboratory and in the field, is required for the less proven techniques.

- Ongoing and planned research and development by oil producers is concentrating on improving the effectiveness of EOR techniques for the most favorable reservoirs which the specific operators control. The greatest attention is being given to those candidates with the highest potential for early positive cash flows. Insofar as such reservoirs are major ones in the U.S., such action is correct and should be supported and expanded by DOE. DOE support should, in addition, be directed to those large reservoirs where, for economic

reasons, specific attitudes of the operator, and/or the risks involved, immediate and direct study of EOR is delayed.

- For the foreseeable future, it appears industry will concentrate on the most favorable reservoirs and will push a portion of the technology to conventional application. Less effort will be focused on seeking new leads for still more reliable technology for increasing recovery efficiency (the second-generation EOR technology) that is essential before EOR can make a substantial contribution to domestic energy supply.

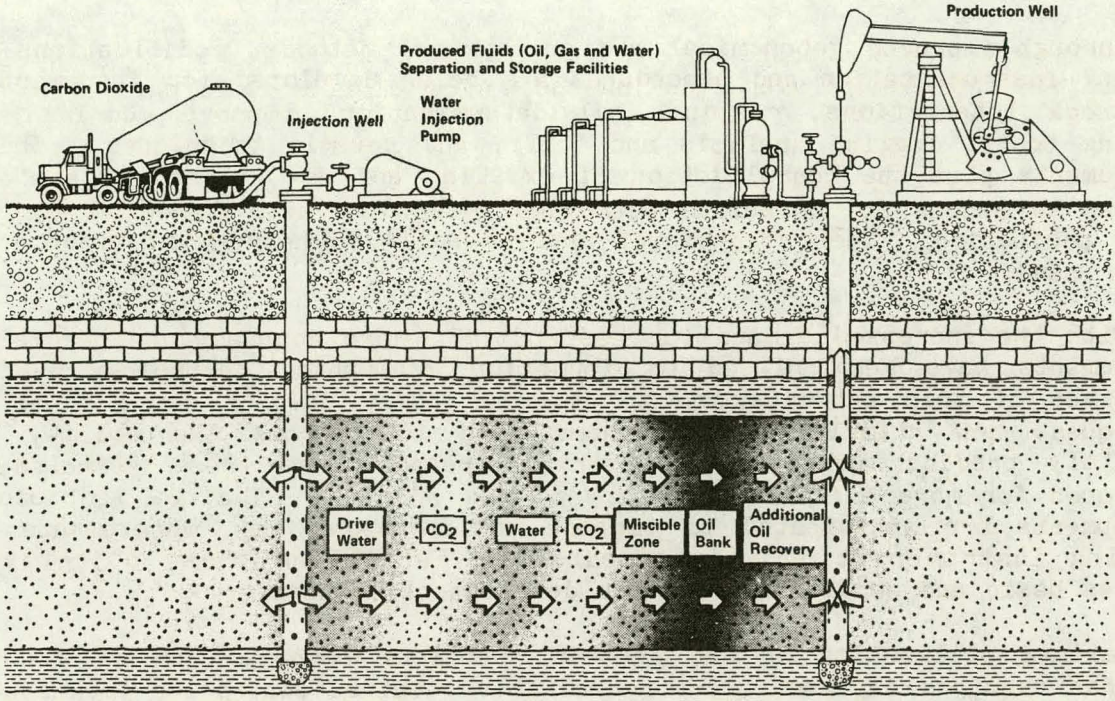
There are two EOR processes of principal interest in the recovery of light oils: micellar-polymer flooding and carbon dioxide flooding.



Micellar-Polymer/Improved Waterflooding Process

Micellar-polymer flooding consists of injecting an appropriate surfactant dissolved in water to displace the residual oil from pores by preferentially wetting the solid matrix. This is followed by a polymer solution that forms a mobility-control bank or buffer in front of the final drive water; the buffer is needed to prevent dilution of the surfactant. This process may be simplified, with some decrease in effectiveness, by adding chemicals such as only polymers or caustic soda to the water of a normal waterflood. The oil recovered may be less than from the micellar-polymer process, but may cost less per barrel.

There are several mechanisms in the CO_2 displacement process which are believed to contribute to improved oil recovery, with the most critical being oil viscosity reduction and oil swelling (up to 40 percent). It is possible to introduce CO_2 into the reservoir by several means: pure CO_2, carbonated water, acid gas (H_2S and CO_2), separator gas (CO_2 and hydrocarbon gas), flue gas, or CO_2 enriched with intermediate hydrocarbons (C_2-C_5). The process can be either miscible or immiscible, and ancillary materials may be added to improve displacement and sweep efficiencies.



Carbon Dioxide Injection Process

In a miscible gas flood (including CO_2), the injected material dissolves in or is dissolved by the residual oil which it contacts, resulting in an increase in volume of the oil phase. The volume increases until it reaches a pore-saturation level where it is mobile. (In tertiary applications, the interstitial water must be displaced ahead of the miscible fluid; otherwise a volume increase in the oil phase would be impossible.) The mobile oil phase, moving through the reservoir, encounters additional quantities of residual oil which are assimilated into a growing oil bank. If injection of the miscible fluid continues, the oil will be swept out of all portions of the reservoir contacted by the fluid. However, the mobility contrasts between the displacing fluid and the oil-rich bank being displaced will affect the efficiency of the displacement. In the end, the reservoir will be filled with the solution of the miscible agent and crude oil and an irreducible water saturation.

Resource Assessment

The energy situation has shown the great need to collect and centralize available data relevant to the petroleum resource. Relevant data include oil and water reserves, water, oil, geologic, and rock and drilling analyses, and logging records. Activities include the analyses of core and rock parameters necessary to evaluate EOR processes, analyses of the economic potential of recovery techniques, and characterization of reservoirs according to their susceptibility to enhanced recovery methods. These data are made available for industry and government use.

Through improved geochemical and geophysical methods, modifications to existing instrumentation and procedures are being developed for fundamental fluid/rock interactions, residual oil determination, improved coring and sampling tools, logging analysis and tools, and seismic techniques. These improvements plus the consolidation of existing and new reservoir data are required to assess and correlate petroleum reservoirs with potential hydrocarbon production. These techniques apply equally to heavy oil, light oil, and tar sand.

With the increased demand for gas and oil, more accuracy and precision requirements have been placed on formation evaluation technology. The objectives of this activity are to improve and/or develop new diagnostic techniques, new stimulation approaches, and to improve the ability to accurately predict and measure reservoir response to these stimulation techniques for more efficient recovery of gas and oil. The new technology developments are anticipated to include modifications and improvements to existing instrumentation and procedures. Fulfilling these objectives requires basic and applied R&D and the development of models.

Maximum utilization of our present petroleum reserves and of future syncrudes requires improved and more reliable chemical separation techniques and methodologies. Thus, improved chemical separation methods are needed to further enhance the characterization capabilities and to provide the data mandatory for obtaining maximum utilization of the fossil fuel liquids. To improve modern geochemical exploration methodologies, the major objectives are the development of more reliable oil-to-oil-to-source-rock correlations through definitive interrelationships of crude oil chemical and physical properties and the determination of unique compositional properties which can relate crude oils to their origins. An effort to reduce the Nation's dependence on foreign sources is being accomplished by the Strategic Petroleum Reserve Office. Problems encountered in the long-term storage of petroleum are being assessed for maximum utilization of this reserve.

Bartlesville Energy Technology Center scientists have developed and standardized analytical techniques, over many years, for analyzing and characterizing crude oils, oil field brines, and related crude oil fractions or products. A vital contribution to U.S. energy suppliers is the continuing acquisition of new data for an already mammoth file of 9,000 crude oil analyses and some 80,000 brine analyses, providing a needed and useful knowledge base for effecting more efficient production of all crude oil types here in the United States. The resulting output of available crude oil and crude oil product analyses to interested researchers nationwide provide for better utilization of crude oils for fuel and for petrochemicals. Annual

surveys of fuel quality for gasolines, diesel fuels, heating oils, and aviation turbine fuels provide an important data base for determining quality trends as well as for establishing bases for fuel or engine improvement.

The purpose of the five individual functions of the thermodynamics research activity is to provide reliable information for increased efficiency of fossil fuel conversion processes, such as coal liquefaction, tertiary petroleum recovery processes and fuel systems for limited volume application such as missiles. The reliable thermodynamic information obtained aids the process engineer in scaleup of pilot plants and in efficiency calculations, the petroleum engineer in designing miscible-type recovery processes, and the mechanical or aeronautical engineer in calculation of performance.

Technology transfer provides for the interchange of information resulting from the research done at government and private sector labs, primarily that from in-house research and monitored industrial contractors. Of particular importance is the transfer of EOR experience to the smaller oil companies who conduct little research on their own but produce much of our domestic oil.

Reservoir Access

This activity primarily involves coordination with the Drilling Technology program, which is described in Chapter IV, Section C of this document.

Preliminary evaluations will also begin during FY 1980 to assess the potential of nitrogen as a recovery agent.

Recovery

Miscible Gas Recovery

The three main objectives of the miscible gas recovery program are to:

- Formulate an understanding of the mechanism of CO_2 flooding.
- Develop economical CO_2 flooding processes with high displacement and sweep efficiencies.
- Determine the potential of nitrogen and inert gases as recovery agents.

To understand the mechanism of CO_2 flooding, DOE has been sponsoring research at several universities to evaluate the phase behavior of CO_2-hydrocarbon systems, and also to evaluate the requirements for miscibility of these systems. Four field tests are currently being sponsored, three of which will be continued into FY 1981. Detailed analysis of these projects will hopefully lead to an improved understanding of the process.

The major problem in developing an effective carbon dioxide process is controlling the mobility. Reduction in CO_2 mobility has been attempted by alternating the injection of carbon dioxide with water, relying on the

consequent reduction in relative permeability due to two-phase flow. Such a procedure would reduce the fingering of the carbon dioxide if the CO_2 and water would flow in the same path, but recent simulation studies suggest that gravity segregation may result and require denser spacing for wells than used in conventional operations. Further, the injection of water along with carbon dioxide may decrease the efficiency of oil bank formation in completely watered-out reservoirs. A still unverified technique proposed for mobility control is the injection of CO_2 with a foam. Further, there is increasing evidence that in tertiary applications significant enhancement of recovery may result from the specific physical chemistry of CO_2-crude oil systems in miscible displacement.

The EOR Activity is sponsoring research into mobility control methods, including one university working on CO_2-foam systems. A small field experiment is planned to begin in FY 1980 or FY 1981 (depending on process readiness) to test an improved CO_2 technique.

Chemical Recovery

The objectives of the research on chemical recovery processes are to investigate and develop the laboratory data needed for designing optimum chemical flooding treatments. This is done through characterizing surfactants and polymers, determining sensitivity to and modifications of wettability, determining stability limits of chemical systems, optimizing interfacial tensions (IFT), and developing the techniques to measure and subsequently reduce chemical adsorption on reservoir rock. These data are required both to design chemical flooding experiments and to interpret their results.

There are currently 13 universities conducting research on the various aspects of the micellar-polymer process mentioned above. The contracts with many of these universities expire during FY 1980, and most will either not be renewed or will be substantially reduced due to decreased program funding in FY 1980.

In addition, eight micellar-polymer field tests and three improved waterfloods are currently in progress (see attached descriptions). All but two will continue into FY 1981. Detailed analyses of these projects, along with the new projects stimulated by the ERA price regulation, are expected to enhance understanding of how the chemical flooding processes operate.

Preparation

This is a low-level activity involving investigations into emulsions associated with EOR production and improved techniques for breaking them.

Environment

DOE is required to assess the environmental consequences of various EOR processes and to help develop control and mitigation measures to ensure that all EOR techniques, particularly those implemented by cost-sharing projects between DOE and industry, are operated in an environmentally acceptable manner as mandated by Congress in the National Environmental Policy Act of 1969. Thus, compliance with all Federal, state and local laws, policies and

regulations must be insured, both on generic and site-specific bases, before any of the EOR processes can attain full commercial potential. Accomplishment of the task is through field-based studies of emissions, environmental data base acquisition, and basic and applied research.

Additional work involves a study of the peculiar logistics problems associated with implementing EOR processes from offshore platforms. This study will be completed early in FY 1981 and may identify areas where additional R&D is needed.

Project Status

Chemical Recovery

The objective of these micellar-polymer and improved waterflooding field tests is to demonstrate the efficiency and economics of recovering tertiary oil from reservoirs already depleted by waterflooding. Laboratory tests conducted by BETC and DOE-sponsored universities indicated that, under optimum conditions, a high percentage of residual reservoir oil can be recovered by a micellar flood. To a lesser extent, improvement can be had by adding chemicals. Data were collected on the recovery from cores using various micellar and polymer fluids, and injectivity tests were carried out with positive results. This and similar work in industry laboratories led to contracts to evaluate the technique on a larger scale (in parallel with similar private field testing by oil companies).

Gary Operating Company, Bell Creek Field, Montana (Micellar-Polymer): The objective of this field project test is to demonstrate the technical and economic feasibility of recovering tertiary oil from a successfully depleted waterflood using a micellar-polymer flooding process. Preflush and micellar injection were completed, the latter being followed by the continuing polymer injection. Site and project confirmation were completed upon analysis of the results from the tracer tests, leveling of production from the single producing well, and numerical simulation work which utilized a geological model derived from petrophysical examination of the reservoir cores. The project is behind schedule due to the slow movement of the tracers and operational problems with the pressure transient tests. Planned activities for FY 1980 include completion of the polymer injection phase, initiation of the water injection, process evaluation at peak oil production, and the feasibility of field expansion.

Gulf Oil Company, Stanley Stringer Field, Oklahoma (Improved Waterflood): The objective of this field test is to demonstrate the efficiency and economics of recovering tertiary oil from a highly heterogeneous reservoir after waterflooding by using a polymer slug of tapered concentration to improve the sweep efficiency of the reservoir. This project was completed on schedule in FY 1979, but showed during the past year a gradual decrease in production rate following the initiation of produced water injection. The project could be considered a technical success but an economic failure due to price constraints on crude oil from this particular field.

Energy Resources Company, Inc. (Improved Waterflood): This field test in the Storms Pool Unit at Carmi, Illinois, will use polymer and water to produce light gravity oil from a depleted waterflood. The project site was relocated to enhance the success of the project. Injection and production wells were subjected to deepening and remedial work to improve mobility control. Flow lines were laid and the fabrication of the injection facilities was initiated. The project is behind schedule due to a long period of inclement weather which affected the scheduling of field operations. Planned FY 1980 activities include the initiation of the preflush which is to be followed by polymer injection, pressure transient and tracer tests.

Cities Service Company, El Dorado Field, Kansas (Micellar-Polymer): The objective of this test is to demonstrate the efficiency of recovering tertiary oil from a successfully depleted waterflood reservoir by using a micellar fluid followed by a mobility control fluid displaced with water. The test consists of two side-by-side field patterns using distinctly different competing technologies. Preflush and micellar slugs have been successfully injected into both patterns. Injection of mobility control fluid, polyacrylamide and biopolymer, was initiated in April and November, 1978, respectively in the south and north patterns. Observation wells drilled in both patterns to monitor fluid changes have shown significant increases in oil cut and resistivity changes, indicating that the recovery processes are mobilizing and displacing oil. Polymer injection will continue in both patterns through 1980 with production response expected in the spring of 1980. Drive water injection will commence immediately after polymer injection is completed. Observation well monitoring of the process fluids will continue until production well response is achieved.

Marathon Oil Company, Robinson Field, Illinois (Micellar-Polymer): The objective of this demonstration is to conduct a commercial-scale test of the micellar-polymer flooding process for improved oil recovery. It is 407 acres in size, with essentially equal acreage drilled on 2.5-acre and 5.0-acre spacing for the purpose of assessing the relationship between spacing and recovery efficiencies. Injection of the micellar slug commenced in February 1977 and was simultaneously completed in both patterns in November 1978. A total of 10 percent pore volume of micellar solution was injected with no operating problems encountered. Polymer injection was initiated in both patterns in November. Polymer concentration will be reduced in steps from 1,156 ppm to 0 ppm until the 140 percent pore volume slug is injected. Completion of the slug in the 2.5-acre pattern is anticipated for late 1983. Injection into the 5.0-acre pattern will last until 1988. Oil cut is increasing in all production wells essentially as predicted from early pilot tests, with encouraging results to date.

Continental Oil Company, Big Muddy Field, Wyoming (Micellar-Polymer): The objective of this field test is to demonstrate the commercial feasibility of the micellar-polymer process in a typical Rocky Mountain reservoir with low matrix permeability, low salinity, and which fractures at bottom hole injection pressures near hydrostatic. Construction of the production facilities and the chemical injection plant is nearly complete. Injection of the preflush began in late 1979, with chemical injection beginning January 1, 1981.

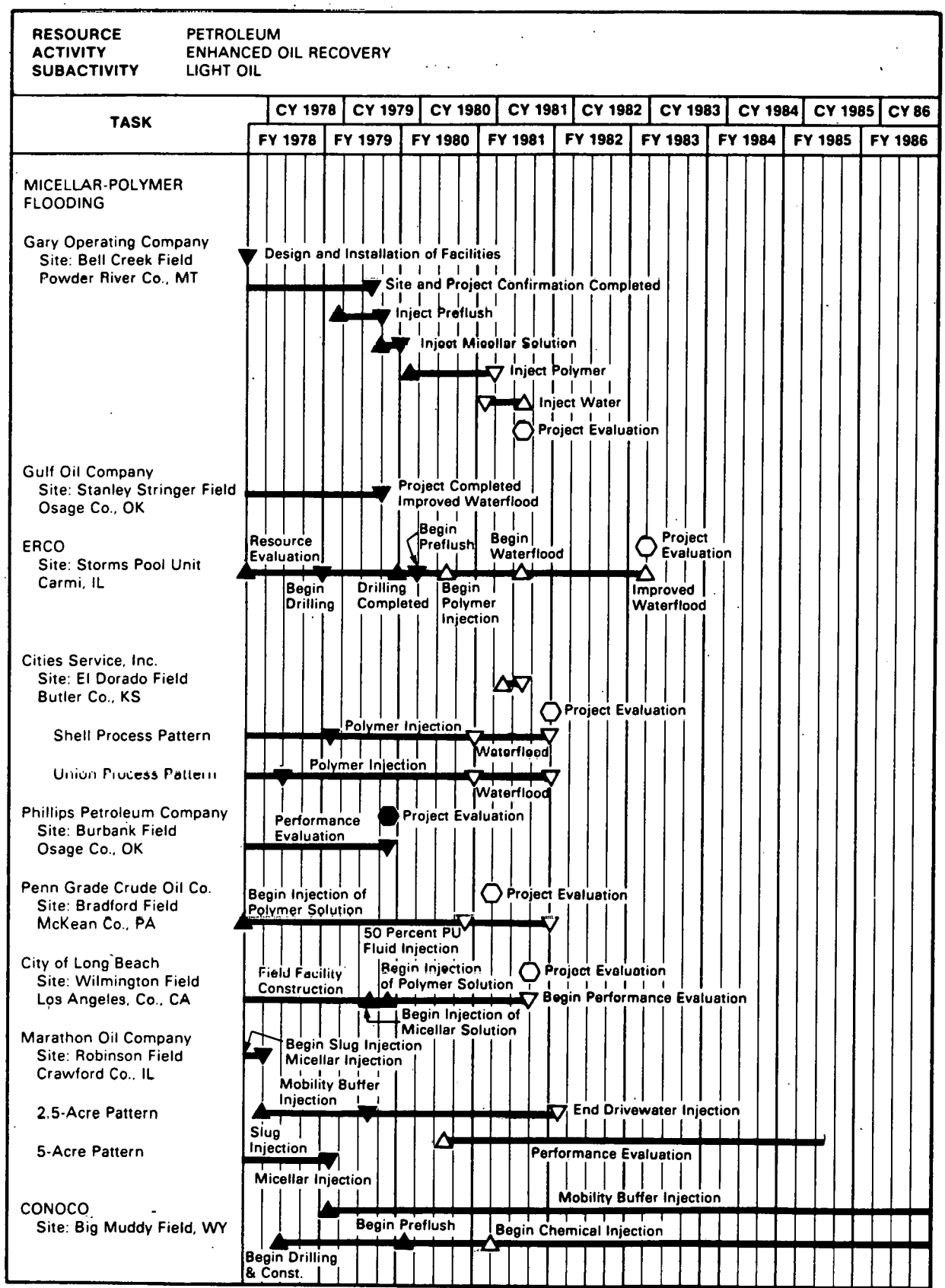
Shell Oil Company, East Coalinga Field, California (Improved Waterflood): The objective of this field project is to demonstrate the relative merits of polymer flooding and waterflooding in a medium viscosity oil reservoir. This project was finished in July 1979 after waterflooding for 23 months and injecting polymer for 12 months. The overall production performance was far less than expected. A reassessment of the reservoir within the pilot area was completed using additional petrophysical data not available when the project was proposed. This data indicated substantially less oil saturation, which accounts for the poor production performance. The operation of the injection facilities during polymer injection was essentially uninterrupted. The quality control of polymer solution prepared by the facilities met or exceeded the stringent specifications imposed on the polymer.

City of Long Beach, Wilmington Field, California (Improved Waterflood): The objective of this field test is to demonstrate the effects of injecting a caustic only solution and a caustic salt solution to sweep the residual oil saturation from a reservoir that has previously been waterflooded. Laboratory core floods in which a caustic only solution was injected showed no increase in oil production and therefore were discontinued. Laboratory core floods in which caustic salt solution was injected have shown increased oil recovery over a normal waterflood recovery. Additional laboratory testing is continuing to optimize slug size. Construction of facilities is completed.

Aminoil, Huntington Beach Field, California (Chemical Flood): This test was started by Aminoil in FY 1976 and joined by DOE in FY 1977. It is an alkaline flood in a reservoir moderately different from the City of Long Beach with respect to reservoir characteristics and oil properties. Laboratory work for optimum design is continuing. Preflush is underway with alkaline injection scheduled for early 1980. Additional tracer tests for better reservoir characterization have been initiated.

City of Long Beach, Wilmington Field, California (Chemical Flood): The objective of this field demonstration is to design a micellar-polymer system that will displace economic quantities of viscous oil otherwise not recoverable from unconsolidated sands. Laboratory testing for slug optimization has been completed. Preflush and micellar slug injection have been completed. Polymer is presently being injected.

Phillips Petroleum Company, Burbank Field, Oklahoma (Micellar-Polymer): The objective of this test was similar to that of the Cities Service project discussed above. Since the completion of chemical injection last year, remedial work has been done on the injection and production wells to even up the distribution of flow. At the termination of the contract over 150 thousand barrels of tertiary oil had been produced, and production was continuing at more than 180 bbl/d at a WOR of 70.



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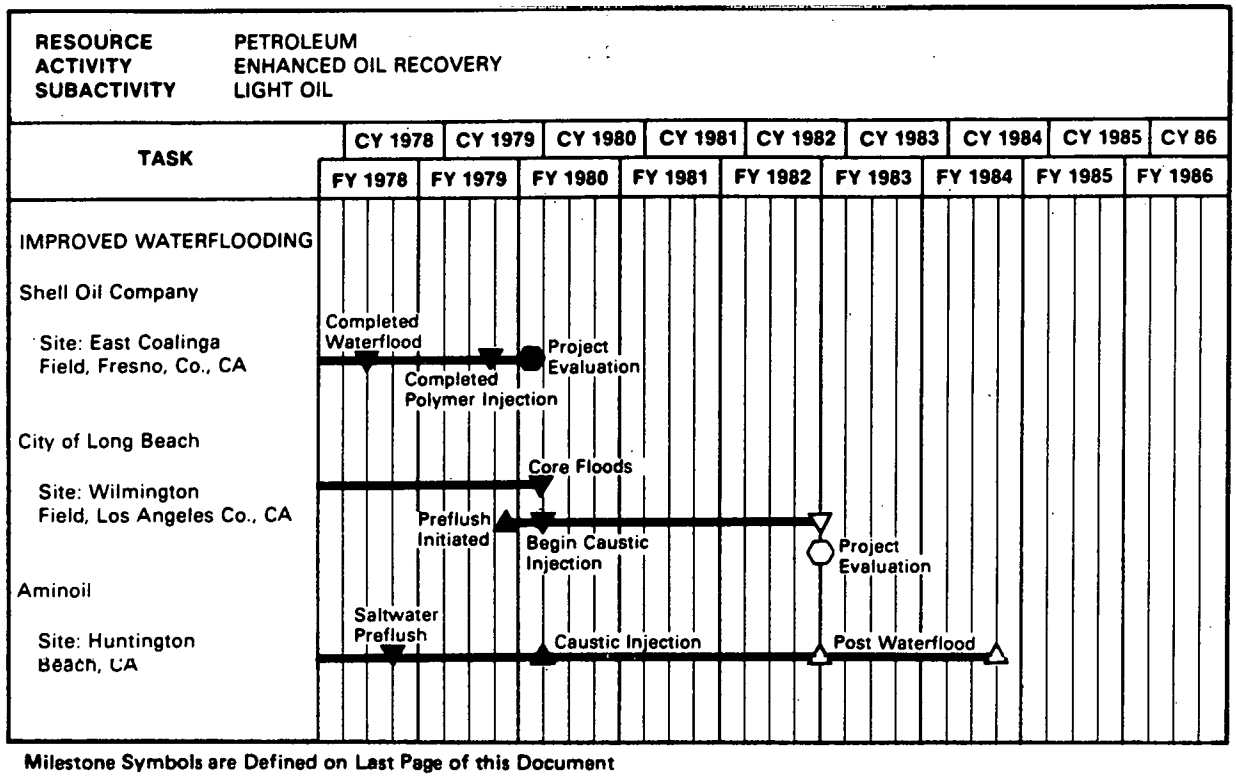

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Project Status

Miscible Gas

Pennzoil Company, Rock Creek Field, West Virginia: The objective of this project is to determine the efficiency and economics of recovering oil from a shallow, low-temperature reservoir using carbon dioxide and water to displace oil. The injection wells have been completed in the producing formation and field pressure has been raised by water injection. CO_2 injection started in February 1979 and will continue until May 1980 with 23,000 tons of CO_2 injected. Water injection to drive the CO_2 will start in May 1980 and continue through 1982. Oil production due to CO_2 injection started in July 1979.

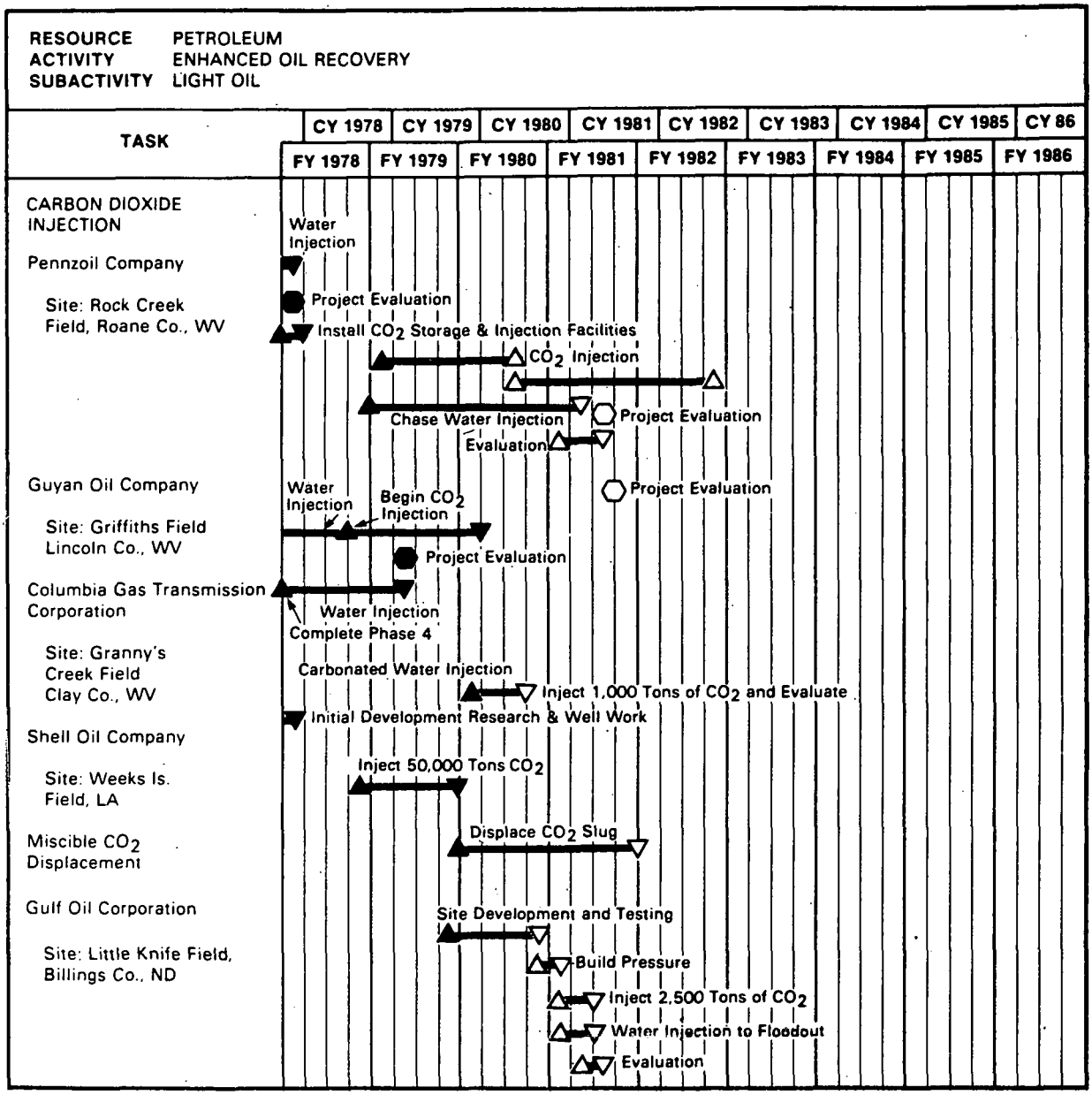
Guyan Oil Company, Griffithsville Field, West Virginia: The objective of this project is to demonstrate the efficiency and economics of recovering oil from a shallow, low-temperature reservoir using carbon dioxide and water to displace the oil. The new wells are drilled and the CO_2 storage facility is operable. Significant delays have resulted from the necessity to perform sizable environmentally protective steps such as prevention of silting and erosion and plugging of old wells. Water injection to build up pressure was completed. The project was running roughly 24 months behind its original schedule. Due to these continuing problems, the contract expired in the first quarter of FY 1980 without CO_2 injection.

Gulf Oil Corporation, Little Knife Field, North Dakota: The objective of this project is to confirm by field testing the results of laboratory CO_2 displacement tests and show that the CO_2 miscible displacement process has

potential for commercialization in carbonate oil reservoirs that have not been extensively waterflooded and have a high remaining oil saturation. This project was funded in the last quarter of FY 1979. The test will be in the Madison Carbonate Reservoir of the Little Knife Field at a depth of 10,000 feet. Site development and testing started in November 1979 and will continue through July 1980. CO_2 injection will start in September 1980 and continue through January 1981. Water injection to floodout and project evaluation will continue through August 1981.

Shell Oil Company, Weeks Island Field, Louisiana: This project was funded in late FY 1976 and is the only EOR project in the deep, high-temperature and high-pressure sands of the Gulf Coast. This project is to use the new technique of employing CO_2 (mixed with methane to make it gravity-stable) as a miscible agent to displace residual oil in the "S" sand reservoir B. The objective is to determine the feasibility of the CO_2 miscible displacement process in the steeply dipping, loosely consolidated high-pressure and high-temperature oil zones of the Gulf Coast. The field work has been completed, and CO_2 injection began during the last quarter of FY 1978. CO_2 injection will be completed in March 1980 with oil production to start by September 1980. Displacement of the CO_2 slug will continue through FY 1982.

Columbia Gas Transmission, Granny's Creek Field, West Virginia: The objective of this project is to demonstrate the efficiency and economics of recovering oil from a shallow, low-temperature, watered-out reservoir using carbon dioxide and water to displace the oil for tertiary recovery. Carbon dioxide injection has been completed and chase water injection continued until floodout. There has been some increase in oil production as a result of this injection. Results are not conclusive, however, and it is necessary for further geological and computer data evaluation to improve production efficiency. An additional 1,000 tons of CO_2 was injected into a well in the pattern starting in November 1979. Completion of the project is anticipated by FY 1981.



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3.0 TAR SANDS

"Tar sand" refers to a reservoir rock whose interstices contain a very viscous to semisolid bitumen or crude oil with a natural mobility insufficient to move the bitumen through the reservoir rock to a wellbore. Any distinction that can be made between tar sands and so-called "heavy oil" deposits would relate to differences in viscosity of the contained bitumen or oil. In tar sand, the bitumen is so viscous or immobile that it prevents displacement and production by primary petroleum production methods. On the average, tar sand oils usually have API gravities of less than 10° to 12°.

About 546 tar sand occurrences have been reported in 22 states, with partial resource estimates made in 7. The resource in known deposits in five

of the states (California, Kentucky, New Mexico, Texas, and Utah) is estimated at up to 30 billion barrels of oil. Most of this estimated resource is in Utah where 27 deposits contain an estimated 29.3 billion barrels. Six of these deposits are classed as giant deposits each containing from about 1 billion to as much as 16 billion barrels. Four of these deposits, Asphalt Ridge, Hill Creek, P.R. Spring, and Sunnyside, are in the Uinta basin and contain up to 11 billion barrels of low-sulfur (less than 0.5 weight percent) oil, a prime target for current interest in developing production from tar sands.

The majority of the known domestic tar sand resource is at depths ranging from 0 to 1,500 feet. However, an estimated 80 percent of the resource is under overburden thicknesses which preclude surface mining and will require in situ processes for commercial oil production. The large Utah tar sand resource, based on available analytical data, is characterized by reservoir rock porosities greater than 25 percent; oil saturations ranging up to 100 percent; reservoir rock permeabilities less than 200 millidarcies with the bitumen in place but ranging from several hundred to several thousand millidarcies after the oil is extracted; and bitumen viscosities, in place, which range up to greater than a million centipoise.

Efforts to utilize the U.S. tar sands date back at least 80 years; however, they have been largely ineffective and have mainly involved small-scale mining operations for production of tar sand for direct use in road paving. Some experimental efforts have involved mining and oil extraction in surface plants as well as in situ oil recovery. Mining and plant extraction processes have included the employment of petroleum solvents, hot water, and combinations of solvents and water. In situ processes have included injection of petroleum solvents, various steam applications through both vertical and horizontal wellbores, and forward and reverse combustion processes. Apparently none of these early efforts resulted in a successful technology for the recovery of oil from tar sand deposits. Some of the deposits should be susceptible to oil recovery by strip mining and surface oil extraction, as is currently being done at Athabasca, Canada. However, as at Athabasca, most of the deposits in the U.S. lie under overburdens too thick for economical open-pit mining, and in situ recovery methods will be required to produce most of the oil.

Potential Benefits

The potential benefits to be derived by research, development, and demonstration efforts directed at the U.S. tar sand resource include:

- More accurate assessment of the resource, of which only 39 of nearly 500 deposits have been subjected to meaningful assessment efforts. These 39 deposits contain an estimated total of 24 to 30 billion barrels of oil in place. Further assessment efforts could increase the estimated resource substantially.

- Development of new technologies or adaptation and demonstration of existing technologies for the U.S. tar sands which can recover an estimated 10 to 30 percent of the currently untapped resource.

- Expansion of the fossil energy resource base by 3 to 10 billion barrels of oil, if the tar sands can be economically exploited.

- A technology potentially exportable to other nations, such as Venezuela, which have large tar sands deposits. This effort could help alleviate the forecast world oil shortage.

Steam drive and in situ combustion are the two processes considered to have the main potential for in situ recovery of bitumen from tar sands. (See process descriptions and diagrams under subsection 1, Heavy Oil).

Resource Assessment and Planning

This activity is composed of work in the areas of resource characterization, reservoir evaluation, and planning.

The resource characterization work is targeted at filling the large gap in knowledge concerning the size, nature, and distribution of the tar sand resource. This will be accomplished by evaluating major deposits and building up a reservoir data base. This work is planned to begin in FY 1980 and continue for several years.

Work in the reservoir evaluation area is primarily concerned with adapting conventional oil diagnostic tools and techniques to work on tar sands. This ongoing effort began in FY 1980.

The planning task is composed of ongoing efforts in the areas of technical, economic, and environmental planning.

Reservoir Access

This activity is divided into three main areas of interest: drilling; well completion and stimulation; and mining.

There are no unique aspects of drilling tar sands. Therefore, planned activity in this area involves only coordination with the general drilling program described in Chapter IV, Section C of this volume.

Most of the work in high-temperature packers, well string insulation, and downhole steam generators being done by Sandia as part of Project Deepsteam (see Heavy Oil, subsection 1) is applicable to tar sands and will be closely coordinated. In addition, field experiments and analyses of tar sand fracturing techniques will be conducted.

A preliminary study of the potential and problems of both surface and underground mining of tar sands will be conducted during FY 1980. It is expected that this study will identify areas where further research is needed, beginning in FY 1981.

Recovery

Thermal Recovery

Most development of in situ processes for thermal mobilization of tar sand bitumen has been directed toward deposits in Canada. In these processes, oil production is controlled by direct combustion, steam injection or a combination of these methods.

Two small-scale feasibility tests in the northwestern Asphalt Ridge area of Utah have identified in situ combustion as a candidate process for oil production from U.S. tar sands. Similar tests of steam injection processes are needed to select the most economical processes for further development and application to specific tar sand deposits.

Laboratory experiments and modeling of steam drive in tar sands began in FY 1979. A steam injectivity test conducted at Asphalt Ridge during the summer of 1979 showed that continuous steam injection was possible at acceptable rates. A small steam drive field project has been designed and is scheduled for startup by mid-FY 1980, with completion by mid-FY 1981. Analysis of the results of this project will be used to determine whether a second steam field test is justified, or if the next field project should be in situ combustion. It is planned to initiate the second field experiment late in FY 1981.

Alternate Extraction Techniques

Many techniques have been proposed for the surface extraction of bitumen from mined and crushed tar sand, but only one such process has been successfully applied in commercial operation. This is the hot water process used by Great Canadian Oil Sands in Athabasca, Canada. The process involves mixing tar sand with hot water and a small amount of caustic soda and has achieved good separation of bitumen from the Athabasca tar sand, which is classed as water-wet. For U.S. tar sands that also exhibit water wetness, the process should be applicable, but many U.S. deposits have little connate water and appear to be oil-wet, and the process probably is not applicable there. Moreover, all known U.S. deposits are much smaller in area, more scattered in location, and have thinner and less continuous saturated zones than those in Canada. Smaller operations (10,000 bbl/d or less) will have to be used in the United States as compared to the huge plants (60,000-150,000 bbl/d) in use by GCOS and Syncrude. Currently, research is being sponsored to develop two processes to extract the bitumen. One is a new thermal concept, and the other is a modification of the Canadian hot water process.

Modified in situ methods have been proposed as a means to break or extensively drill the tar sand in place so as to provide a permeable field. By this means, injectivity of fluids for application of bitumen extraction processes, which is difficult to obtain and control with true in situ methods, would be greatly enhanced. These methods have been tested on oil shale, but not on tar sand.

Several novel in situ techniques been proposed for recovering oil from tar sands. Some of the foremost processes are electrical induction heating,

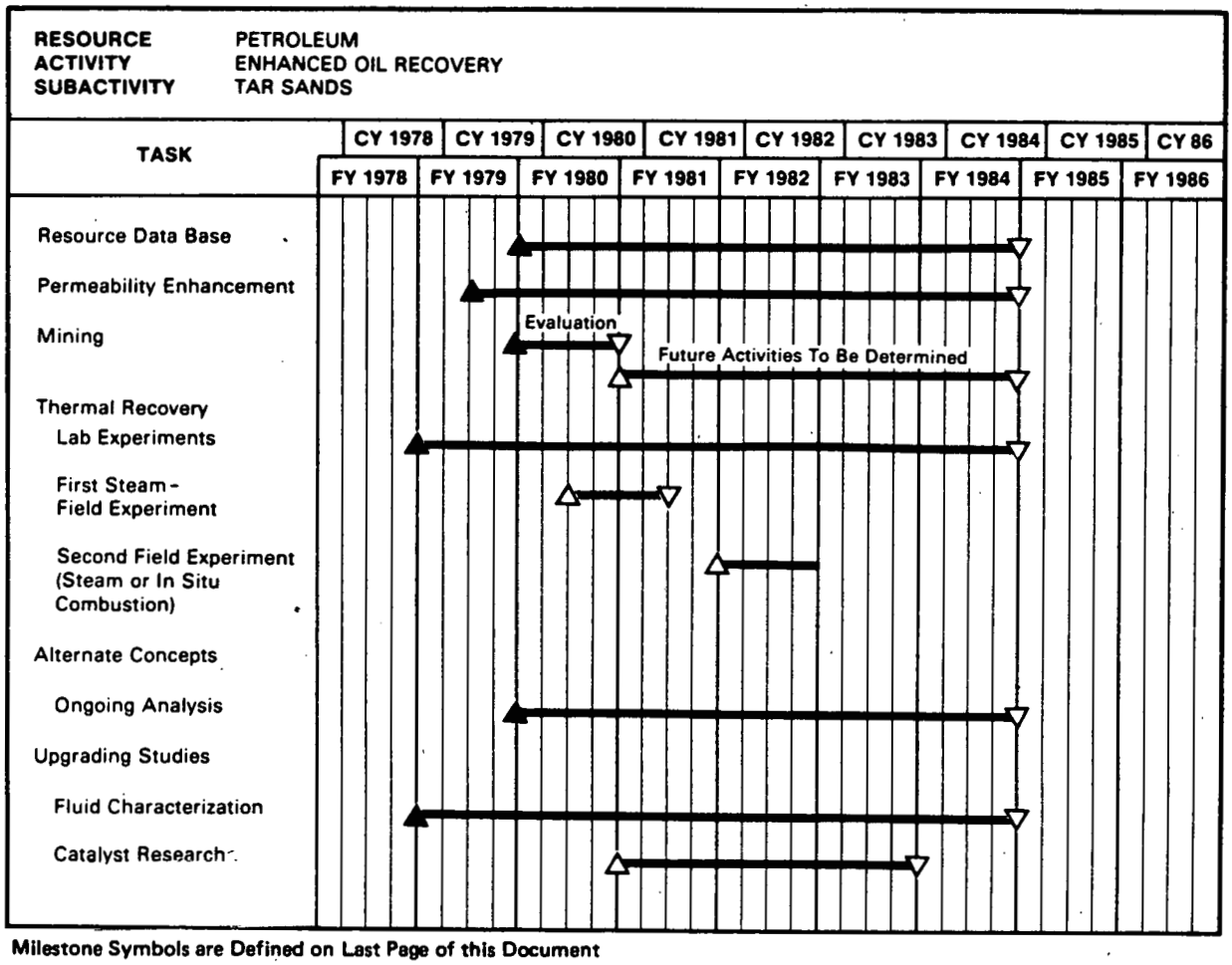
microwave heating and microbial oxidation; however, none of these processes have had enough testing to determine their feasibility.

Preparation

This activity is primarily concerned with the upgrading of produced bitumen to an acceptable petroleum feedstock. Work begun in FY 1979 and FY 1980 that will carry into FY 1981 includes the characterization of field and lab products, and an evaluation of upgrading processes. In FY 1981, catalyst research and an evaluation of mild hydrogenation will begin.

Environment

This activity will be an ongoing effort involving monitoring, characterization, and control methods for effluents from field experiments.



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B. OIL SHALE

The Nation's abundant oil shale resources are a major potential source of energy. The technology for conventional mining and surface retorting of oil shale has advanced to a level believed to be capable of early commercial application to the richer grades of oil shale, averaging over 25 gallons per ton, although commercial-scale equipment and operations have not been demonstrated. Present DOE activity in this area is focused mainly on commercial-scale engineering design for surface retort processes, cooperatively with industry. The principal R&D thrust is to develop in situ extraction processes that are capable of exploiting the leaner and deeper shales with a potential cost-savings and lower environmental impact. In addition, DOE is conducting laboratory-scale supporting research on problems relevant to general oil shale processing and environmental concerns, both surface and in situ; contracting for development of advanced processing concepts; providing general consultation to industry and technical information transfer via research publications; resource characterization; and making the Anvil Points facility available for industry-sponsored projects.

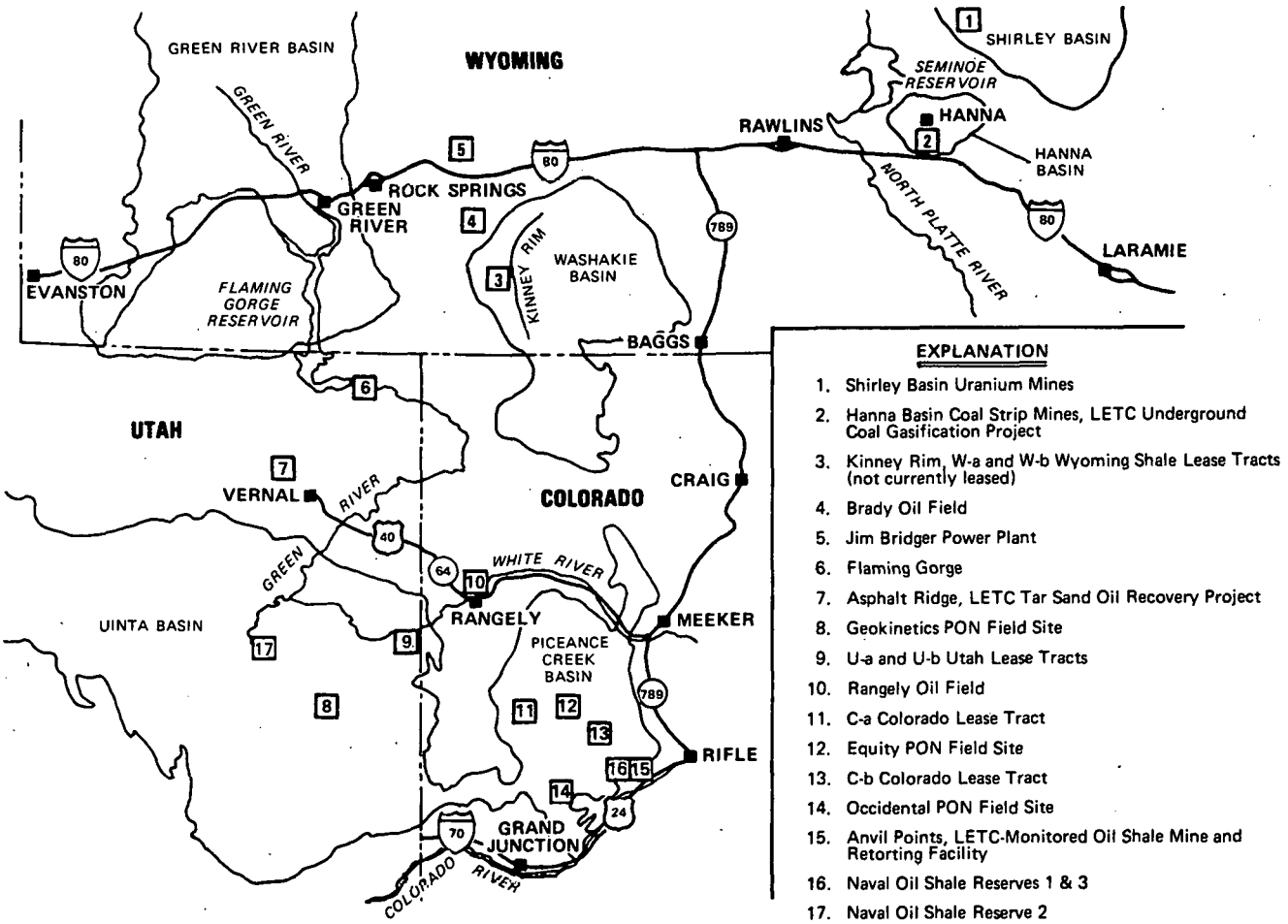
The near-term objective of the Oil Shale Activity is to provide by 1985 the technology base for initial commercial implementation of first-generation processes that have progressed to pilot stages of development. This objective will be promoted by focusing research and development on critical technology problems associated with present industry process development efforts, in active cooperation with industry.

The longer term objective (1985-2000) is to provide substantial improvements in the economics and environmental acceptability of shale oil and gas recovery through research on advanced surface and in situ processes that show promise of significant breakthrough in energy efficiency, resource recovery, and reduced environmental emissions and residuals.

The present Oil Shale Activity includes:

- Oil production research involving true in situ methods that require no mining
- Modified in situ methods that enhance the void volume and permeability, by mining a portion (15 to 25 percent by volume) of the mineral material from the oil shale formation and creating a rubbled volume
- Advanced processing technology with potential for reducing environmental impacts and improved energy efficiency of second-generation commercial plants
- Production research targeted to both eastern and western oil shales

- Environmental studies related to the in situ processes being developed
- Supporting research for oil shale processing that is not tied to any specific technology but rather to oil shale development problems in general.



DOE and Industry Energy Projects in Oil Shale Region

Advantages of in situ methods are potentially lower water, manpower, and shale disposal requirements. Potentially greater environmental impacts are a disadvantage. The potential application to lower grade shales is important in that two-thirds of the total estimated resource of 1.8 trillion barrels of shale oil in the western Green River formation is in low-grade deposits that may never be recovered by techniques that involve conventional mining and surface retorting. Laboratory-scale research on new process technology includes applied research on methods potentially offering similar advantages for aboveground processing.

There are three basic alternative technologies for commercial shale oil production: aboveground, true in situ, and modified in situ. In each method, the oil shale is retorted in place, producing both oil and gas. The heat breaks down the kerogen in the shale (a process called "pyrolysis") releasing a liquid hydrocarbon mixture, some combustible gases, and leaving a coke-like residue of spent shale. The amounts of oil and gas produced are dependent on the retorting conditions and the richness of the shale. The oil contains nitrogen, water, and other impurities, and must be upgraded before it can be refined in a conventional oil refinery. The gas usually has a lower heating value than natural gas, and may be used for generating electricity for process and onsite power. The refined products from shale oil have the same applications as conventional oil products.

Although in situ conversion of oil shale to liquid products offers several potential advantages over conventional mining and surface processing, no single version of in situ technology is applicable to the full range of oil shale deposit types.

True in situ techniques require no mining, but rely instead on either natural permeability (found only in the leached zone of Colorado) or artificial permeability created by hydraulic and/or explosive fracturing from wellbores. Success with the explosive fracturing technique has thus far been demonstrated only in very shallow Utah shales, where a project by Geokinetics, Inc., continues to show promise. Deeper tests in western shales have given unsatisfactory results. Final assessment of hydraulic/explosive fracturing in eastern shale (Dow project) is to be completed in FY 1981.

Modified in situ techniques use partial mining prior to explosive fracturing to achieve enhanced void volume as well as improved rubble-size and void distribution. Present void targets are in the range of 15 to 25 percent of the total rubble mass.

Of the in situ methods, vertical modified in situ (VMIS) techniques are believed to offer the most promise for early development. They are especially promising for deeper and very thick (more than 300 feet) deposits. Four major variations of modified in situ are of interest, the choice of the particular variation being partially governed by the actual thickness of oil shale to be processed. Two of these variations are conceptually similar in that an initially mined void volume is subsequently redistributed throughout a much larger mass of rubbled shale. Physical dimensions of the completed retort modules have led to the general description of these processes as "vertical" or "horizontal." Two versions of the vertical process are under active development, with one having reached the stage of testing modules (Occidental contract) of approximately the size required for commercial operations. Both utilize a downward-moving combustion zone to process the shale. Two processing concepts have been proposed for "horizontal" retorts, one using a downward-moving combustion zone and the other using a laterally moving combustion zone.

The following products result from in situ retorting operations:

- Shale oil syncrude that can be refined into the various products (diesel fuel, jet fuels, LPG, and coke) needed in the commercial market

- Low- to medium-Btu gas that can be used onsite in a gas turbine generator to provide electricity for process operation
- Ammonia and sulfur products.

Technology transfer is achieved by publications of in-house and cooperative research results in the form of DOE reports and papers presented at symposiums. To the extent possible, fundamental data, laboratory results, small pilot-test data and results and technical analyses are published.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

OIL SHALE	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
In Situ Conversion	32,700	27,000	34,298
Surface Conversion	15,000	0	750
Capital Equipment	900	1,200	1,000
TOTAL	48,600	28,200	36,048

1.0 IN SITU CONVERSION

Technology Base Program

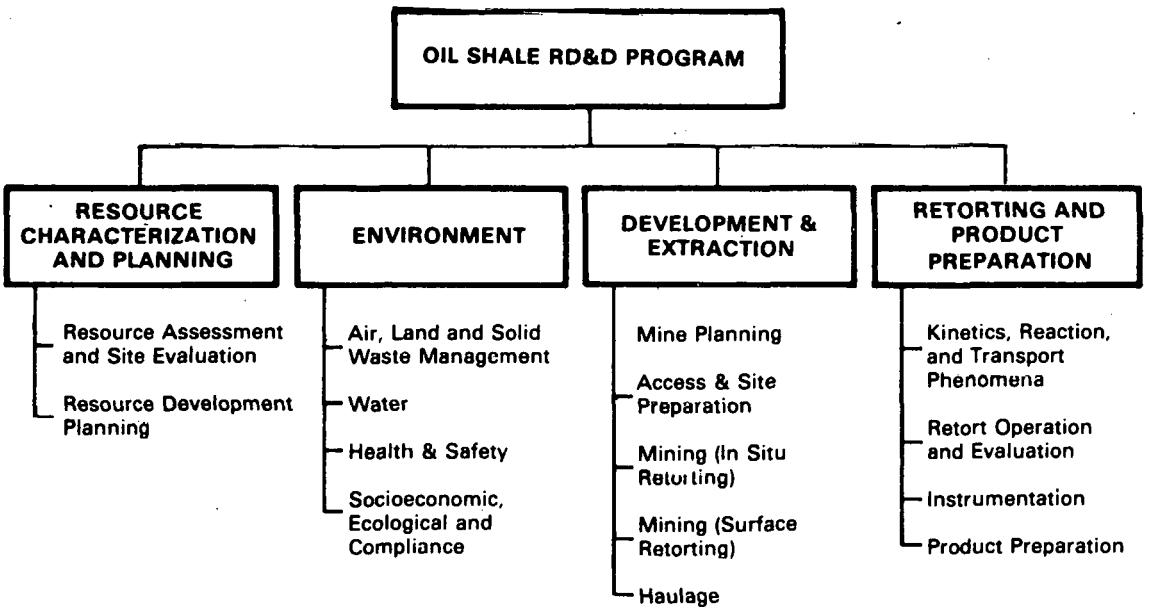
The major emphasis of the Oil Shale RD&D program is on in situ retorting processes. Engineering analyses indicate that in situ processes have the potential to be more cost effective and less disruptive to the environment than surface retorting. Therefore, the in situ oil shale research program is focused on developing the necessary technical and environmental information from which an economically acceptable in situ technology can be engineered. In addition to the technology base program, the DOE is also sponsoring three major in situ oil shale field demonstration tests. The field demonstration test program and the technology base R&D programs are interactive, in that the field demonstration sites are often used for the technology base R&D program efforts, and information gained from the field tests is used to guide the overall RD&D program.

A major portion of the technology base R&D program is directed toward VMIS approach which has the objective of producing a significantly improved design for a commercial-size process. The objective is to provide a comprehensive technical data base to industry so that companies may make informed decisions regarding in situ oil shale developments. In addition, environmental, fracturing, and process (kinetics, modeling, etc.) research is

included which is applicable to and supportive of surface retorts and true in situ retort processes.

The Oil Shale RD&D program is structured to parallel and complement activities that commercial/industrial developers would need to undertake in establishing a commercial oil shale operation. The initial activities include the tasks of characterizing the resource under consideration and initial site planning for resource development, followed by consideration of potential physical and socioeconomic impacts. Development and extraction of the oil shale resource entail site preparation, mining (except for true in situ technologies) and rubbling the in situ retort or transporting the mined oil shale to a surface retort facility.

Based on this sequence of events, the In Situ Oil Shale Activity is divided into tho following task efforts.



Oil Shale Activity Organization

Resource Characterization and Planning

- Resource Assessment and Site Evaluation. The characterizations of various oil shale resources and evaluation of their economic and development potentials form the overall objective of this effort. A further objective includes the analysis of resource assessment data to find promising sites for specific measurements to determine suitability for utilization.

- Resource Development Planning. The development of methods to establish technical and economic resource development plans on both site-specific and resource-wide bases are the objectives of this effort.

Environment

- Air, Land, and Solid Waste Management. The assessment of air and land impacts (including retort abandonment), and the development of control strategies to mitigate these impacts, assuring regulatory compliance, are the objectives of this effort.

- Water. The preservation of water resources and control of aqueous effluents within environmentally acceptable limits define the objectives of this effort.

- Health and Safety. The development of necessary technology, methods, equipment, or systems to assure that workers are provided a healthy and safe environment is the primary objective of this effort.

- Socioeconomic, Ecological, and Compliance. The prediction and mitigation of socioeconomic and ecologic impacts associated with development of an oil shale industry in a rural regional environment and compliance with regulations are this effort's major objectives.

Development and Extraction

- Mining Planning. The development of planning tools (economic models, equipment selection criteria, mining simulation models, etc.) that will define an optimal total mining system for a particular oil shale resource is the objective of this effort.

- Access and Site Preparation. The two objectives of this effort are: (1) development of site preparation plans and methods that will allow preparation of required site installations for all types of oil shale mines in a timely and economical manner, and (2) development of rapid, cost-effective methods of accessing the shale production area.

- Mining for In Situ Retorting. The development of methods, equipment, systems, and techniques for fracturing in situ oil shale retort beds suitable for processing are the objectives of this effort.

- Mining for Surface Retorting. The development of high volume, cost-effective mining methods for extracting oil shale surface retorting is the specific objective of this effort.

- Haulage. This effort will develop haulage systems capable of efficiently transporting men and materials required for the operation of various-sized oil shale operations.

Retorting and Product Preparation

- Kinetics, Reaction, and Transport Phenomena. The identification of performance limitations for retorting process configurations, simulation of oil shale retorting process configuration

performance, development of control strategies, and evaluation of retorting process configurations of experimental developments and model application are the objectives of this effort.

- Retort Operation and Evaluation. This effort will develop a commercially viable in situ retorting technology for controlling retort and burn operations.

- Instrumentation. The objectives of this effort include the development of instrumentation, systems, and techniques for (1) evaluation of the resource (general and site specific), (2) monitoring processes and effluents which may impact the environment surrounding an oil shale retorting site, (3) acquiring, recording, reducing, and analyzing experimental data pertinent to rock fragmentation, rubble pile properties, and the integrity and stability of the rock mass surrounding the rubble zone, and (4) diagnosing, monitoring, controlling and evaluating the retorting processes which are under development.

- Product Preparation. The determination of the most economical process schemes for shale oil recovery, transport, and upgrading are the objectives of this effort. Included are tasks related to the collection and separation of shale oil mist from retort off-gas, separation of water and solids from retort liquid product, improvement of storage stability and fluid flow characteristics for pipeline transportation, and production of synthetic crude oil for conventional petroleum refineries.

The following major centers are involved in this effort:

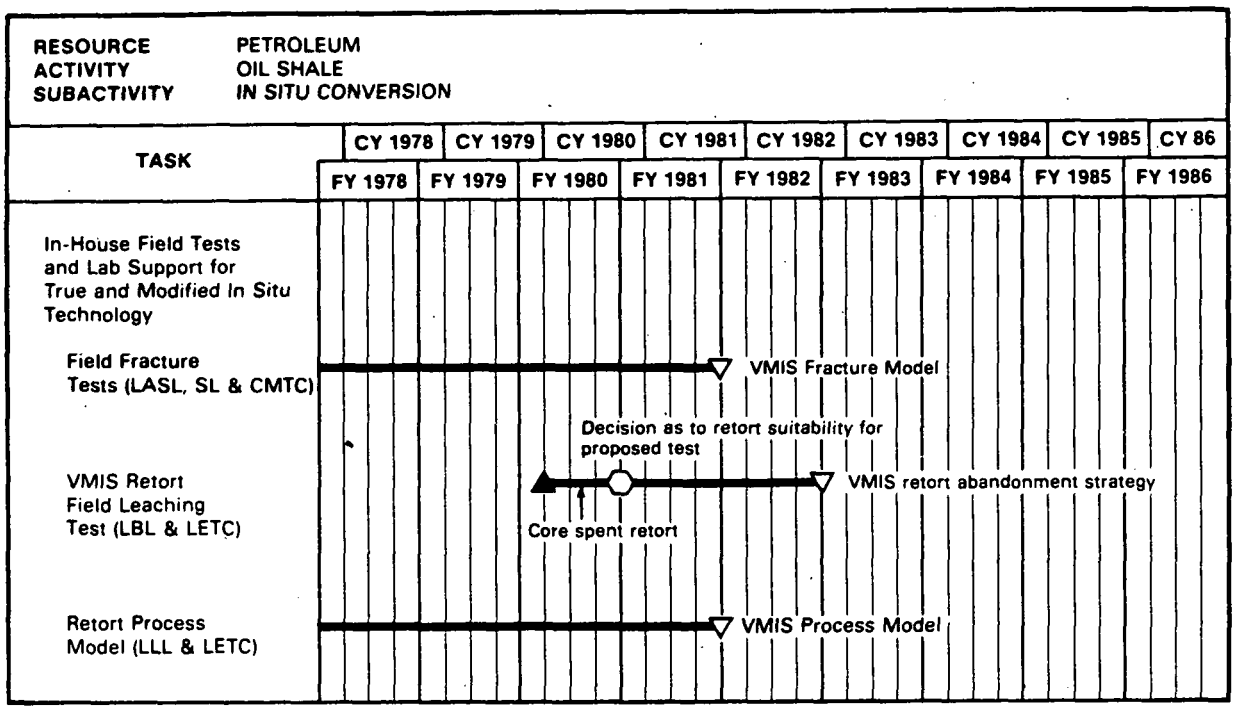
Laramie Energy Technology Center (LETC). LETC conducts a broad-based research program in support of several methods of oil shale retorting applicable to different portions of the total shale reserves and provides technical oversight for contracts with industry. The in-house supporting research includes fundamental modeling of reaction kinetics and rock mechanics; development of analytical methods for online monitoring of product properties and process events; environmental monitoring and compliance activities; characterization of oil shale deposits to assist in site selection for field tests, and operation of engineering-scale retorts that simulate underground processing to provide data for the process modeling activities.

Lawrence Berkeley Laboratory (LBL). Objectives are to (1) determine the distribution of major and minor elements between shale oil, process water, off-gas, and spent shale as a function of retort operating conditions; (2) identify and quantify the organo-metallic species that are released to retort waters and off-gases during in situ retorting; and (3) develop and apply an in-place monitoring technique and sampling system for gaseous emissions from an in situ retort. Data from these investigations will be used to assess the impact of field in situ operation on the environment.

Los Alamos Scientific Laboratory (LASL). Objectives are to provide dynamic material property data and explosive characterization data within the context of a cooperative project with Sandia Laboratories to develop the

ability to control and predict the result of explosive blasting in oil shale. The end result of this cooperative project is expected to be an improved capability in preparing in situ retorts with desired properties of rubble size and permeability distribution.

Sandia Laboratories (SL). Objectives of this project are to (1) develop oil shale material response models and numerical computational techniques to aid in design and analysis of modified and true in situ fracturing; (2) develop advanced instrumentation systems and measurement techniques to monitor, control, and evaluate both fracturing and retorting processes; and (3) apply these systems and techniques in support of both in-house field projects conducted by LETC, LASL, and DOE-funded industrial field projects where such support materially enhances quality and understanding of experimental data.



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Carbondale Mining Technology Center (CMTC). CMTC is responsible for overall management of the Development and Extraction activitiy. Within Development and Extraction, LASL provides leadership for "Mining for In Situ Retorting." CMTC conducts research in cooperation with LASL for developing equipment, systems and techniques for preparing (mining) in situ oil shale retort beds suitable for processing. CMTC provides leadership in the remaining four subactivities of Mine Planning, Access and Site Preparation, Mining for Surface Retorting, and Haulage.

Resource development planning research by LETC in FYs 1980 and 1981 will continue the new efforts in expanding the data base including the development of a computer system to analyze oil shale data and produce geologic quality maps of Colorado, Utah, and Wyoming. Paralleling this effort will be development of a Devonian shale resource data base. Technical and economic

planning for oil shale resource development will be integrated with commercial in situ designs and an environmental data base. LETC has recently published a new quantified assessment of the Colorado oil shales that are potentially targets of VMIS development.

An updated Environmental Development Plan (EDP) has been formulated for the Oil Shale Activity. This plan provides for a comprehensive oil shale environmental strategy and an implementation plan to ensure that all environmental concerns are addressed. Environmental Impact Assessments are prepared for all major DOE oil shale field projects.

The development of comprehensive retort abandonment plans is important for compliance with the National Environmental Policy Act (NEPA), DOE's policy of developing environmentally acceptable technologies, and permit requirements. The RD&D effort will collect data on retort abandonment and evaluate its usefulness. Existing hydrological models will be used to estimate pollutant dispersion, a data base will be developed, the potential subsidence in the vicinity of an in situ retort will be assessed, and natural flooding of abandoned retorts will be studied. Based on information gained from the risk analyses, new controls will be identified, developed, field tested, and evaluated. The expected result of this effort will be an environmentally acceptable retort abandonment plan. This work in FYs 1980 and 1981 will include laboratory studies by LBL, cofunded by the Assistant Secretary for Fossil Energy and the Assistant Secretary for Environment, to assess abandonment strategies, such as grouting or pre-leaching, and comparative cost analyses of such strategies. A test of leaching spent shale in a field retort at the Occidental VMIS site is to be evaluated including core drilling of the retort. Design criteria for VMIS atmospheric emission controls will be accelerated in FY 1981. Solid waste design criteria research will be continued.

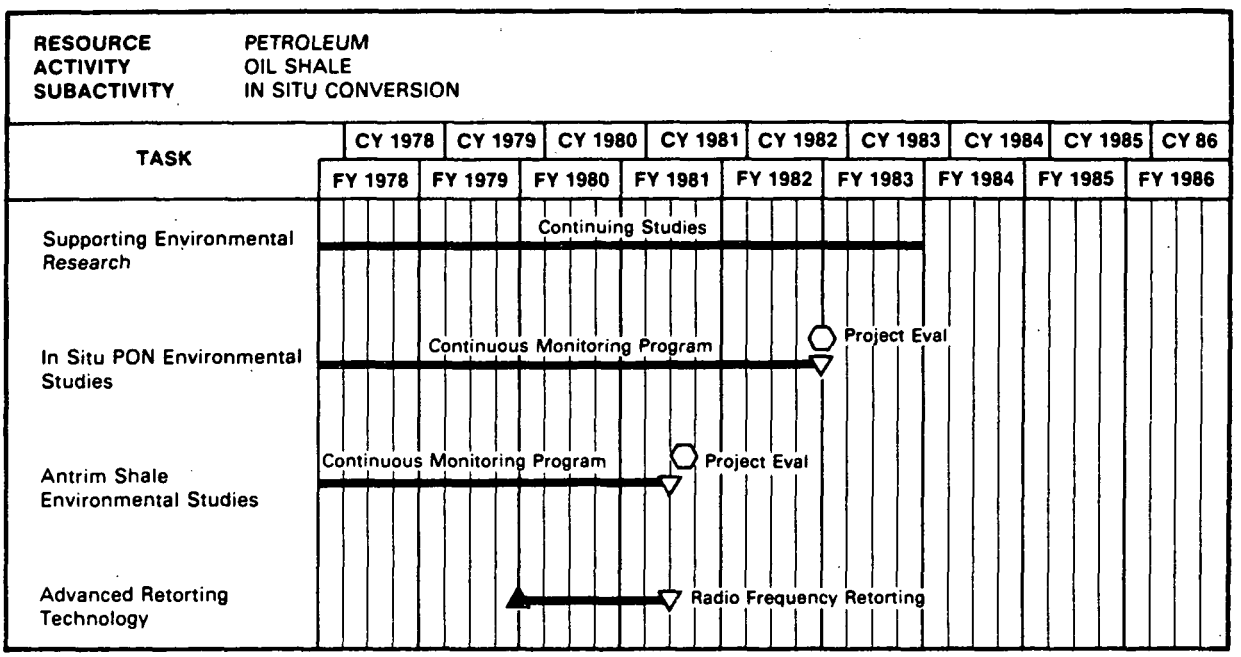
LASL will continue a series of small field tests on oil shale response to explosive shock in FY 1980 and intermediate-scale tests in FY 1981 to refine empirical models. These tests and data from major field projects will be used to complete the VMIS rubbling design. Instrumentation of these tests will be supported by Sandia Laboratories.

Continued development of a commercially viable technology for controlling the in situ retort and burn operation will be supported by Lawrence Livermore Laboratory (LLL) and LETC, using data from contractor field operations and large laboratory retorts to provide kinetic, reaction chemistry, and transport phenomena data to a mathematical process model. This model will reach a stage of preliminary usefulness for predicting Moon Shot design performance in FY 1981, although final development and verification will require input from actual commercial-scale VMIS retorts.

In addition to the in situ base technology program supporting near-term process development, the In Situ area of the Oil Shale Activity has conducted studies of advanced process concepts such as microwave or radio-frequency retorting of oil shale. Advanced retorting processes are those that show promise of substantial economic improvements and/or reduced environmental impacts compared to existing programs. Such advanced processes have typically undergone bench-scale development or are presently in an active laboratory or small PDU-development phase that has provided promising data.

Certain concepts require laboratory research to provide the first level of confirmation of potential benefits.

Work on one such process involving radio-frequency heating will be ongoing in FY 1980 as a result of a contract awarded to the Illinois Institute of Technology Research Institute (IITRI) under DOE's FY 1979 Program Research and Development Announcement (PRDA) for innovative processes for retorting oil shale. Future support of such research will be considered under the Advanced Process Technology budget line.



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Major Field Tests

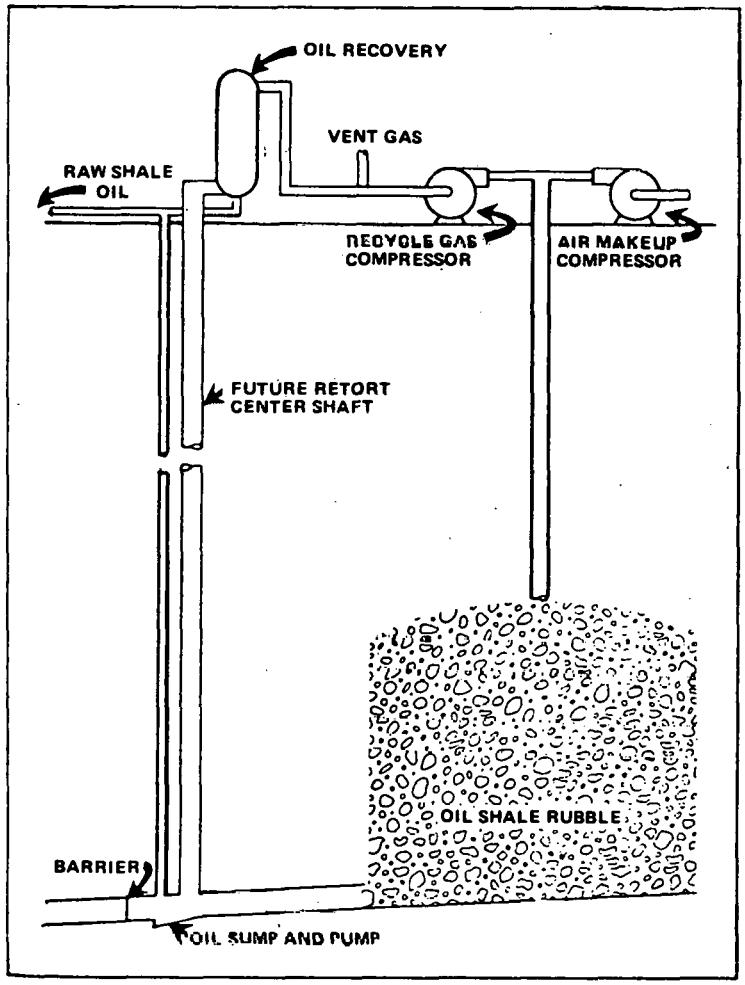
In the production of oil from oil shale, major accomplishments for FY 1980 and anticipated progress during FY 1981 are as follows.

Three field tests are underway via three major in situ government/industry cost-sharing contracts.

Occidental Oil Shale, Inc., Debeque, Colorado. Final analyses of the results of Phase I will be completed in FY 1980. Preliminary calculations indicate that about 47,000 barrels of shale oil were produced by retort No. 6. Preliminary mining for access to Phase II retort locations is underway.

Negotiations on a detailed Phase II scope of work will be completed with the objective of overcoming presently known design deficiencies in retort No. 6 and simultaneously establishing cluster operating procedures, pillar requirements between retorts, retort stability data, and environmental data and procedures for retort abandonment, through tests that will include a two-retort cluster at the present site. Planned tests on site C-b have been deferred due to actual time requirements for mine preparation.

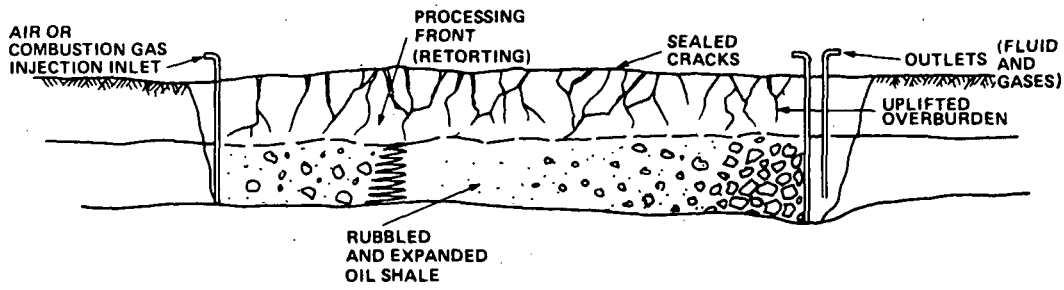
Phase II contract will contain provisions for the DOE to conduct independent research and development activities necessary to the successful completion of the VMIS project. As presently planned, final designs for the two-retort cluster will be completed in FY 1980. Work in FY 1981 will include two miniretort startup tests, rubbling of the full-scale cluster, completion of diagnostic tests on the rubbled retorts, and ignition in September 1981.



Occidental Oil Shale Process Retort Operation

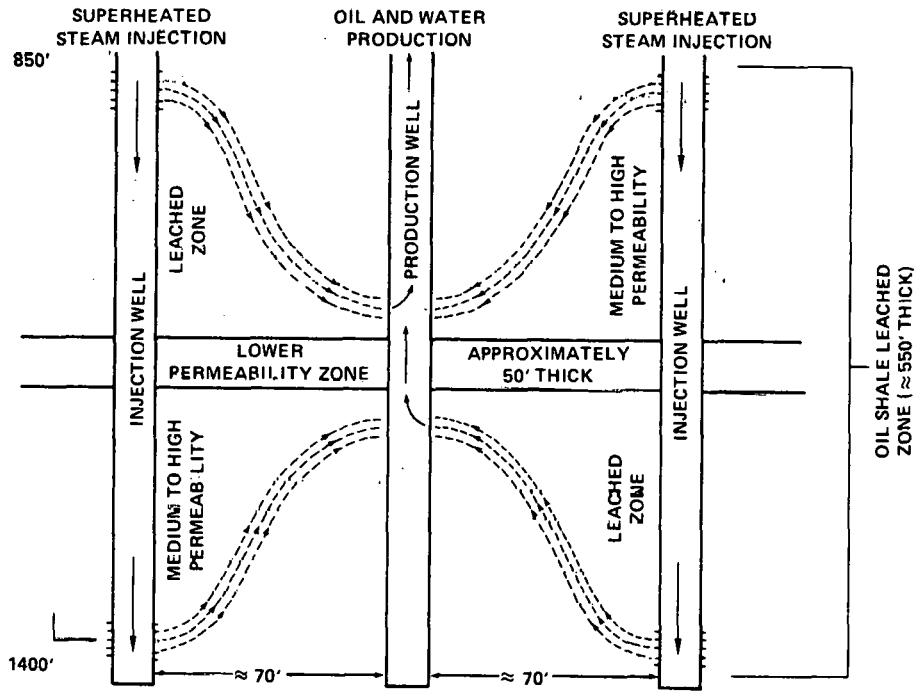
Geokinetics, Inc., Uintah County, Utah. Retort No. 17, the largest retorting experiment to date in this project, will be completed in FY 1980 with expected production of at least 4,500 barrels of shale oil. This retort is 126 feet wide, 182 feet long, and 30 feet thick. It had produced 3,150 barrels by the end of FY 1979. Present Geokinetics work plans for the FY 1980-1981 period include two full-scale retorts 200 feet wide by 30 feet thick under as much as 90 feet of overburden and a three-retort cluster at staggered depths. This size exceeds the original target for cross section and would achieve all contract goals. The objective is to begin two-year technical feasibility demonstrations of minicluster (three to five retorts)

based on optimum design and size developed in prior phases, involving substantial overburden uplift by explosives and expansion of rubbled oil shale into the created void. Retorting is accomplished in a horizontal direction using direct combustion sustained by low-pressure air injection. The technique is considered applicable to thin-to-medium-thickness shales with up to 100 feet of overburden. The demonstration phase beginning in FY 1980 is expected to use commercial retort cross sectional dimensions of 6,000 square feet. The contractor has estimated that this process could be economic if the larger retorts give as equally successful results as those achieved to date. Up to 12,000 barrels of shale oil are expected to be produced by each of the demonstration-size retorts in FY 1980-1981.

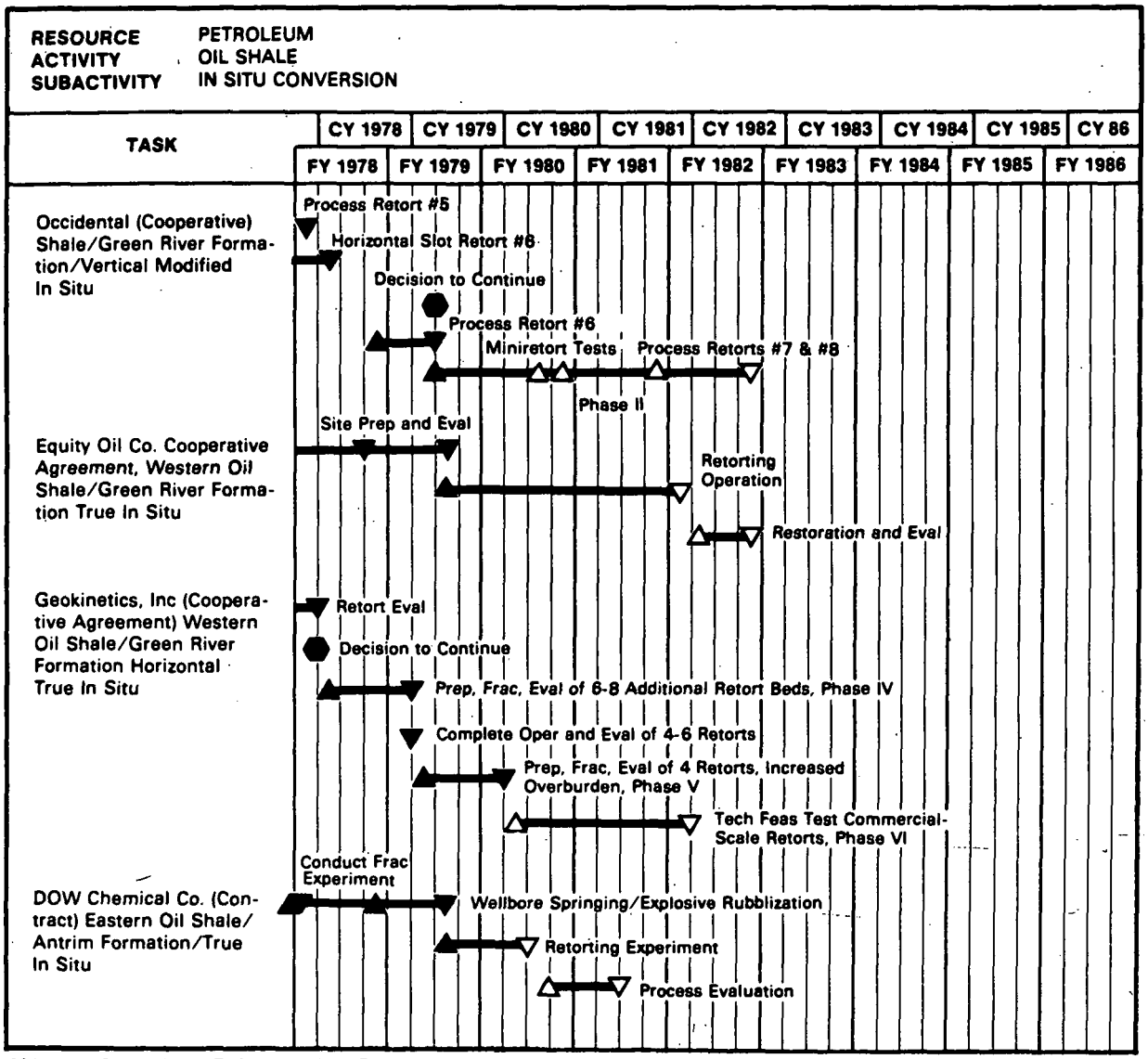


Modified Horizontal In Situ Process — Geokinetics, Inc.

Equity Oil Company, Rio Blanco County, Colorado. A semivertical in situ process is under development for processing the leached zone in Colorado that utilizes the void space created by dissolution of water-soluble salts originally distributed throughout this approximately 500-foot-thick section of oil shale. That zone contains an in-place resource equivalent to over 1 MMbbl/acre of shale oil. Injection of superheated steam into the leached zone began mid-FY 1979. Oil production is expected to begin during FY 1980 and should continue throughout FY 1980-1981. The 0.7-acre test is presently expected to produce over 300,000 barrels during a two-year retorting test, at 50 percent Fischer assay. Computer analyses indicate that more than half of the total production should occur during the first year.



Equity In Situ Project, Idealized Injection/Production (Current Pattern is Backed-up 5-spot Pattern)



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2.0 SURFACE CONVERSION

Technology Base Program

Principal technology base activities related to surface oil shale processing that will be ongoing in the FY 1980-1981 period are related to process modeling and environmental concerns. An interagency study on spent shale stability will be completed. LLL will complete adaptation of an in situ processing model to the moving-bed conditions of a surface retort to assist DOE in evaluating the surface retort module designs discussed under Major Projects.

An advanced technology project on surface hydrogen retorting was initiated under the FY 1979 PRDA discussed under the In Situ section, and is scheduled for completion in FY 1981. This contract with the Institute of Gas

Technology (IGT) is aimed at establishing the technical and economic feasibility of recovering shale oil or combustible gas from both eastern and western oil shales, using the IGT HYTORT process.

Major Projects

Although the DOE strategy for surface retort development is largely dependent on financial incentives, the DOE is pursuing a surface module demonstration plant program as described in P.L. 95-238. The objective of this program is to stimulate the development of an oil shale industry by demonstrating the engineering, economic, and environmental feasibility of a surface retorting process at the scale necessary to prove commercial feasibility. This program will be divided into two phases.

Phase I is the procurement of technical designs, cost estimates, and environmental data for site-specific construction and operation of one or more of the modern oil shale surface retorting processes that have previously shown feasibility at pilot scale. These designs will be for modular equipment configurations at a size that could be replicated in commercial practice.

Phase II, if needed due to problems with implementing incentive approaches, will include the actual construction and operation of a retort process selected subsequent to Phase I, leading to either commercial expansion or abandonment. Operating data and costs and environmental information will be collected and evaluated to determine performance and acceptability.

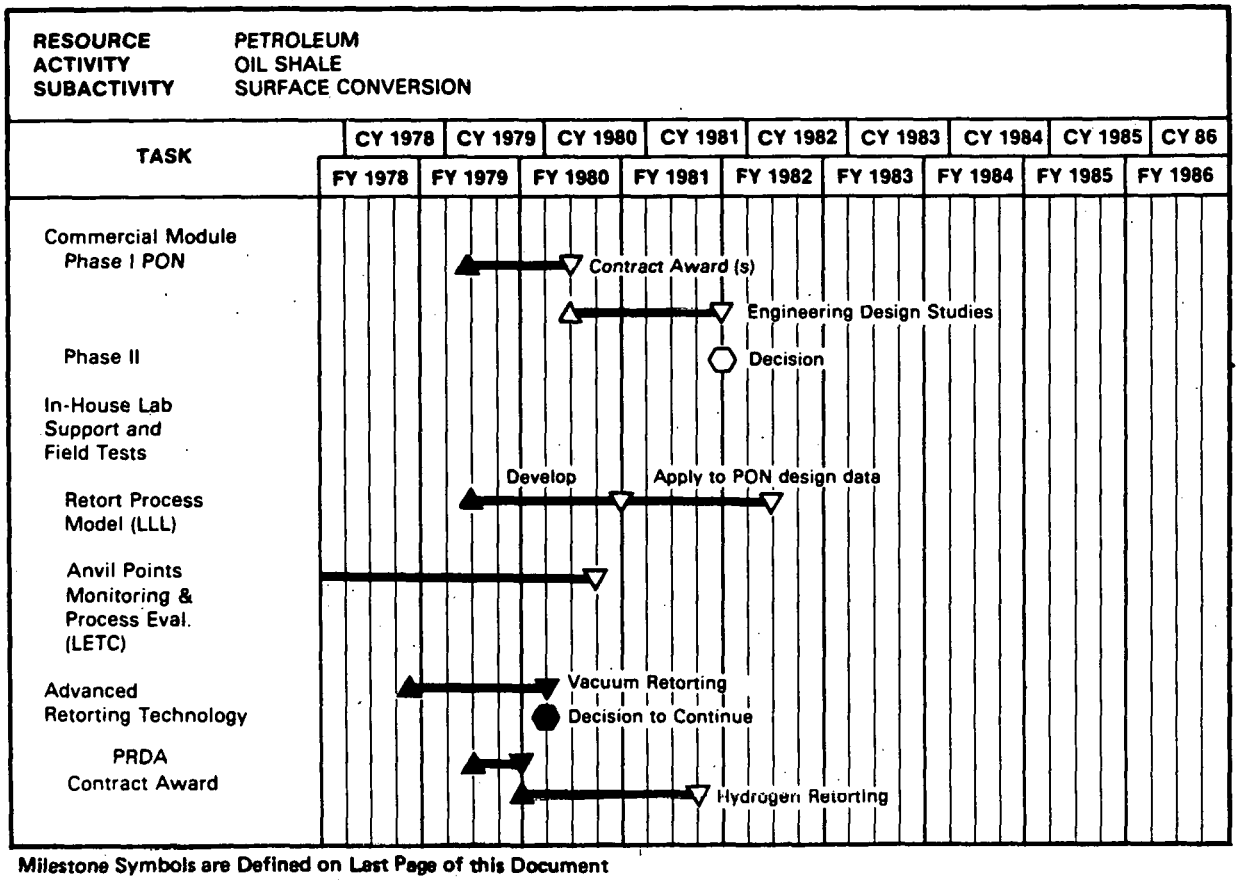
Under a Program Opportunity Notice issued in FY 1979 for Phase I, one or more contracts will be awarded in FY 1980. It is presently estimated that required work under these contracts will require 18 months for completion.

In Phase I a number of tasks are expected to be completed during the design of the modules. Technical criteria for the design will be established based on operating and performance data from pilot-scale retorts and laboratory experiments. The size of the module will then be determined. This will be an engineering scaleup such that it could be duplicated for commercial oil shale development. Included in the design of the module will be several crucial elements as listed below:

- A management plan including a schedule and cost estimate for accessing a site for the demonstration program
- Identification of all environmental, health, and safety permits required by Federal, State, county, and local agencies before, during and after Phase II
- An environmental compliance plan depicting all environmental work necessary to comply with DOE environmental regulations and permit requirements
- The compilation of all data necessary to complete an EIS to comply with NEPA and to acquire all necessary permits

- A detailed design for construction of a surface retort module and preliminary design of all auxiliary facilities needed for the demonstration
- A management plan for scheduling and estimating costs associated with construction, operation, and maintenance of the demonstration facility
- A plan for the transportation and marketing of the crude shale oil product
- Development of the technical and economic criteria for evaluating the design, construction, maintenance and operation of the demonstration facility
- A cost estimate for the production of 100,000 barrels per day of shale oil based on projected performance of commercial-scale retorts in an industrial plant facility
- The preparation of an abandonment plan, including schedule and cost estimates for dismantling, preservation, or alternate use of the facilities after the demonstration.

The schedule for completing Phase I designs should permit DOE to complete design evaluation and initiation of the potential Phase II program early in FY 1982.



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C. DRILLING AND OFFSHORE TECHNOLOGY

For the foreseeable future, the United States must rely upon fossil energy resources to supply the bulk of its energy. Drilling is an integral technology required for exploration and production of all petroleum, natural gas, coal, oil shale, and tar sand resources. Although the bulk of these domestic fuel resources is located onshore, the petroleum industry estimates that 60 to 70 percent of all additional petroleum discoveries will be made offshore on the Outer Continental Shelf (OCS). DOE estimates (1979) that in order to maintain current domestic levels of production at 10 MMbbls/day, some 37 percent (20 percent oil and 17 percent gas) of all production in 1990 must come from the OCS. Estimates of potentially producible reserves in the U.S. OCS areas include 32 billion barrels of oil and 210 trillion cubic feet of natural gas.

Development of efficient, cost-effective drilling and offshore technology can have a pronounced effect upon the pace at which both conventional and unconventional fossil fuels are produced. In some cases (e.g., methane from coal, underground coal conversion and oil/gas production from waters greater than 1,000 feet in depth), the development of new technology may determine whether a resource becomes a commercial reserve.

Drilling and Offshore Technology research activities address the following program objectives:

- Improve the productivity of conventional drilling systems to increase average penetration rates and thus increase the total footage drilled per year by the U.S. drilling rig fleet.
- Develop longer lived, more efficient, advanced ("revolutionary") drilling concepts.
- Develop required technology to drill and produce fossil fuels from both onshore and offshore "frontier" areas:
  - very deep formations (greater than 30,000 feet)
  - deep offshore waters (greater than 1,000 feet)
  - Arctic environments.
- Reduce or eliminate any adverse health, safety and environmental impact of both new and existing technology applications.
- Coordinate and/or provide direct research support to the Office of Oil and Gas Research development programs and to related programs within DOE (Geothermal, Energy Research and Environment) and other Federal agencies (Departments of Interior and Commerce).

Although the program research activities are affected by both technical and nontechnical (environmental, legal and socioeconomic) constraints, there

are no known technological or physical barriers to development of improved drilling and offshore technology. Definition of specific goals and objectives coupled with the dedication of adequate funds, manpower and research facilities will produce specific improvements in drilling and offshore technology.

The program is separated into three subactivities:

- Drilling Technology
- Offshore Technology
- Environment and Support.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

DRILLING AND OFFSHORE TECHNOLOGY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Drilling Technology	1,509	1,500	500
Offshore Technology	585	1,000	1,300
Environment and Support	506	500	200
Capital Equipment	0	0	370
TOTAL	2,600	3,000	2,370

1.0 DRILLING TECHNOLOGY

This program subactivity sponsors development of more productive, more cost-effective and safer drilling methods through generic research which is applicable to the broad spectrum of drilling technologies. Direct government R&D is most appropriate for:

- Basic research that underlies systems and hardware development
- Development of new technologies characterized by potentially large benefits, but also by high risk, and the prospect of an extended wait for return on investment.

At the request of the House Committee on Science and Technology, a formal Management Plan for drilling technology R&D is being developed. This comprehensive document identifies four major program elements and provides detailed task descriptions, deliverables, and cost figures for each element. Subject to congressional approval of the plan, several of the higher priority R&D tasks will be initiated in FY 1981, with complete program implementation scheduled for FY 1982.

Major program elements of the Management Plan include:

- Conventional Technology Development

  Improve the productivity of conventional drilling systems through the application of basic and supporting research to augment industrial development of drilling technology. Specific research areas include:

  - data and methodology required to identify needed high-impact projects and selection of appropriate proposals
  - support of research in materials, fluid dynamics, drilling fluids and rock mechanics
  - instrumentation systems
  - assessment of impact of new technologies on the environment.

- Advanced Concepts

  Identify, evaluate and develop new technologies for fossil fuel extraction that have the potential to produce significant improvements in drilling system performance and application. Major research areas will include advanced completion technology, new telemetry systems, new power transmission systems, and novel rock removal systems (melting and vaporization, thermal spalling, chemical reactions, and mechanical breakage).

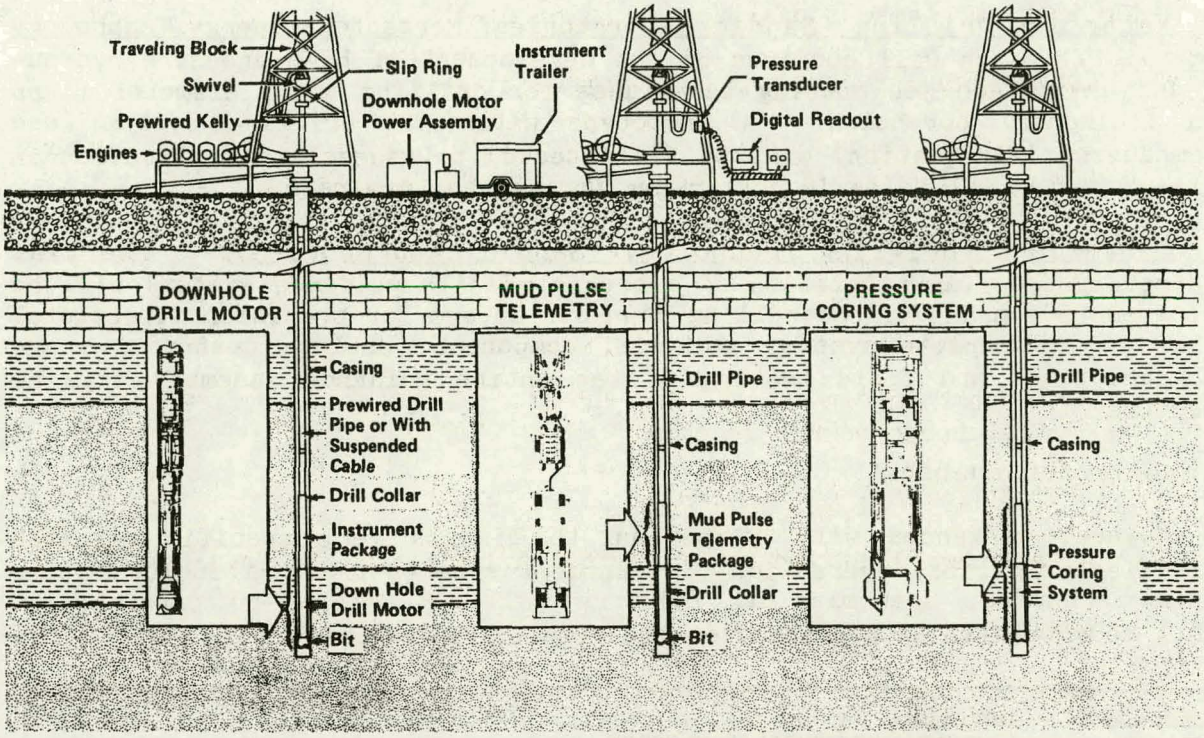
- Technology Interchange

  Provide rapid and effective dissemination of results of government sponsored research to the appropriate user community. Specific activities will include:

  - publication of semiannual research summaries
  - improved coverage of drilling technology in technical publications
  - promotion of active technical interchange through personal contacts (workshops, symposia, project review sessions).

Examples of improved drilling technology efforts which have been and are being jointly investigated by FE and industry are shown in the following illustration. The Teleco mud pulse telemetry system (center) is currently in commercial service.

Research continuing or planned for FY 1981 under the Drilling Technology subactivity includes conventional drilling technology and advanced concepts, as discussed below.



Improved Drilling Technology

Conventional Drilling Technology

High Performance Bit Technology (Sandia Laboratories): This research activity is directed toward optimizing rock removal techniques and bit hydraulics performance for newly developed polycrystalline diamond compact (PDC) drag bits. This work will investigate and quantify rock removal mechanisms, hydraulic behavior, heat transfer and other dynamic characteristics of drag bits used with high-speed downhole drilling motors.

Fluid System Investigations (Sandia Laboratories, Bartlesville Energy Technology Center): This activity will evaluate and quantify cuttings removal capabilities for various drilling fluids employed in very deep (greater than 20,000 feet) and highly deviated (30°-90° angle) directionally drilled wells. Laboratory and field experiments will be augmented by computer modeling. Hole stability and particle transport phenomena in aerated fluids also will be experimentally investigated.

Materials Research (Sandia Laboratories): New high-temperature, high-pressure, and corrosion resistant alloys and elastomers will be tested to determine whether they are superior and more cost-effective materials for use in coatings, fillers, strengthening agents and fabrication of equipment components.

Instrumentation Development (Sandia Laboratories): This activity will provide for the development of downhole and surface sensors to be used in collection and processing of data required to optimize drilling operations.

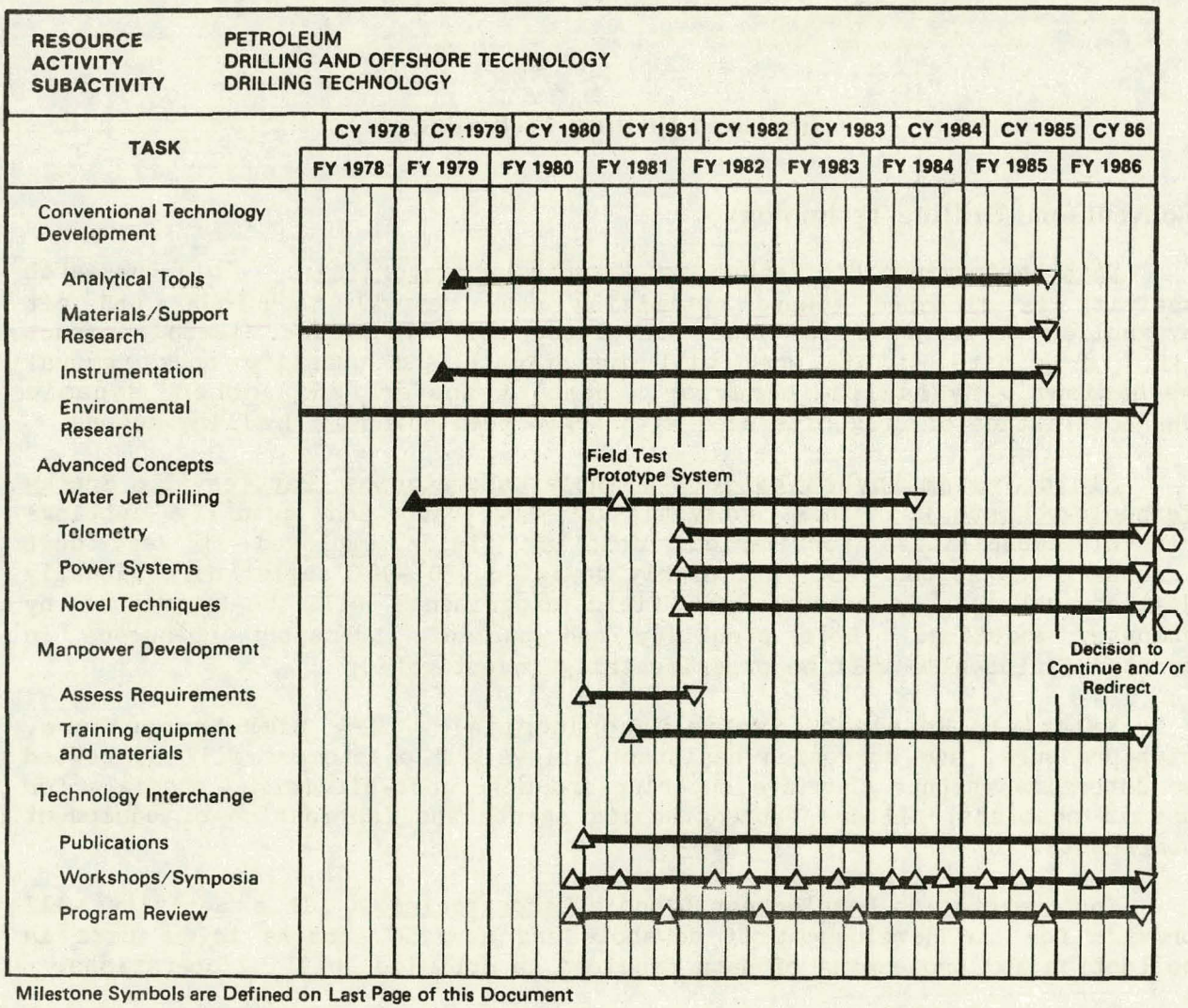
Advanced Concepts

Water Jet Drilling (Sandia Laboratories, Morgantown Energy Technology Center): Research will continue on the development of high-pressure hydraulic and cavitation jet cutting techniques for drilling small diameter (less than 18-inches) boreholes. A prototype water jet drilling system (see accompanying illustration) will be field tested to assess its application in drilling horizontal holes in coal seams for methane drainage.

Directional Drilling Technology (Sandia Laboratories): Inertial guidance systems (an adaptation of a cruise missile guidance system) will be evaluated as a means of controlling downhole motors for precision directional drilling. A complete systems analysis, component testing (destructive and nondestructive) and field testing of the entire guidance assembly will be conducted.

Technology Interchanges

Several workshops will be set up to discuss very specific research activities (e.g., bit hydraulics). Technical experts from within DOE, other Federal agencies, academia and industry will be invited to participate. Formal reports will be published on the results of each workshop.



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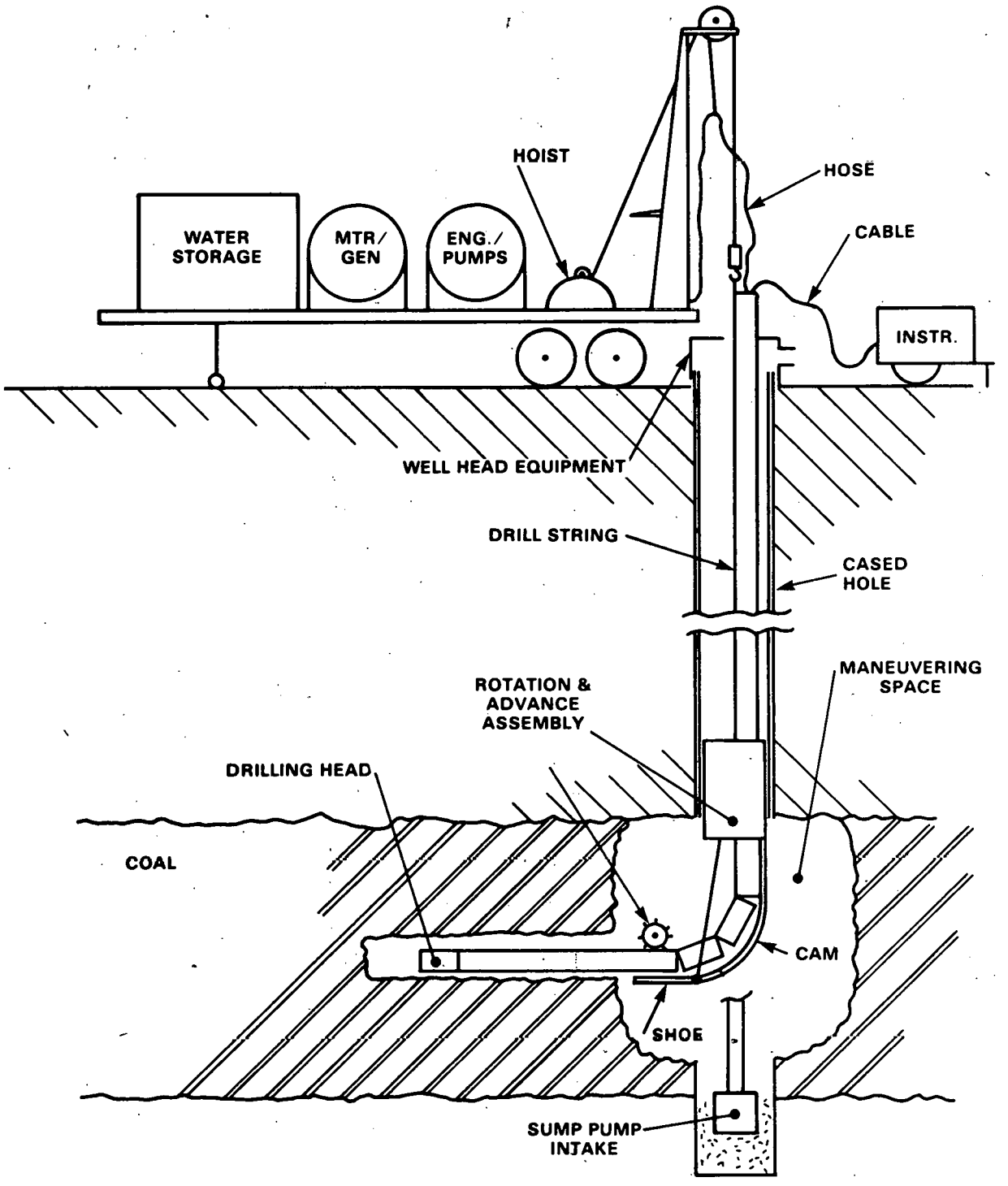


Water Jet Drilling System Layout

2.0 OFFSHORE TECHNOLOGY

The major objective of this subactivity is to accelerate development of oil and gas drilling and production technology in deep water (greater than 1,000 feet) and hostile climatic environments. Federal development of offshore technology is a fundamental national need, given the large potential for oil and gas production from the OCS. At present the pace at which offshore energy resources are developed is constrained by inadequate data, inadequate technology, long lead-time requirements and a general lack of cohesion both within the industry and between the industry and Federal agencies.

A comprehensive R&D management plan for offshore technology development will be prepared during 1980. This plan will identify, describe, and provide costs for specific research tasks required to meet the stated program objectives. The plan will be focused upon two major elements:

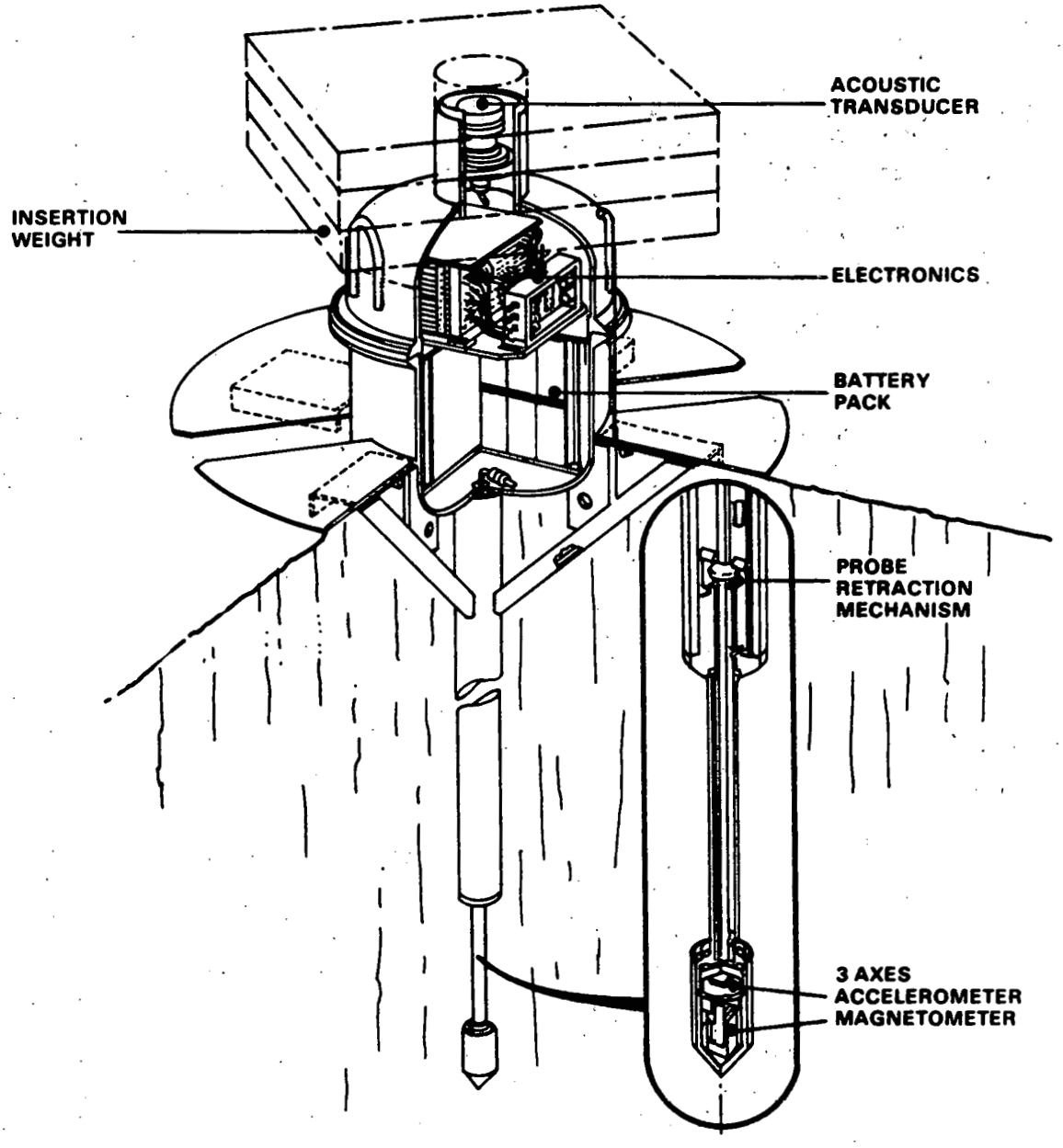
- Instrumentation Development
- Acquisition, Analysis, and Dissemination of Environmental Data.

Continued DOE cooperation with other Federal agencies (USGS, NOAA, and NSF) and institutional bodies (National Research Council, Committee on Atmosphere and Oceans) will strengthen and focus the program on major technological issues.

Instrumentation Development

Seafloor Geotechnical Instrumentation (Sandia Laboratories): This ongoing research is focusing its efforts on development of instrumentation systems capable of collecting marine geotechnical data to aid in engineering design studies for offshore structures. Specific activities planned for FY 1981 include:

- Demonstration of an advanced, long-lived, recoverable Seafloor Earthquake Measurement System (SEMS)
- Testing of a prototype, quick-response sediment shear-strength measurement device (Geotechnically Instrumented Seafloor Probe or GISP)
- Analytical land experimental studies of in situ state-of-stress measurement techniques on bottom muds
- Investigation and development of improved acoustic telemetry systems for data retrieval
- Laboratory investigation of the effects of fundamental marine geotechnical phenomena (e.g., wind, wave, current, and ice stress) on offshore operations.

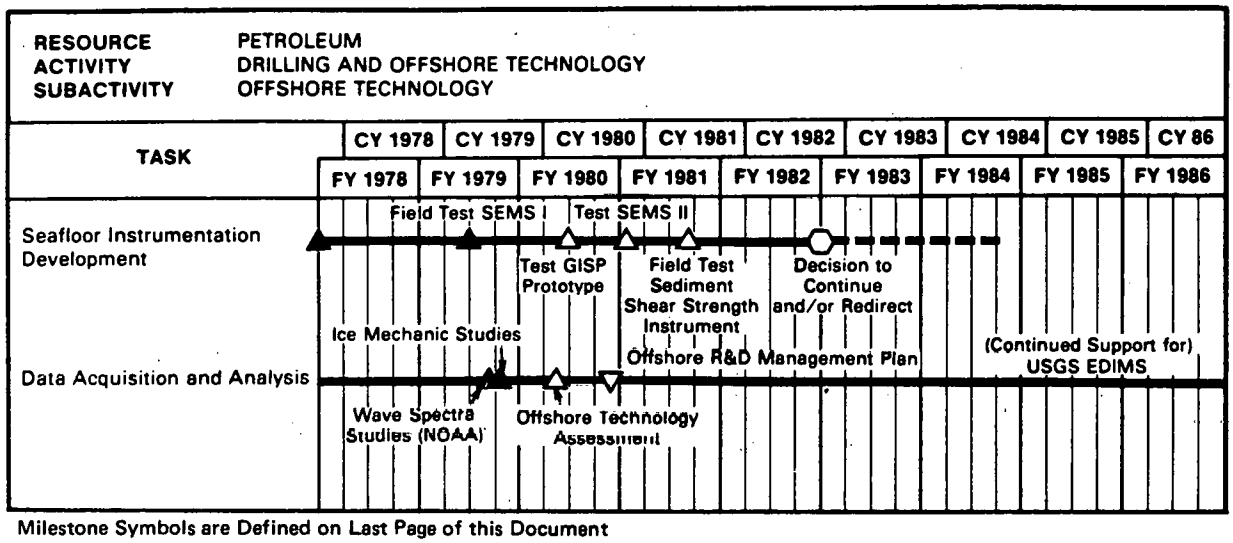


Seafloor Earthquake Measurement System

Data Acquisition, Analysis, and Dissemination

EDIMS Program (USGS): Continued support for the USGS-managed Environmental Data Information Management Systems (EDIMS) will assure collection and collation of a comprehensive data base on existing environmental information (current, wind, wave, ice, and bottom sediment conditions) for a variety of offshore locales.

Data Acquisition Program (various): This effort will identify users and needs for specific geotechnical data not presently available. A cooperative cost-share effort with other Federal agencies (e.g., USGS, NOAA, NSF, and USCG) will provide required geotechnical data in critical offshore areas such as the Beaufort Sea.



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3.0 ENVIRONMENT AND SUPPORT

Environment and support studies are conducted on an ad hoc basis to provide both technical review and direction for both the Drilling and Offshore Technology subactivities.

Program Management Support

A comprehensive Drilling R&D management plan is being prepared for delivery to Congress in 1980. The plan provides a logical strategy for drilling research and identifies specific research activities and deliverables required to meet program goals of improving the mechanical efficiency and cost-effectiveness of drilling technology.

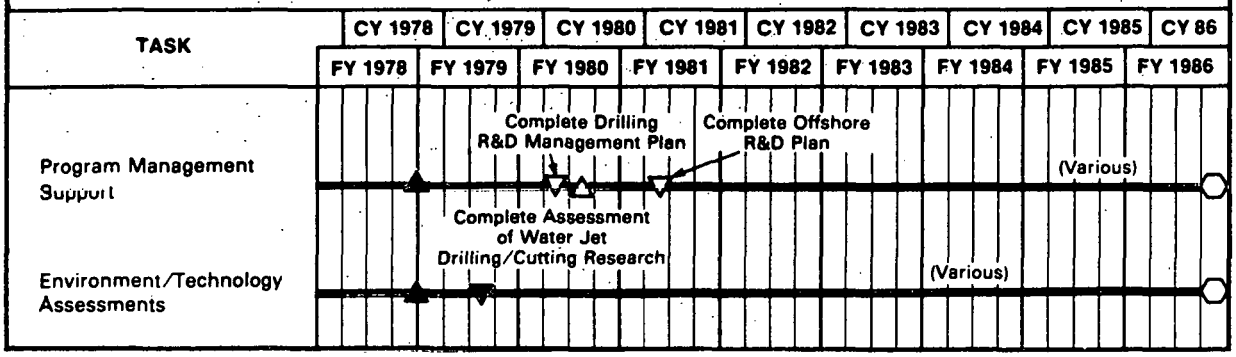
An analogous management plan identifying specific Offshore Technology R&D activities will be prepared during FY 1980 for delivery to Congress in 1981.

Supporting research funds are also provided to special technical advisory committees such as the Marine Board of the National Research Council. These advisory groups provide technical oversight and direct liaison between private industry, academia, and the program managers.

Environmental/Technology Assessments

Technical assessments and analytical studies are funded to assure nonduplication of federal research activities and that all new technologies meet existing and foreseeable environmental and health and safety requirements.

RESOURCE PETROLEUM
ACTIVITY DRILLING AND OFFSHORE TECHNOLOGY
SUBACTIVITY ENVIRONMENT AND SUPPORT



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D. ADVANCED PROCESS TECHNOLOGY

The Advanced Process Technology (APT) program has been organized into three subactivities: Advanced Exploratory Research, Product Characterization and Utilization, and Shale Oil Refining and Utilization which also includes heavy oil refining. Since these elements differ in technology and approach, each is described separately. In-house R&D is primarily performed at Lawrence Livermore Laboratory (LLL), Lawrence Berkeley Laboratory (LBL), Sandia Laboratories (SL), Los Alamos Scientific Laboratory (LASL), and the Bartlesville (BETC), Laramie (LETC), and Morgantown (METC) Energy Technology Centers.

The following table summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

ADVANCED PROCESS TECHNOLOGY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Advanced Exploratory Research	0	1,700	2,200
Product Characterization and Utilization	1,200	1,300	1,300
Shale Oil Refining and Utilization	1,000	2,500	1,000
Capital Equipment	0	500	500
TOTAL	2,200	6,000	5,000

1.0 ADVANCED EXPLORATORY RESEARCH

Although domestic petroleum reserves are declining, petroleum still contributes a large fraction of U.S. energy consumption, and large resources of coal and unconventional energy sources exist. The Advanced Exploratory Research (AER) element is directed at developing advanced and innovative technology which could make significant improvements in extraction of resources. Specific areas for which these technologies will be sought are enhanced oil and gas recovery (EOR, EGR), in situ conversion of coal and oil shale, recovery of heavy petroleum deposits, and shale retorting.

The AER subactivity will pursue two major thrusts: Basic Technology Development and New Process Concepts. Basic Technology Development includes developments in rock mechanics and fragmentation and in situ heat and mass transfer with fluid flow (hydrology). Rock mechanics and fragmentation (the development of enhanced permeability in the rock matrix) is a controlling factor in virtually all in situ processes and is thus applicable to oil shale

retorting, enhanced oil and gas recovery, and in situ coal gasification. The properties and characteristics of the resource-bearing formations in the in situ environment must be understood to be assured of the success of in situ processes. The DOE has the capability to perform a key role in this generic area and to transfer the techniques and knowledge to other DOE programs and to industry. The potential payoff of this activity is too long term for industry to do the required work on its own.

Hydrology (the flow and composition of formation water) also has an impact on the success or failure of in situ processes involving EOR by micellar and surfactant flooding, EGR, oil shale retorting, and in situ coal gasification.

New Process Concepts includes new approaches to oil shale retorting and improved recovery of conventional hydrocarbons. Advanced oil shale retorting will develop techniques using steam mixtures, which should provide higher yields and better quality products than are currently obtained by air-based systems. The option of producing hydrogen or high-Btu gas from the product gas also exists.

Improved recovery by the use of microorganisms is in the experimental stage. It is well known that certain bacteria can break down the structure of kerogen and heavy oil into more valuable forms. Application of this phenomenon, in situ, may result in high resource recovery at low cost and high energy efficiency. This will be a long-term effort in which industry is not active. Thus, the formation of a DOE program is required to develop this novel approach.

These advanced technology projects will undergo regular review directed toward deletion of unsuccessful effort and concentration of resources on processes that exhibit promise. Special effort will be made to maintain communications with other groups involved in development of less advanced technology.

To accomplish the programmatic and strategic objectives, the AER program has been organized into elements comprised of core technologies plus a novel concept element. The strategy of each element is to:

- Perform preliminary tests of process concepts at small scale to determine the performance of these new ideas.
- Transfer the promising concepts to the respective resource program elements for continued development.
- Develop a core technology base by acquiring data and understanding of the critical physical and chemical phenomena that form the basis of the processes being developed under the extraction program.
- Emphasize technical areas that are useful to more than one resource or extraction process.
- Transfer the resulting information to other extraction program elements to help support process design, testing and improvement.

The engineering, scientific, and systems analysis core technology elements are:

- Fracturing and Rock Mechanics. This element applies to oil shale mining and rubbling of in situ retorts, opening formations for enhanced gas and oil recovery, coal mining, and preparing coal seams for underground gasification. Characterize nonideal explosives; determine the effect of gas production from explosives on rubbling; develop staged shaped charges for linking in underground coal gasification; and determine the effects of charge size and placement on rubble characteristics.

- Instrumentation and Automation. This element applies to all extraction programs and includes, for example, resource assessment, process monitoring, and automatic control. Refine remote-sensing methods for locating underground flame fronts; develop high-temperature logging techniques; determine critical automation problems in mining, including detection of the coal/roof or floor interface; tracer systems for measuring in situ permeability and reaction paths; remote measurement of reaction zones in oil shale rubble, in situ coal gasification, and heavy oil fire flooding.

- Transport Processes. This element is the controlling step in most underground combustion processes and includes fluid flows through geologic formations applicable to all extraction systems. Characterize multiphase flows through packed beds; develop models for fluid flow through low-permeability fractured media; expand hydrology model capability to include trace-element transport rates; measure mass-transfer rates from shale particles; determine scaling parameters for large in situ reactors; computer modeling of underground processes.

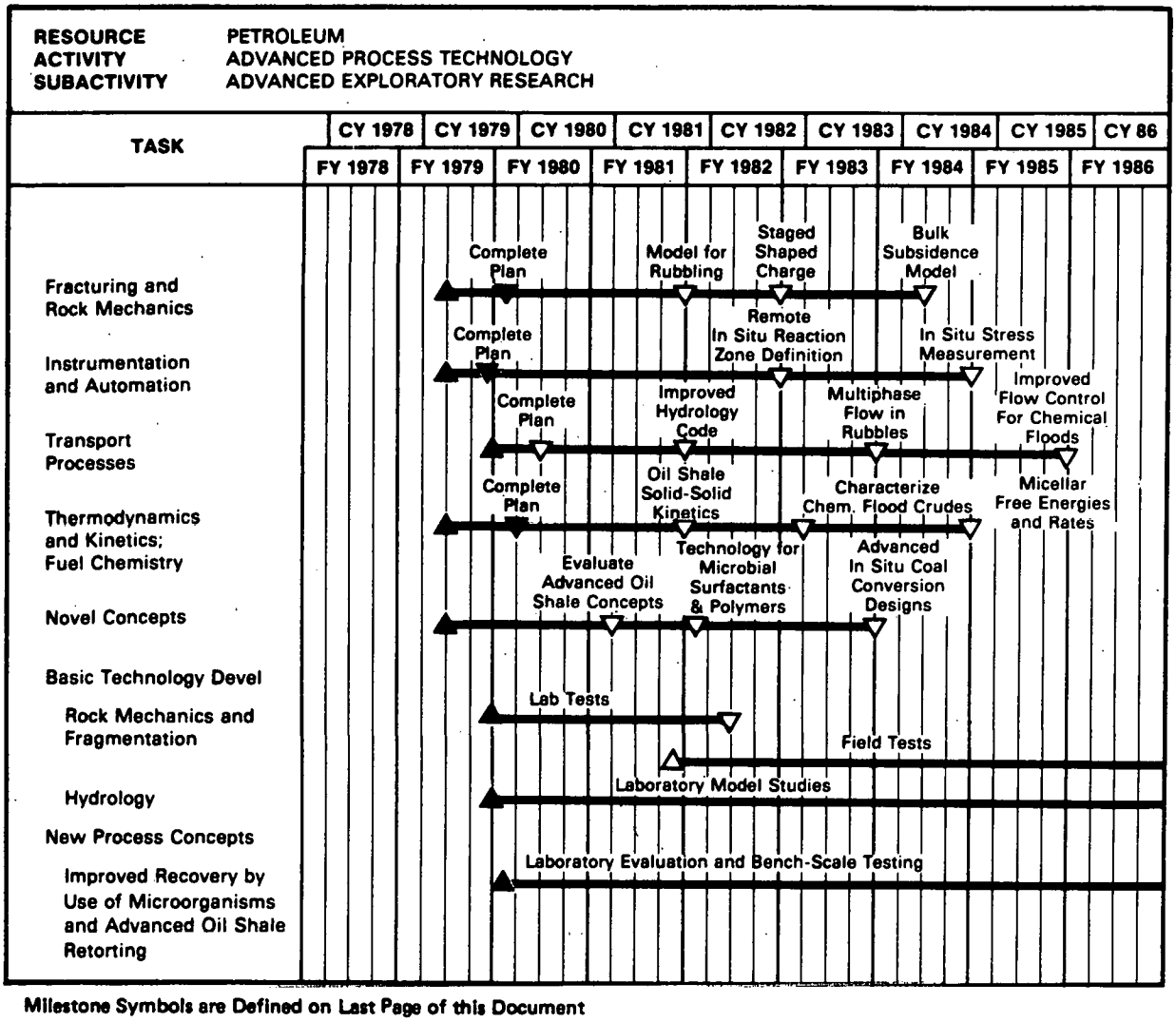
- Thermodynamics and Kinetics. This element applies to all extraction programs and includes, for example, the requisite information to design and operate processes for chemical floods in petroleum fields and in situ coal gasification and oil shale retorting. Determine reaction paths in shale retorting and measure rates; conduct phase studies related to carbon dioxide floods; measure interfacial-tension dependence of oils as a function of temperature and viscosity; determine heat balances in thermal recovery of oil, tar sands, and shale.

- Fuels Chemistry. This is a broad element, but only select topics will be addressed in the areas of coal preparation, petroleum recovery and in situ processing. Characterize crude and refined products from enhanced oil recovery and oil shale; determine the chemistry and removal of organic sulfur, nitrogen, and metal oxides from coal and oils; study reactions affecting fuel stability.

- Geology and Economic Resource Characterization. This element deals with the geological science needed for extractive processes, mine design, and evaluation of the economic feasibility and value of resource recovery. An analysis of R&D needs in this element is being started.

- Novel Concepts. This element supports new and novel ideas for extraction processes that have little or no previous work and carry high risk. Acceptable concepts will be developed through analytical and experimental work. Promising concepts will be transferred to the main extraction programs. Develop basic performance of oil shale process concepts such as microwave, radio frequency, vacuum, and noncombustion retorting; use microbes to produce enhanced oil recovery surfactants and polymers; examine the feasibility of biochemical in situ extraction techniques; develop designs for oil shale and coal gasification in situ processes that use novel subsidence control and module sequencing; explosive shaped charges for controlling underground flow reaction paths; experiments in retorting oil shale with solar energy.

In FY 1981, the emphasis will be to accelerate present research on advanced oil shale retorting technology, utilizing such systems as microwave conversion, radio frequency conversion, and vacuum retorting. These studies will include research such as the heat transfer characteristics of oil shale, kinetics of shale oil reactions, and the fracturing phenomena of oil shale.



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Also, work will be performed to increase the knowledge base for the development of improved chemical flooding technology, utilizing more efficient and less costly chemicals and basic research on the use of microorganisms for enhancing oil recovery.

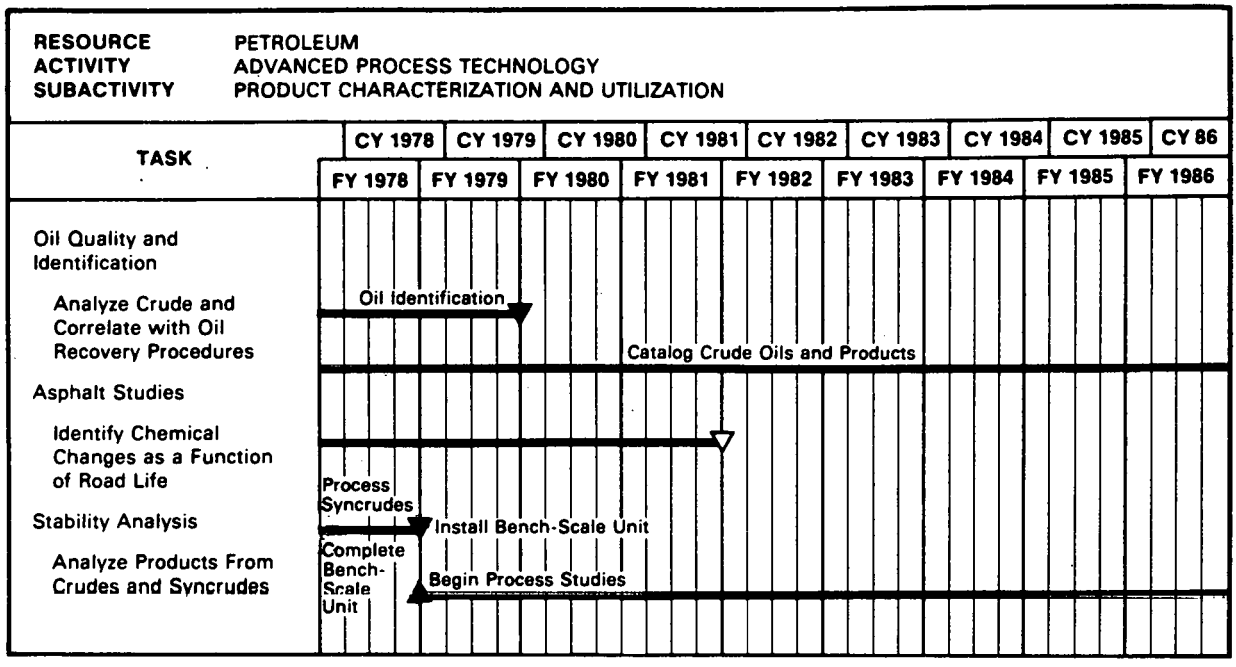
2.0 PRODUCT CHARACTERIZATION AND UTILIZATION

The Product Characterization and Utilization (PC&U) element focuses on the analysis and characterization of crude oil, heavy oil, and tar sands, including analysis of asphalt as a function of road life. For many years, research in these areas has been conducted at BETC and LETC.

The objectives of the PC&U subactivity are to maintain and improve the existing data bank on crude oils and products, establish the chemistry of fuel stability, and develop asphalt materials with increased road life.

Expected results are increased utilization of heavier petroleum fractions in producing quality fuels; matching of enhanced oil recovery chemicals with oil type, resulting in more efficient resource recovery; design of improved processes for heavy oil and tar sand recovery; data collection on the chemistry of fuel stability; and efficient utilization of asphalt through improved road life. Characterization of the materials described above will provide important data on metals and heteroatom content. These are important environmental parameters impacting on utilization. Maintaining data on the quality of crude oils will provide a unique and valuable resource of data on domestic and foreign crudes for use by government and industry. Correlation of asphalt wear with changes may yield new asphalt compositions with increased road life.

The strategy for the PC&U element involves (1) the continuation of the analyses and tabulation of data on crude oils and products; (2) stability studies on blends of synthetic and conventional crudes and products; and (3) analytical studies of asphalt road life and correlation of road life with chemical breakdown of asphalt structure. The oil data bank activities are carried out with relatively conventional analytical techniques but aim at developing characteristic data useful to the production of low-quality petroleum deposits. Also, more sophisticated techniques have been developed which can now be used on a routine basis to allow differentiation between old and new oil. Fuel studies apply a vast background of expertise on fuel stability to resultant stability problems from blending petroleum crudes and products with synthetic crudes and products. Heavy ends studies provide composition and chemical reactivity data on asphalt with reference to properties and useful road life. A number of compositional factors affecting road life have been identified. Additional information to be determined will include aging mechanisms, component compatibility, and the potential for recycling used asphalt.



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The data collection aspect of this technology is carried out in close cooperation with the petroleum industry to ensure the transfer of data to industry. To ensure that the generated data are the type needed for improving the efficiency of EOR techniques, close contact with the EOR program is maintained. The transfer of technical data to industry is ensured through publications and participation in scientific and professional meetings. FY 1981 funding will continue support for ongoing in-house projects at BETC and LETC. Projects at BETC include oil-spill identification, characterization of the heavy ends of petroleum, determination of the quality of crude oils and products, storage stability of products, and refinement of process technology. Projects at LETC are correlation of asphalt characteristics with road stability and characterization of heavy liquids. All of the research and development is conducted in house. These research projects are basic in nature and provide a base of fundamental data for advancing petroleum-research efforts.

3.0 SHALE OIL REFINING AND UTILIZATION

In the area of Shale Oil Refining and Utilization (SORU), a number of uncertainties exist which cause major impediments to shale oil commercialization. These uncertainties result from the fact that all crude shale oils have a high nitrogen content, and the known methods for nitrogen removal are costly. Also, crude shale oil fractions are unstable and, therefore, not currently suitable for direct use as fuels. In addition, there are significant differences in the physical properties of the crude shale oils produced by different recovery processes. Finally, the relationship between product specification and end-use performance for conventional petroleum fuels is essentially empirical and may not be applicable to shale-oil-derived fuels, and most crude shale oils have pour points and viscosities that make conventional pipelining costly or unfeasible.

Preliminary indications are that conventional refinery procedures, using high-pressure, high-severity hydrotreating, can be applied to shale oil refining but that the cost of these techniques would be higher than that of refining conventional crude. It may be possible to blend hydrotreated shale oil with petroleum crudes with minimal changes in refinery operation, but the product distribution and performance characteristics are not known. Since all crude shale oil fractions are unstable and not suitable for direct use as fuels, optimum levels of stabilization and nitrogen removal for combustion and transportation uses must be determined to establish appropriate trade-offs between refining severity and combustion procedures. Since petroleum contains very little nitrogen, no nitrogen specifications exist for conventional refined transportation fuels. To optimize shale oil refining, it is essential to establish definite relationships between nitrogen content and fuel stability and NO_x emissions for combustion.

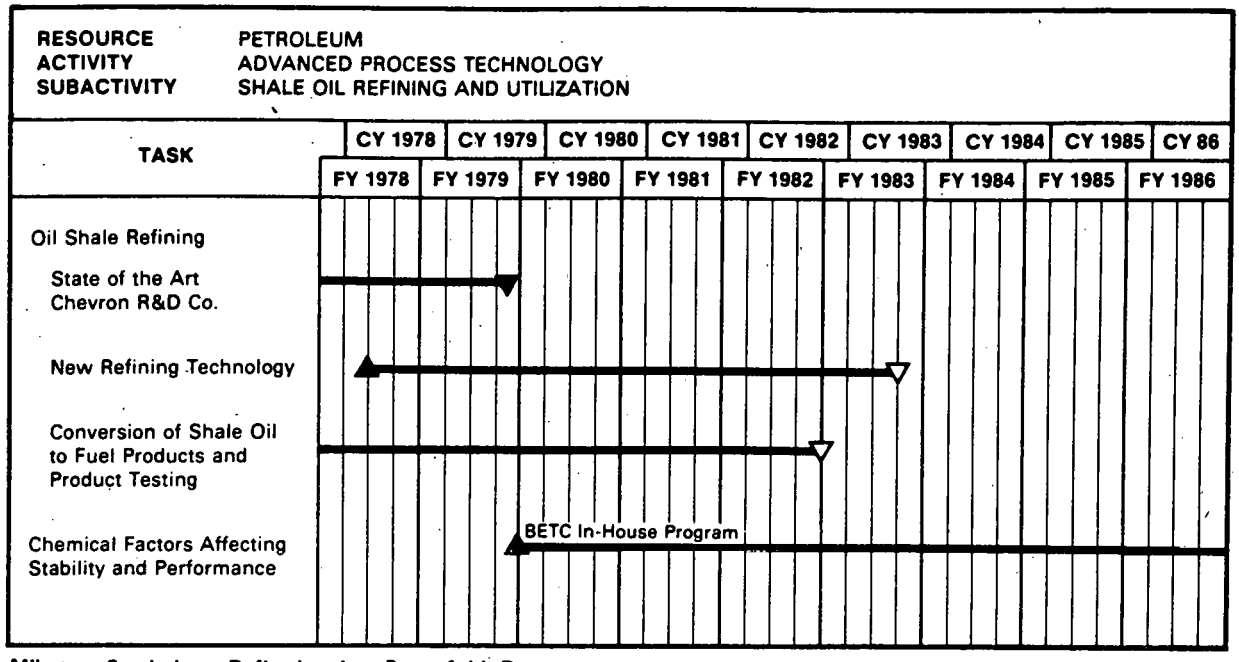
The refining of heavy oil produces excessive amounts of heavy components. For example, straight distillation can produce over twice as much heavy residual-fuel oil from a heavy California crude compared to a light midwestern crude from Oklahoma. Although the heavy component can be converted to gasoline and diesel fuel by hydrodesulfurization and catalytic cracking, the added processing is expensive and complex. It is desirable to develop cheaper technology to use these heavy components.

The objectives of the SORU program are to continue the state-of-the-art shale oil refining studies, develop processes related to the refining of heavy crude oil, determine the nature of stability and performance of shale oil fuel products, and develop technology to remove nitrogen with minimum H_2 consumption.

The strategy of the SORU is to continue studies that will enhance the ultimate utilization of liquid products derived from shale oil and heavy oil. The shale oil refining studies include defining capabilities of existing technology, developing a lower pressure hydrotreating, hydrocracking catalyst, evaluating hydrotreating-physical separation processing schemes, and determining the performance of the fuel products from these refining modifications.

The U.S. heavy oil resource is significant but largely underutilized. Because of its high-viscosity and high-sulfur metals and asphaltene content, it is difficult and costly to refine. There is existing commercial technology which can be used to upgrade heavy oil to clean fuels but the cost is very high and the liquid product yields are low. The DOE program to increase the use of the U.S. heavy oil resource seeks to develop and demonstrate improved recovery and production methods. The goal is to reduce cost and increase the production of useful transportation fuels by decreasing the amount of heavy ends and low-Btu gas produced from the distillation process. The planned approach is to adapt other synfuels technology to hydrotreat or chemically crack the large molecules that make up the heavy ends to produce more transportation fuels and medium- to high-Btu gas.

Since the chemical nature of fuel stability is not well understood, studies will be initiated to characterize the heteroatomic compounds in hydrotreated shale oils and to correlate fuel performance with the content of these heteroatomic compounds.



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V. ACTIVITY DESCRIPTION — GAS

GAS RESOURCE OVERVIEW

Natural gas, despite a 15 percent decline in production in the past 5 years, remains the largest contributor to domestic energy supply. Continued decline in gas production will increase reliance on imported oil and gas. If more of this clean, versatile fuel becomes available, the decline could be offset and gas could be diverted to industrial users of oil, thus reducing oil imports. Production from unconventional gas sources could play an important role in achieving this goal.

Natural gas accounts for about 25 percent of the Nation's energy requirements. In recent years, demand for natural gas has been restrained to the level of available supply by nonmarket factors such as residential hookup moratoria, regulations on industrial and electric utility use, and, in extreme cases, curtailments. Recent projections indicate that constrained gas demand will remain at the current level of about 20 trillion cubic feet (Tcf) at least through the 1990s. Unconstrained demand could be considerably higher; the American Gas Association has estimated a gas demand of 25 to 30 Tcf by 1990 if constraints were removed. Thus, gas consumption is expected to hold constant or to increase, depending on availability of supply and gas-use regulations.

However, domestic production and reserves, dominated by conventional gas resources, have declined steadily. Production in 1978 was 19.3 Tcf, down from the 1973 peak of 22.6. Reserves have dropped to 200 Tcf from their 1967 peak of 293. In only 1 year since 1967 have additions to reserves kept pace with depletion of reserves through production. (That year was 1970, when the associated gas reserves of Prudhoe Bay were "booked.") The ratio of reserves to production for the lower-48 states at the end of 1978 was an all-time low of 8.8 to 1, compared to almost 15 to 1 only a decade earlier. Reserve additions (excepting Prudhoe Bay) have replaced only 46 percent of withdrawls during the 1970s.

This serious decline in production, reserves, and reserve-production ratios has continued despite a nearly tripling of average natural gas price (in real terms) since 1973, the emergence of still higher price intrastate markets, and a corresponding doubling of exploratory effort. Additions to reserves per successful exploratory well drilled since 1970 have decreased from 10.7 to 2.3 billion cubic feet (Bcf)/well. Costs in conventional gas resources in the two areas for which a re-evaluation is complete resulted in a 60 percent decrease in the estimated recoverable resource. The prior estimate was in 1974. Similar downward revisions have been made in estimates of inferred reserves for these areas.

These data point to sharply declining availability and rapidly increasing costs of conventional gas production from the contiguous United

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States. The phased decontrol and special provisions of the Natural Gas Policy Act (NGPA) of 1978 provide incentives for accelerated exploration, but the apparent decline in the number and quality of conventional gas prospects suggests that numerous supplementary gas sources will be required to meet the demand of gas.

Rationale for Current Program

National policy set forth in the 1977 National Energy Plan (NEP) calls for substantially increased domestic energy supplies at economically acceptable costs and identifies unconventional gas resources as potential increased-natural-gas-supply targets. As a result, the DOE Gas Recovery Research, Development, and Demonstration (RD&D) Program was established. Four large, unconventional gas resources have been identified as having significant potential for development and positive impact on future supplies. These are:

- Low-permeability (tight) lenticular and blanket-type gas sandstones of the western United States
- Gas-bearing Devonian and Mississippian shales of the eastern United States in Appalachia and the Midwest
- Natural gas present within coal seams and associated strata
- High-temperature, high-pressure (geopressured) aquifers of the Gulf Coast. Geopressured aquifers are not included in this document because they are the responsibility of the Assistant Secretary for Resource Applications.

Need for Federal Involvement

Several reasons have been advanced for Federal research and development activities in energy. Two of these are particularly pertinent to the Federal role in the unconventional gas resources:

- Market forces may lead to a level of private R&D investment less than what is desirable from a national perspective.
- The Federal Government uniquely requires information for national and/or international energy policy formulation.

Unconventional gas sources compete poorly for investment dollars with traditional exploration for conventional oil and gas. The substantial improvements in the performance of the technology required to improve the attractiveness of the unconventional resources relative to lower risk gas sources, including foreign sources, require complex, expensive, and high-risk R&D. There is little that is patentable or licenseable and individual holdings are so small that the R&D cost per unit of production is high. Consequently, companies are reluctant to expend sufficient R&D funds to develop the technology required to produce any but the geologically most favorable unconventional gas resources. Industry R&D, to date and in the foreseeable future, therefore, is limited to high payoff, near-term efforts, mostly pursued through trial and error with little research.

The second reason for Federal R&D is the need for policy information. The projected U.S. supply-demand situation compels the Nation to provide for adequate gas supplies. The magnitude of the potential of the unconventional gas resources makes them one of the leading prospects, but the vast uncertainty surrounding this potential must be reduced if their proper role relative to alternative gas (and other energy) sources is to be assessed. Accurate assessment of the UGR potential could influence a number of controversial policy issues that entail massive dollar commitments, long lead times, and even longer term consequences.

In the gas domain, the Federal Government is being called upon to guarantee completion of the Alaskan pipeline, guarantee completion and/or offer price support for surface gasification facilities, allow rolled-in pricing of any new gas supply, allow new LNG, Canadian or Mexican imports, allow industry and electric utilities to burn gas, and set gas pricing for residential, commercial, and industrial users. In the larger energy sphere, the issues include the Nation's posture toward oil export and toward alternative energy sources. Gaining this information on UGR is essential for making prudent decisions on fundamental national energy policy issues.

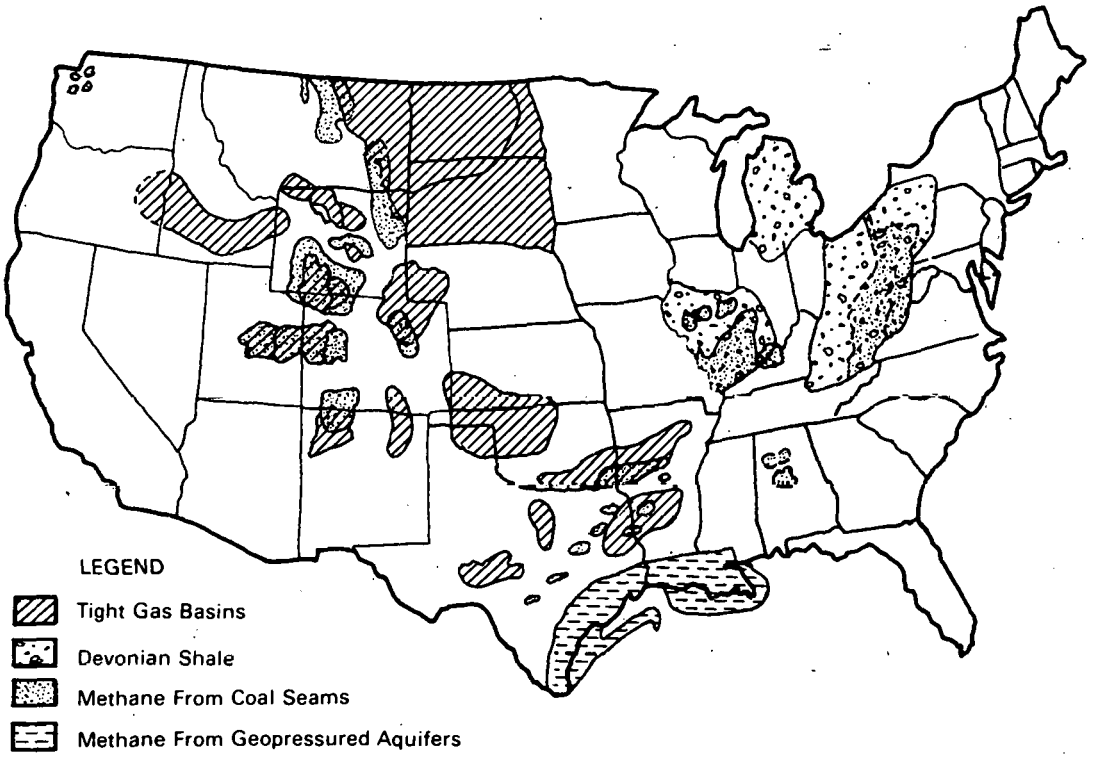
Program Goals

- Goal 1: Develop and improve extraction technologies to the point of technical readiness for commercial development; i.e., increase the economic attractiveness of the unconventional gas resources to private industry. The objectives that support the technology improvement goal seek to increase the economic attractiveness of the unconventional gas sources to the private sector by decreasing risks, increasing reliability, reducing costs, and/or improving recovery efficiency.

- Goal 2: Reduce the uncertainty surrounding the potential magnitude of reserves of the unconventional gas resources and the conditions under which they will be produced. From the policy perspective, the critical uncertainties concerning the unconventional gas sources largely focus on the overall rate of production over time at various costs.

The first goal is to complement and accelerate industry's R&D so that the fullest possible benefits of the unconventional gas potential are realized. The second goal directly supports policy decisions concerning the role of the unconventional gas sources in the Nation's future energy supply.

As shown in the illustration that follows, these resources are dispersed across nearly the entire Nation. Many are close to major existing pipelines and markets. The Department of Energy Gas Recovery Program is a multiyear effort directed towards developing the full potential of these unconventional gas resources.



Unconventional Gas Resources of the United States

Analyses, to date, have concluded that the potential of the unconventional gas resources could be substantial. Numerous studies have attempted to estimate the magnitude of the resource in-place and that portion which is technically recoverable.

	Gas-in-Place (Tcf)	Technically[1] Recoverable (Tcf)
Tight Gas Formations	400 - 1,100	50 - 600
Eastern Gas Shales	300 - 900	10 - 600
Methane Occluded in Coal Seams	300 - 700	1 - 300
Methane in Geopressured Aquifers	1,000 - 59,000	10 - 1,500

These broad ranges illustrate the vast uncertainty surrounding the potential of these resources. While the economically recoverable portion of the resources, or reserves, would be considerably smaller than the technically recoverable resource estimates, the potential of the unconventional sources is significant.

[1]Technically recoverable gas is that portion of the gas-in-place that can be produced by the best technology expected to be available by the year 2000. The economics of recovery are not considered in estimates of technically recoverable gas.

Some of the unconventional gas sources are relatively near to commercial status and may contribute to domestic supply while the longer term alternatives are being developed. The geologically more favorable portions of the tight gas formations and eastern gas shales already produce nearly 1 Tcf/year, or about 5 percent of the total supply.

Thus, the unconventional sources are needed and could play an important role in the Nation's energy supply within the near term and throughout the remainder of this century.

The table below summarizes the funding levels by Activity for the FY 1979 to FY 1981 period.

GAS RESOURCE	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
ACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Enhanced Gas Recovery	33,602	35,310	30,548
Program Direction	209	276	273
TOTAL	33,811	35,586	30,821

A. ENHANCED GAS RECOVERY

Significant progress has been made in the DOE Energy Technology programs in all four resources. The critical technical issues affecting each goal have been defined and work is underway to resolve the most pressing of these issues.

Progress toward the technology improvement goal has been made in the DOE programs. The critical technological issues have been defined and activities designed to address these issues. Efforts are underway, in concert with industry, to overcome the constraints imposed by current technology. New instrumentation, interpretative methods, and recovery technologies have been developed and are being tested in the field, although significant additional instrument development, resource characterization, research, and testing efforts are still required.

The uncertainty-reduction goal has been pursued by the generation of first-order estimates of the potential in the form of ranges that differ according to explicit, alternative assumptions concerning the resource and its recovery technology. The resource estimates differ by one to two orders of magnitude, which is too broad to assist policy making but is significantly reduced over earlier estimates. Significant uncertainties controlling the potential of each resource have been identified and specific activities have been designed for their reduction.

Specific activities have been planned and are underway in each of the unconventional gas resources.

The table below summarizes the funding levels by subactivity for the FY 1979 to FY 1981 period.

ENHANCED GAS RECOVERY	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Eastern Gas Shales	18,000	13,000	12,400
Western Tight Gas Sands	7,500	12,800	12,400
Methane from Coalbeds	4,000	5,000	5,000
Environment and Support	3,902	4,110	248
Capital Equipment	200	400	500
TOTAL	33,602	35,310	30,548

Benefits of the Unconventional Gas Program

Successful execution of the activities in the program will offer significant benefits to the Nation. These include:

- Increase domestic gas production: improved economic attractiveness of the unconventional gas resources to the gas production industry will increase the level of investment in domestic production, offsetting the decline in the conventional gas reserves/production ratio.

- Enhance security of supply and balance of payments: production from domestic unconventional gas sources reduces U.S. dependence on imported oil and mitigates the political consequences of vulnerability. Each 1 Tcf of new unconventional gas produced per year could lower the amount of imported oil by nearly 500,000 barrels/day.

- Provide timely, policy-relevant information for future decisions concerning alternative supplemental gas sources such as liquefied natural gas (LNG), Mexican, Canadian imports, and surface coal gasification.

- Minimize environmental degradation: gas from the unconventional sources is relatively clean to produce and to use.

- Reduce consumer costs: some unconventional gas sources are currently cheaper (on a Btu equivalent basis) than imported crude oil. As crude oil prices rise, more unconventional resources will become cheaper than imported oil and gas. Even if deregulated gas prices rose to equivalent world oil price levels, the Government would still have the option of collecting a windfall profits tax in order to protect the consumer without discouraging production. In areas where excess gas supplies result from the development of unconventional sources, gas prices will probably not reach equivalent world oil prices and the consumers will capture the savings.

1.0 EASTERN GAS SHALES

The Eastern Gas Shales Project (EGSP) is a multidisciplinary research effort directed towards increasing natural gas production from the Devonian shales of the Appalachian, Illinois, and Michigan basins of the eastern United States.

The overall goals of the EGSP are (1) to develop the technologies that will establish effective and environmentally acceptable means for locating and producing natural gas from Devonian shales, and (2) to reduce the uncertainty surrounding the potential magnitude of reserves so that the private sector will be encouraged to develop the resource on a large scale. Specific objectives of this project are:

- Development of accurate estimates of gas-in-place and economically recoverable resources

- Development of exploration rationales for the identification of prospects
- Development and improvement of cost-effective extraction methods.

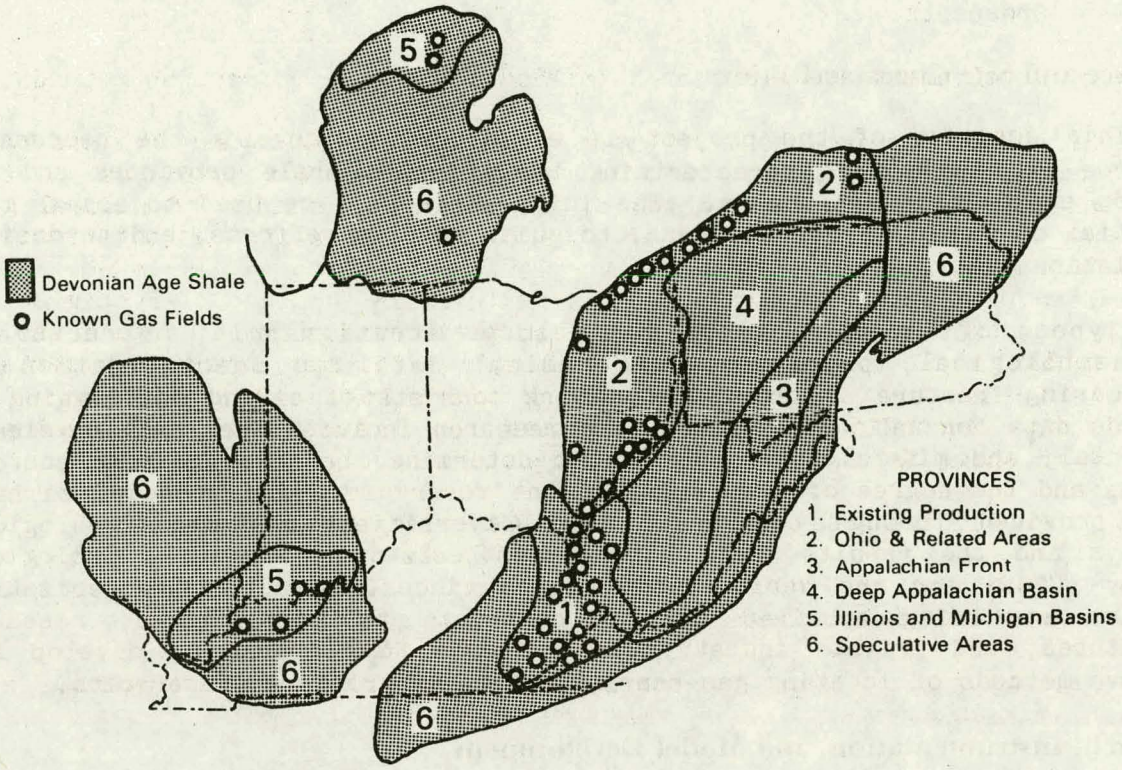
EGSP efforts during the first four years of the eight-year project have been directed at determining the geologic character and magnitude of the Devonian shale gas resource and toward increasing production of natural gas from this resource base. Almost all the planned formation-characterization work required to update the resource knowledge base has been completed. Geological evaluations are available to ascertain basin limits and stratigraphic targets as potential gas sources. Based on these evaluations, large areas of the Devonian shale have evolved as geologic provinces exhibiting certain characteristics that require particular technological developments for extraction. Accordingly, EGSP activities are planned for each geologic province as shown in the following illustration, namely:

- Productive areas of Kentucky and West Virginia
- Ohio and related areas in New York, western Pennsylvania, and northern West Virginia
- Appalachian front in Pennsylvania, Maryland, West Virginia, and Virginia
- Deep Appalachian basin in Pennsylvania and West Virginia
- Illinois and Michigan basins
- Speculative areas in all eastern states.

EGSP research has identified the nature of producible gas containment to be the micro- and macrofractures of the shale formation. Knowledge of these fractures, their directionality, and density has enabled the development and testing of effective techniques to connect the gas-bearing natural fractures to the borehole. Tests of stimulation techniques in light of the geologic environment in the respective gas provinces have permitted the development of a rationale for stimulation strategy. The results of these pilot tests are undergoing systematic evaluation to permit refinement of R&D objectives. Initial economic analysis of Devonian shale stimulation ventures has been encouraging and indicate that shale gas production should be technically and economically viable in some geologic provinces.

The EGSP is structured into the following functional categories or program activities:

- Evaluation
- Resource and Site Characterization
- Research, Instrumentation, and Modeling
- Production Technology Development.



Devonian Age Shales by Province

The first three activities provide for resource data acquisition and the development and testing of techniques for locating probable areas of gas-bearing natural fracture systems and for predicting the probable production from a particular stimulation method in a certain geologic province. The fourth activity is directed at the development and testing of cost-effective methods for extracting gas from the various geologic provinces in the shale. Specific task activities are discussed in the following sections.

Evaluation

The Evaluation activity is designed to integrate facts as they develop; to assess recent technological developments and related industry activities; to ensure compliance with environmental regulations and address site-specific environmental problems; to develop a systems model for updating estimates of the potential resource; and to develop and monitor program plans that reflect the integration of the technical, geologic, enconomic, and other types of data.

Accomplishments completed include an environmental impact plan for the project, economic analyses of stimulation techniques for the various basins, the establishment of a computerized information retrieval system and pilot resource assessment studies. The technology being developed in the project is being transferred to the private sector through symposia, an open-file

library, semiannual progress reports, newsletters, publications, and presentations.

Resource and Site Characterization

This activity of the project is structured to develop the necessary resource data base for characterizing the Devonian shale provinces and to develop exploration rationales. The information will be used to assess the potential of various resource areas, to guide modeling efforts, and to design stimulation tests.

Types of data collected include stratigraphic, structural, sedimentological, physical, and chemical data for identification of gas-bearing fracture systems. Field work consists of coring and logging to provide data for lab work. Laboratory research includes chemical, physical, elemental, and mineralogical studies to determine the stratigraphic sources of gas and the degree of fracturing in the reservoir. The needed data have been provided through contracts with universities and state geological surveys and the results compiled and synthesized by the U.S. Geological Survey (USGS) for the various geologic provinces. Shale characterization studies are being acquired through contracts to universities, research institutes, and private industry for province R&D efforts to develop and improve methods of locating gas-bearing naturally fractured reservoirs.

Research, Instrumentation, and Model Development

This activity is directed towards development of new diagnostic tools, stimulation approaches, and predictive capability to accurately forecast reservoir performance whenever extraction methods are applied to particular geologic provinces in the Devonian shale. Meeting these objectives requires basic and applied R&D in the laboratory and the field and the development of models. The models serve to describe the present understanding of the stimulation processes, gas flow from the reservoirs, and economic parameters related to fracturing and production.

Types of achievements to date include the characterization of geologic provinces for susceptibility to water base fracturing fluids, the development of predictive codes for evaluation of stimulation techniques in specific geologic provinces and the verifications of production performance models for the shale gas reservoirs. The necessary developments were achieved through contracts with universities, DOE's national labs, and private industry. Synthesis of results are the responsibility of the Morgantown Energy Technology Center (METC) and its technical support contractor.

Production Technology Development

This activity is directed towards the development of effective stimulation methods for various geologic environments and testing of these designs in field applications. The tested designs are conceptual models that have evolved from sequential laboratory and simulation studies. Detailed documentation of field tests under controlled conditions complemented with systematic well testing is conducted through cost-sharing contracts with private industry.

Project Status

Field tests (16) and demonstration projects have shown that advanced stimulation technology (foam, cryogenic, massive hydraulic fracturing (MHF), and chemical explosive fracturing) will produce considerably more than conventional wellbore explosive fracturing in the gas province associated with historical shale production. Limited data (2 wells each) for gas provinces 2, 4, and 5 in the previous figure preclude further establishment of new technology advances as yet. Particular emphasis is placed on the use of energy-assisted fracturing fluid for the low-pressure fractured reservoirs. Results of displaced liquid explosives are encouraging but as yet require further development. Directional deviated-well technology is achievable but additional demonstrations are warranted in other regions to complete an economic assessment. Evaluation of the effectiveness of dual completion wells awaits the identification of geologic prospects in the province which includes Ohio and adjacent areas. Factors affecting production appear to be associated with frac length and reservoir permeability. Location of regions of increased fracture intensity is required to assure the likelihood of commercial wells. The stress ratio concept (minimum horizontal/vertical) is an estimator of fracture intensity in gas provinces. This technique, along with siting wells adjacent to phototraces from aerial photography analyses, is being used for both exploration and extraction testing in geologic province 2. Contracts in progress are:

Columbia Gas System: A total of 10 wells have been drilled in Lorain and Trumbull Counties, Ohio, for production tests of new prospects in gas provinces. Comparative analyses of two stimulation techniques in each area are planned.

Mitchell Energy Corporation: A total of 11 wells have been drilled in Gallia County, Ohio, in gas province 2 to test and verify a new exploration concept for locating gas-bearing fractured reservoirs. The concept is based on the depositional model for clastic sedimentation wherein natural compaction fractures are found along the flanks of the depositional highs.

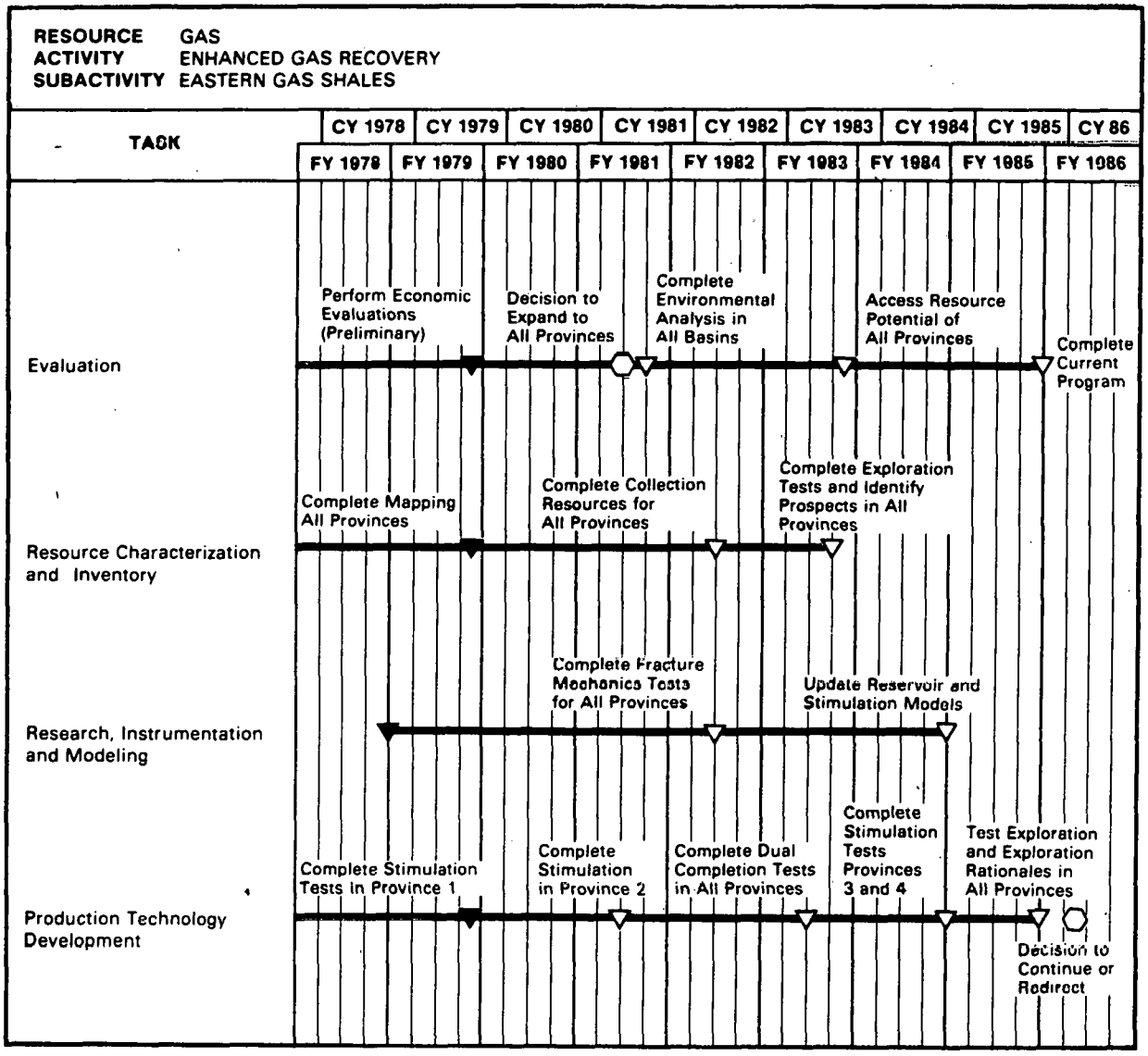
Donohue, Anstey and Morrill: Three wells are planned for Noble County, Ohio, to test the production potential of prospects selected on the basis of seismic velocity measurements which are indicative of naturally fractured reservoirs. The concept being evaluated is a new exploration technique applicable to all the geologic provinces in the shale. The project is a cost-sharing venture with the Ohio DOE in gas province 2.

Donohue, Anstey and Morrill: A 10-well project for the Southern Tier Counties of New York is in progress to test the production potential of new prospects based on the exploration concept being tested in Ohio. The project is a cost-sharing cooperative venture with the New York ERDA in gas province 2. Stimulation techniques selected for testing will be based on site-specific geological factors.

Thurlow, Weed and Associates: This contract is a four-well test program to determine the most effective means of stimulating gas production from the shale in the Knox County, Ohio, area of geologic province 2. Support for this test program has been obtained from the Ohio DOE.

DuPont Corporation: An eight-well test project in Putnam County, West Virginia, of geologic province 1 is in progress to evaluate the effects of an improved explosive fracturing technique in the peripheral area of established shale production.

Additional requests for proposals are intended to investigate the production potential of areas identified as prospects in geologic provinces 3 and 4.



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2.0 WESTERN GAS SANDS

The Western Gas Sands Project (WGSP) is directed toward accelerated exploitation of natural gas accumulations within "tight" sandstone formations of the western United States. These unconventional gas reservoirs contain large quantities of natural gas trapped in underground rock formations with

permeability too low to permit recovery by conventional technology. Twenty basins have been identified as containing significant amounts of gas in such "tight" formations. These basins extend westward from the Cotton Valley Trend in Louisiana, through Texas and the Rocky Mountains, to the Uinta basin of Utah, then north through the Northern Great Plains and Williston basin, and ultimately into Canada.

In addition to their low permeability, these reservoirs typically have low bulk porosities and high water saturations, resulting in low gas-filled porosity. In many of these basins (e.g., Denver and Cotton Valley), the principal tight formations are broad, highly continuous reservoirs, or "blanket" formations. In others (e.g., the Green River and Piceance), the reservoirs are highly discontinuous lenses that sharply restrict the potential drainage of an individual well. Lenticular formations generally are more technically challenging with regard to gas extraction than blanket reservoirs with otherwise comparable properties.

Recent production from tight gas formations has been primarily from the San Juan, Denver, Cotton Valley, and Sonora basins. The recent R&D accomplishments of industry made production in these basins possible and have also helped direct DOE R&D efforts to other, more difficult basins.

To date, DOE R&D activities have been primarily directed toward the Greater Green River, Piceance, Uinta and Northern Great Plains basins. The technological problems associated with recovering gas from tight lenticular sands in these basins are more severe than recovery problems in many of the remaining 16 basins. The solutions of certain technological problems will result in the recovery of a considerable amount of gas from these basins and will provide technological advances that are applicable to the other basins.

An accelerated commercialization effort will concentrate on demonstrating early production potential from the blanket formations. The objectives are to delineate and characterize blanket formations wherever they occur in the 20 target basins and demonstrate economic gas producibility. Successful accomplishment of these objectives in the blanket formations will provide a reasonable expectation of significant production by 1990.

The WGSP has two primary goals: (1) development of improved extraction technologies to a point of economic attractiveness to industry, and (2) a substantial reduction in the uncertainty presently associated with the total gas-in-place and that portion of the total which is economically extractable from these unconventional types of reservoirs.

Achievement of these goals will require concerted and coordinated efforts in each of the following work categories or activities.

- Evaluation
- Resource and Site Characterization
- Research, Instrumentation and Modeling
- Production Technology Development.

These activities and their specific objectives are summarized below:

Evaluation

This activity is directed towards reducing the uncertainty regarding the potential of the tight gas sands and directing program priorities toward realization of that potential.

- Acquisition and maintenance of existing geologic and technological data base
- Identification of the technological problems requiring federal effort
- Identification of environmental and other nontechnical constraints
- Update of estimates of gas-in-place, technically and economically recoverable gas.

Resource and Site Characterization

This activity is directed towards: providing a sufficiently accurate geologic understanding of specific local sites to guide the design of effective extraction technologies; and extrapolating from these results to support overall resource base estimates.

- Performance of basic geologic studies
- Performance of detailed characterization of lenticular sand basins and other types of tight gas basins
- Coring, logging, and testing wells of opportunity
- Development of detailed geologic descriptions
- Mapping and delineation of occurrences of blanket formations in all basins.

Research, Instrumentation, and Modeling

This activity is directed towards developing the tools, procedures, measurements, concepts, and models required for diagnostic, production, and environmental technologies related to economic production of natural gas from the tight gas sands.

- Development/improvement of geologic diagnostic technology
- Development/improvement of stimulation technology
- Development of stimulation models
- Improvement of production testing capability and reservoir model(s)
- Development of systems model.

Production Technology Development

The Production Technology Development activity is directed towards developing and testing of cost-effective means for recovering the gas from tight formations.

- Performance of single- and multiwell experiments
- Performance of field confirmation tests
- Specification of stimulation design procedures for technology transfer.

Performance and completion of these activities provide for an integrated project approach toward achievement of the two main project goals. For example, the Evaluation activity creates the estimates of the potential of each resource to serve the program's uncertainty reduction goal and, in so doing, defines the Federal role, direction, and priorities for the other activities. The next two activities prepare the components for developing the technology. The Resource and Site Characterization activity also provides geologic data to the evaluation activity. Production Technology Development integrates these components in the context of field tests, the results of which feed back into the Evaluation activity for use in updating and redirecting the program. Several "loops" of the program logic may be required before cost-effective technologies are developed to the level of commercial readiness.

Each of these tasks contributes in a major way to at least one of the major program objectives. Given the current state of understanding of the tight gas sands resource and the technology for exploiting it, success in these R&D tasks will meet the program objectives and, through them, will result in adequate estimates of the tight gas sands potential and economically attractive investment opportunities for industry.

Project Status

The R&D program in tight gas sands has been underway since 1974 when the first government-sponsored MHF test was initiated in the Piceance basin. In 1977 an integrated program was developed. Since then three main activities have been funded by DOE in an overall effort to increase gas production from low-permeability gas sands:

- Geological and geophysical studies to characterize the resource base in the priority basins. This work has been performed primarily by the USGS.
- Research and development to improve mathematical models to develop new instrumentation systems and data analysis techniques, and to better understand rock mechanics. This work has been performed primarily by the national laboratories.
- Field tests in the priority basins and other low-permeability basins to improve the application of stimulation techniques. These tests have been primarily government/industry cost-shared projects.

Efforts to date in these areas have resulted in a firm identification of the problems associated with collecting diagnostic information in the low-permeability basins and with designing and carrying out stimulation treatments. Identification of pertinent problem areas has provided a great deal of guidance in the development of the current program.

A preliminary data base has been compiled for 13 of the 20 tight gas basins. Permeability, gas-filled porosity, net pay, thickness, and lenticularity are the critical reservoir parameters that determine gas producibility. Additional issues are introduced by uncertain mechanical and chemical properties of the rock and regional stress characteristics. Significant variation in reservoir properties within small geographic areas further complicates reservoir assessment.

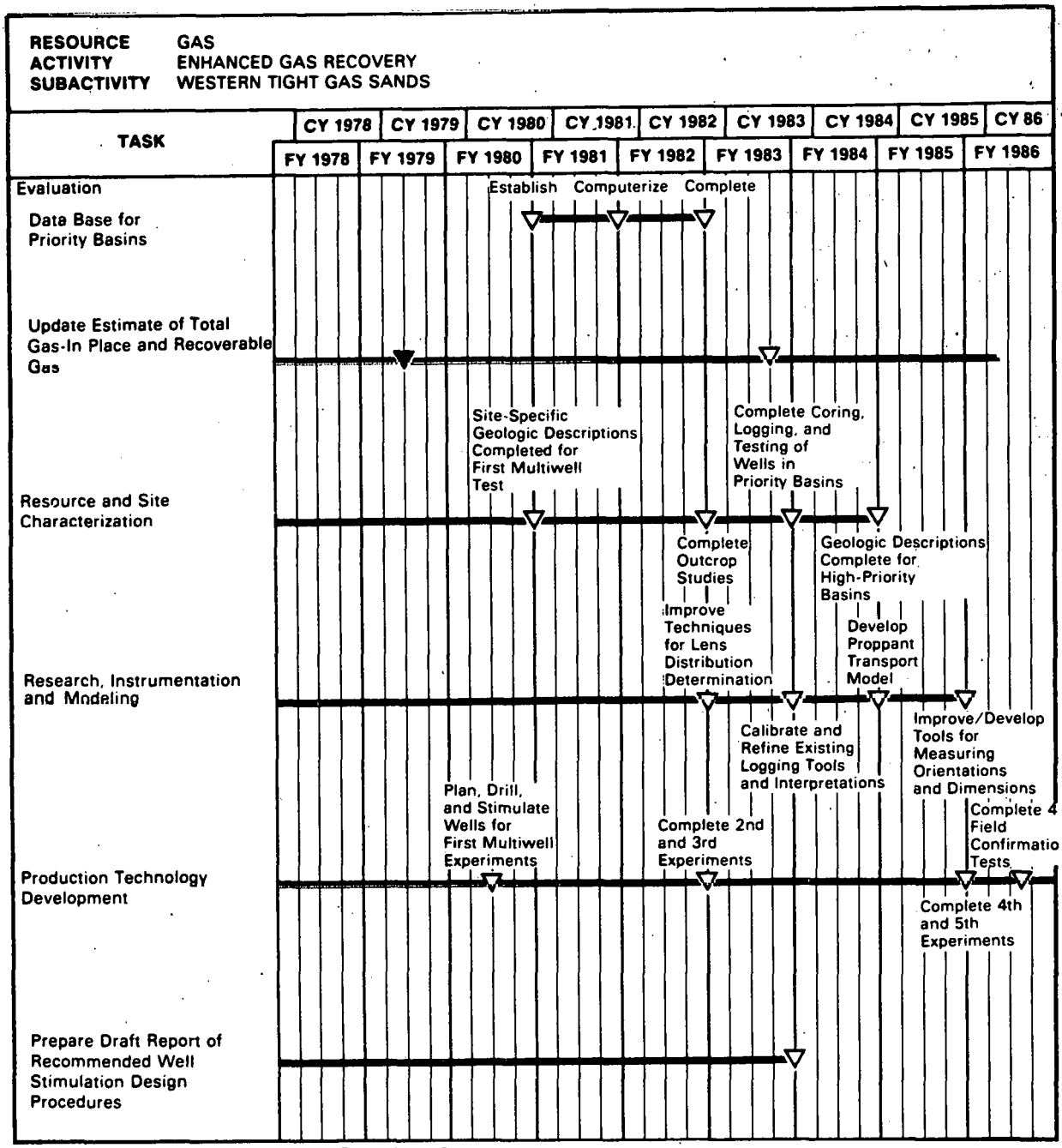
The most promising extraction technology applicable to tight gas reservoirs is MHF. Its purpose is to overcome the problem of low permeability by creating and propping open an artificial fracture which penetrates deeply into the reservoir. This provides a conduit(s) for gas to flow to the well.

Fractures are created by pumping fluid (generally gelled water, foams, or polyemulsions) into the selected lithologic zone until the hydraulic pressure breaks the rock. As more fluid is pumped, the fracture extends deeper into the reservoir rock. Depending on the amount (up to 1 million gallons) and nature of the fracturing fluid, the fractures are believed to be propagated to distances of 500 to 2,000 feet (in both directions) from the wellbore (1,000 to 4,000 feet tip to tip). Due to earth stresses, the fractures tend to extend in the vertical plane, especially at depths greater than about 3,000 feet.

About 0.9 Tcf of gas per year, or about 4.5 percent of total domestic consumption, is currently produced from the tight basins. About one-third of this production is from zones with permeabilities that are near, but still below, conventional levels. This production represents a substantial increase in industry's interest in tight formations.

The two major field experiments for FY 1980 are:

- Colorado Interstate Gas: Dry Gas Injection Project, Wattenberg Field, Colorado
- Sandia/CER Corporation: Multiwell Test Experiment, Piceance Basin, Colorado.



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3.0 METHANE FROM COALBEDS

During the natural process of coal formation, methane (the principal constituent of natural gas) is generated and trapped in the coal seam as well as in the adjacent rock strata. All coal deposits contain methane; however, the concentrations vary from seam to seam and within a particular seam. The total magnitude of the U.S. coal-associated resource has been estimated at approximately 700 Tcf (700 Quads). Given current and conservatively projected economic and technological factors, the recovery of some 300 Tcf of

this resource optimistically appears to be feasible. This is equal to a 10- to 12-year supply based on present consumption.

The shortage of natural gas during the winter of 1976-1977 focused attention on the urgent requirement to utilize this energy resource. Safety considerations in active mines have led to much developmental work by the U.S. Bureau of Mines in techniques for methane removal.

Techniques now practiced by some mine operators result in approximately 250 MMcfd of methane being emitted annually to the atmosphere. This gas is now being irretrievably wasted. The utilization of this valuable resource, including methane available from unminable[1] coalbeds, is the objective of the DOE Methane Recovery from Coalbeds Project (MRCP) which provides the RD&D necessary for economical utilization.

Due to the recent deregulatory legislation for natural gas (e.g., NGPA), economics are becoming more favorable for commercial exploitation of this resource. There are, however, still many barriers to extensive recovery and utilization of coalbed methane on a commercial basis:

- Although a variety of technologies and techniques give promise of profitable utilization of coal-associated methane, the technical, operational, and economic viability of these methods have not yet been sufficiently demonstrated to attract private investment.
- The quality of coal-associated gas varies from essentially pure methane for predrained gas, to variable combinations of methane and air for gob gas, to extremely diluted methane-air mixtures in ventilation air.
- Gas sources are generally located remotely with respect to demand, and individual wells have relatively low production rates.
- Gas prices historically have been insufficient to attract interest to this resource.
- Although coal operators have a legal right to release methane in the course of mining, they are wary of the legal implications of gas recovery, since, generally, natural gas rights are held by others.
- Since the market value of a ton of coal is on the order of 100 times the value of the methane contained therein, coal mining companies have scant interest in gas-derived revenues relative to their primary objective of coal production. (Recent interest in gas recovery by a few coal companies is due primarily to the prospect of increased coal production. The methane-derived revenues are of secondary importance.)

[1] "Unminable" refers to those coalbeds not presently being mined because of economic or technical considerations.

The ranges of quantitative availability, gas quality, and geographic locations of coalbed methane sources make it apparent that no single solution is appropriate for all cases. Recent studies conducted for ERDA (now DOE) and the Bureau of Mines indicate a high probability of economic gas recovery/utilization of several approaches, including direct pipeline injection, LNG production, onsite power generation, and petrochemical production. A variety of specific techniques and technologies have been considered under each of the preceding major headings. In some cases, off-the-shelf technology which could be modified for this application is available (i.e., gas turbines, LNG production units, and ammonia production units). However, further investigation, research, development, and demonstration is necessary.

The MRCP will include development of methods and systems that establish technically and economically viable means for the recovery, conservation, and use of the methane gas associated with both minable and unminable (deep and/or thinly bedded) coalbeds.

Major project objectives include:

- Location and characterization of methane resources
- Development of improved, cost-effective methane recovery and utilization technology
- Development of methane conservation techniques and systems
- Development of methane recovery prediction/projection techniques (models for well productivity)
- Development of field tests for pilot systems
- Investigation of legal, institutional, and regulatory constraints
- Transfer of applicable technologies to private industry.

The MRCP contains four primary activities:

- Evaluation
- Resource and Site Characterization
- Research Instrumentation and Modeling
- Production Technology Development.

The Evaluation activity is directed toward reducing uncertainty regarding the potential of the coalbed methane resource and directing project priorities toward realizing that potential.

The Resource and Site Characterization activity is directed towards acquiring a sufficiently accurate geologic understanding of reservoir areas and specific local sites to guide the design of effective recovery technologies.

The Research, Instrumentation, and Modeling activity develops the tools, procedures, measurements, concepts, and models that provide the diagnostic, production, and environmental technologies necessary to produce the methane from coalbeds.

The last activity includes the design, development and field testing of cost-effective equipment and methods to produce gas from coalbeds.

Evaluation

The objectives of the Evaluation activity are to: (1) develop and monitor project plans that reflect the integration of technical, geologic, economic, and other types of data that result from the project; (2) continue the development of the coalbed methane data base; (3) assess recent technological developments and related industry activities; (4) update estimates of the potential of the resource; and (5) assess the results of the other activities.

The Evaluation effort will involve:

- Analysis and Assessment of the Resource: evaluating resource properties, developing exploration methods, selecting target areas and drilling sites, updating estimates of the resource/reserves, and providing characterization test planning and analysis.
- Provision of Project Information Management and Technology Transfer: providing for management of information resulting from the project and making pertinent information available to all potential users.
- Provision of Project Direction, Integration, and Support: identifying and initiating project support activities, identifying and analyzing constraints to exploitation of the resource, and by determining the economics of methane extraction/preparation and upgrading systems.

Resource and Site Characterization

The characterization of the methane content of our nation's coalbeds has been done on a very limited basis, mostly in conjunction with active mining. Previous work includes only a small percentage of the coal resources and does not provide the knowledge needed to locate recovery and utilization projects in coalbeds with the greatest potential for methane production.

The Resource and Site Characterization effort will involve:

- Acquisition of resource characterization data from existing sources
- Analysis and evaluation of existing data
- Identification of potential recovery system sites

- Acquisition of reservoir geologic data for the target reservoir areas, obtaining of the geologic data necessary to support evaluation and assessment of the coalbed methane resource. Correlation of the data obtained with other available data in order to extrapolate producibility from reservoir to reservoir within a basin

- Performance of coring, logging, and testing of wells of opportunity. Performance of core tests, logging, sample analysis, and flow tests (where possible) to obtain and correlate coal and methane data

- Compilation of an all-inclusive data base for transfer to private industry.

The existing sources of public information on methane in coalbeds include the USGS, U.S. Bureau of Mines, several state geological surveys, various universities, and private research foundations.

Some of the major contractors engaged in this research as of FY 1979 include:

- Colorado Geological Survey
- Intercomp, Inc.
- TRW Energy Systems
- Utah Geologic and Mineral Survey
- Iowa State University.

Research, Instrumentation, and Model Development

The objectives of this activity are to improve or develop new diagnostic techniques, to improve or develop new stimulation approaches, and to improve the ability to accurately predict and measure reservoir response to stimulation techniques. Fulfilling these objectives requires basic and applied R&D in the laboratory and the field and the development of models. Models and instrumentation will be evaluated and refined based upon the performance of tests conducted in the field.

Tasks and elements supporting the Research, Instrumentation, and Model Development activity are listed below:

- Conduct Extraction Technology R&D

  This task will continue through most of the life of the project. The level of effort will increase to a maximum as R&D activities are identified and initiated early in the project and will decrease thereafter as the project progresses.

  Develop/Modify Drilling Techniques and Equipment: Drilling techniques include horizontal drilling and directional drilling, while equipment includes downhole motors and waterjet drilling.

  Perform Stimulation Experiments: From single vertical boreholes, perform multiseam stimulation and completion. Design stimulation, to maximize production but to minimize roof damage, especially in

minable coal seams. Hydraulic, foam, gas, and dendritic stimulation designs will be tested.

- Conduct Preparation R&D

  This task will continue through most of the life of the project. The level of effort will increase to a maximum as R&D activities are identified and initiated early in the project and can be expected to decrease thereafter as the project progresses.

  Develop LNG Conversion Capacity: Develop equipment sized for cost-effective liquification near the recovery site of gas from coalbeds.

  Develop Membrane Separation Capability: Develop equipment and technique to upgrade low-quality gas from coalbeds so that it is suitable for pipeline injection.

  Develop Mixed-Gas Upgrading Capability: Develop equipment and techniques to remove contaminants from gas recovered from coalbeds to the extent that its use will be feasible and cost effective.

Production Technology Development

A number of techniques are available for producing methane from coalbeds:

- Drilling of vertical wells with the option to stimulate methane production using hydraulic fracturing techniques
- Drilling of horizontal holes from the bottom of vent shafts or from the headings within the mine
- Drilling of directionally controlled wells from the surface so as to intercept the major continuous fracture system (face cleats) within the coalbed.

None of these techniques have been developed to the degree that they are generally efficient and cost effective.

The objectives of the Production Technology Development activity are to (1) design, operate, and field test coalbed methane integrated systems; (2) investigate and resolve issues encountered under field (operational) conditions; and (3) evaluate the systems/subsystems and operating methods tested for technical and economic feasibility and readiness for commercial ventures. The activity is in progress. Tasks and elements which support the Production Technology Development activity are listed below:

- Technology Test Projects Associated with Active Mine Coalbeds

  The elements of this task are a series of individual field test projects; each usually involves an integrated system.

Multiple Well Projects: Methane will be drained in advance of mining operations. New and improved gas extraction methods will be investigated (well spacing, geometric patterns, etc.).

Horizontal Borehole Drainage Projects: Methane will be drained prior to or during mining operations. New and improved equipment and methods will be investigated for horizontal borehole drainage.

Advanced Systems Test Projects, (Minable Coalbeds): New equipment and methods will be field tested.

- Technology Test Projects Associated with Presently Unmined Coalbeds

The elements of this task are a series of individual field test projects; each usually involves an integrated system.

Deep Coalbed Drainage Projects: Methane is extracted from deep coal horizons, many of which will not be mined in the foreseeable future.

Drainage Projects for Coalbeds in Underdeveloped Areas: Methane will be extracted from coal seams that cannot be mined because of their location in underdeveloped areas such as an urban community having multiple improvements on the surface.

Directional Drilling Coalbed Drainage Projects: Methane drainage is accomplished using directional drilling techniques.

Advanced Systems Test Projects (Unmined Coalbeds): New equipment and methods will be field tested.

Utilization options for methane from coalbeds include space heating, power generation, and use as a chemical feedstock. Typical utilization system concepts include:

- Direct injection into commercial gas transmission pipelines
- Conversion to LNG
- Heating
- Electric power generation
- Conversion to ammonia.

Project Status

Major research, instrumentation, and model development and production technology development ongoing in FY 1980 include:

Westinghouse Electric Corporation (Pittsburgh, Pennsylvania): Westinghouse was awarded a contract (FY 1977) to test the feasibility of operating a 600 kW turbine/generator on predrainage (in advance of mining) and "gob" gas volumes.

Mountain Fuel Resources, Inc. (Book Cliffs, Utah): Mountain Fuel Supply Company was awarded a contract (FY 1979) to demonstrate recovery and utilization subsystems relating to methane from a number of unmined coalbeds in the Uinta basin, Carbon County, Utah. The three-year contract will involve drilling a series of vertical wells, hydraulically fracturing the wells, monitoring reservoir performance, developing completion techniques, and perfecting predictive reservoir modeling of methane production. Any commercial quantities of gas will be compressed and injected into an existing nearby Mountain Fuel pipeline.

Westinghouse Electric Corporation (Pittsburgh, Pennsylvania): The Westinghouse Contract (FY 1978) involves testing the recovery technology of using multiple-seam, vertically drilled, and hydraulically fractured wells in advance of mining (predrainage of the methane). The produced methane will be utilized for space heating in a nearby plant and as a feedstock for fuel cell development.

Emerald Mine/H.F. Scott (Waynesburg, Pennsylvania): The Emerald Mine/H.F. Scott contract (FY 1978) is designed to establish the necessary procedures and to demonstrate the capability of directional drilling for coalbed degasification. Approximately 10,000 feet of horizontal directionally drilled borehole has been completed in a 5-toe "bird's foot" pattern (2 of the toes extend 3,000 feet horizontally into the coal seam).

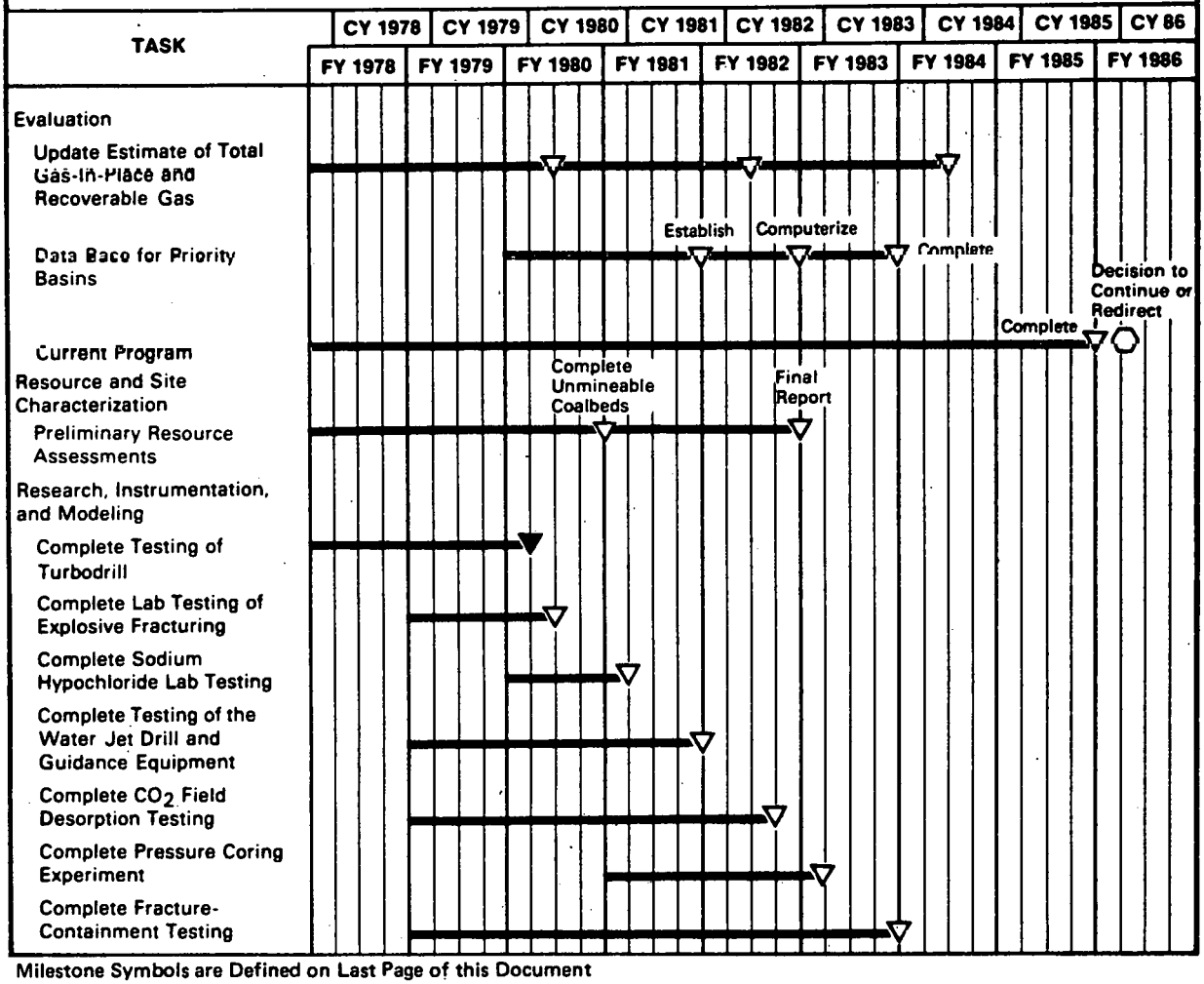
U.S. Steel Corporation, Oak Grove Mine (Jefferson County, Alabama): The U.S. Steel contract (FY 1975) initially involved utilizing approximately 28 vertical boreholes near U. S. Steel's Oak Grove Mine for degasifying the Mary Lee coalbed prior to mining. Seventeen of the boreholes have been completed in a degasification grid test pattern. Current production from this well pattern is well over 1 MMcfd of methane and 400 bbl/d of water. Plans have been completed for pipeline utilization of the produced methane to be implemented in FY 1980. It has been shown in this mine that the total methane gas emission can be reduced by over 40 percent in mine sections containing vertical gas-drainage holes given 1 year of predrainage activity.

TRW Energy Systems, Inc. (Morgantown, West Virginia): TRW is an integrating contractor for selection, design, and coordination of the resource characterization effort and several recovery/utilization systems technology projects which have been initiated in both mined and unmined coalbeds (FY 1979).

- The Occidental Research/Island Creek contract involves the use of multiple horizontal boreholes in a longwall mine development program. This project includes several technology developments including that of a drilling technique for long boreholes (greater than 2,000 feet) to drain the entire length of a longwall panel. The gas drained by this project will be utilized to produce LNG.

- The Waynesburg College (Pennsylvania) contract involves the development of multiple methane production zones in a single well in an unmined, extensively developed surface area.

RESOURCE GAS
ACTIVITY ENHANCED GAS RECOVERY
SUBACTIVITY METHANE FROM COALBEDS



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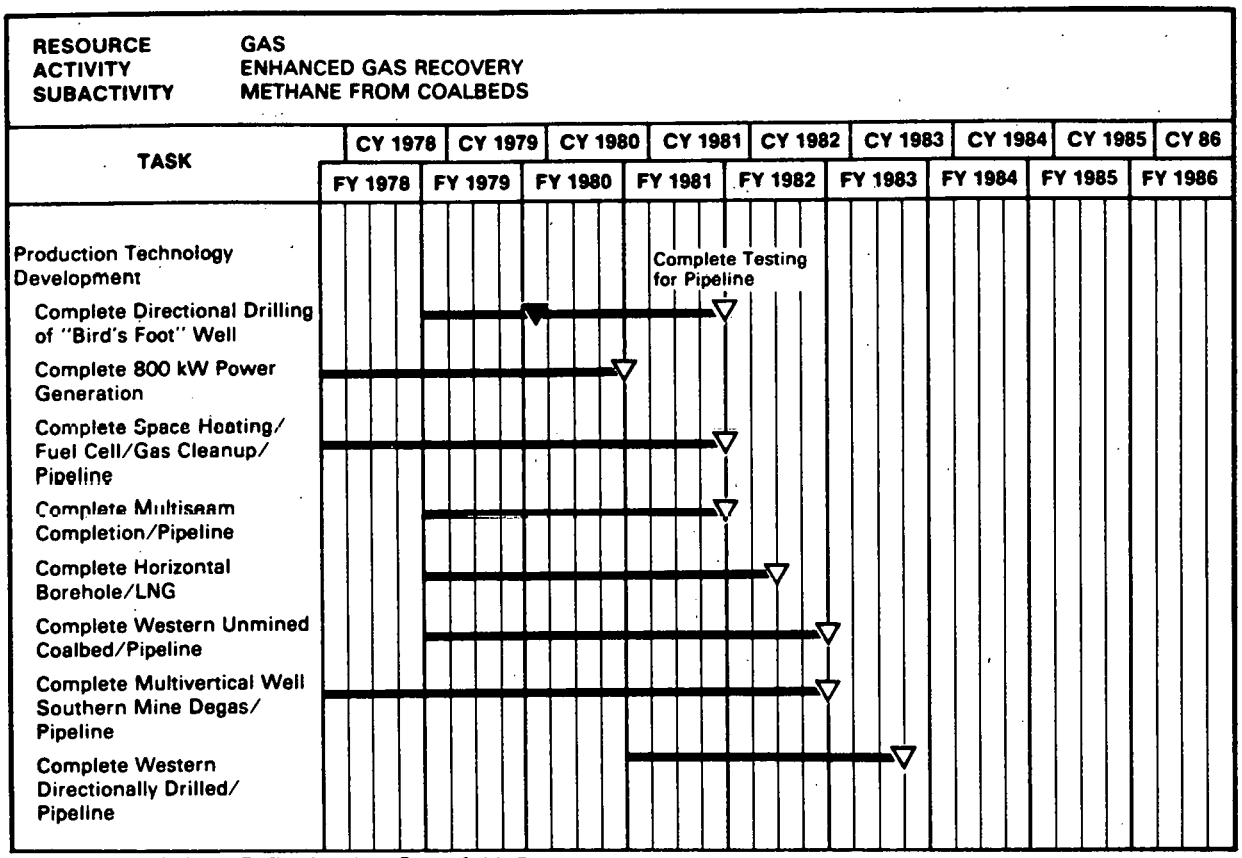

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4.0 ENVIRONMENT AND SUPPORT

The Environment and Support subactivity includes controls to ensure that all field projects will be conducted in accordance with existing and foreseeable environmental and health and safety requirements. A thorough understanding of the environmental implications of drilling and fracturing techniques is important to the success of UGR. Environmental assessments will be made of all planned field activities to ensure proper consideration of all potential problems and to minimize adverse environmental impacts. Data compiled and analyzed during the program should provide a sound basis for predicting the environmental impact of commercial operations utilizing similar technologies.

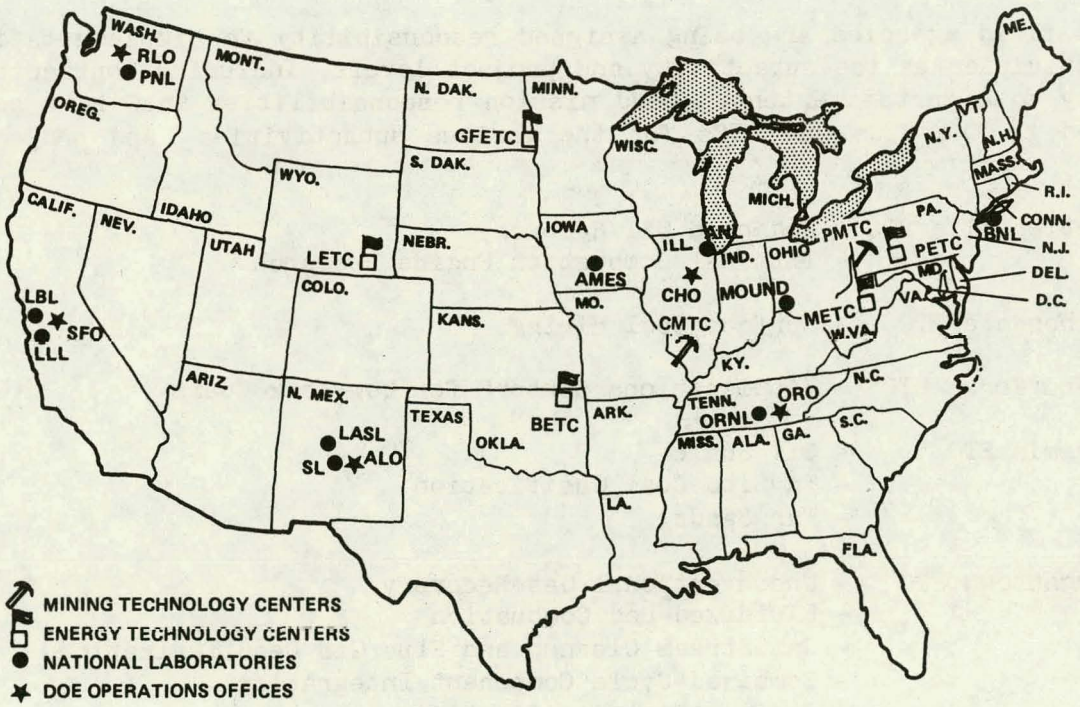
Additional support work may be necessary to define and refine the overall UGR activities. Management support from professional systems analysts and engineering consultants will be used to update the Gas Resources R&D Management Plan. However, the major support effort provided by the national laboratories will be directed through the Morgantown Energy Technology Center, the lead center for UGR, under the appropriate UGR activity: Evaluation; Resource and Site Characterization; Research, Instrumentation and Modeling; Production Technology Development; and Preparation and Utilization.

VI. FIELD ACTIVITIES

During the past year there has been a steady implementation of the extensive decentralization effort that DOE initiated in FY 1979. Project management of specific development activities is now predominantly in the hands of supervisory personnel in the energy technology centers (ETCs), mining technology centers (MTCs), and national laboratories (NLs), while program management is retained at the DOE headquarters level.

This approach has provided improved utilization of technical and managerial personnel in two basic ways. First, field agency personnel have been delegated authority to accomplish on-the-scene technical supervision which allows more effective day-to-day management control of projects. Second, headquarters personnel, being freed of the detailed technical aspects of project management are now able to devote more time to program management, including planning and coordinating activities that are the responsibilities of higher government organizational positions.

DOE field agencies are located throughout the country (see following map) in geographically advantageous positions to accomplish their assigned



Location of DOE Fossil Energy Technology Centers Mining Technology Centers, and National Laboratories

missions. The roles of the energy technology centers, the mining technology centers and the national laboratories are described in this chapter.

As indicated in Chapter II, program management, policy initiatives, and governmental interface with the Congress, OMB, other agencies and industry, and international programs are performed by DOE headquarters. Specific responsibilities of headquarters include:

- Prescribe policy for the Fossil Energy program.
- Establish those technologies in which the program will be developed.
- Establish and maintain liaison with other assistant secretaries.
- Develop program plans for each assigned area.
- Develop and justify budgets.
- Interface with the Congress and other groups that influence the program.
- Measure work progress in the various program/project areas and inform DOE management of program results.
- Approve field procurement plans.

DOE field agencies are being assigned responsibility for implementation of FE activities at the subactivity and project levels, including contracting authority to a certain extent. Lead mission responsibilities that have been delegated to the ETCs and MTCs for the various subactivities and projects are:

Bartlesville ETC - Enhanced Oil Recovery
- Internal Combustion Engine Research

Carbondale MTC - Surface Coal Mining

Grand Forks ETC - "Applications Center" for Low-Rank Coals

Laramie ETC - Oil Shale
- In Situ Coal Gasification
- Tar Sands

Morgantown ETC - Unconventional Gas Recovery
- Fluidized-Bed Combustion
- Gas Stream Cleanup and Flue Gas Desulfurization
- Combined-Cycle Component Integration
- Surface Coal Gasification
- Component Development for Coal Conversion/ Utilization Processes

Pittsburgh ETC
- Coal Liquefaction
- Synthetic Fuels Characterization
- Coal-Oil Mixtures
- Combustion Phenomena
- MHD Combustion

Pittsburgh MTC
- Underground Mining
- Coal Preparation
- Surface Test Facility

Responsibility for other subactivities and projects such as fuel cells, anthracite, etc., will be delegated to field agencies as specific program plans are developed.

Project management responsibility for the various university projects is also assigned to its appropriate field activity.

The field activities will include responsibility for the following:

- Development of integrated and individual plans for subactivities and projects
- Development of procurement plans
- Chairing source evaluation boards and technical advisory committees
- Management of projects consistent with milestones and costs
- Maintenance and reporting of obligations/costs on project and program bases
- Development and maintenance of adequate technology bases for each program area.

The decentralization process (i.e., technical management of projects to field) is continuing. It has been, and will continue to be, the approach applied to existing and new projects.

A. ENERGY TECHNOLOGY CENTERS

The ETCs play an important role in achieving DOE goals in Fossil Energy technology. They have demonstrated the ability to achieve solutions to specific technology-base problems affecting the timetable of major Fossil Energy systems development. In addition to the in-house technical capability at each center, personnel at energy technology centers have functioned in supervisory and liaison capacities in the management of contract research work with universities, laboratories, private industry and other ETCs in every major area of the Fossil Energy development program. The mission of the ETCs has been expanded greatly to encompass the role of manager for Fossil Energy projects. Although relatively small, the ETCs are staffed by highly skilled scientists, engineers, and technicians with a long history of accomplishments in R&D to technology-base problems in the production and utilization of fossil fuels. They have produced new ideas, new data, and new processes for better utilization of Fossil Energy resources.

Although the ETCs are under the administrative jurisdiction of the Assistant Secretary for Fossil Energy, projects are conducted for other DOE organizations, primarily in the Conservation, Environment and Safety, and Physical Research program areas.

A summary table of funding levels devoted to each program at the ETCs is provided below.

1.0 BARTLESVILLE ENERGY TECHNOLOGY CENTER (BETC)

The Bartlesville Energy Technology Center is the Department of Energy's lead center for petroleum research. Since this responsibility embraces the entire liquid fossil fuel cycle (LFFC), from exploration to ultimate use, the work performed at BETC can best be categorized under the three major divisions of the LFFC as follows:

- Petroleum Extraction. This program was designed to accelerate the development of enhanced oil and gas recovery technologies through research and to make the results of this research readily available to the private sector. BETC has been in the forefront of this cost-sharing program since 1974, not only with petroleum research expertise, providing technical evaluation of proposed EOR projects and monitoring ongoing projects, but also with an aggressive program of technology transfer through the literature and DOE-supported symposia, seminars, conferences, meetings and workshops.

- Petroleum Processing. For the past 60 years BETC has conducted research in petroleum chemistry and refining. One project in this area is a growing data bank of over 9,000 crude oil analyses from most of the world's major oil fields. Characterization of the heavy ends of petroleum and syncrudes from coal and shale oil is

Table 5. Energy Technology and Mining Technology Center Funding Levels

	ACTUAL FY 1979	APPN FY 1980	ESTIMATE FY 1981
BARTLESVILLE ENERGY TECHNOLOGY CENTER			
Operating Expenses:			
Coal	1,940	2,670	3,100
Petroleum	14,401	12,349	12,400
Gas	8,211	8,800	9,550
Total Program Operating Expenses, BETC	24,552	23,819	25,050
GRAND FORKS ENERGY TECHNOLOGY CENTER			
Operating Expenses:			
Coal	6,714	8,994	6,700
Petroleum	0	0	0
Gas	0	0	0
Total Program Operating Expenses, GFETC	6,714	8,994	6,700
LARAMIE ENERGY TECHNOLOGY CENTER			
Operating Expenses:			
Coal	4,510	6,430	3,100
Petroleum	19,882	29,023	32,450
Gas	529	0	0
Total Program Operating Expenses, LETC	24,921	35,453	35,550
MORGANTOWN ENERGY TECHNOLOGY CENTER			
Operating Expenses:			
Coal	24,622	71,868	83,655
Petroleum	8,671	3,000	0
Gas	22,038	19,620	16,500
Total Program Operating Expenses, METC	55,331	94,488	100,155
PITTSBURGH ENERGY TECHNOLOGY CENTER			
Operating Expenses:			
Coal	31,482	43,968	69,509
Petroleum	58	0	2,300
Gas	0	0	0
Total Program Operating Expenses, PETC	31,540	43,968	71,809
ENERGY TECHNOLOGY CENTERS			
Operating Expenses:			
Coal	69,268	133,930	166,064
Petroleum	43,012	44,372	47,150
Gas	30,778	28,420	26,050
Total Program Operating Expenses, ETCs	143,058	206,722	239,264
CARBONDALE MINING TECHNOLOGY CENTER			
Operating Expenses:			
Coal		4,127	6,700
Petroleum		675	4,450
Gas		0	0
Total Program Operating Expenses, CMTC	2,560	4,802	11,150
PITTSBURGH MINING TECHNOLOGY CENTER			
Operating Expenses:			
Coal		22,481	25,690
Petroleum		0	0
Gas		0	0
Total Program Operating Expenses, PMTC	2,850	22,481	25,690

being done as an aid to refining. Petroleum products surveys are done each year on properties of gasolines, diesel fuels, heating oils, and aviation fuels providing a reference of seasonal and yearly changes. One of the most viable research areas is waste-oil recycling. Preliminary economic analyses are favorable, and design of a refining facility based on BETC research is underway.

- Petroleum Utilization. Research is conducted to provide both government and industry with technical information on preferred combinations of fuels and engines for best use of available energy resources. The work involves experiments with both automotive and industrial engines to measure emissions, fuel economy, and general suitability of engines to use varied fuels. Encompassed in this research are experiments to assess the potential of advanced engine systems to meet energy efficiency and environmental goals in the eventual transition to alternative fuels.

2.0 GRAND FORKS ENERGY TECHNOLOGY CENTER (GFETC)

GFETC is concerned primarily with near- and mid-term technologies for the utilization of low-rank coals, including lignite and subbituminous coals, in an environmentally sound manner to alleviate urgent energy supply problems in the western and midwestern United States. GFETC has been designated as the DOE lead center for low-rank coal applications.

Research and development activities are continuing at GFETC to produce technology base data relating to the use of low-rank coals and peat in the areas of preparation, gasification, liquefaction, conventional pulverized coal combustion, fluidized-bed combustion and advanced environmental control technology. A 25 ton per day slagging fixed-bed gasifier is being operated at GFETC to develop operating data on a variety of coals and to characterize and develop treatment techniques for the liquid effluents. The objective of the liquefaction studies is to develop basic scientific and engineering data on the liquefaction behavior of low-rank coals and to relate this data base to the major developing liquefaction processes. Combustion and associated environmental control technology studies are being conducted to obtain data that will promote the use of low-rank coals for power production and provide the necessary technology base to insure compliance with environmental regulations.

3.0 LARAMIE ENERGY TECHNOLOGY CENTER (LETC)

Laramie Energy Technology Center is the lead center for technology-base activities in Underground Coal Conversion (in situ), Tar Sands and Oil Shale. LETC is charged with the responsibility for the full and effective implementation of Fossil Energy's effort in these areas.

- Underground Coal Conversion. As lead center for underground coal conversion LETC is responsible for ongoing field efforts and supporting research at various universities and national laboratories. In FY 1980 the main program thrust will be the development and demonstration, in conjunction with industry through a cost-sharing agreement, of a commercially feasible process for underground coal gasification (UCG) in low-rank coal.

Complementing this activity will be the continued efforts by LETC, METC, LLL, SL, and Gulf R&DC at their respective field sites. Plans for new site selections and series of small-scale linkage and gasification tests are underway.

- Tar Sands. LETC is the lead center for managing field experiments and evaluation of data for Tar Sands. In FY 1980, principal activities will include initiation and completion of the first steam process field experiment, completion of design of second field experiment, completion of prioritization of major tar sand deposits for detailed characterization and complete acquisition of samples and data for one major deposit, and completion of evaluation of applicability of available mining technologies to U.S. tar sands.

- Oil Shale. LETC is the lead center for technology-base activities on the production and utilization of the vast oil shale resources. In FY 1980, principal R&D activities include completion and evaluation of laboratory and field experiments by LETC and LLL, initiation of environmental monitoring and related control system research at LETC field sites, continuation of resource assessment of selected oil shale sites, and continued assessment of retorting techniques in surface, in situ, and modified in situ oil shale processes.

4.0 MORGANTOWN ENERGY TECHNOLOGY CENTER (METC)

Major activities at METC include research, development and technology-base activities on fluidized-bed combustion, gas stream cleanup, coal gasification, and coal-feeding systems. Unconventional gas recovery and enhanced recovery of oil are also being investigated including in situ gasification of coal.

- Coal. Implementation of decentralized project management for fossil energy programs in fluidized-bed combustion, gasification, gas stream cleanup, component development, and combined-cycle component integration is underway. These project management activities are complemented by continued in-house development on a stirred, fixed-bed gasifier, fluidized-bed combustors, and gas stream characterization for cleanup applications. Construction of the atmospheric fluidized-bed component test and integration unit, which was started in 1977, will continue with operation to begin in FY 1982.

- Petroleum and Natural Gas. Characterization, resource inventory, and field tests of United States unconventional natural gas reservoirs will continue, with emphasis on the Appalachia, Michigan, Illinois, New Mexico, Colorado, and Wyoming areas. Results of FY 1979 studies will be analyzed for major impacts on needed recovery technology. Additionally, the center provides technical support for DOE laboratory studies and field test projects on enhanced oil recovery.

- In Situ Technology. Program objectives are to demonstrate new technology, including directionally deviated wells that can be combined to degasify, devolatilize, carbonize, and gasify relatively thin, deep eastern coal seams. Test sites will be evaluated, and a field test will be designed and started using directional drilling technology to test the longwall generator flow concept.

5.0 PITTSBURGH ENERGY TECHNOLOGY CENTER (PETC)

The Pittsburgh Energy Technology Center conducts a broad spectrum of research and development for the industrial use of coal and its derived synthetic fuels in an environmentally sound manner that emphasizes overall energy conservation. PETC is the largest Federal laboratory devoted to maintaining a technology-based R&D program on coal. Projects in coal-oil mixture combustion and chemical cleaning of coal have major near-term impacts. Projects in coal liquefaction, direct combustion, coal gasification, and magnetohydrodynamics represent multiyear efforts with mid- and far-term impacts.

Extensive process research is being conducted. A promising method of removing much of the sulfur from coal by pressurized air-water treatment is under development. Techniques for refining and upgrading coal liquids and producing valuable chemicals, such as ethanol and ethylene, are being investigated. Research is being conducted to develop new and improved catalysts for coal liquefaction and gasification processes. An important effort is devoted to development of new analytical tools and techniques to characterize coal and coal products from energy conversion processes. Both experimental and theoretical engineering studies are being performed on reactor modeling. In all research and development studies, environmental impact and conservation techniques are an integral part of each project scheme.

The center is currently in the process of participating in the management of selected projects being moved out of headquarters and into the field organizations. Projects in coal liquefaction, coal process technology, coal-oil mixture combustion, direct combustion, and MHD combustion are in the process of transfer to PETC. In the realignment of personnel and organization, emphasis is placed on technical support of larger liquefaction demonstration plants, Solvent Refined Coal, H-Coal, and Exxon Donor Solvent processes.

B. MINING TECHNOLOGY CENTERS (MTCs)

1.0 CARBONDALE MINING TECHNOLOGY CENTER (CMTC)

CMTC conducts development of high-productivity mining systems for fossil fuels. The center implements this technology-based program by integrating new mining equipment, economic effects, safety and environmental considerations into mining systems to achieve increased fossil fuel mining productivity.

- Coal. CMTC conducts research on surface mining of coal including (1) mine planning, aimed at mitigating surface mining effects, increasing productivity and minimizing reclamation costs; (2) develoment and production systems including area, contour, and highwall mining techniques; (3) logistics of mine utilities; and (4) reclamation of mined lands in a socially acceptable manner.

  Other research activities include: seam access, primarily larger diameter shaft-sinking equipment and systems, automation of mining equipment for improved productivity and a novel approach using hydraulic jet cutting from the surface to mine out underground cavities (hydraulic mining).

- Petroleum. The center is currently responsible for the development of mining technologies for oil shale, tar sand, and heavy and light oil mining. Long-range plans have been prepared and are being implemented for the underground mining of oil shale for use in surface retorts, as well as the development of in situ retorting of oil shale deposits. Plans also include mining of tar and oil sand deposits.

2.0 PITTSBURGH MINING TECHNOLOGY CENTER (PMTC)

The mission of the Pittsburgh Mining Technology Center is to advance the technology needed to mine and prepare coals for direct combustion, conversion to metallurgical coke, synfuels, and export in a safe, conservative and efficient manner.

PMTC activities include:

- Coal Mining. Research in all facets of underground coal mining to include: mine planning; mine development; production systems; and logistics.

- Coal Preparation. In-house and contract research in all facets of coal preparation to include: coal characterization; physical and physicochemical beneficiation; ancillary unit operations; and coal analysis.

- Use of Test Facilities. Develop, test, and evaluate mining machines, mining subsystems and mine systems in simulated mine environments. Major facilities include: an equipment maneuverability area; a cutting trials area; a dynamic mine-roof simulator; and a hydraulic transport test loop.

C. NATIONAL LABORATORIES

In addition to the significant contributions made by the energy technology centers and the mining technology centers to the overall Fossil Energy technology-base program, 11 national laboratories provide supportive contributions. These DOE laboratories possess unique facilities and in-house expertise which can contribute significantly in providing specialized task support to projects managed by Fossil Energy. These laboratories, like the ETCs, submit proposals for R&D work relating to Fossil Energy development in their respective areas of expertise. Many of these proposals are accepted and provide significant benefits to the various Fossil Energy technology-base programs.

A brief summary of planned activity in support of Fossil Energy programs is provided in the following 11 sections.

1.0 AMES LABORATORY (AL)

Ames Laboratory primary support is directed toward coal preparation. General areas of work include: (1) physical cleaning, (2) chemical cleaning, and (3) support studies. This program benefits greatly from having onsite a semi-industrial-scale coal preparation pilot plant.

2.0 ARGONNE NATIONAL LABORATORY (ANL)

Argonne's work focuses on the coal resource, including studies in fluidized-bed combustion in support of Combustion Systems Activity technology and work on high-temperature/pressure samplers (High-Btu Gasification). Argonne provides engineering support to the demonstration plant efforts, and has a second major effort in the MHD Component Development and Integration Facility (CDIF) as well as to other areas of open- and closed-cycle MHD technology and is involved in the U.S.-U.S.S.R. effort in MHD. Materials research for coal conversion processes is also included in ANL's task for Fossil Energy. Argonne also provides R&D support for the Heat Engines and Heat Recovery and the Fuel Cell Activities.

3.0 BROOKHAVEN NATIONAL LABORATORY (BNL)

Brookhaven National Laboratory provides limited basic research support in the coal R&D area, specifically relating to flash hydropyrolysis of coal and regenerative processes for desulfurization of high-temperature combustion and fuel gases. Additional efforts in principal alternate fuel combustion and fuel cells are being conducted.

4.0 IDAHO NATIONAL ENERGY LABORATORY (INEL)

The Idaho National Energy Laboratory provides research support in the area of high-temperature materials and manages the construction of the MHD-CDIF.

5.0 LAWRENCE BERKELEY LABORATORY (LBL)

LBL provides support for two task areas: research in high-temperature erosion/corrosion resistance materials development and tertiary recovery with mobility control and surface active agents for enhanced oil recovery.

6.0 LAWRENCE LIVERMORE LABORATORY (LLL)

LLL is involved with supporting tasks in the massive hydraulic fracturing process for stimulating natural gas recovery. Supporting work in modified in situ oil shale recovery techniques and development of the packed-bed process for the In Situ Coal Gasification Activity are also being accomplished at LLL.

7.0 LOS ALAMOS SCIENTIFIC LABORATORY (LASL)

LASL has two tasks in the Oil Shale and In Situ Technology Activities. Specifically, these efforts are explosively produced fracture of oil shale and in situ coal gasification of southwest coals with minimal water requirements. LASL also is investigating the explosive stimulation of natural gas and laser pyrolysis for characterization of Devonian shale, ceramic heat pipes, and fuel cell transportation applications.

8.0 MOUND LABORATORY (ML)

The Mound Laboratory is providing technical support for the fuel gas demonstration plant project and has a project for characterization of Devonian shale.

9.0 OAK RIDGE NATIONAL LABORATORY (ORNL)

Oak Ridge is the principal support NL for coal technology and is performing many support tasks in the areas of demonstration plants by providing technical assistance. ORNL also has been selected as the lead laboratory for materials technology. Several research support tasks primarily in materials and component development are also planned, along with coal liquefaction research support. In the Gas and the Petroleum Resources Activities, ORNL is providing support in the enhanced oil recovery and processing and utilization areas. ORNL is supporting In Situ Coal Gasification technology by pyrolysis of large coal blocks, and the Heat Engines and Heat Recovery Activity.

10.0 PACIFIC NORTHWEST LABORATORY (PNL)

Pacific Northwest Laboratory has several tasks involving hot gas cleanup with molten salt and an electrode/insulation program for MHD technology development. In addition, PNL currently has a major role in support of the mining research program.

11.0 SANDIA LABORATORIES (SL)

Sandia provides major support work for the Gas and Petroleum Resources Activities and In Situ Coal Gasification Activity. These efforts include work in the massive hydraulic fracturing technology for enhanced gas recovery

and instrumentation; diagnostic, bed preparation work for in situ oil shale recovery and coal gasification; and offshore drilling technology development. Studies on direct-injected stratified charge engine combustion are also being conducted, as well as research on improved drill bits and coal cutting picks.

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VII. COMMERCIALIZATION

1.0 BACKGROUND

The fossil energy technology programs conducted by the Assistant Secretary for Fossil Energy (ASFE) are responsive to the National Energy Policies and Goals described in Chapter I. Some FE technology developments will provide the FERC, the Assistant Secretary for Resource Applications (ASRA), the proposed Energy Security Corporation and the Energy Mobilization Board with options to reduce petroleum imports. These include activities directed toward increasing the direct use of coal, introducing new methods of using coal and coal-based products, and enhancing petroleum, oil shale, and natural gas production. The principal output of fossil technology development programs is data on the technical, economic, and environmental feasibility of commercialization. This data is a primary input both for governmental and private sector decisions concerning deployment of new technologies into the U.S. economy.

"Commercialization" encompasses the activities of introducing a promising technology to the marketplace. It involves one or more of the following commercialization mechanisms: regulation, incentives, public investment, and private investment. In recognition of the importance of commercialization, DOE in FY 1979 established a Commercialization Committee comprised of Assistant Secretaries and other selected members. The committee, which was chaired by the Deputy Undersecretary for Commercialization, reviewed pertinent issues and reported to the Undersecretary.

Task forces were convened to examine energy technologies in detail, each focusing on a single technology. Members were drawn from Energy Technology, Resource Applications, Conservation and Solar, Energy Research and other offices within DOE. Industry, university, and non-DOE government experts were consulted on an as-needed basis. The task forces reviewed all aspects pertaining to commercialization of the technologies under review, prepared analyses and presented findings and recommendations to the Commercialization Committee, the Deputy Undersecretary for Commercialization and the Undersecretary.

The findings of the task forces reporting on fossil energy technologies provided basic foundations upon which commercialization programs are being developed in the following areas:

Gaseous Fuels

- Low Btu
- Medium Btu
- High Btu (First Generation, Advanced Technology)
- Enhanced Gas Recovery

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Liquid Fuels

- Coal Liquefaction
- Oil Shale - In Situ
- Oil Shale - Surface Retort
- Enhanced Oil Recovery

Direct End-Use Applications

- Industrial Atmospheric Fluidized-Bed (AFB) Combustion
- Utility Atmospheric Fluidized-Bed Combustion
- Combined Cycle with Integrated Gasifier for Utility Application
- Fuel Cell Power Plant

2.0 COMMERCIALIZATION FACTORS

The principal factors considered in determining the readiness of a technology for commercialization are:

- Technical readiness: Are the technology risks within industry's normal bounds. Are demonstrations needed to verify technical feasibility or to show operations, maintenance, reliability.

- Economic readiness: Does the private market need stimulus for accelerating timing and/or increasing the size of the market.

- Environmental feasibility: Can the technology meet environmental requirements.

- Institutional support: Is it able to fit into government and/or private sector operations. What are the institutional, regulatory, and legislative barriers confronting the introduction of the technology.

- Cost benefit: Is it cost effective from both a government and a private view.

Technical Readiness

- Decide which efforts will be the sole responsibility of the private sector and determine at what point the technology will be ready.

- Determine if the government could and should help with demonstrations, lab developments, or research.

- Define the worst problems or unknowns, and decide whether their resolution is in the normal domain of industry.

- Determine the schedule of technical projects and what and how close the competing technologies are.

Economic Readiness

- Determine the composition of industries that will be users and suppliers.
- Determine the quality of existing information, what needs to be generated in market analysis and venture analysis, what suppliers and users have done to date, in what areas DOE should stimulate industry and obtain desired information, and what efforts DOE should do in-house.
- Define the size of the market and its rate of development.
- Identify critical factors, including DOE policies, process complexity, technology status, economics, environmental concerns, industry interest, regulatory issues, demonstrations required, and the government role in providing incentives.

The market assessment should include, to the extent possible, information from the industry that would be investing in and using the product, and from the equipment suppliers who will develop, sell, and warrant the product.

Environmental Feasibility

In assessing the environmental suitability and determining the problems inherent to commercializing a technology, the following general procedures are required:

- Determine the process characteristics in terms of temperature, pressure, fuel feed, fuel quality and quantity, other ingredients, etc., that may affect resultant pollutant levels.
- Identify appropriate pollution controls to reduce air, water, and waste related emissions.
- Define the environmental data on all aspects of the technology as it exists and as forecast in commercial applications. The confidence levels associated with current data and forecasts should be stated.
- Determine environmental impacts associated with location in nonattainment regions, expected cumulative environmental effects of colocation of facilities and other possible siting restrictions.
- Review laws and regulations and other environmental requirements to determine their applicability to the technology under consideration.

Of particular concern are the uncertainties posed by future environmental legislation and regulations that may be changed in a 4-year cycle. Development time for industrial processes and technologies may in some cases take two or three times longer and may be unable to accommodate the changes that could be imposed. Also of significant concern is the

ability of law suits to stop implementation of a project until legal settlement, thus causing delay or termination.

Current Federal environmental laws include the Clean Air Act and Amendments, the Federal Water Pollution Control Act and Amendments, the Occupational Safety and Health Act, the Resource Conservation and Recovery Act, the Toxic Substances Control Act, and the Safe Drinking Water Act.

Procedural requirements include NEPA assessments, environmental impact statements and Section 13 water assessments.

Institutional Support

- For the private sector, determine what the technology will replace, possibility of resistance to change, and what will increase its attractiveness.

- For the government, determine existing institutional barriers and the actions to be considered at local, state, and Federal levels to assist in the introduction of technology.

Cost Benefits

Is commercialization economically attractive to private industry? If the government helps, is it worth it? What is the government cost to participate versus the cost saved by reducing imported oil? Analysis should be conducted to determine if the government should actively support commercialization in some form, such as demonstration projects, capital grants, investment tax credits, fuel subsidies, fuel taxes, environmental regulations, and product indemnity guarantees.

3.0 COMMERCIALIZATION ACTIVITIES

DOE Organizational Relations

The ASFE has overall responsibility for a technology during its development cycle. When the R&D for a technology is nearing completion, and where applicable, resource managers are appointed in the ASRA office to provide a DOE-wide point of focus for the integration of all activities required to achieve the earliest possible commercialization.

Functions performed by ASFE personnel before the appointment of resource managers and continuing during the commercialization phase include:

- Identifying technical barriers or issues that may impact on the commercialization of a technology, and serve as a focal point for resolving problems arising from these barriers or issues.

- Performing analyses or reliability studies of site-specific issues, design criteria, process engineering, demonstration and test requirements and other technical aspects of the proposed commercialization effort.

- Providing advisory assistance, working with industry and coordinating within the government for technical matters.

- Evaluating technical aspects of proposals and approaches considered by government and the private sector in commercialization planning.

As a technology nears its commercialization phase, responsibility for "marketing" activity is transferred from ASFE to ASRA. When technology is somewhat mature but requires additional engineering support, the resource manager will report to ASRA and will call on ASFE for technology support in a matrix management system.

When large demonstrations are still needed or the technology is not ready for commercialization because of cost or other barriers, a resource manager will be appointed. In these cases, market and cost analyses and marketing research will be conducted by ASRA as appropriate to insure that ASFE efforts are directed toward a logical end market.

Some modification of these procedures can be expected upon the establishment of the Energy Security Corporation and the Energy Mobilization Board.

Plans for Initiating Commercialization Programs

In addition to the pilot and demonstration plants, described in Chapters III, IV and V, that contribute to technical progress toward commercialization, DOE is continually preparing plans for large-scale commercial activities, particularly in the synfuels and direct combustion areas. In support of the administration goal of reducing oil imports by 8.5 million barrels of oil per day by 1990, coal gasification and liquefaction processes are being analyzed to determine the best possible potentials for large-scale commercial production of fuels.

An example of a government/industry cost-sharing commercialization plan is the proposed Great Plains Gasification Associates (GPGA) plant at Mercer County, North Dakota. GPGA is a consortium of seven companies investing in a plant for the commercial production of pipeline-quality gas derived from coal. The DOE has been working with GPGA to establish the degree of government participation. Twenty-two million dollars have been provided by P.L. 96-126 for the project. ASRA is responsible for the DOE commercialization effort with ASFE providing technical assistance.

In addition to the projects that will be commercialized in accordance with procedures explained above, there are certain activities that will be commercialized directly to the private sector without requiring the establishment of ASRA Resource Manager responsibilities. These projects will progress directly from well-developed technology to private sector implementation. Typical of this are the projects described in Chapter III, Section H-1.2, AFB Industrial Applications. A specific example is the Georgetown University Atmospheric Fluidized-Bed installation recently activated in Washington, D.C. In this case, DOE (FE) was responsible for developing the design and construction of a prototype commercial-size AFB installation to provide heat for the Georgetown University campus. Interesting features in this advanced plant include indoor coal delivery and

ash removal systems, an experimental coal feeding system, an indoor baghouse dust collector, and no visible exhaust stack. Georgetown University will assume operation of the unit when the initial phase-in period has been completed, now scheduled in FY 1982.

Other spinoffs and technology transfers directly to the private sector from DOE development efforts will occur on a continual basis throughout the development cycle on components, materials and portions of technologies that can be absorbed by industry, without government participation or establishment of incentives. ASFE will continue to provide advice and encouragement to the private sector on these commercialization activities.

Within DOE other commercialization efforts are also underway. P.L. 96-126 signed by the President on November 27, 1979, appropriated $2.2 billion for DOE to "expedite the domestic development and production of alternative fuels ... at maximum levels at the earliest time practicable." The appropriations include the following initiatives:

- $100 million for project development feasibility studies; a maximum of $4 million per project
- $100 million for cooperative agreements; a maximum of $25 million per project
- $500 million as a reserve for loan guarantees; not to exceed $1.5 billion in total guarantees
- $1.5 billion for purchase commitments or price guarantees.

The technologies considered in these initial commercialization efforts are coal liquefaction, low-/medium- and high-Btu gasification, shale oil, tar sands, lignite, unconventional natural gas, peat, biomass, and solid waste.

VIII. ENVIRONMENTAL AND SOCIOECONOMIC IMPLICATIONS OF FE TECHNOLOGY DEVELOPMENT

Fossil Energy (FE) seeks to advance the availability of environmentally and socially acceptable energy resources. The strategy to achieve this goal incorporates independent activities conducted within each FE program and close cooperation among FE and its industrial partners; the Office of the Assistant Secretary of Environment; Federal, State, and local regulatory agencies; and the public.

The Fossil Energy strategy considers the need to develop a broad range of environmentally sound technology options for utilizing domestic fossil energy resources. This means that the technology should have acceptable impacts on the physical and biological environment, protect the health and safety of workers and the public, enhance socioeconomic values, especially for the communities most affected, and contribute to the high efficiency of energy production and use. Consequently, environmental, health and safety, and socioeconomic issues associated with the operation of fossil energy processes are identified as early as possible, and research projects are developed to resolve these issues.

In the Fossil Energy area, coal can be used as an energy source for many diverse applications. It can be combusted directly to produce steam for power generation; it can be gasified to yield a fuel gas or a pipeline-quality gas; it can be liquefied to produce a fuel or alternate petrochemical industry base; and it can be used to fuel advanced power systems that are thermally efficient.

1.0 ENVIRONMENTAL IMPLICATIONS

Most coal technologies can be associated with similar impacts:

- Requirements and techniques for solid waste disposal
- Consumption of water
- Accidental discharge of toxic or hazardous products or by-products
- Carbon dioxide emissions and unknown cumulative effects
- Air pollutant emissions
- Surface water pollution
- Land and water disturbances from mining
- Occupational and health and safety effects.

Major common issues are the:

- Application of air and water control technologies
- Potential limitations upon commercialization posed by environmental protection regulations.

The wide variety of projects in FE results in many instances of unique and site-specific implications that are best handled on a case-by-case basis. For example, because synthetic coal conversion plants have not been constructed in the United States, there are apprehensions about possible environmental, safety, and health impacts associated with such plants.

Among the specific issues for a given plant are:

- The ability of a site to accommodate the plant physically (e.g., water and coal availability)
- The ability of a community to absorb the socioeconomic impacts of a plant (e.g., adequate housing and schools)
- The ability of a plant to meet existing standards (e.g., air and water quality)
- The ability of a plant to avoid introducing new pollutants in the ambient environment or the worker environment (e.g., trace metals and carcinogens)
- The ability of a plant to meet future standards.

Operations other than those based on coal are also under investigation in Fossil Energy. These include enhanced oil and gas recovery and the extraction of liquid products from oil shales. Many of the same types of environmental, safety, and health implications apply. DOE is aware of possible problems and has initiated procedures and programs designed to define possible hazards and to implement or develop mitigative measures.

FE conducts several basic types of environmental activities, i.e., those related to policy analysis, planning, National Environmental Policy Act (NEPA) compliance, and development of suitable control technology. Generally, these environmental activities are directed toward areas that develop new knowledge in FE chemistry, materials, technology, processing, engineering, analysis, sampling, worker management and protection, and property management and protection. In this context, the term "environmental" refers to health and safety, socioeconomic, and energy process conservation issues as well as to the physical impact of processes on the environment.

Policy Analysis

The results of the environmental policy analysis activities serve as input to the technology goals. FE sponsors studies that consider how current and emerging laws, standards, and regulations affect its programs and technologies and their potential for commercialization. The technical

performance, resource requirement, and economic data resulting from such studies are used to review new regulations and are exchanged with regulatory agencies.

Planning

Planning activities are carried out at both the programmatic and project levels to assure that environmental problems are addressed at the earliest possible point. Programmatic considerations are addressed in the environmental development plans (EDPs) prepared for each activity. FE planning activities address the ability of FE projects to meet current environmental requirements, the development of technical resources, and economic performance information about FE technologies for input into future regulatory decisions. FE works closely with the Office of the Assistant Secretary for Environment in the preparation of EDPs, Environmental Readiness Documents, and Energy Systems Acquisition Program Plans.

NEPA Compliance

NEPA requires that an environmental impact statement (EIS) be prepared for each major Federal action that could have an adverse effect on the environment. FE has prepared environmental assessments for all field projects; EISs are prepared for those projects that could have major environmental impact or are considered controversial. In addition, FE must consider the cumulative impacts of the programs and the ultimate commercialization of the technologies; these topics are addressed in programmatic environmental impact statements. Finally, FE reviews NEPA documents prepared by other DOE offices and other agencies.

Control Technology Development

Fossil Energy has a positive program underway with regard to control technology development. Substances such as sulfur; nitrogen, alkali and halogen compounds; and volatile trace metals are all abundant in coal, and are released in various forms under conversion and combustion conditions. Fossil Fuel cleanup technology is currently available for compliance with environmental standards controlling emissions from coal combustion. However, many of the technologies are costly, mechanically unreliable, or highly energy consumptive. Fuel cleanup, gas stream cleanup, and flue gas cleanup are therefore all being pursued for the development of viable and improved hardware systems to remove contaminants, control emissions, and protect equipment.

The following priorities have been established for control technology development:

- Lime/limestone flue gas desulfurization (FGD)
- Advanced flue gas/cleanup hardware
- Gas stream cleanup hardware
- Particulate control and NO_x control
- Waste disposal techniques.

An indicator of the growing emphasis in this area is the increase in authorized budget (from $7 million for FY 1979 to over $40 million for FYs 1980 and 1981). The FY 1980 budget includes:

- Evaluation of gas cleanup systems
- Development of lime/limestone FGD prototype
- Test and evaluation of alternate FGD systems
- Hot gas cleanup systems development
- Waste management of FGD sludge and waste.

These activities are discussed in Chapter III, Section F, Advanced Environmental Control Technology.

Early Consideration of Environmental Factors by Fossil Energy

Since environmental performance is an integral criterion of technology performance, pertinent environmental considerations are included in each step of the development of a project.

The preprocurement step involves the preparation of the request for proposal (RFP), program opportunity notice (PON), or other type of procurement package. An Evaluation Board (EB) is established with rules for evaluation and selection of the best proposals. The FE Procurement Procedures Manual provides for consideration of NEPA requirements at the preprocurement stage by requiring that the responsible program official (Division Director) complete an Environmental Provisions Form. For projects involving construction activity, emissions and associated activities, the program official must indicate the steps that will be taken for conducting environmental reviews, assessments, or impact statements. Once the relative environmental significance has been established for the proposed project, environmental goals, criteria, and requirements are established and incorporated in the document (RFP, PON, etc.). Instructions are also included for preparing environmental data as part of the proposal and proposal evaluation criteria. Thus, the preprocurement step is critical in establishing the quantity and quality of the information submitted in proposals and in establishing the ground rules for the evaluation of the environmental aspects of a project.

The procurement step involves evaluating and grading the proposals. For large projects, environmental review committees are established to conduct reviews with pertinent factors as established by the Source Evaluation Board (SEB). Site evaluations and oral presentations are also conducted to further assist in the evaluation process. The site evaluation process includes preparation of a preliminary site evaluation report for each proposal in order to determine, at a minimum, the air, water and solid waste permitting requirements for each location and potential environmental impacts of the proposed facility. In the later contract phases, more intensive site studies are conducted. Local officials are usually contacted as well to determine the existence of local support or opposition to the project. Oral presentations are frequently scheduled to request further information regarding technical, economic, and environmental aspects of each proposal.

The contract implementation stage involves establishment of preliminary design, detailed design, construction, and operation of the facility. NEPA

compliance activities are normally scheduled during the design stage, which extends for 12 to 18 months for large projects, and is concluded prior to the decision regarding construction. Large projects are incrementally funded, with decision points within and at the conclusion of each phase. EIS preparation during the design stage enables trade-offs to be made regarding the need for major pollution control hardware. The emphasis in major projects has been to complete the EIS prior to the detailed design phase, resulting in obvious advantages with regard to reducing the environmental and financial risks to the project. Some variation from these procedures occurs in small- to medium-sized projects.

During the construction and operation phases, environmental activities continue. Most of the field activities, actual data gathering, and control technology development activities performed by FE are done in conjunction with or in support of these phases. Typical and specific activities are described in appropriate sections of this document under the individual programs. Examples of such activities follow. Monitoring is initiated prior to construction and continues through the operational phase to verify the true impacts on the environment. Sampling and monitoring activities are conducted to obtain compliance-oriented data and to determine whether new pollutants are introduced into the environment. Projects are carried out under representative environmental conditions to allow adequate assessment of their consequences. Processing conditions are varied to obtain a range of environmental safety and health, and resource efficiency data. Environmental and safety control technology is developed when adequate technology does not exist.

Implementing the environmental strategy requires close coordination between FE and its industrial partner. To facilitate this coordination, selected responsibilities are assigned to each of the cosponsors. FE establishes the criteria necessary to carry out these activities, reviews and approves the environmental protection plan prepared by the industrial partners, monitors the effort, and undertakes supporting and complementary research to assure the completeness and validity of the information being gathered.

2.0 SOCIOECONOMIC ASPECTS

The implementation of new energy technologies will have various impacts on society. The social impacts can be beneficial or adverse. Impacts of the deployment of a given technology will differ as a function of the size of the industry, its location, and the rate of implementation. That is, the social impact of building 50 coal liquefaction plants is different from that of building 1; if all the plants are built in 1 area, the impacts are greatly different than if the plants are dispersed over the entire country. Similarly, the social impact of building 20 coal gasification plants in 10 years is quite different than if 20 plants were built in 20 years. Socioeconomic impacts during the construction phase are also usually different from those associated with operation.

Socioeconomic impacts will also change as a function of other technology deployment activities which are concurrent, as well as other economic activity in general. For example, obtaining financing for five oil shale surface retorts would be much easier if no other construction projects were

being undertaken simultaneously than if financing were being sought at the same time for a number of coal conversion plants.

The objectives of social impact analysis are to (1) provide information on significant social impacts to decision makers so that these factors can be considered in planning the Fossil Energy Program, and (2) insure that social impacts of Fossil Energy projects (pilot and demonstration plants, etc.) are adequately considered in designing the project. The kinds of issues addressed by social impact analysis include: the cost of energy from different technologies and their relative impact on inflation; their impact on regional economies; infrastructure changes associated with the deployment of new technology; and changes in lifestyle associated with the deployment of new technologies. These questions and issues, among others, are of great concern to the public and to Fossil Energy, and will be addressed during the early phases of the programs.

3.0 ROLE OF THE FE ENVIRONMENTAL DIVISION/OFFICE OF PLANS AND TECHNOLOGY ASSESSMENTS

Within FE, the line program offices and the Environmental Division conduct complementary projects. The technology programs are primarily responsible for site-specific activities, while the Division is policy oriented and serves as advisor to supplement and coordinate the activities of the technology programs. The environmental component of each energy technology center provides support to the Environmental Division and performs similar functions in the environmental area for those technologies for which the center has lead responsibilities.

The primary goal of the FE Environmental Division is to assure the environmental acceptability of FE technologies by working to attain these specific objectives:

- Collection and interpretation of environmental data to: (1) provide a sound basis for future environmental regulatory decisions, and (2) formulate environmental policy options for the Assistant Secretary for Fossil Energy
- Incorporation of environmental activities, including health and safety and socioeconomic, into FE funding proposals
- Assessment of EH&S research and development programs with respect to need, scope and priority within FE
- Full consideration of environmental values when projects are selected from among competing alternatives for FE funding
- Compliance by FE program with applicable Federal and State environmental laws.

Increased efforts to analyze major environmental policies are underway in order to ensure that FE is successful in projects with early payoff potentials. The desire to rapidly commercialize such technologies frequently must be balanced with proper concern for the environment. In particular, increased utilization of coal, as proposed in the National Energy Plan,

requires increased attention to the environmental and health implications. Also, the impact of new legislation and regulations upon FE technologies must be considered. For example, work to understand the implications of new standards of performance and offset policies, as prescribed by the Clean Air Act Amendments of 1977, is already well underway. Analyses of provisions of the Toxic Substances Control Act, the Resource Conservation and Recovery Act, the Water Pollution Control Act, the Occupational Health and Safety Act, and other legislation are ongoing, and these efforts will be intensified as FE processes become better understood and new regulations are formulated.

Programs to develop an integrated approach to potential occupational health problems associated with FE development have been started. The upgrading of worker health data collection programs at key sites is a high priority for the FE program. Several projects are underway to strengthen environmental guidelines and review criteria for site evaluations of pilot, demonstration, and commercial-scale projects. As program development and project support activities proceed, additional issues for study are identified. Examples of such studies include the development of environmental control technology; the definition of resource requirements of FE projects; identification of the need for additional monitoring activities and characterization studies and determination of the impact of FE technologies on health, the environment, and the socioeconomic structure of the communities involved.

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IX. SMALL AND DISADVANTAGED BUSINESS UTILIZATION

The following paragraphs summarize the FE policies and procedures that provide contracting and subcontracting opportunities available for small and disadvantaged business concerns.

1.0 SMALL BUSINESS SET-ASIDES

The small business set-aside program provides that certain contracts may be designated for the exclusive competition of small businesses, if it can be ascertained that the particular goods and services are available from small business and reasonably expected that a sufficient number of small businesses will submit proposals to ensure competition. These "set-aside" small business procurements are announced in the Commerce Business Daily, and awards may be made only to firms eligible under applicable small-business size standards established by the Small Business Administration. Also, with the enactment of Public Law 95-507, certain procurements are reserved for small business. Each contract for the procurement of goods and services which has an anticipated value of less than $10,000 and which is subject to small purchase procedures is reserved exclusively for small business concerns unless the contracting officer is unable to obtain offers from two or more small concerns that are competitive.

2.0 SMALL AND DISADVANTAGED BUSINESS UTILIZATION

Changes in the Small Business Act and the Small Business Investment Act of 1958 have enhanced opportunities for small business and socially and economically disadvantaged firms. Public Law 95-507 provides for broader participation by small and disadvantaged firms in the Federal procurement process. This program assists minority and socially and economically disadvantaged small businesses through investment, procurement, management, and technical assistance administered by the Small Business Administration. The Fossil Energy Program participates in the procurement facet of the program by channeling selected noncompetitive procurement contracts to socially and economically disadvantaged businesses so as to build them up to the point where they can viably compete in the normal, competitive Federal procurement process.

P.L. 95-507 provides statutory guidelines for eligibility in this program. In general, eligibility is limited to socially and economically disadvantaged small business concerns which are (1) at least 51 percent owned by one or more socially and economically disadvantaged individuals (or, in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more socially and economically disadvantaged individuals), and (2) whose management and daily business operations are controlled by one or more such individuals.

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This program, generally known as the SBA 8(a) Program, provides for the participation of socially and economically disadvantaged concerns as subcontractors to the Small Business Administration, which acts as the prime contractor to the DOE. Eligible concerns are selected jointly by the Department of Energy and the Small Business Administration. If competent, eligible small-business concerns can be identified to furnish particular goods or services required by the Department of Energy.

3.0 SMALL BUSINESS SUBCONTRACTING OPPORTUNITIES

Each prime contract over $500,000, or $1 million in the case of construction, requires the prime contractor to submit a subcontracting plan which includes percentage goals for the utilization as subcontractors of small business concerns and small business concerns owned and controlled by socially and economically disadvantaged individuals.

4.0 UNSOLICITED PROPOSALS FOR SMALL AND DISADVANTAGED BUSINESS

The Assistant Secretary for Fossil Energy in concert with the Procurement and Contracts Management Directorate has established a reserve with which to fund worthy and technically sound small and disadvantaged business unsolicited proposals. All such proposals for DOE should be sent to: Procurement and Contract Management Directorate, Attention: Unsolicited Proposals, Small Business Administration, Mail Stop RB-400, Washington, D.C. 20585.

X. INTERNATIONAL PROGRAMS

How to provide an adequate supply of clean fuels and how best to use them efficiently poses technical, economic and political problems worldwide. International cooperation among oil consuming nations is becoming increasingly significant as countries look for ways of meeting the commitment to reduce oil consumption. DOE/FE, through joint international activities, seeks to accelerate the development of fossil energy technologies worldwide. In the near future the conversion of coal and oil-shale fossil resources to synthetic fuels can provide an attractive practical solution. Additional answers to energy problems can be provided by improving technology for combustion of coal in an environmentally satisfactory manner, enhanced oil and gas recovery, new mining techniques, as well as more efficient generation of electricity by means of MHD or fuel cells.

The Office of International Cooperation is the focal point for international activities in the Office of the Assistant Secretary for Fossil Energy. Fossil Energy International Programs establishes a vital link between foreign and domestic fossil energy technologies, and provides opportunities for early and economical introduction of new and promising (and possibly unproved) fossil energy technologies to the United States. It prevents unnecessary duplication of technical activities, and gives insight into choices of technologies that have had varying degrees of success or acceptance abroad. Cooperative international programs permit acceleration of FE R&D, by participation in the development of untried technologies, with a sharing of both the technological risks and the costs of participation. Joint R&D, T&E activities accelerate the transition to commercialization of a technology either in the U.S. or for U.S. industry abroad. Moreover, foreign technologies are evaluated and the potential for their commercial survival in the U.S. competitive economy is established.

Cooperation may be bilateral, multilateral, or government/industry. International cooperative activities range from information exchange to major demonstration projects. Many are carried out in cooperation with the International Energy Agency (IEA). The joint technology development and demonstration projects are significant in that they allow for substantial participation by private industries. The participation of U.S. personnel in joint projects abroad not only gives the U.S. the opportunity to assess foreign technologies in its own social and economic environments, but also provides proven means for technology transfer to the U.S.

At the end of 1979, the Office of the Assistant Secretary for Fossil Energy had technology projects or cooperative agreements with 20 countries. The total or completion cost of these projects to all participating countries as of fall 1979 is about $200 million. Furthermore, international cooperation in developing the SRC-II process involved an additional $1.3 billion.

New agreements negotiated in FY 1979 were:

- Agreement on joint participation in the SRC-II program by Japan and the Federal Republic of Germany (FRG)
- FRG participation in the "Mobil-M" (gasoline from methanol) process
- Joint R&D in Tar Sands and Heavy Oil extraction with Canada
- U.S.-Canada joint technology sharing on Coal-Oil Mixture (COM) technology
- Multinational Enhanced Oil Recovery Program with Austria, Canada, FRG, Japan, Norway and the U.K.
- Energy technology sharing agreement with Italy
- Agreement with the Netherlands on MHD technology development.

It is expected that the scope and number of multinational and bilateral international programs and cooperative agreements will continue to increase at an even more rapid pace in CY 1980, as energy supplies continue to have a greater impact on national economies.

The major international projects are:

- Solvent Refined Coal-II
- Pressurized Fluidized-Bed Combustion of Coal
- Magnetohydrodynamics (Poland, U.S.S.R., Netherlands)
- Coal Liquefaction (Poland)
- Methanol-to-Gasoline.

Overview cooperation coal projects include:

- Technical Information Service (TIS)
- Economic Assessment Service (EAS)
- Mining Technology Clearing House (MTCH).

The following table is a list of multilateral and bilateral activities; the remainder of this chapter contains detailed descriptions of IEA and bilateral international FE projects.

U.S./DOE/FE International Programs

RESOURCE/ SYSTEM	ACTIVITY	PARTICIPANTS		PERIOD
		IEA	NON–IEA	
Coal	Pressurized Fluidized-Bed Combustion	FRG U.K.		1975-1983
	Technical Information Service	Austria Belgium Canada FRG Italy Japan Netherlands New Zealand Spain Sweden U.K.		1975-1982
	Economic Assessment Service	Canada FRG Italy Netherlands Spain Sweden U.K. Denmark Ireland		1975-1982
	Mining Technology Clearing House	Belgium Canada FRG Italy New Zealand Spain U.K.		1975-1982
	Coal-Oil Mixture	Canada		1979-1980 (Letter of Intent)
	Coal Mining & Utilization		Australia	1978-1983
	Solvent Refined Coal (II)		FRG	1979-
	Coal Mining		FRG	1977-
	Coal Testing & Analysis		Italy	1979-1984
	MHD		Netherlands	1979-1984
	Coal Mining & Utilization		National Coal Board (U.K.)	1974-1980
	MHD		U.S.S.R.	1972-1984
	Coal Mining		U.S.S.R.	1974-1984
	MHD		Poland	1974-1984
	Coal Mining & Utilization		Poland	1974-1982
Oil	Enhanced Oil Recovery	Austria Canada FRG Japan Norway U.K.		1979-1984
	Tar Sands		Canada	1979-1983
	Enhanced Oil Recovery		U.S.S.R.	1974-1984
Natural Gas	Enhanced Gas Recovery		U.S.S.R.	1974-1984
Shale Oil	None			
Combustion	Energy Conservation in Combustion	Italy Sweden U.K.		1977-1980
Heat Transfer	Heat Transfer Systems	Sweden Switzerland U.K.		1977-1980

A. UNITED STATES — INTERNATIONAL ENERGY AGENCY

The International Energy Agency, established at U.S. initiative in 1974 to promote the development of more secure energy supplies, has undertaken an extensive program in the development of technologies for the utilization of a wide range of energy resources. The Department of Energy/Fossil Energy has been actively participating in development and implementation of cooperative IEA programs in the area of Coal Technology, Combustion, Enhanced Oil Recovery and Heat Transfer.

Since 1975, the following IEA agreements were signed and implemented by DOE/FE:

- Pressurized Fluidized-Bed Combustion
- Technical Information Service
- Economic Assessment Service for Coal
- Mining Technology Clearing House
- Energy Conservation in Combustion
- Heat Transfer Systems
- Coal-Oil Mixture Combustion Technology
- Enhanced Oil Recovery.

The policy and program of work for IEA-sponsored programs are usually controlled by an Executive Committee (EC) consisting of one member from each participating country. The EC meets periodically to approve work programs and budgets and to review progress. Responsibilities for day-to-day operations are normally delegated to an "operating agent" appointed by the EC. The "operating agent" can be either Government organization or a private company. When needed, EC can set up the Technical Committee (TC) to provide support to the EC. TC members are appointed by each EC member.

Responsibility for the development of IEA Fossil Energy cooperative programs has been delegated to the IEA Working Party on Coal Technology (WPCT) by the IEA Committee on Energy Research and Development. The WPCT is continuing to develop additional cooperative programs, with active DOE/FE participation.

In December 1979, the U.S. proposed to the IEA Coal Working Party an accelerated worldwide program for development of COM technology involving cooperative planning, supporting research, technology transfer, and testing in commercial utility and industrial applications, including blast furnaces. It is expected that this program will be instituted in 1980, with the United States as lead country.

1.0 PRESSURIZED FLUIDIZED-BED COMBUSTION

(Participating Countries: United States, United Kingdom, and Federal Republic of Germany.)

Fluidized-bed combustion of coal under pressure offers a major new technology for the direct combustion of coal in a highly efficient and environmentally acceptable manner.

Fossil Energy International Cooperative Activities

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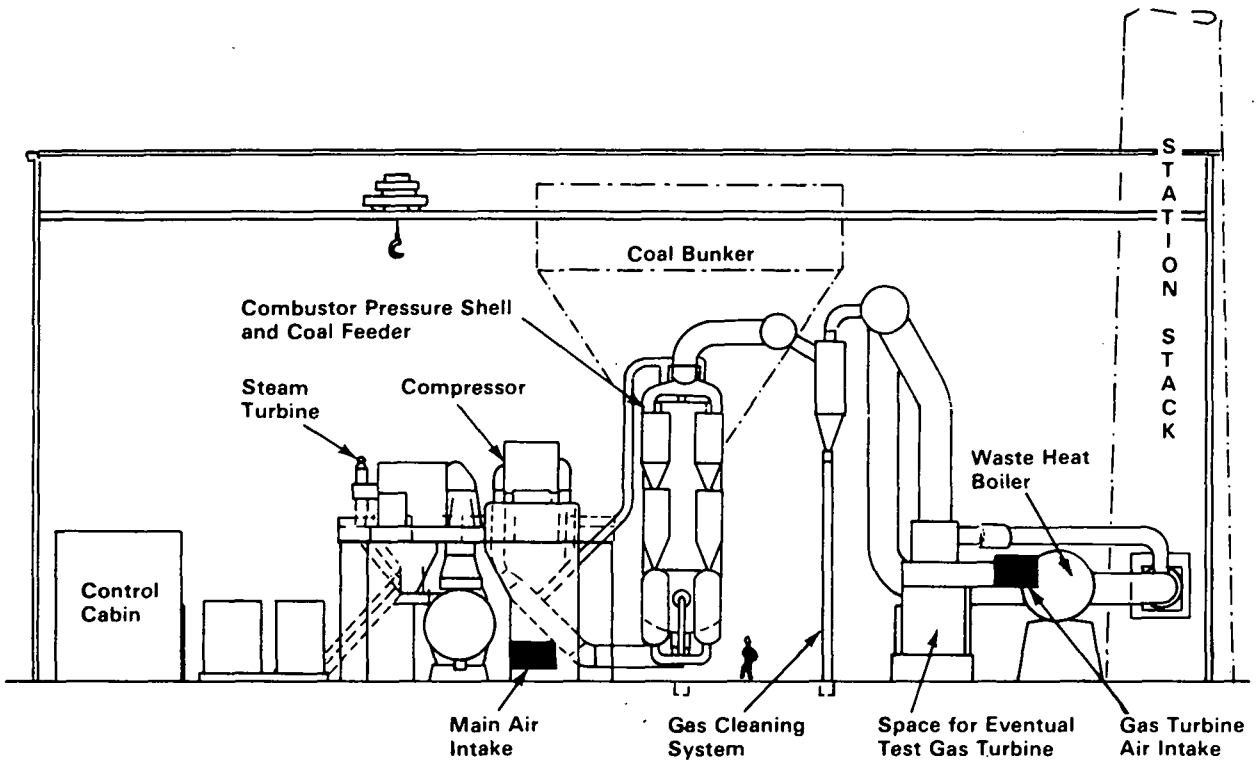
The major objective of this program is to design, build, and operate an experimental facility (at Grimethorpe, Yorkshire, U.K.) for investigating combustion, heat transfer, corrosion, and energy recovery in pressurized fluidized-bed systems, which require more advanced technologies than systems operating at atmospheric pressure.



International Energy Agency 80 MW (Thermal) Pressurized Test Facility at Grimethorpe

The PFB combustor/boiler (85 MW_t burning 14 tons/hr) is expected to be the first of its kind to operate and the first available source of data on such large systems. The in-bed boiler tubes will produce steam sufficient for a 20 MW_e turbine and also, pressurized combustion gases will operate a turbine of up to 3.5 MW_e. The facility is expected to add a 3.5 MW_e gas turbine test unit for operation in early 1980s. Results from these experiments will be used in the design of commercial-scale pressurized fluidized-bed combustion plants.

The duration of the project is 8 years (1975-1983), with start of plant construction in late 1977 and operation by early 1980; construction and operating costs are shared equally by the United States (DOE/FE), the United Kingdom, and the Federal Republic of Germany. The experimental program will make use of coals from the United States, the Federal Republic of Germany, and the United Kingdom in a test program now being decided upon by the participating nations. A full participant of the IEA project, DOE/FE has

complete access to the plant's design and performance data through drawings, reports, and operating logs, as well as through direct participation by U.S. representatives in all aspects of the program. The United States is benefiting by serving as Head of the Experimental Program on site at Grimethorpe. The project provides excellent opportunities for American industry personnel to obtain first-hand experience at the plant. U.S. secondment provides for the inclusion of up to eight qualified persons from U.S. industry on the Grimethorpe team. Experience in the day-to-day operations at Grimethorpe will provide valuable data to be used in the U.S.

Accomplishments as of the end of 1979 were:

- Plant mechanical construction completed
- Cold commissioning of plant begun
- Experimental test program developed
- Management and staffing organizations agreed for operation
- Key management and technical staff hired.

Hot commissioning tests are scheduled to start in 1980. The experimental test program is expected to begin in 1981.

2.0 TECHNICAL INFORMATION SERVICE

(Participating Countries: United States, Austria, Belgium, Canada, Denmark, Federal Republic of Germany, Ireland, Italy, Japan, Netherlands, Spain, Sweden, and United Kingdom.)

The objective of the Technical Information Service is to report on worldwide developments related to all aspects of coal utilization and to facilitate exchange of information between participating countries. Work is done in the U.K. by a specially created organization which is a subsidiary of the U.K. National Coal Board (NCB) IEA Services, Ltd.

The TIS is gaining increased recognition as a source of data on worldwide developments in coal technologies. Increased interest is seen in the recent joining of Ireland and Denmark as well as interest expressed on the part of Australia which recently joined IEA.

The Service is collecting and disseminating information relevant to coal RD&D in the areas of geology; prospecting and mining; coal utilization, including coal preparation and waste disposal; environmental and health problems; coal transport; legislative measures; and government policy statement. It is not the intent to replace existing information services in member countries which serve their own coal industries and are tailored to their particular needs. The Service aims to supplement them by making available a complete collection of technical information on all aspects of coal production and utilization and by ensuring that all sources of useful information are being tapped. Input is received from member countries in the form of abstracts of articles, technical periodicals, conference papers and reports; and arrangements are made for scanning literature of nonmembers such as Eastern European Countries. Additional information is assembled from some 700 journals in 28 countries. All this data base is regularly transferred to DOE and is incorporated into the U.S. data base system at the Oak Ridge Technical Information Center.

As of the end of March 1980, TIS was preparing to put its data base on commercial computerized systems. Information in the TIS system will be available to members for a nominal fee, with a higher charge to nonmembers.

In addition to the computerized data base, TIS has been publishing the monthly "Coal Abstracts" as well as a regular news bulletin. These are available by subscription to members and nonmembers of TIS.

The Service also produces reviews of recent literature on subjects of great current interest, as requested by the TIS Executive and Technical Committees and by others with committee approval. Reviews which will be undertaken or completed in 1980/1981 cover:

- Molecular Structure of Coal
- New Analytical Techniques for Coal Analysis
- Coal Combustion Plant Design and NO_x Emission
- Physical and Chemical Coal Cleaning Methods
- NO_x from Coal Combustion
- Solid Waste Disposal and Utilization
- Geophysical Techniques for Exploration
- Less Conventional Underground Mining Methods.

New programs under development also include the compilation of a World Directory of Coal R&D Technology. The Directory will permit easy identification of R&D work and affiliated people and places.

TIS works closely with the other IEA energy R&D projects to support their information needs. For example, TIS documentation is used as a starting point by the Economic Assessment Service and the Mining Technology Clearing House. These services do more specialized studies than TIS.

3.0 ECONOMIC ASSESSMENT SERVICE FOR COAL

(Participating Countries: United States, Canada, Denmark, Federal Republic of Germany, Ireland, Italy, Netherlands, Spain, Sweden, and United Kingdom.)

The aim of the EAS is to evaluate the cost of coal conversion and utilization from mine to end user. To accomplish this goal, a number of projects have been instituted to examine the cost of mining, transporting, and utilizing coal in the production of gaseous, liquid, and solid fuels. Additional projects examining the impact of these various technologies on the environment (such as the control of sulfur emissions; waste water quality, and related matters) have also been undertaken as parallel studies to the primary examination of the economics of coal use. To make the results of such assessments applicable to the particular economic and environmental circumstances of each member country, the EAS analyses are designed to be "context free." Thus, an important feature of the service is that it takes into consideration the economic standards and conventions in different countries.

The work is carried out in the U.K. by a specially created organization which is a subsidiary of the U.K. National Coal Board IEA Services, Ltd. The U.S. representative is an integral part of the EAS group. As such he learns

first-hand how to work foreign processes, evaluate cost, and better understand the logic of foreign operations.

EAS is gaining an international reputation from its sophisticated analyses of the economics of coal utilization. This reputation has encouraged new members to join, most recently Denmark and Ireland. Australia, a relative newcomer to IEA, is also considering joining the Economic Assessment Service.

The service has published numerous reports, of which the most recent are:

- The Control of Sulfur Oxides Emitted in Coal
- Economic & Technical Criteria for Coal Utilization Plants

  Part I: Economic & Financial Conventions
  Part II: Gasification Processes
  Part III: Liquefaction
  Part IV: Power Generation

- Published Plans and Projections for Coal Production, Trade & Consumption
- The Future Economics of the Ocean Transport of Coal
- The Economics of Coal-Based Electricity
- The Costs of Electrical Generation By Coal, Nuclear & Regenerable Energy Plants.

The service has also published a large number of working papers. A list is available on request from the Office of International Cooperation.

EAS projects for the future involve work in three areas: the economics of coal conversion and coal supply; transport and trade; and environment and energy systems. There will also be an examination of the economics of coal as a petroleum substitute.

4.0 MINING TECHNOLOGY CLEARING HOUSE

(Participating Countries: Australia, Belgium, Canada, Germany, Italy, New Zealand, Spain, United Kingdom and United States.)

The basic aim of the MTCH service is to collect, collate, and disseminate information on ongoing research in all aspects of coal mining and coal preparation technologies, including the improvement of operational efficiency and safety and health. As it develops, the service will cover all relevant R&D, arrange contacts between experts in particular disciplines, and assist in the formation of new cooperative projects. The operating agent is the same as that of the EAS.

Most recently the MTCH has identified hydrotransport as a new cooperative effort. Considerable individual R&D is being carried out by

members in hydrotransport and if coordinated and integrated, the results would represent a major contribution. Hydrotransport has come to MTCH attention as a result of the service's aggressive program of identifying gaps in R&D efforts and attempting to avoid duplication of effort by developing cooperative efforts between member nations.

The MTCH has also published a set of 15 project registers which delineate R&D efforts in member countries. The registers currently being distributed include:

- Mechanized drainage of roads, slopes, and shafts
- Coal seam exploration techniques
- Monitoring and control of machines and mining systems
- Reliability of equipment
- In situ coal conversion
- Prospecting, surveying, and mining planning
- Transport.

Reports of technical investigations have been prepared for the following subjects:

- Underground transport of solids
- Optimization of cutting techniques
- Trackless transport of men and materials underground
- Mining methods to improve reserve recovery
- Certification of equipment for underground use.

5.0 COMBUSTION

(Participating Countries: United States, Sweden, Italy, and United Kingdom.)

In 1976, energy conservation in combustion was established as a separate project area with the objective of improving the energy efficiency of combustion technologies and developing the fuel-switching capability of combustion equipment. Cooperative research and development efforts and information exchange among participating parties are currently underway.

In March 1977, an implementing agreement and an annex entitled "Energy Conservation in Combustion" were signed. The contracting parties will investigate methods for improving the information, instrumentation, and calculating procedures used in the design, manufacture, and operation of combustion equipment. Within the agreement, three specific areas for investigation have been identified: (1) combustion-system modeling; (2) instrumentation and studies of fundamental processes in combustion; and (3) resource exchange.

Research in combustion-system modeling is directed towards developing combustion technology for engines and furnaces. In the work related to fundamental processes in combustion, participants will develop instruments and experimental techniques for measuring fundamental parameters and properties of combustion systems, and investigate the basic physical phenomena relevant to the combustion process. The purpose of the third area, resource exchange, is to provide for information exchange among the

contracting parties on such subjects as the objectives and results of past programs, numerical analysis methods, laboratory analysis, and experimental test facilities.

In 1979 the project completed a survey of combustion research facilities in the U.S. and western Europe. The Executive Committee has prepared a new annex which became effective in January 1980. The new annex, designating the United States as operating agent, will provide for continuation of cooperative R&D in the following areas:

- Fundamental combustion processes
- Engine combustion
- Furnace combustion.

The annex also will provide for task-sharing projects, and a number of proposals for such projects are being considered by its committee. Included among these are projects to: develop an optical probe for flame velocity measurement; measure and model fuel spray characteristics; and study the reaction kinetics of liquid hydrocarbon combustion.

6.0 HEAT TRANSFER

(Participating Countries: United States, Netherlands, United Kingdom, Sweden, and Switzerland.)

A 3-year implementing agreement was signed in June 1977 incorporating 3 annexes: heat-exchange network synthesis and optimization; extended surface-heat transfer; and flow-induced tube vibration. The United States participates in the latter two annexes.

The participants in the heat transfer project are seeking, through cooperative R&D and information exchange, to improve the design and operation of heat-transfer systems, particularly heat exchangers, as a means of conserving fuel. The specific objectives of the project are to: (1) increase the efficiency of thermal-energy conservation through the development of more effective heat-transfer systems; (2) reduce free energy losses in processes by facilitating the operation of heat-exchange systems at reduced temperature differences without unacceptable capital-cost requirements; and (3) investigate mechanical and other design constraints to the achievement of higher thermal efficiencies. A critical evaluation of the state of the art in vibration problems has been published and an international workshop on vibration problems was conducted.

7.0 COAL-OIL MIXTURE

(Participating Countries: United States and Canada.)

The United States recently signed a Letter of Intent to cooperate with Canada to develop coal-oil combustion technology for utility boilers. The agreement, under the auspices of the IEA, commits the parties to develop and implement a program which demonstrates the technical feasibility, reliability and economics of employing the COM combustion technique in existing utility boilers originally designed to be fueled by oil alone.

As a first phase, Canada and DOE/FE will study the New Brunswick Electric Power Commission facility to determine the feasibility of retrofitting the New Brunswick facility and using it as a demonstration plant for a period of one year or more. Another similar study will be made of a U.S. facility. The second phase will involve operation of demonstration plants in either or both countries to provide the needed data base for converting existing oil-fired utility boilers to COM.

8.0 ENHANCED OIL RECOVERY

(Participating Countries: United States, Austria, Canada, Federal Republic of Germany, Japan, Norway, and United Kingdom.)

An agreement was signed in the spring of 1979 for cooperation between participating countries in the area of enhanced oil recovery (EOR).

The objective is to undertake a coordinated task-sharing program in the following areas:

- Development of techniques for measurement of residual oil saturation on a spatial basis
- Fundamental research on surfactants and polymers
- Development of techniques for carbon dioxide miscible flooding.

Work is done by members in specified areas; the level of effort is in accordance with IEA Agreement, whereby U.S. is contributing 50 percent of the total effort and the other participants are contributing the remainder. The operating agent is U.S. DOE.

Joint subtasks include participation by Canada and the Federal Republic of Germany in research into surfactant absorption characteristics on surfaces of porous media in brine/oil systems. Canada is also researching the stability of polymers under reservoir conditions. In another joint task with the FRG, Canada is studying the influence of SO_2 on the miscibility pressure of CO_2. FRG is evaluating production sources for CO_2, including flue gas and fertilizers. On the same task Japan is planning binary component experiments for CO_2 and a hydrocarbon, leading to four or five component tests over a two-year period. The United Kingdom is participating in the same task.

The U.S., Norway and Austria are participating in a joint task involving various tests with sandstone cores. Austria has reported on tests with core samples from 3,000 feet. Norway is experimenting with laboratory flooding of sandstone cores and examining the influence of wetability. U.S. participation involves DOE projects at Wilmington, California and Bell Creek, Colorado, where core samples have been taken for study.

The U.S. is also participating in other tasks with CO_2 production and mobility control of CO_2. A major CO_2 field demonstration is being undertaken by Chevron at the SACROC Unit of the Kelly Snyder Field.

Interim input on work in progress was submitted in December 1979. The first joint meeting to evaluate the results is scheduled for April 1980 at the Bartlesville Energy Technology Center.

B. UNITED STATES — AUSTRALIA

In the summer of 1978, a broad memorandum of understanding for exchanges of information concerning coal conversion, extraction, and utilization was signed by representatives of the United States and Australia with the objective of developing and implementing joint projects to accelerate R&D in coal technology. Essential agreement has been reached on the first joint project whereby Australia will continue the development of the U.S. CO-steam liquefaction process (bench-scale technology). Data to aid in construction of a bench-scale continuous unit have been transmitted to Australia and there are plans for an exchange of personnel.

Further definition of the cooperative program is under development; Australian coal R&D projects are being reviewed for identification of appropriate cooperative areas. The U.S. is planning to send samples of U.S. low-grade coals (western and/or Gulf lignites) so that petrological and chemical data can be obtained for these coals comparable to the type of data obtained for Australian coals.

The bilateral agreement is in effect through 1983; each party is paying its own expenses.

C. UNITED STATES — CANADA

In June 1979 Canada and the U.S. signed a memorandum of understanding to establish a formal framework for cooperation on the development of tar sands and heavy oil.

Participants in the joint R&D effort will be the U.S. Department of Energy, the Alberta Oil Sands Technology & Research Authority (AOSTRA), the Department of Mineral Resources of the Province of Saskatchewan and the Canadian Federal Department of Energy.

Agreement is intended to lead to closer cooperation between researchers in Canada and the U.S., accelerating research on technical problems obstructing the development of heavy oils. A study aimed at resolving chemical and physical problems in the characterization of the resource is the first specific cooperative project under the agreement. The purpose of this study will be to accumulate comprehensive data on the major Canadian and U.S. oil sands deposits as a first step in determining the technology to be used for extraction.

Other areas of cooperation projected by the agreement include the comparative economics and efficiencies of steam flooding and in situ combustion methods, design and evaluation of results of permeability enhancement technology, treatment and use of water produced during resource development, and steam flooding with additives. Cooperation at the working level is expected to take the form of staff exchanges, task-sharing arrangements, exchange of technical information, shared use of some research facilities as well as visits to these facilities.

D. UNITED STATES — FEDERAL REPUBLIC OF GERMANY

1.0 SOLVENT REFINED COAL

In the fall of 1978, DOE and the Federal Ministry for Research and Technology of the FRG entered into a bilateral memorandum of understanding for a cooperative and cost-shared effort in the Solvent Refined Coal-II (SRC-II) demonstration plant program. Other parties in the proposed SRC-II program include industrial firms.

An agreement was signed in the fall of 1979. The FRG will contribute 25 percent of the total cost of a demonstration plant near Morgantown, West Virginia. Preliminary cost estimates are over $1 billion.

The coal-to-liquids demonstration plant will convert 6,000 tons of high-sulfur coal per day into a variety of synthetic fuels equivalent to 12,000 to 20,000 barrels of oil per day.

The West Virginia project is intended to provide the technical, economic and environmental information needed to construct full-scale plants.

The newly signed agreement is contingent upon negotiation of a cost-sharing contract between DOE and Gulf, an agreement between Gulf and several FRG firms, and conclusion of an agreement between DOE and the Federal Republic of Germany on the technical and financial aspects of the project and the project schedule. Negotiations are ongoing to include Japanese participation in this project.

2.0 COAL MINING

A cooperative agreement in the areas of mining engineering and safety was signed in March 1977 by the U.S. Department of Interior (DOI) research organization, the Bureau of Mines (BOM), and Bergbau Forschung, a West German corporation. Since much of the work of mutual interest was tied to programs that were transferred from DOI to DOE/FE, the DOE/FE activities are being continued in FE under the auspices of the DOI agreement. There are two cooperative projects underway involving development of mining equipment and two others involving exchange of information. There are also periodic exchanges of specialists.

E. UNITED STATES — ITALY

A formal energy resource development agreement was signed with Italy in 1979. The agreement includes U.S. commitment to test Italian coal in order to determine optimal utilization systems. A detailed program plan is under development.

F. UNITED STATES — NETHERLANDS

In October 1979 an agreement was signed between the U.S. and the Netherlands to conduct a joint program to test the closed-cycle magnetohydrodynamics system and to exchange pertinent information.

Testing of a closed-cycle MHD system is scheduled to begin in late 1980-early 1981. The U.S. will provide key components (an advanced design closed-cycle MHD channel and auxiliaries, preheat loop) which will be installed and tested in the Dutch facility located at the Technical University of Eindhoven, the Netherlands. In addition, the U.S. will provide technical assistance, software and systems analyses, while the Netherlands will provide testing facility and operating costs. Both countries will share the data obtained from the joint tests. The initial agreement is for a five-year period.

G. UNITED STATES — UNITED KINGDOM

On January 24, 1974, an international agreement covering both coal mining and utilization technologies was executed by the Department of Interior with the National Coal Board, England, with the objectives of program enrichment via information exchange relevant to coal programs, and joint equipment development. The agreement was written for a three-year period, with an automatic extension for future periods of two years each and a provision for discretionary termination by either country.

1.0 COAL MINING AND UTILIZATION

The mining technology program activity includes the exchange of information in the field of coal mining. During 1976, seven detailed joint projects were formalized in this area. Exchanges of specialists occurred approximately on a six-month basis. The exchange to date has produced one joint project involving fabrication of mining equipment, one project involving exchange of prototype equipment developed by the respective countries, and five projects involving exchange of information.

The coal utilization program activity included exchange of personnel, equipment, research material, and basic information on all aspects of utilization of coal from resource identification to end use. Currently, the United States is studying several new areas of joint activities proposed by the NCB, including supercritical solvent extraction.

H. UNITED STATES — UNION OF SOVIET SOCIALIST REPUBLICS

On June 28, 1974, a broad Agreement on Cooperation in the Field of Energy was signed by representatives of the United States and the Soviet Union. Cooperative activities include the development and implementation of programs that would accelerate R&D efforts in both existing and alternative sources of energy. To implement the agreement, a joint U.S./U.S.S.R. Committee on Cooperation in the Field of Energy was established. The Committee's functions include approval of specific joint projects and establishment of working groups to perform specific assignments. The cooperative MHD program was officially transferred to this agreement in June of 1974 and in June 1979 elevated to the status of a full working group; programs in the areas of coal, oil, and gas were officially established in December 1976. The agreement was signed for a 5-year period (1974-1979); an automatic extension for an additional 5-year period was included.

1.0 MAGNETOHYDRODYNAMICS

The international cooperative program on MHD power generation is based on the complementary nature of MHD development in the two countries. In the United States, emphasis in MHD has been on gaining a scientific understanding of the process and through this, learning how to predict the behavior of the key components, especially the MHD generator channel itself. In the Soviet Union, emphasis has been on the modeling and construction of plants of increasing size and complexity. A further balancing factor is the Soviet Union's concentration on natural gas as a fuel for MHD, while U.S. emphasis has moved increasingly to the utilization of coal as the primary fuel. The objectives of the cooperative program are to obtain jointly as much engineering experience as possible, utilizing both U.S. and Soviet facilities, where practical, for testing components and materials, and to share the techniques developed for analysis of key MHD components. Two significant installations developed in the Soviet Union are the U-02 MHD systems test facility and the U-25 MHD pilot plant, both located in Moscow. In addition, there is a small plant located in Kiev in the Ukrainian Republic.

The cooperative effort has focused on joint work which is contributing to the development and operation of the MHD channel, the major component of a commercial MHD power plant. Joint tests of U.S. components at the Soviet installations and Soviet instrumentation at U.S. facilities, analysis and interpretation of results, symposia and meetings have provided for extensive exchange of engineering experience and technical information in the field of open-cycle MHD.

2.0 OIL

In December 1976, the U.S.-U.S.S.R. Joint Committee on Energy established a Joint Working Group of Oil Experts and charged it with the responsibility for identifying specific R&D activities of interest to both countries in the field of exploration and production of oil. The first meeting of the group was held in the United States in the fall of 1977. The group agreed on cooperative activities in the following five areas:

geochemical exploration; fundamental properties of petroleum; pressure maintenance; enhanced oil recovery methods; and heavy oil production. These were approved by the Joint Committee in December 1977. Project groups have been established and exchange of information has been occurring as scheduled.

3.0 GAS

Although a Joint Working Group of Gas Experts was formally established by the U.S.-U.S.S.R. Joint Committee on Energy in December 1976, a number of discussions on subjects of mutual interest took place earlier in both countries. These preliminary meetings resulted in identification of a number of topics.

On December 7, 1977, the Joint Committee affirmed mutual interest in the development of cooperation and urged that specifics be developed on topics of mutual interest. Some topics suggested by the Soviet Union are outside the scope of the DOE program but within the interest of the U.S. Gas Industry (e.g., gas condensate recovery, gas transport in an Arctic environment). U.S. DOE/FE has proposed a number of programmatic topical areas and agreement on these is being negotiated with the Soviets.

4.0 COAL

Although preliminary discussions have taken place between the representatives of both countries, the specifics of cooperation in the area of coal mining and utilization have not been agreed upon. A working group of coal experts was officially established by the Joint Committee in 1978. The group proceeded with the identification of specified R&D activities of interest to both countries in the areas of coal mining and preparation. This program of work has been approved by the Joint Committee and is now awaiting implementation of the broad proposal defined in a June 1978 protocol.

I. UNITED STATES — POLAND

In accordance with the agreement between the Governments of the People's Republic of Poland and the United States, signed on October 8, 1974, the Marie Sklodowska-Curie Fund was established to finance joint scientific and technological research projects, including joint activities in the areas of coal mining and utilization technologies and MHD systems. Joint activities utilize P.L. 480 special foreign currency funds as well as contributions by Poland. Specific projects agreed upon by the end of 1978 are described below.

1.0 MAGNETOHYDRODYNAMICS

The two objectives of the U.S.-Polish MHD program are joint coal combustor development using U.S. and Polish coals and investigation of the use of exhaust gases from an MHD generator for coal gasification. The agreement for mutual cooperation in these areas was signed in June 1977. Two or three joint experiments per year are being performed in Poland.

The MHD research under this agreement will include: (1) joint tests in the Polish 5 MW coal combustor to compare the effects on plasma characteristics between using either 1300°K preheated air or 1300°K vitiated air as the oxidant; (2) electrical conductivity measurements of coal-generated plasmas using Polish and U.S. coals; and (3) supply of U.S. instrumentation to record high frequency plasma fluctuations via a computer-controlled data acquisition system.

This U.S./Polish People's Republic Program will supply the necessary experimental data for comparison with theoretical studies for the interpretations of data developed on MHD plasmas. The application of the results of this program will be used on large-scale equipment such as the Component Development and Integration Facility (CDIF) Butte, Montana and at the Engineering Test Facility (ETF).

2.0 COAL LIQUEFACTION

An agreement for mutual cooperation in 6 coal liquefaction projects was signed in June of 1977. The projects are:

- Test on the Suitability of Pumps for Their High-Parametric Operation

  An engineering problem associated with direct coal liquefaction is the large-scale pumping of coal slurries into the preheater-dissolvers. This work will assist in evaluating Polish pump designs which should be of value to our program.

- Catalysts for Hydrogenation Processes

  Catalytic liquefaction processes like H-coal utilize catalysts developed for petroleum. Catalysts designed for coal liquid upgrading represent a possible major improvement. This project will test Polish-developed catalysts and should be applicable to our coal liquefaction projects.

- Coal Extraction and Ash Removal from Extracts on a Laboratory Scale

  An evaluation of the critical solids-liquid-separation step with applicability to all coal liquefaction processes.

- Carbonization of Solid Residues from Coal Liquefaction Processes

  Use of fluid-bed pyrolysis on coal liquefaction residues to increase liquefaction yields.

- Effects of Hydrogen Donor Solvent and Extraction Recycle Solvent Proportion on the Results of the Coal Extraction Process

  An in-depth analysis of the chemistry of donor solvent extraction and the relationship between donor solvent composition and coal extraction performance. This is a critical step in primary coal liquefaction.

- Noncatalytic Coal Liquefaction in the Presence of Hydrogen and Studies of Disposable Catalysts

  An analysis of the SRC approach to coal liquefaction as applied to Polish coals. The work should supplement the U.S. program at Fort Lewis, Washington and Wilsonville, Alabama.

Poland sends progress reports, at intervals, to the U.S. where DOE representatives assess the results. DOE personnel also periodically review the work in Poland.

3.0 COAL GASIFICATION FOR COMBINED-CYCLE POWER GENERATION AND FLUIDIZED-BED COMBUSTION OF COAL

The basic 5-year agreement was signed in June of 1977. In January of 1978, an attempt was made to identify specific projects. It was agreed that the initial stages of the implementation of this project will be in the form of information (reports) exchange and the investigation of the possibility of exchange visits. Other forms of implementation will be determined and agreed upon if and when the need for such arises. Currently Poland is preparing a detailed program plan for U.S. approval. Preliminary information indicates that work contemplated by Poland may be of interest to the U.S.

4.0 COAL MINING AND PREPARATION

Programs for projects in the area of coal mining and preparation technologies were developed and finalized by the U.S. Department of Interior and Poland in October of 1976. Three of these projects are being monitored by DOE/FE. They are:

- Modern Underground Mining Technologies for Pitching Coalbed Extraction

- Subsidence Prediction and Control

- Methods of Investigation Estimation and Classification of Roofs in Mines in the U.S.A. for the Selection of Suitable Mechanized Supports for Longwalls

The three remaining projects are nearing completion.

Additional projects, to be financed totally by Poland, have been negotiated and the Poles are implementing them now:

- Improvements in methods for testing and forecasting the quantity and quality of waters entering underground coal mines

- Investigation of effectiveness of means applied to suppress coal dust explosions in experimental galleries

- Methods of ventilating ventilation districts in longwall mining taking into consideration spontaneous combustion in seams

- Methods of forcing longwall roofs to cave in
- Methods of extinguishing mine fires by ventilation means in longwall mining
- Geophysical methods of determining variability of coalbeds ahead of the working face
- Automation of the mud and water circulation process in the coal preparation plant
- Investigation of coal enrichment process in circulating steam, enforced to pulsation
- Investigation of the extraction of coal, methods of its identification and examination in situ.

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XI. UNIVERSITY ACTIVITIES

A principal objective of the Fossil Energy Program is to seek new ideas, data, and processes to utilize the Nation's fossil energy resources with greater efficiency and environmental acceptability. One means to this end has been to obtain the involvement of universities and colleges through the support of research projects in order to accomplish the following objectives:

- Ensure a foundation for innovative technology through exploration of novel process concepts and acquisition of data relevant to existing processes.
- Provide an effective, two-way channel of communication between DOE and the academic community.
- Ensure development of trained technical manpower to conduct basic and applied research in support of DOE's mission.

Since its inception in 1974 with 17 university projects funded at $2.88 million, this involvement has grown steadily over the past 5 years. In 1979 there were more than 400 active joint Fossil Energy/academic institution projects with a total annual funding of about $38 million. Among the many accomplishments from this effort, specific projects have:

- Established the geologic framework of the coal-bearing areas of Iowa (Iowa State University)
- Demonstrated that ash and pyrite can be effectively removed from bituminous coal, while maintaining high- (greater than 85 percent) Btu recovery, in a coal-cleaning circuit employing fine grinding, froth flotation and high-gradient magnetic separation (Michigan Technological University)
- Developed and applied an electrotechnical kinetic model to interpret absorption of reagents by pyrite in a froth-flotation coal-cleaning process (University of Utah)
- Developed a correlation that defines optimal conditions of surfactant chemistry and salinity for tertiary oil recovery via miceller-polymer flooding (University of Texas)
- Quantified the effect of second-phase particles on the abrasion resistance of alloys (Notre Dame University)
- Demonstrated, on a laboratory scale, a novel electrochemical process for gasification of coal (University of Connecticut)

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- Analyzed the data base of both CO_2 acceptor and HYGAS coal gasification processes to uncover fundamental relationships between process variables and amounts and types of effluents (Carnegie-Mellon University)

- Found an inexpensive, easily regenerated sorbent for virtually complete removal of sulfur impurities from coal-derived fuel gas (University of Kentucky)

- Discovered novel synthetic procedures for preparation of surfactants and cosurfactants for enhanced oil recovery, using a wide variety of petroleum fractions (Pennsylvania State University)

- Developed new methods for modeling the physical phenomena occurring in a fluidized-bed combustor (Massachusetts Institute of Technology)

- Found improved approaches to the control of nitrogen oxide pollutants in MHD processes (University of Tennessee).

In FY 1980 under the Fossil Energy Program, University Activities is planned to continue, with an expansion to a funding of $42.4 million. A significant fraction of this effort will be concerned with advanced research and technology, based on proposals that are either unsolicited, or in response to Program Announcements. Programs in advanced research and technology are managed by the different Fossil Energy technical groups (Magnetohydrodynamics, Coal Processing, etc.), and are described in greater detail elsewhere in this book. The technical monitoring of individual projects, historically conducted primarily by persons stationed in the Washington, D.C. area, will be performed almost exclusively by engineers and scientists at the various energy and mining technology centers throughout the country.

In addition, several universities are engaged in larger magnitude projects with the Fossil Energy Program. These include operation of a coal gasification plant at the University of Minnesota Duluth Campus, and a fluidized-bed coal combustion plant at Georgetown University.

To improve liaison with the academic community, and to overview its advanced R&D effort, the Fossil Energy Program has established an Office of Advanced Research and Technology. Among other activities, this office provides a source of information and guidance to faculty members seeking support for their research projects. It also manages several categorical programs involving the university community including the following:

- Advanced Research Awards: This program is intended to support Fossil Energy-related exploratory research in universities that is on the "leading edge" of technology development not adequately covered in our current program. Some of the awards are to support outstanding ideas that are more "basic" than are normally supported by the other technical divisions of FE, yet are too "applied" to be supported by the Office of Energy Research.

This program was initiated in September 1979 with award of three grants:

- Short-Residence-Time Hydropyrolysis of Coal, Princeton University

- Measuring and Monitoring Solids Movement in a Large, Coal Fluidized-Bed Test Facility, Oregon State University

- Active Feedback Control for Stabilization of Rotating Machinery, University of Virginia

- Faculty and Student Participation at Energy Technology Centers, Mining Technology Centers, and National Laboratories: This program provides summer salary support for college professors to perform research of mutual interest at a Fossil Energy or national laboratory (usually for two or three months in the summer). The student participation is similar in nature, except that the period of research varies from 3 to 12 months. The participants' program is administered for the Fossil Energy Program by Oak Ridge Associated Universities and Associated Western Universities who employ the participants.

  This program has grown steadily in size and popularity since its inception in 1976. To date more than 180 faculty and students have participated and become acquainted with fossil energy problems. At the same time, the research they have performed has contributed to the missions and objectives of the ETCs and MTCs to which they were assigned.

- Fossil Energy Speakers Program: This program provides for a roster of speakers (researchers supported by Fossil Energy at energy technology centers and in universities) who visit campuses as well as DOE headquarters and laboratories to present lectures and seminars on fossil energy research and technology. Oak Ridge Associated Universities is the contractor for this program.

  Significant progress has been achieved in this program during the initial year of its operation. A roster of 114 speakers with 210 topics has been established. The affiliation of speakers is 54 percent university, 40 percent ETCs and MTCs, and 6 percent other. The activity to date has been as follows: 8 lectures presented; 8 lectures scheduled; 28 requests for speakers pending; and 4 lectures declined by speakers because of time conflict.

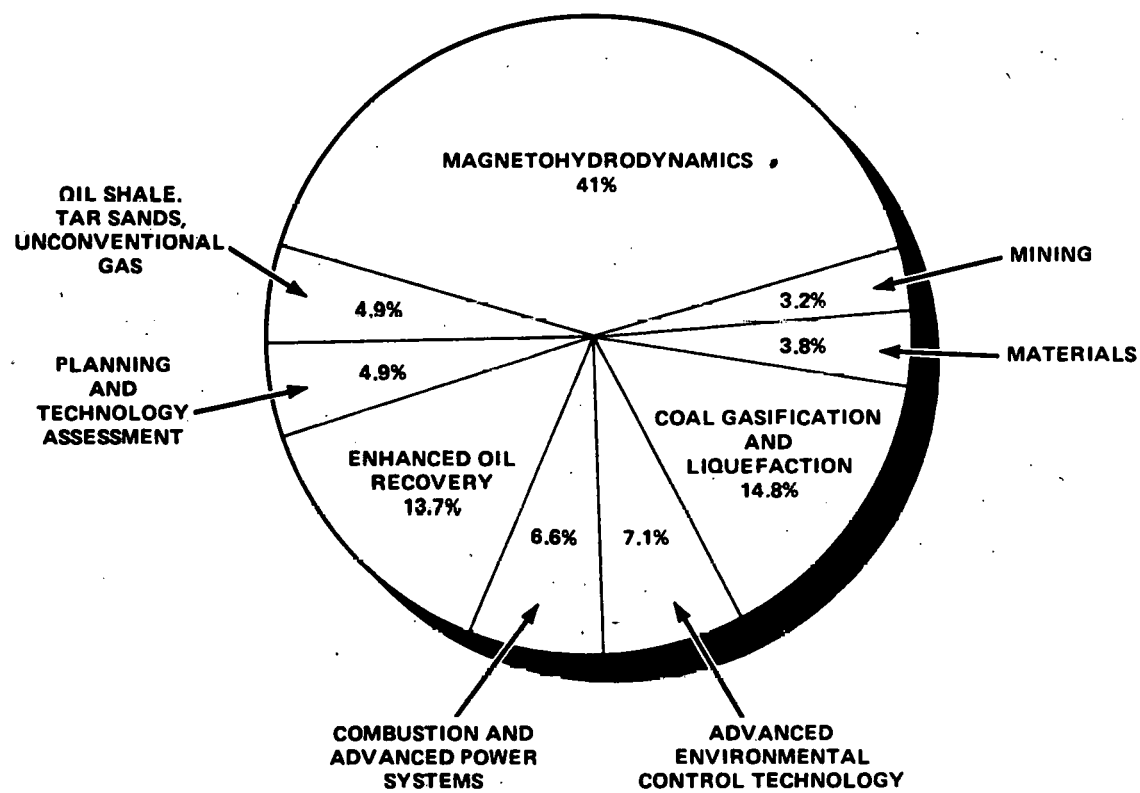
  The first mailing of the brochure was in April 1979, to 4,500 Department Chairmen in chemistry, geology and various types of engineering. The above described level of activity is based primarily on that mailing.

- Summer Workshops for High School Teachers: High school and college teachers are invited to participate in a nationwide program of summer energy-education workshops sponsored by DOE. Seventeen such workshops have been supported in the past four years. The purpose

of these workshops is to provide teachers with current information on the Nation's energy problems, and to assist them in development of educational materials for classroom use. The workshops program serves as an important vehicle for advancing the capabilities for energy education within the academic community. The program is managed by DOE's Office of Education, Business and Labor Affairs, Branch of Education and Training, which works with the Fossil Energy Program in proposal evaluation and the selection of those for support in fossil energy ideas.

Fossil Energy's support of this program spans the last 4 fiscal years, with support of 17 workshops producing approximately 520 teachers who are much better informed about the Nation's energy problems, at a total cost of about $480 per teacher. Judging from the reports and comments from the participants, each of the workshops was operated in accordance with the DOE-approved proposals and was received enthusiastically.

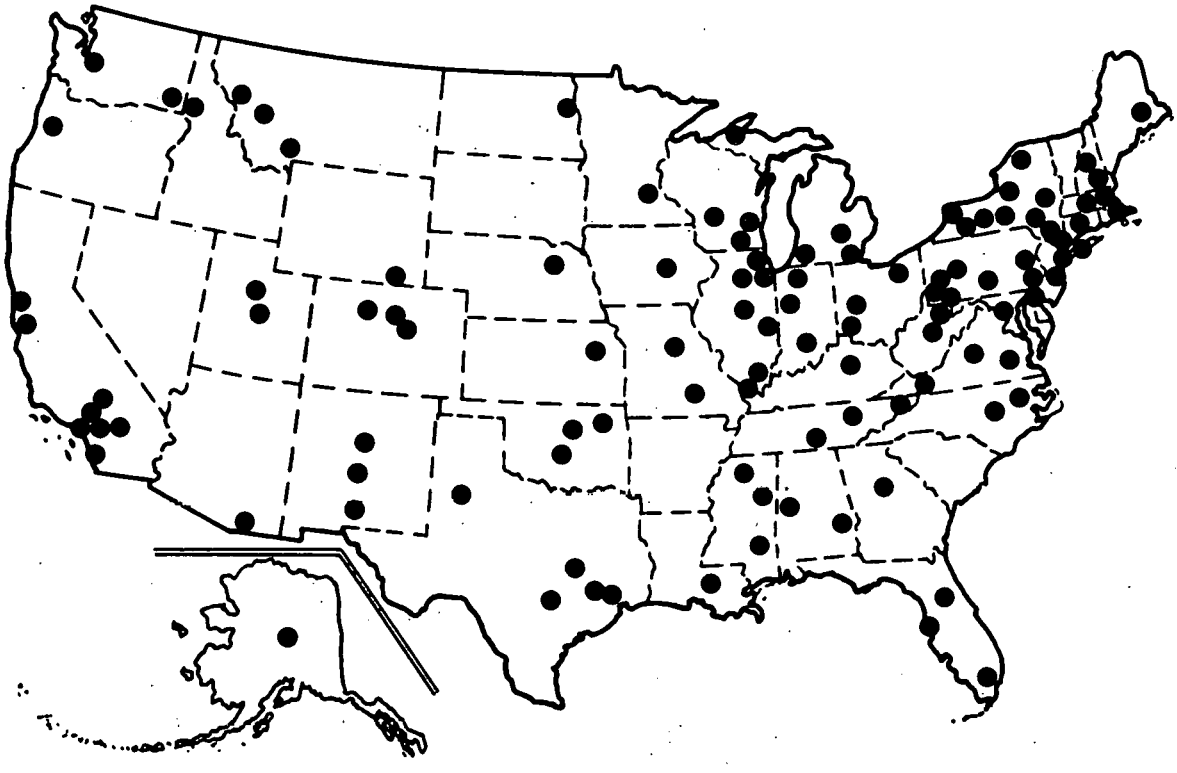
A chart and table depicting the technology profile of the anticipated funding of university projects in 1980 are provided below. Also shown is a map indicating the geographical location of projects active in FY 1979.



Technology Profile of Fossil Energy Support of Universities in FY 1980

TECHNOLOGY	ESTIMATED FUNDING (DOLLARS IN MILLIONS)
Advanced Environmental Control Technology	3.0
Coal Gasification and Liquefaction	6.3
Coal Combustion	1.6
Fuel Cells and Advanced Power Systems	1.2
Materials	1.6
MHD	17.4
Mining	1.3
Oil Shale, Tar Sands and Unconventional Gas	2.1
Enhanced Oil Recovery	5.8
Plans and Technology Assessment	2.1
TOTAL	$42.4

Fossil Energy University Activities in FY 1980



Geographical Distribution of University Projects Supported by the Fossil Energy Program

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XII. DEFINITIONS, ABBREVIATIONS, & ACRONYMS

A. RD&D SCALEUP PHASES

This section provides definitions of the various research, development, and demonstration scaleup phases as they pertain to the Fossil Energy Coal Resource. Included are the distinguishing features of:

- Process Development Units
- Pilot Plants
- Demonstration Plants
- Commercial Demonstration Plants.

The key to the definition is not so much the size as the purpose, i.e., the kind of information the activity is designed to yield. In this context the relative scales can be differentiated as follows:

Process Development Unit (PDU)

The purpose of a PDU is to establish the basic technical feasibility of the process; acquire basic physical, chemical, and engineering data needed to evaluate the process; and develop the design data necessary to allow further scaleup to a larger stage if feasible.

Other distinguishing features of the PDU are as follows:

- PDUs follow laboratory "bench" experimental work.
- PDUs incorporate results of bench-scale work on key process steps to form an integrated small-scale process to test key variables on performance (technology development phase of R&D).
- PDUs generally operate continuously and process the minimum amount of raw material necessary to test the process feasibility.
- PDUs are never facilities in themselves, but are a component of or contained in an existing facility, (e.g., laboratory or plant), and can undergo considerable modification to enhance the process.

Pilot Plant

The purpose of a pilot plant is to establish the integrated process feasibility by combining commercial-type (not commercial-size) components into a small model plant to test and evaluate the critical parameters of scaleup, and to acquire engineering data needed to assess economic feasibility and to design a larger near-commercial-size plant.

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Other distinguishing features of a pilot plant are as follows:

- Pilot plants are the first scaleup facility to produce enough end-product to permit product testing and refinement.
- Pilots, as experimental facilities, are subject to continuing and significant modifications to help identify candidate processes and components that could be used for further scaleup to larger plant sizes (engineering phase of RD&D).
- Pilot plants are limited to three years or less of operating life and in most instances are dismantled after fact-finding is complete unless they can be modified to cost effectively test new processes.
- Determination of the projected economics and cost of a prospective commercial-sized plant is a significant R&D objective of pilot plants.
- Large pilot plants for some technical development may provide sufficient data about operations before pseudocommercial conditions to allow the development to proceed directly to commercial demonstration.

Demonstration Plants

The purpose of demonstration plants is to demonstrate and validate the economic, environmental, and productive capacity of a near-commercial-size plant by integrating and operating a single modular unit using commercial-sized components.

Other distinguishing features of demonstration plants are as follows:

- They are still developmental in the sense that technological scaleup problems may occur and require engineering modification; however, the risk is much lower since the plant production process was developed and tested at the pilot stage.
- They have a long life and are planned to be expanded to become part of the commercial plant, after their successful demonstration periods by the industrial cost-sharing partner. In this case the industrial partner will purchase the facilities at a fair market value.
- They are used only to demonstrate and verify second-generation technologies (those not currently used commercially) and will demonstrate only the most feasible process surviving competition of alternatives regardless of whether previous pilot plant work was done in private industry or government.
- They are neither formal systems acquisitions nor full-scale development but are the final stage in the R&D process aimed at accelerating and reducing the risks of industrial process implementation.

Commercial Demonstration Plants[1]

The purpose of commercial demonstration plants is to resolve commercial investment uncertainties by establishing the actual economic factors, environmental feasibility, socioeconomic impact, capital and resource requirements, constraints and product markets for currently available, as well as newly introduced, synthetic fuel products and encourage creation of a viable industry using these technologies.

Other distinguishing features of commercial demonstration plants are as follows:

- They demonstrate viability of a facility and/or process to produce a commercial-grade product at a rate of production considered to be commercially significant using commercial-scale equipment under commercial conditions.
- The Government's role is to provide financial incentives to stimulate industry construction and commercial production and marketing of synthetic fuel products by loan guarantees or other incentives.
- They do not constitute R&D work. Most technical problems have been solved. Their demonstration value is limited to setting industry standards and precedents for a viable synthetic fuels industry.
- They represent a scale of three to five times the productive capacity of demonstration plants by combining modular production units of the type singularly demonstrated in a demonstration plant to achieve full-scale commercial production.

[1]Commercial Demonstration Projects are the responsibility of the Assistant Secretary for Resource Applications in DOE.

B. ABBREVIATIONS AND ACRONYMS

A

A&E	Architect and Engineer
ac	alternating current
AECT	Advanced Environmental Control Technology
AEDC	Arnold Engineering Development Center
AER	advanced exploratory research
AFB	atmospheric fluidized-bed
AFBC	atmospheric fluidized-bed combustion
AFB/CTIU	atmospheric fluidized-bed/component test and integration unit
AGA	American Gas Association
AHF	advanced hydraulic fracturing
AL	Ames Laboratory
ANL	Argonne National Laboratory
AOSTRA	Alberta Oil Sands Technology and Research Authority
API	American Petroleum Institute
APS	advanced power systems
APT	advanced process technology
AR&TD	Advanced Research and Technology Development
ARD	agricultural research development
ASFE	Assistant Secretary for Fossil Energy
ASPEN	Advanced System for Process Engineering
ASRA	Assistant Secretary for Resource Applications
ASTM	American Society for Testing and Materials
ATLF	advanced technology longwall face
atm	atmosphere (of pressure)

B

BACT	best available control technology
bbl	barrel
bbl/d	barrels per day
Bcf	billion cubic feet
BCR	Bituminous Coal Research, Inc.
BETC	Bartlesville Energy Technology Center
BGC	British Gas Corporation
BITE	built-in test equipment
BNL	Brookhaven National Laboratory
BOM	Bureau of Mines
BSB	blind shaft borer
Btu	British thermal unit
BTX	benzene, toluene, and xylene

C

CAFB	chemically active fluidized-bed
CaS	calcium sulfide
CBC	carbon burnup cell
CC	coal conversion
CCC	coal combustion for cogeneration
CCU	coal conversion and utilization
CDIF	component development and integration facility
CDTF	component development test facility
C-E	Combustion Engineering, Inc.
CEF	chemical explosive fracturing
CFFF	coal-fired flow facility
CFR	continuous flow reactor
CG	coal gasifiers
CM	continuous miner
CMTC	Carbondale Mining Technology Center
CO	carbon monoxide
COED	coal-oil energy development
COM	coal-oil mixture
CONOCO	Continental Oil Company
CO_2	carbon dioxide
CPS	central power systems
CTAS	Cogeneration Technology Alternatives Study
CTIF	component test and integration facility
CTIU	component test and integration unit
CURL	Coal Utilization Research Laboratory
CY	calendar year

D

DAS	Deputy Assistant Secretary
dc	direct current
DISC	direct-injected stratified charge
DOA	Dragline Operational Aids
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DPS	decentralized power systems
DPS	dispersed power systems
DPS	Division of Power Systems

E

EA	environmental assessment
EAS	Economic Assessment Service
EB	evaluation board
EC	executive committee

ECAS	Energy Conversion Alternatives Study
ECTP	Environmental Control Technology Program
EDIMS	Environmental Data Information Management Systems
EDP	environmental development plan
EDS	engineering development system
EDS	Exxon donor solvent
EGR	enhanced gas recovery
EGSP	Eastern Gas Shales Project
EH&S	Environmental Health & Safety
EIA	environmental impact assessment
EIS	environmental impact statement
EMAC	Energy Materials Advisory Committee
EOR	enhanced oil recovery
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERA	Energy Reorganization Act
ER&E	Exxon Research and Engineering Company
ERCO	Energy Resources Company
ERDA	Energy Research and Development Administration
ESCOE	Engineering Societies Commission on Energy
ESEERCO	Empire State Electric Energy Research Corporation
ESP	Electrostatic Precipitator
ETC	energy technology center
ETEC	Engineering Test Evaluation Center
ETF	engineering test facility

F

FBC	fluidized-bed combustion
FBHX	fluidized-bed heat exchanger
FE	Fossil Energy
FFE	Fossil Fuel Extraction
FFU	Division of Fossil Fuel Utilization
FGC	flue gas cleanup
FGD	flue gas desulfurization
FIV	flow-induced vibration
FRG	Federal Republic of Germany
FWPCA	Federal Water Pollution Control Act
FY	fiscal year

G

GBF	granular-bed filter
GFETC	Grand Forks Energy Technology Center
GISP	geotechnically instrumented seafloor probe
GPGA	Great Plains Gasification Associates
GRI	Gas Research Institute

H

H-Coal	hydrogen-fed coal
HGMS	high-gradient magnetic separation
HLS	heavy liquid separation
HMF	high mass flux
hp	horsepower
HPDE	high-performance demonstration equipment
HR&SR	heat recovery and seed recovery
HRI	Hydrocarbon Research, Incorporated
H_2S	hydrogen sulfide
HUD	Department of Housing and Urban Development

I

IC	internal combustion
ICE	increased conversion efficiency
ICGG	Illinois Coal Gasification Group
IEA	International Energy Agency
IFT	interfacial tensions
IGT	Institute of Gas Technology
IHT	Institute of High Temperatures
IITRI	Illinois Institute of Technology Research Institute
INEL	Idaho National Energy Laboratory

J

JPL	Jet Propulsion Laboratory

K

KoH	potassium hydroxide
kWh	kilowatt hour

L

LASL	Los Alamos Scientific Laboratory
lb/hr	pound(s) per hour
LBL	Lawrence Berkeley Laboratory
LDC	lesser developed country
LETC	Laramie Energy Technology Center
LFFC	liquid fossil fuel cycle
LG	longwall generator
LLL	Lawrence Livermore Laboratory
LNG	liquefied natural gas

LPG	liquefied petroleum gas
LTAS	Liquefaction Technology Assessment Study
LVW	linked vertical well

M

M	thousand
MAF	moisture- and ash-free
Mcf	thousand cubic feet
MCFC	molten carbonate fuel cell
md	millidarcy
METC	Morgantown Energy Technology Center
MFB	multicell fluidized-bed boiler
MHD	magnetohydrodynamics
MHF	massive hydraulic fracturing
Minnegasco	Minnesota Gas Company
MIT	Massachusetts Institute of Technology
MIUS	modular integrated utility systems
ML	Mound Laboratory
MM	million
MMbbl/d	millions of barrels per day
MMscf	millions of standard cubic feet
MR&D	Mining Research and Development
MRCP	Methane Recovery from Coalbeds Project
msec	millisecond
MSP	marine sediment penetrators
MTC	mining technology center
MTCH	Mining Technology Clearing House
MUCH	multiple unit conveyor hauler
MVMA	Motor Vehicles Manufacturing Association
MW	megawatt
MW_e	megawatt electrical
MW_t	megawatt thermal

N

N/A	not applicable
NaCl	sodium chloride
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NCB	National Coal Board (British)
NEA	National Energy Act
NEP	National Energy Plan
NEPA	National Environmental Policy Act
NGPA	Natural Gas Policy Act
NIOSH	National Institute of Occupational Safety and Health
NL	national laboratory
NO_x	nitrogen oxide
NOAA	National Oceanographic and Atmospheric Administration
NSF	National Science Foundation

NSPS	New Source Performance Standards
NTIS	National Technical Information Service

O

OCGT	open-cycle gas turbine
OCM	Office of Coal Mining
OCR	Office of Coal Research
OCS	outer continental shelf
OMB	Office of Management and Budget, Executive Office of the President
ORC	Occidental Research Corporation
ORC	organic Rankine cycle
ORNL	Oak Ridge National Laboratory
OS/IES	onsite/integrated energy systems

P

PA	performance assurance
PAF	principal alternate fuels
P&M	Pittsburg & Midway Coal Mining Company
PAS	Performance Assurance System
PC&U	product characterization and utilization
PDC	polycrystalline diamond compact
PDU	process development unit
PETC	Pittsburgh Energy Technology Center
PFB	pressurized fluidized-bed
PFBC	pressurized fluidized-bed combustion
PFB/CTIU	pressurized fluidized-bed/component test and integration unit
P.L.	Public Law
PMTC	Pittsburgh Mining Technology Center
PNG	petroleum and natural gas
PNL	Pacific Northwest Laboratory
PON	program opportunity notice
PPBS	Policy, Programming and Budget System
PRDA	program research and development announcement
psi	pounds per square inch
psig	pounds per square inch, gauges

Q

Q_e	Quads of electrical energy
Q_f	Quads of fossil fuel consumption
Q_r	Quads of heat rejection
Quad	10^{15} (quadrillion) Btus

R

RALFE	reliable advanced liquid fuel turbine engine
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RD&D	research, development and demonstration
RDU	reactor development unit
REAP	Residual Energy Applications Program
RFP	request for proposal
RW	residue fuels

S

SAI	Science Applications, Inc.
SARS	Safety Analysis and Review System
SBA	Small Business Administration
SBM	shaft boring machine
scf	standard cubic feet
scf/d	standard cubic feet per day
scf/h	standard cubic feet per hour
SDB	steeply dipping bed
SEB	source evaluation board
SEMS	seafloor earthquake measurement system
SGT	small gas turbine
SiC	silicon carbide
SIC	Standard Industrial Code
SIPS	State Implementation Plans
SL	Sandia Laboratories
SNG	synthetic natural gas
SOFC	solid oxide electrolyte fuel cell
SORU	shale oil refining and utilization
SO_2	sulfur dioxide
SO_x	oxides of sulfur
SRC	solvent refined coal
SRL	solvent refined lignite
SRT	short residence time
Syngas	synthetic natural gas

T

TBD	to be determined
TBM	tunnel boring machine
TC	technical committee
Tcf	trillion cubic feet
t/d	tons per day
TEC	total estimated cost
TETAS	Total Energy Technology Assessment Study
TG	transport gas
t/h	tons per hour

TIS	Technical Information Service
TPO	Texaco partial oxidation
TQ	transition quarter
TSL	two-stage liquefaction
TTU	turbine test unit
TVA	Tennessee Valley Authority

U

UCG	underground coal gasification
UGR	unconventional gas recovery
U.K.	United Kingdom
UOP	Universal Oil Products
USCG	United States Coast Guard
USGS	United States Geological Survey
U.S.S.R.	Union of Soviet Socialist Republics
UTC	United Technologies Corporation
UTRC	United Technology Research Center

V

V	volts
VMIS	vertical modified in situ

W

WGSP	Western Gas Sands Project
WPCT	Working Party on Coal Technology

Z

$ZnCl_2$	zinc chloride

ENERGY UNITS AND CONVERSION FACTORS

Approximate Energy Conversions

Unit	Btu	Coal ton	Oil Bbl	Gas Cu ft.
Btu	1	38×10^{-9}	17×10^{-8}	10^{-3}
Coal ton	26×10^{6}	1	4.5	25,000
Oil Bbl	5.8×10^{6}	.22	1	5,600
Gas Cu ft	1,000	38×10^{-6}	17×10^{-5}	1
Quad	10^{15}	40×10^{6}	$.6 \times 10^{6}$	10^{12}

APPROXIMATE ENERGY EQUIVALENTS

Fuel Source	Units	Average Heat Value (Millions of Btu)
Average U.S. Coal	Short Ton	24.0
Bituminous Coal	Short Ton	26.0
Lignite Coal	Short Ton	13.5
Crude Oil	Barrel	5.8
Residual Fuel Oil	Barrel	6.3
Residential Fuel Oil	Barrel	5.9
Gasoline	Barrel	5.2
Jet Fuel	Barrel	5.6
Natural Gas (Dry)	$Cu.ft.x10^3$	1.0
Synthetic Gas: Low Btu	$Cu.ft.x10^3$	0.15
Med Btu	$Cu.ft.x10^3$	0.3
High Btu	$Cu.ft.x10^3$	1.0
Wood	Cord	20.0

ENERGY CONSUMPTION INFORMATION

Energy Use Per Capita

Nation	Million Btu/yr
U.S.	300
Germany	150
U.S.S.R.	130
Chile	100
China	13
India	5
Nigeria	1.5
Nepal	.3
World Average	35 million

U.S. Household Energy Expenditures:

Item	1,000 Btu/yr
Automobile	900,000
Home Heater	180,000
Air Conditioner	40,000
Stove	9,000
Color TV (tube)	9,000
Dishwasher	4,000
Black and White TV (solid state)	2,000
Hair Dryer	150
Egg Beater	50

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SUMMARIES OF DECISIONS AND REVIEWS

SYMBOL	TASKS
⬡ Acceptance Test	Review performance demonstration test data and other supporting data, including analyses, lower level test data, and vendor test data. Inspect facility configuration, configuration control records, test logs and pertinent documentation required to demonstrate compliance to the statement of work and performance specifications.
⬡ Bid Package Review	Review construction bid packages.
⬡ Construction Status Review	Review (periodically) of construction against established subcontract schedules that utilize critical path methods for construction or equivalent control mechanisms.
⬡ Critical Design Review	Review detail design drawings and specifications, analytical and experimental verification data, long lead item procurement list, bid package plan, siting and environmental impacts, final test and evaluation plan, configuration and change control procedures.
⬡ Performance Review	Establish degree of compliance with planned testing and evaluation program. Evaluate progress towards determination of commercial feasibility of process.
⬡ Pilot Plant Construction	Review procurement plans, adequacy of construction go-ahead actions, construction schedules, and plans for subcontracting.
⬡ Process Concept Review	Evaluate feasibility of proposed process concepts using the best available empirical and theoretical information. Review process systems practicality by estimating operating conditions and general economics.
⬡ Process Development Unit Construction	Review procurement plans, adequacy of construction go-ahead actions, construction schedules, and plans for subcontracting.
⬡ Project Evaluation	Review project progress and accomplishments, compare achieved results with established objectives. Review outcome may be used to redirect future project goals.
⬡ Technology Assessment	Evaluate feasibility of the proposed technology concepts, using the best available empirical and theoretical information. Review the technology's practicality by estimating operating conditions and general economics.

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SYMBOL DEFINITIONS

△ Begin Milestone

▽ End Milestone

⬡ Decision Milestone

▲ Begin Milestone (Task Completed)

▼ End Milestone (Task Completed)

⬢ Decision Milestone (Decision Made)

● 1 Release Request for Proposals or Program Opportunity Notice

● 2 Proposals Received

● 3 Contractor Selected

● 4 Contract Award

● 5 Order Long-Lead Items

● 6 Final Environmental Impact Statement

Information Transfer