Issue Paper on

Oil Shale Technologies

for the

July 18, 1979
Section 11 Workshop
Denver, Colorado

United States Environmental
Protection Agency
Office of Energy, Minerals
and Industry

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

GLOSSARY

AOSS	Area Oil Shale Supervisor
ASEV	Assistant Secretary for Environment
CS	Office of Conservation and Solar Applications
DOE	Department of Energy
DOI	Department of Interior
EA	Environmental Assessment
ECC	Environmental CoordinatingCommittee
EDP	Environmental Development Plan
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERD	Environmental Readiness Document
ERDA	Energy Research and Development Administration
ESAAB	Energy Systems Acquisition Advisory Board
ESAPP	Energy System Acquisition Project Plan
ET	Office of Energy Technology
EV	Office of Environment
MIS	Modified In-Situ
NEPA	National Environmental Policy Act
OSEAP	Oil Shale Enviromental Advisory Panel
PPMS	Program and Project Management System
RA	Office of Resource Applications

EXECUTIVE SUMMARY

The 1979 Section 11 analysis is focused on the Department of Energy's Program and Project Management System (PPMS) and its Environmental Research Planning and Assessment Process. Section 11 now charges EPA with the responsibility of reviewing the DOE program for the emphasis given to environmental concerns. EPA is interested in making known its procedures for this review and soliciting participation from a broad spectrum of participants.

This paper's specific objectives, in conjunction with the background document-"The Federal Nonnuclear Research and Development Act (PL 93-577), Section 11, Environmental Evaluation" (June 1979)-are to:

- provide information on DOE's environmental planning and review process
- discuss how that process has functioned in the case of the oil shale technology
- raise issues to stimulate and focus discussion at the July 18, 1979, public workshop in Denver.

Of particular importance are the issues associated with increasing public involvement-the concerned public; local, state, and Federal agencies; and industry-in the oil shale technology decision-making process.

Although oil shale deposits occur in many parts of the United States about 50 percent of the highest-quality oil shale resources are found in a sparsely populated, semi-arid plateau region (the Green River Formation) of southern Wyoming, northeastern Utah, and western Colorado. The history of oil shale development in this region has been split between technology development on public and privately owned lands. The U.S. Department of the Interior (DOI) has been deeply involved in oil shale development efforts primarily because the Federal Government owns about 80 percent of the oil shale reserves and controls some of the major water resources which will be needed for oil shale development. DOI's efforts to interest private companies in oil shale development was highlighted by their Prototype Oil Shale Leasing Program in the late 1960s.

Although DOI has been the Federal "lead" agency in oil shale development. The Energy Research and Development Administration was the lead agency for oil shale commercialization efforts. This responsibility has now passed to the Department of Energy.

In May 1979, DOE completed a comprehensive "Oil Shale Research, Development, and Demonstration (RD&D) Program Management Plan," whose primary objective is to foster the development of a commercial oil shale industry by the mid-1980s. The plan consists of four principal activities for research and development to assist in the growth of the industry. One of these activities is research on environmental concerns.

The most serious environmental concerns related to oil shale appear to be land reclamation, air pollution emissions, water pollution, and worker health and safety. Much of the ongoing environmental research is still involved with characterizing the pollutants. Once characterized, technicians hope that control technologies can be developed to handle them. However, the cost of such controls may make oil shale more expensive than alternative natural and synthetic fuels.

There is substantial regional and local concern in Colorado, Utah, and Wyoming that planned economic growth, availability of water, and other development issues be properly considered in decisions on oil shale projects in the area.

DOE's Planning and Review Process

DOE's research and development programs are organized around general energy technologies (such as nuclear, fossil, solar, and geothermal) and are designed to move these technologies through sequential development phases from basic research to commercialization. Development activities are divided into two stages, each consisting of several phases. The technology-based stage is comprised of basic applied research phases and an exploratory development phase. The second stage, energy systems acquisition, includes four phases—technology development, engineering development, demonstration, and commercialization.

In early 1978, DOE formulated an internal Program and Project Management System (PPMS) to guide expenditures (Outlay Programs) for technologies through the various development phases. Outlay Program Plans are comprised of two components—Technology Program Plans (TPP) and Environmental Development Plans (EDP). The objective of the TPP is to define a development strategy for a project or group of projects of the same technology moving through the development phases. The EDP will then identify and integrate required environment safety, and health research within the appropriate phases of the technology project or projects.

As site-specific technology projects are supported, separate Project Environmental Plans (PEP) detailing the necessary environmental research and jointly prepared by the DOE Office of Environment and the appropriate program office. Environmental Readiness Documents (ERD), independent assessments prepared by the Office of Environment to determine the "readiness" of the technology to move to the next development phase, provide the basis for the Office of Environment's position on the environmental acceptability of a DOE technology program or project at the major decision points in the PPMS.

The combination of the EDPs, PEPs, and ERDs, coupled with a formal management structure for their preparation and implementation, comprise the Environmental Planning and Assessment Process for DOE's planning and review system for emerging technologies. While the EDPs, PEPs, and ERDs are not intended to be part of the formal National Environmental Policy Act (NEPA) requirements, they are perceived as building blocks leading to the preparation of Environmental Assessments (EA) and Environmental Impact Statements (EIS).

A recent development in oil shale planning and review has been the preparation of the Oil Shale RD&D Management Plan. This plan lays out in substantial detail the technological and enviornmental research required for oil shale during the next 10 years if a major effort is undertaken to commercialize the technology. The Management Plan builds upon the Oil Shale ERD and parts of the plan will be included in the updated Oil Shale EDP currently being written.

Oil Shale Issues

This paper identifies a number of issues concerning DOE's environmental planning and review process as it has impacted the oil shale technology. The potential impact of oil shale on a national basis and in the Colorado, Utah, and Wyoming area makes it imperative that there be substantial local and public involvement in DOE's environmental planning and review process including the new Oil Shale RD&D Management Plan.

Since the DOI Prototype Oil Shale Lease Program was initiated in the early 1970s, there has been a number of National Environmental Policy Act (NEPA) documents prepared on oil shale. There was a Project and Program Environmental Impact Statement prepared by DOE in 1972 and 1973, respectively. In 1977, at least seven project Environmental Assessments and a programmatic Alternative Fuels EIS—only part of which covered oil shale—was prepared by the Department of Energy.

At the same time (1977), Colony Development Corporation prepared a project EIS for the Department of the Interior. Currently two programmatic and one project EIA are under preparation by the Development of Energy. (See Table 1.)

As the Prototype Program evolved, the need was recognized for a continuing mechanism for review and coordination between the government and public sectors concerned with oil shale after leasing and during development; this resulted in the creation of the DOI Oil Shale Environmental Advisory Panel (OSEAP) in 1974.

During the 1974-1999 period, the Panel held 24 public meetings, had 15 temporary workgroups, and prepared a number of papers and annual reports. The Panel's charter expired in late 1977, and was reactivated in late 1978. Under its new charter, the primary objective of the Panel is to advise the Department of the Interior in the enforcement of the provisions of the prototype oil shale leases for the protection of the environment. Upon special request, the Panel may review the environmental aspects of the oil shale paogram of the Department of Energy.

In 1978, at the request of the State of Colorado, DOE formed the Environmental Modified In-Situ Task Force to coordinate a DOE-Colorado comprehensive program of environmental research at the Occidential Modified-In-Situ Project. The Chairman of the Task Force, the DOE Assistant Secretary for the Environment, formed an advisory group with representatives from environmental groups, a single oil shale workers union, industry representations, and others.

DOE representatives meet with members of environmental groups on an informal basis to exchange views and information on DOE environmental research. The public, state or local governments, or environmental groups have not yet been involved in the drafting of the new Oil Shale RD&D Management Plan. DOE plans to solicit public comment on its Plan following the formal submission to Congress in late June 1979.

TABLE 1

ENVIRONMENTAL PLANNING AND REVIEW DOCUMENTS FOR OIL SHALE

YEAR DOCUMENT COMPLETED	EA*	EIS	EDP	ERD	PEPT
1971					
1972		DOI Oil Shale Retort Research Project (2/72) PB-203-318-F			
1973		DOI Prototype Oil Shale Leasing Program (8/73) EIS-73-1423F			
1974					
1975					
1976					
1977	• Geokinetics Proj. • Equity Oil Proj. • Occidental Proj. • Talley-Frac Proj. • Dow Chemical Proj. • Anvil Point Proj. • Rock Springs Proj.	• DOI Colony Oil Shale Resource Project (6/77) • DOE Alternative Fuels Demo Prog. (includes oil shale)	Oil Shale (6/77) EDP/F-01(77)		
1978				Oil Shale (9/78)	
1979		• *Programmatic* • *$3 per Barrel Tax Credit* • *Paraho Project*	*Oil Shale (7/79)*		
1980					

*Because no central list of EAs is maintained, some EAs may be missing from this table.

NOTE: Italics indicate document is in preparation.

The Department of the Interior and the Department of Energy have held a large number of meetings and technical comments and allowed considerable public participation in the oil shale development program:

- Had sufficient information on the environmental consequences of oil shale been developed?
- Has this information been disseminated widely enough?
- Environmental research is clearly a part of the Oil Shale RD&D Management Plan; however, the dual role of the Plan (i.e., technological and environmental development toward commercialization) raises questions as to how conflicts will be resolved.

There has been some progress regarding program coordination at the Federal level on oil shale technologies. However, the adequacy and effectiveness of these efforts may be questioned.

- Has the Federal Government coordination efforts on these technologies been useful at the state and local levels?

The above issues, and the issues presented in the background document, "Section 11, Environmental Evaluation," should serve as the basis for the workshop discussion in Denver.

I. INTRODUCTION

One of the primary purposes of the Department of Energy is to carry out the planning, coordination, support, and management of a balanced and comprehensive energy research and development program, including programs for the optimal development of various forms of energy production and conservation.

This paper is part of the 1979 Section 11 analysis, which is focused on DOE's management procedures for ensuring that adequate emphasis is given to environmental protection measures as emerging energy technologies are developed. The paper examines the functioning and effectiveness of DOE's environmental planning review process with respect to the oil shale technology.

The paper's objectives are to:

- Discuss how DOE's Environmental Planning and Review Process has functioned in the case of the oil shale technology;
- Raise issues on selected aspects of the process; and
- Provide a basis for stimulating discussion at the July 18 workshop in Denver.

Oil shale has long been regarded as a potential source of energy, with a U.S. interest in developing an oil shale industry stretching back nearly 60 years. However, with the discovery and ready availability of large petroleum reserves both in the United States and abroad, interest in developing an oil shale industry declined rapidly.

Renewed enthusiasm for oil shale appeared in the mid-1960s resulting in increasing pressure from industry and state governments for new Federal oil shale leasing. Planning for the Prototype Program coincided with the national upswing in environmental concern and passage of the National Environmental Policy Act (NEPA) in 1969. By late 1969, interest in oil shale development once again waned as a result of the identification of environmental problems and for lack of strong economic incentives.

In 1971, President Nixon in his "Clean Energy Message" directed the Department of the Interior, then the lead agency in oil shale programs, to develop a Prototype Oil Shale Leasing Program to lease shale deposits to companies interested in technology research. The Arab Oil Embargo of 1973 and the subsequent drastic changes in world oil prices served to reinforce the new wave of interest among government and industry in oil shale development.

The U.S. Department of the Interior (DOI) has been deeply involved in oil shale development efforts primarily because the Bureau of Land Management has primary management responsibilities for the Federally owned oil shale reserves (approximately 80 percent of known reserves), and the Bureau of Reclamation manages the very complex water resources that are vital to oil shale development.

Although DOI has been the Federal "lead" agency in oil shale development, the Energy Research and Development Administration and now the Department of Energy is the "lead" agency for oil shale commercialization efforts.

In May 1979, DOE completed a comprehensive "Oil Shale RD&D Program Management Plan" whose primary objective is to foster the development of a commercial oil shale industry by the mid- 1980s. The thrust of the overall DOE oil shale program is to assist in the development of this industry through research and development and financial incentives, not to mandate the choice of technology or markets to be served.

The Oil Shale RD&D Plan is structured to parallel and complement activities that commercial and industrial developers would undertake in establishing a commercial oil shale operation. The major emphasis of the Plan is on in-situ retorting processes because the technology has not advanced to the point where it has been proven to be technically or economically feasible. By 1985, DOE hopes to provide the oil shale technology base required for first-generation commercial operations in surface retorting and vertical modified in-situ retorting (Draft DOE, Oil Shale Environmental Development Plan, June 1979).

Organizationally within DOE, four program offices have major responsibilities in the development of oil shale technologies. The Office of Energy Research carries out basic and applied research on oil shale. Those technology processes selected for further development are passed to the Office of Energy Technology. The Oil Shale RD&D Program Management Plan is under the cognizance of the Office of Fossil Energy within the Office of Energy Technology.

Oil Shale processes that successfully pass through the technology development, engineering development, and demonstration phases are assigned to a resource manager in the Office of Resource Applications for the fourth and final phase -- commercialization.

The Office of Environment has primary responsibility for identifying and assessing oil shale environmental concerns at each phase of the developmental sequence. The Office of Energy Technology also has staff with environmental responsibilities for specific technology processes or program.

Section II of this paper summarizes information on both the oil shale technology and the environmental concerns associated with it. Section III examines the DOE environmental planning and review process as it has influenced oil shale technology. A more detailed description of the oil shale technologies is included in Appendix A.

II. TECHNOLOGY BACKGROUND AND ENVIRONMENTAL CONCERNS

A. OIL SHALE TECHNOLOGY

Although oil shale deposits occur in many parts of the United States, about 50 percent of the highest quality oil shale resources are located in a single geological formation in parts of Colorado, Utah, and Wyoming known as the Green River Formation (see Figure 1). A ton of this shale can be processed to yield approximately 25 gallons of crude oil. The U.S. Department of the Interior (DOI) has estimated that 80 billion barrels of oil can be recovered from the Green River Formation using existing technology, and as much as 800 billion barrels might eventually be recovered by more advanced technology and more expensive technology.* About 80 percent of the land covering the Green River Formation is owned by the Federal Government.

Shale oil can be produced from oil shale by three general retorting processes: surface or aboveground, modified in-situ, and true in-situ. In each case, the oil shale must be heated to 400°C or higher to bring about pyrolysis of the depth, assay, and geographic location of the shale formation or deposit, and the technological, economic, and environmental factors (Draft DOE, Oil Shale Environmental Development Plan, June 1979).

The following are brief descriptions of the three types of oil shale retorting techniques:

1. Surface Retorting

Surface processes involve the mining and crushing of oil shale, which is then heated in a retort vessel built above ground. The heating can be either indirect, through the use of heated recirculating solids or gases in the vessel, or direct, by creating a combustion zone in the shale itself. The products and residuals from these two heating methods differ in their chemical and physical properties.

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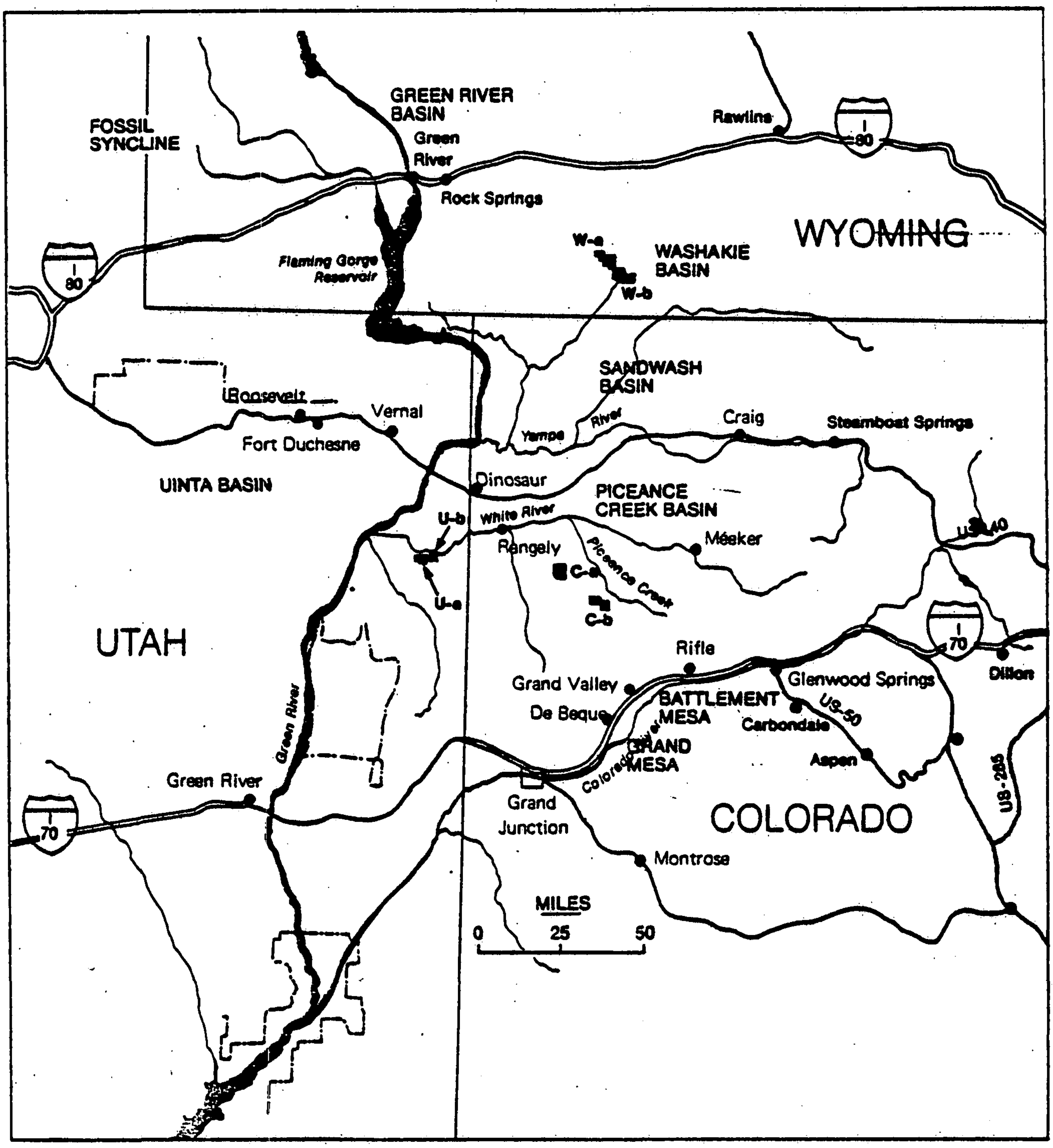
*Current U.S. consumption of petroleum products is about 6 billion barrels annually.

Figure 1. SHALE OIL DEPOSITS IN WESTERN UNITED STATES



KEY:
Federally-owned leases in the Green River Formation
—C-a, C-b, U-a, U-b, W-a, W-b

PHOTO CREDIT:
Shale County, Mountain Empire Publishing, Inc.

The surface retorting processes are the most technologically advanced. The three main surface retorting projects are:

- The Paraho Project, initially developed by the U.S. Bureau of Mines and then leased by the U.S. Department of the Interior/Navy to Development Engineering, Inc. Two newly designed Paraho oil shale retorts were placed in operation in 1974. The retorts can be operated in either the direct or indirect heating modes.

- The Oil Shale Corporation Project (TOSCO II), developed by TOSCO and Colony Development Corporation on privately owned land. This project is the only U.S. surface retorting method which uses solid-to-solid heat transfer between hot ceramic pellets and crushed oil shale, in a horizontal rotating retort, for shale oil production.

- The Union B. Project, developed by Union Oil Company of California. The development of Union's oil shale retorting technology on privately owned lands was initiated in the early 1940s, and several variations of a vertical kiln retorting process, with upward flow of shale and counter current downward flow of gases and liquids, have been developed. Two variations are known as the Retort A and the Retort B, with the latter being an improved version of the process.

2. <u>True In-Situ Retorting</u>

In-situ processes involve fracturing the shale in place underground and igniting it via a central injection well. The volatile gas and oil derived from the heated shale migrate through fractures in the rock formations to wells where they can be drawn to the surface.

True in-situ processes are still in the development stage. Many technical and environmental problems such as shale fracturing techniques and control of retort burning still need to be resolved. In-situ processes have been demonstrated by the DOE's Laramie Energy Research Center at nine sites between Rock Springs and Green River, Wyoming; by the Geokinetics Project in the Uinta Basin, the Dow Chemical Company Project in Michigan, and the Equity Oil Company Project in the Piceance Creek Basin. All these privately developed projects have been partially funded by DOE.

3. <u>Modified In-Situ (MIS) Retorting</u>

The MIS process combines aspects of both surface and true in-situ retorting. Part of the shale (15-30 percent) is mined and brought to the surface, where it is processed with conventional surface retorting technologies. The remaining oil shale, directly above the mined zone, is fractured using explosives, and then heated by igniting it in place.

Three modified in-situ processes are of current interest to DOE: vertical modified in-situ processing, horizontal modified in-situ processing preceded by mining or removing some of the shale, and modified in-situ processing preceded by solution mining of soluble salts.

The Occidential Oil Shale Project is a "vertical modified in-situ" project. It is considered the most advanced of the various MIS processes; however; the technology is still being developed and is not ready for commercialization. One major technical problem is to develop a fracturing technique which will provide a higher percentage conversion of shale pieces of uniform size.

The Dow Chemical Project in Michigan employs both true and modified in-situ approaches. Some of the Dow Project is modified in-situ because it involves undermining and chemical leaching of the oil shale. The Dow processes are significantly different from processes employed in western shale development.

A more detailed description of the oil shale technologies is given in Appendix A.

With the development of the Oil Shale RD&D Management Plan and its goal of demonstrating the commercial feasibility of the oil shale technology by 1985, two efforts are under way by DOE in supporting first-generation oil shale commercial operations. The first effort is a DOE Program Opportunity Notice (PON) for a commercial scale surface retort facility. A PON is a DOE solicitation for proposals for jointly sponsored technology development projects. The surface retort PON will be announced later this year. The second effort is directed toward the commercialization of a vertical modified in-situ (MIS) retort design. The research and development activities required to overcome the technological and environmental problems associated with the vertical MIS design have been grouped together to form a project entitled 'Moon Shot'.

The objectives of the Moon Shot project is to produce a design of a commercial state-of-the-art vertical MIS retort and mining system within 2½ years. The system design will be tailored to the requirements of Federal lease tracts C-a and C-b in the Piceance Creek Basin in Colorado. The combined shale oil output of these two tracts in the mid-1980s is expected to be 100,000 to 125,000 barrels per day.

DOE believes that the combined results of the Program Opportunity Notice and the Moon Shot Project will make shale oil production commercially feasible.

B. ENVIRONMENTAL CONCERNS

The September 1978 DOE Environmental Readiness Document stated: "There is a high probability that commercial-scale aboveground retorting will be found environmentally acceptable. The primary unresolved problems that this technology faces are; stringent air quality regulations, management of solid wastes, and lack of data regarding the environmental, health, and safety impacts of the total fuel cycle.

Significant environmental concerns have been identified with respect to the in-situ technologies which may delay their development. However, further data are required to judge the environmental acceptability of in-situ processes. The concerns include: acquifer disruption and/or contamination, occupational health of the working force in the underground environment (modified in-situ), and lack of data regarding the environmental, health, and safety impacts.

There appears to be differences of opinion among government, industry, and public interest groups as to the most serious environmental concerns associated with oil shale development. A recent analysis done by DOE in conjunction with development of the Oil Shale RD&D Management Plan listed the following concerns for Modified-in-situ processes in order of decreasing seriousness:

1) Worker Safety and Health—mining operations and underground retorting create a new and unique work environment with unknown health and safety risks.

2) Retort Abandonment—toxic substances remaining in oil shale after retorting may contaminate aquifers in an area in the United States where water is a precious resource.

3) Treatment of process wastewater leftover after surface retorting of the mined shale.

4) Disposal of mined shale brought to the surface. If piles of retorted shale are not adequately stabilized (by vegetation or cemeting), rain can cause leaching of toxic material into groundwater supplies.

5) Air emissions exhausted from underground retorting.

6) Land disruption resulting from surface operations, subsidence in mined-out areas, and the need for space to hold piles of raw shale and spent shale.

A ranking of oil shale environmental problems by 17 companies interested in oil shale list groundwater contamination and leaching of spent shale as the two most important issues.

A number of basic questions about limited degradation in Class 1 air quality areas, the adequacy of water supplies and the potential for harming aquifiers or causing deterioration in regional water quality have not been answered. For instance, under certain assumptions the background level of various air pollutants exceed Federal and state clean air standards. A current issue is the impact on air quality and visibility in the Flat Tops Wilderness area resulting from the siting of the Colony Oil 50,000 bbl per day Plant in Northwestern Colorado. The plant is not yet scheduled for development and thus changes in project design, changes in control technology, and future protective designations of Federal lands could change Colony's impacts significantly.

Another set of issues complicating plans for shale oil development is whether sufficient water supplies exist to support the industry and its associated development. Much of the water resources are legally committed to agriculture and livestock watering and river water is further controlled by an intricate system of water rights. The areas of uncertainty include: What constitutes a source of water supply? What is the geographical distribution and the timing of its availability? How much water will the industry and associated developments use on a sustained basis?

Although there has been some initial research there remains considerable uncertainty about the success and costs to reclaim waste disposal sites. Revegatation of spent oil shale will probably have to be approached on an area specific basis because of differences in the plant communities where the shale is mined and differences in the nature of the processed shale.

Estimates of the amount of water needed for dust control and revegatation will depend upon the particular local conditions. However, even the most favorable estimates suggest that the total amount of water will be relatively large compared to reclaiming strip-mined coal lands in arid regions.

An important RD & D concern is the need for a continuing comprehensive environmental study of oil shale development. The September 1978 ERD for Oil Shale Commercialization acknowledges that "the development of an environmental data base upon which to structure an assessment of the probable environmental consequences of commercialization is a key requirement" for further commercialization efforts.

Scientists and regional planners have, over the past 10 years, repeatedly urged a Green River Formation (which includes the Green River, Uinta, Washakie and Piceance Basins) Study to assess the impacts of full-scale development. It is not clear how oil shale development activities on private lands in the southern part of the Formation will affect the northern federally owned lands.

An economic issue that appears repeatedly is the need for a demonstration plant of a size that is sufficiently large to provide data that can be used to assess the impact of a commercial-size oil shale plant. Many scientists feel the need to observe a commercial-scale plant in operation to collect credible data on the impacts that have stirred public concern.

Table 2, adapted from several DOE environmental planning and assessment documents and an independent analysis by MITRE Corporation, discusses environmental concerns for all processes by general area (e.g., air quality, water quality), and describes possible mitigation methods to deal with the concerns. The DOE Office of Environment has indicated that it will probably be technologically possible to mitigate nearly all environmental impacts likely to arise in the production of shale oil.

Table 2. Environmental Concerns and Possible Mitigation Methods

Environmental Concern	Mitigation Methods
AIR QUALITY	
• Dust and particulates from mining, transportation, rubblization, crushing, and disposal.	• For undergoing mining: - Dust masks for air masks for miners. - Forced air ventilation with wet venturi scrubbers, fabric filters, or cyclones. • For disposal of mined shale: - Fabric filters or wet venturi scrubbers for emissions from all conveyors. - Wetting down roads and truck loads. - Revegetation of oil shale disposal areas.
• Retort Offgases.	• Desulfurization of gases by Stretford Process. • Denitrification, by scrubbing and subsequent recovery of NH_3. • Combustion of desulfurized and denitrified gases for electric power production or for steam production. • Flaring—to be used only in emergencies or failure of other controls.
WATER	
• Water supply is limited in the Colorado River Basin. Withdrawal of too much water will increase salinity, violating some water usage agreements and also treaties with Mexico.	• Treat and return all water left over after retorting to groundwater or surface runoffs.
• Leaching of toxic chemicals from spent shale piles.	• Cementing or vegetation of shale disposal areas. • Covering disposal areas (e.g., gullies) with impervious linings before filling with spent shale.
• Contamination of aquifers passing through a spent retort.	• Cementation of all retort surfaces. • If aquifer is above retort (usual expectation), cement passages in aquifer zone only.
LAND DISRUPTION	
• Disposal of spent shale.	• Transport rubblized shale to selected landfill locations, then compact, and revegetate.
• Disruption of habitats for plants and animals.	• Minimize extent. • Reclaim and revegetate where possible.
HUMAN HEALTH EFFECTS	
• Exposure to contaminants and toxic chemicals	• Depends on characterization research and adequacy of controls for dust, water pollution, etc.
OCCUPATION HEALTH AND SAFETY (Most occupational concerns are related to underground mining)	
• Dust and retort gases.	• Dust masks or air masks for miners. • Forced air ventilation with wet venturi scrubbers, fabric filters, or cyclones.
• Blasting.	• Strict adherence to Mining Enforcement and Safety Administration regulations and procedures.
• Diesel fumes.	• Vehicle-mounted scrubbers and filters. • Frequent mine air changes.
SOCIOECONOMIC	
• Social and economic disruption in sparsely populated oil shale basins ("Boom Town" phenomenon).	• Community planning by local governments. • Economic assisance from state and Federal authorities.

However, the cost of some controls (particularly those dealing with water pollution problems) could be large enough to seriously affect the economic competitiveness of oil shale.

In Fiscal Year 1979, theOffice of Environment is spending over $4 million on oil shale environmental research. Much of this research deals with characterization and monitoring of effluents and emissions, and the effects of oil shale byproducts on human health. Only after potential problems have been better defined can more advanced control technology research be accomplished.

III. DOE ENVIRONMENTAL PLANNING AND REVIEW PROCESS AND THE OIL SHALE TECHNOLOGY

It is difficult to evaluate DOE's environmental planning and review process -- described in the background document "Section 11, Environmental Evaluation" -- until one of the oil shale technologies have been designated a major systems acquisition or a significant energy system acquisition project. None of the technologies have yet been so designated. Evaluation is further complicated by the development of the Oil Shale RD & D Management Plan wherein DOE is apparently going from exploratory development to commercialization without completing a phase in the energy system acquisition process.

The following four criteria are used as a basis for evaluating DOE's environmental planning and review process:

- The extent to which DOE has followed the process;
- The extent to which DOE has carried out the planned environmental research;
- The extent to which the results of DOE's environmental research has affected oil shale technology development decisions; and
- The opportunities for the concerned public, local, state and Federal agencies and industry to participate in the process.

A. THE EXTENT TO WHICH DOE HAS FOLLOWED THE PROCESS

1. Environmental Planning and Assessment Documentation

The first Environmental Development Plan (EDP) for oil shale was published in June 1977. It contained: (1) a description of the technology; (2) environmental concerns; (3) associated research needs (mostly dealing with characterization and monitoring) which were given low, medium, or high priority; (4) timetables for research and NEPA document preparation at each project site; (5) lists of ongoing research projects keyed to DOE's Research Project Information System or the Federal Inventory of Research; and (6) organizations responsible for each research requirement. This EDP was quite comprehensive, however its implementation may be questionable since nearly half of the 91 research tasks were assigned the highest priority.

In September 1978, an Environmental Readiness Document (ERD), was prepared as part of a Commercialization Task Force effort to identify which energy technologies had avanced far enough towards commercialization to warrant additional emphasis. It provided an assessment of the existing knowledge of each environmental concern listed in the 1977 EDP, estimated the likelihood that research results would apply environmental constraints to commercialization, and estimated the costs and delays involved in controlling or mitigating each adverse impact if it should occur. The probablilities given showed "a medium likelihood for surface retorting and a high likelihood for in-situ retorting that there would be environmental constraints to commercialization." Although a resource manager was appointed to manage commercialization efforts, it is unclear what effects the oil shale ERD had on that decision.

At this time, no oil shale projects have been designated "major systems" within the PPMS process. Therefore, the Environmental Systems Acquistion Advisory Board will not meet on any oil shale projects prior to their passing to another technology development phase. Additionally, no oil shale projects have been designated as requiring Energy System Acquisition Project Plans (ESAAP), although an ESAPP is being prepared to accompany the Program Opportunity Notice for the commercial surface retorting project. No oil shale Project Environmental Plans have been prepared, although one will be required as an annex to the ESAPP for the commercial surface retorting project. See Table 1.

DOE has major involvement in several oil shale projects through cooperative funding agreements with private companies, and technology grants to both national laboratories and private companies. For these projects, decisions (including decisions relating to environmental concerns) are generally made within the responsible program office with advice from Office of Environment staff -- there is no formal process calling for the Assistant Secretary for Environment's personal involvement.

Until this spring, it appeared that DOE's oil shale research program had been characterized by a lack of coordination among the cognizant offices. The Offices of Environment, Energy Technology, and Resource Applications, as well as the field personnel at Laramie Energy Research Center (LERC), were sometimes preparing their own management plans for sponsoring and conducting both technological and environmental research. This lack of coordination was highlighted in an April 1978 report by the General Accounting Office on "Opportunities to Fully Integrate Development Into Developing Energy Technologies". An internal DOE study completed in December 1978 by the Office of Policy and Evaluation led to a series of recommendations* approved by the Under Secretary dealing partly with defining responsibilities and roles of the various DOE offices concerned with oil shale.

2. The Oil Shale RD&D Management Plan

The spring of 1979 has seen a major change in the relationship of the Offices of Environment and Energy Technology. These two Offices have worked together to develop a comprehensive management plan -- The Oil Shale RD&D Management Plan -- for oil shale development. The plan outlines a schedule for required research in four major activities:

- Resource Characterization and Planning
- Environment
- Development and Extraction, and
- Retorting and Product Preparation.

The plan provides specific environmental research tasks in significant detail, including the responsible organization.

Because the Plan has just been developed and has not yet been approved by Congress, (it is to be formally submitted in late June 1979), it will be some time before its effectiveness can be judged. However, both the Office of Environment and Office of Energy Technology staffs, including the cognizant Assistant Secretaries, have expressed optimism that this Management Plan will be able to get the oil shale program "on track", and that the Plan will be copied in other technology areas.

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*Although oil shale was the principal subject of the recommendations, many of the problems identified were not limited to oil shale, but were wider problems affecting all emerging technologies. Various recommendations dealt with: defining the roles of various offices, prioritizing research needs, and maintaining central lists of envrionmental concerns and ongoing research projects.

A second Oil Shale EDP is now in preparation. The June 1979 draft of this EDP has been quoted several times in this paper. This new EDP will incorporate the environmental research program from the overall Management Plan.

Coordination of DOE oil shale environmental research takes place through three committees:

- The Environmental Coordination Committee (ECC). The ECC Oil Shale Subcommittee has membership from a number of DOE Program Offices. It is chaired by a representative from the Office of Environment. Its primary role is the preparation of Environmental Planning and Assessment Process Documents.

- The Environmental R&D Working Group. This group consists of Office of Environment representatives only. It is chaired by a representative from the Office of Health and Environmental Research. Its principal responsibility is for developing detailed research plans for all Office of Environment-sponsored research in oil shale.

- The Implementation Working Group or Management Coordinating Committee.* This group includes the members of the R&D Working Group (and is chaired by the same person) as well as representatives from the Offices of Energy Technology, Resource Applications, and Planning and Evaluation. Its function is to facilitate communication between the various offices to implement the environmental research identified in the EDP. Much of the most effective research coordination takes place through this committee rather than the ECC Oil Shale Subcommittee.

Under the Oil Shale RD&D Management Plan, a fourth coordinating group will be set up:

- This group will consist of the four DOE Managers who will direct activities in each of the major research areas—Resource characterization and planning, environment, development and extraction, and retorting and product preparation. The activities are further divided into subactivities, each with its own manager. The environmental subactivities are: air, land, and solid waste; water, health, and safety; and socio-economic, ecological, and compliance. DOE hopes that regular meetings of the subactivity managers and activity managers will be a major coordinating and feedback mechanism for technology program and environment staff at the working levels.

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*The group is referred to by both titles.

The development of the new Oil Shale RD&D Management Plan will now control the oil shale technology and environmental research program. There is a question as to how this may impact the existing planning and review process for technology RD&D (the PPMS process).

3. National Environmental Policy Act Documentation

Several Environment Assessments were issued by ERDA for specific oil shale projects, but the only Environmental Impact Statement (EIS) issued by ERDA was on the Alternate Fuels Demonstration Program. This EIS discussed a variety of fuels and was not specifically focused on oil shale. DOE now has three EISs under preparation: a Programmatic Oil Shale EIS, an EIS for the Paraho Project, and an EIS to support the $3/barrel tax credit.

Three EISs have been issued by the Department of the Interior: one in 1972 for an Oil Shale Retort Research Program, one in 1973 for its Prototype Oil Shale Leasing Program, and one in 1977 for the Colony Development Corporation TOSCO Project (see Table 1).

B. THE EXTENT TO WHICH DOE HAS CARRIED OUT THE PLANNED ENVIRONMENTAL RESEARCH

Environmental research projects are generally based on an assessment of environmental concerns, identification of research needed to resolve these concerns, and a set of budget decisions required to fund the necessary research. It appears that all major concerns raised in the original EDP and ERD are, at present, being addressed by environmental research programs.

Under the new Oil Shale RD&D Management Plan, however, the direction and extent of the ongoing oil shale environmental research program will change. The new program calls for a larger commitment of resources for technology research, in contrast to the recent decreases in DOE funding for oil shale.* If this increased funding is not approved, some of the research listed in the Management Plan could be postponed or cancelled.

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*Environmental research funding in the Office of Environment has remained at a fairly constant level.

C. THE EXTENT TO WHICH THE RESULTS OF DOE'S ENVIRONMENTAL RESEARCH HAS AFFECTED OIL SHALE TECHNOLOGY DEVELOPMENT DECISIONS

Because the formal Environmental Planning and Assessment Process has only been in place since 1978 there has been little opportunity for the system to report research results which could affect oil shale technology decisions. The funding for oil shale technology research has decreased in recent years, but DOE representatives say that it is more likely due to the lack of planning coordination than because of adverse environmental impacts. Oil shale (especially the in situ processes) was identified in the 1978 ERD as having severe environmental constraints to commercialization. However, this would not have impacted budgeting decisions before the FY 1980 budget.

If environmental research were to identify problems which could not be mitigated by control technology, or controlled only at great expense (e.g., aquifer contamination) this would likely have an adverse impact on commercialization efforts. Following the September 1978 Commercialization Task Force Report (which was accompanied by the ERD), a resource manager was appointed for oil shale. A decision was made to push ahead with commercialization efforts despite the environmental concerns noted in the ERD.

D. THE OPPORTUNITIES FOR THE CONCERNED PUBLIC, LOCAL, STATE, AND FEDERAL AGENCIES, AND INDUSTRY TO PARTICIPATE IN THE PROCESS

Two major objectives of an environmental review and assessment process should be to collect data on issues of concern to interested parties early in the planning process, and to disseminate widely both technology and environmental research findings. Accomplishing these objectives tends to allay concerns about motives and research priorities, to help eliminate research gaps and redundancies, and to help provide for the entry of and access to new information by the interested parties.

Accomplishing these objectives is particularly important for future oil shale technology development because previous oil shale development activity has a history of disagreements and conflicts. Opposition to oil shale development by conservationists has centered on the environmental effects of surface and modified in situ technologies. State and local governments in Colorado and Utah have a critical interest in oil shale development because the industry would have statewide effects in terms of investment, jobs, environmental effects, and water consumption. Utah has been generally supportive of oil shale development, and Colorado has encouraged the development by easing sulfer dioxide emission standards and by reclassifying air quality regions in the oil shale development areas to allow less stringent pollution control.

1. Environmental Conflicts

Significant environmental opposition to oil shale development occurred at the time the Department of Interior started planning for the Prototype Oil Shale Leasing Program in 1969. When a proposed leasing program was submitted to Interior Secretary Hickel in 1970, he postponed announcement pending further environmental study. Regional involvement began in early 1970 with the formation of a Colorado Governor's Committee on Oil Shale. This committee consisted of federal, state and industry members. The committee, which did not have representatives from environmental groups, issued a report to the Colorado Governor on development related problems. Following objections by several environmental groups, a new committee was formed and they subsequently issued a report that was to be the basis for the Draft Environmental Impact Statement for the Prototype Program.

Another early planning activity in Colorado was the formation of a three-county Oil Shale Regional Planning Commission that was organized with representatives from Garfield, Rio Blanco and Mesa Counties. This Commission had as its goal the orderly and planned development of the region. Subsequently, a Council of Governments, consisting of elected officials from Garfield, Rio Blanco, Mesa and Moffat Counties was formed and took over the activities of the Oil Shale Regional Planning Commission.

Another controversy involving the DOI Leasing Programs arose in 1976 when the three lessee groups (two in Colorado, one in Utah) requested 1-year suspensions of operations because of legal, technical, and economic problems which had developed in connection with immediate development as then planned.

The suspensions were granted effective September 1, 1976, for the two Colorado leases and November 1 for the two in Utah. The suspension period ended September 1, 1977, for the two Colorado tracts but because of litigation over title to the oil shale lands and resources in Utah, the suspension remains in effect for the two Utah tracts.

In addition to the litigation, two lawsuits have been instituted against the Prototype Program by environmental groups. The first, filed in December, 1976, challenged the legality of the suspensions. It was dismissed for failure to include the lessees as indispensable parties. The second suit, filed in December 1977 by the Environmental Defense Fund, the Colorado Open Space Council, and Friends of the Earth, challenged the approval of the Development Plans for the two Colorado projects, arguing that additional Environmental Impact Statements should be required. The Federal District Court rejected that argument and affirmed the Department's actions under the Prototype Program on August 25, 1978. An appeal on that decision is now pending.

2. Opportunities for Public Involvement

DOI feels they have shown good faith by allowing public participation in program planning. The Oil Shale Environmental Advisory Panel was established in 1974. Key provisions of the Panel charter were to:

- Assist the Department in attaining the objectives of the Prototype Program.
- Ensure maximum public participation
- Advise the Area Oil Shale Supervisor of the Geological Survey and District Managers of the Bureau of Land Management of environmental matters in connection with their responsibilities under the Prototype Oil Shale Leasing Program.
- Advise the Department of Energy on environmental aspects of its oil shale programs upon special request to the Department of the Interior Assistant Secretary - Land and Water Resources by DOE.

During the 1974-1977 period, the Panel held 24 public meetings, had 15 temporary work groups and prepared a number of papers and annual reports. The Panel's charter expired in late 1977, and was reactivated in late 1978. The new charter authorized a 26-member Panel comprised of members from Federal, state, and county governments as well as four public members named by the DOI (two representing the industry/energy sector and two from the environmental/public interest sector).

DOI also feels they have complied with both the spirit and letter of the National Environmental Policy Act. However, environmentalists and public interest groups feel that they have been excluded from access to decision makers and that there is no accountability in the system. The major factors contributing to the controversies and disputes surrounding this Prototype Program were lack of trust of the goals and motives of the various parties, a lack of agreement about what access to decision making meant, and the fact that major program decisions and the associated EIS preparation were conducted in Washington with very little local involvement (Resolving Environmental Issues, Rand Corporation, 1979).

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APPENDIX A

OIL SHALE TECHNOLOGY DESCRIPTION

APPENDIX A

OIL SHALE TECHNOLOGY DESCRIPTION

TECHNOLOGY BACKGROUND

Oil shale is the common term used for a sedimentary rock containing a waxy organic material known as "kerogen," which has been compacted within deposits of clay, mud, and silt. When the shale is heated to temperatures of 800° F to 1000° F, the kerogen undergoes a chemical change (pyrolysis) whereby about 65% of the kerogen is converted to hydrocarbon liquids, about 10% to a low Btu gaseous product, and about 25% to a carbonaceous residue. After pre-refining, the liquid product can be turned into a high-quality synthetic crude oil that substitutes for conventional crude oil.

Retorting is the heating of oil shale to obtain the energy-rich oil and gas products. Currently, there are three retorting processes. In the first, "surface retorting," oil shale is mined, crushed, and then heated in a retort vessel above ground. In the second process, " in situ retorting," the rock is heated in place in the ground and then the volatile products of kerogen conversion are forced through fractures in the rock formations condensed and brought to the surface. The third process, "modified in situ" (MIS) retorting, combines the above two processes, whereby part of the shale is mined and brought to the surface (where it may be retorted), while the balance is reduced to rubble and retorted in the ground.

Oil shale generally occurs in geologic basins, sandwiched between layers of other kinds of sedimentary rock. Low grade deposits underlie large parts of the eastern and central United States and northern Alaska, but about 90% of the identified oil shale resources of the U.S. are located in a single geological formation in western Colorado, Utah, and Wyoming known as the Green River Formation. About 80% of this 16,500 square mile basin is owned by the Federal government, and it is the richest source of oil shale presently known in the world.

The U.S. Department of the Interior estimates that 80 billion barrels of oil can be recovered from the Green River Formation using existing technology. However, this is only one tenth of the 800 billion barrels of shale oil that might eventually be recovered by more advanced technology and with more favorable economics than presently exist. Total shale oil resources of this formation are about 1.8 trillion barrels. Considering that the U.S. consumption of petroleum products is about 6 billion barrels annually, one can perceive the enormous magnitude of shale oil resources potentially available.

There are a large number of oil shale retorting processes which have been conceived, and several have been successfully developed through the pilot plant or demonstration plant stage. In descending order of demonstrated competence, the list would appear approximately as shown in Table A-1. For the first three processes (Paraho, TOSCO II, and Union B, which are all surface retorting processes), the extended demonstration technology has been completed and specific engineering design is available or is being developed. Of the four in-situ processes, the Occidental Modified In-Situ (MIS) process is considerably more advanced. The next two processes -- Geokinetics and Equity -- are worthy of consideration as they have successfully completed the pilot plant stage of development and still appear viable. The remaining processes in Table A-1 are in too early a stage of development for serious consideration.

At present, the major DOE involvement is a cooperative funding program with Occidential Petroleum, Geokinetics, and Equity Oil for MIS research. Proposals have been requested for a cooperative program in surface retorting processes, but no awards have been made.

TABLE A-1

Shale Oil Processes and Status
(listed in descending order of development)

PROCESS	
1. Paraho*	Ready for pre commercial plant status
2. TOSCO II	Ready for precommercial plant status
3. Union B	Ready for precommercial plant status
4. Occidential Modified* In-Situ	In field test demonstration
5. Geokinetics Horizontal* In-Situ	In field test demonstration
6. Equity Steam In-Situ*	Field test demonstration starting soon
7. Rio Blanco Side Entry In -Situ	No demonstration planned for near future
8. Superior Rotating Grate	Pilot plant tests completed
9. Lurgi	Pilot plant tests completed
10. Radio Frequency Processes	Bench scale or theoretical
11. Multi-Mineral	Bench scale or theoretical
12. Batch Process	Bench scale or theoretical

* Indicates major DOE involvement.

SPECIFIC RETORTING PROCESSES

1. Paraho Oil Shale Process

History of Technology Development

The Paraho Oil Shale Process, probably the most technologically advanced of all oil shale retorting processes, is an outgrowth of: (a) the gas combustion process initially devloped by the U.S. Bureau of Mines (USBM) at Anvil Points, Colorado, in the 1940's and 1950's; and (b) research extending over many years by Developing Engineering, Inc. (DEI) on the calcination of limestone, and on the pyrolysis of oil shales.

"During World War II, a high demand for liquid fuels prompted Congress to pass the Synthetic Liquid Fuels Act of April 5, 1944. This act gave the Secretary of the Interior 5 years to construct a demonstration plant to produce synthetic liquid fuels from oil shale. The plant would give cost and engineering data to the Government for developing a synthetic liquid fuel industry. With two extensions and additional appropriations from Congress, the Department of the Interior (DOI) constructed an aboveground retorting facility at Anvil Points, Colorado, where research was conducted until expiration of the act in 1955.

Following expiration, a jurisdictional void existed for several years. In 1962, the problem was resolved with the creation of Naval Oil Shale Reserves 1, 2, and 3. Congress delegated administration of the reserves, excluding the experimental facilities, to the Secretary of the Navy, and the Secretary of the Interior was empowered to take possession and encourage the use of the Anvil Points Oil Shale Facility reserves. From 1964 to 1968, DOI leased the Anvil Points facility on Naval Oil Shale Reserve 3 to the Colorado School of Mines Research Foundation, Inc., for research on oil shale retorting.

On April 24, 1972, the lease was reactivated with a new lessee, Development Engineering, Inc. (DEI) for 5 years (until July 1977). The Paraho Development Corporation was formed with DEI as a subsidiary, and the Paraho Oil Shale Project was launched in late 1973 with funds provided by 17participating companies, including many with long experience in oil shale research. DEI continued as the operating company, and Arthur G. McKee and Co. was selected as engineering contractors.

DEI constructed a semiworks plant on the same pad holding the pilot retort built under the Synthetic Liquid Fuels Act. The lease allowed DEI to mine 400,000 tons of oil shale. In 1975, DEI's lease was extended from July 1977 to July 1982. Also in 1975, the Secretary of the Navy, with the approval of the Committees on Armed Services of Congress, authorized DEI to mine 11 million tons of oil shale from the Anvil Points facility for operating a proposed full-size module.

DOE has been delegated the responsibility for the oil shale facility. An Environmental Impact Statement is under preparation for the commercial module at Anvil Points to evaluate the environmental consequences of DOE approval for mining 11 million tons of shale and operating the proposed full-sized module."*

PROCESS TECHNOLOGY

A schematic representation of the Paraho direct-mode retort** is pictured in figure A-2, which illustrates the physical and chemical changes which occur in the various retorting zones.

The Paraho retort vessel is a vertical cylinder of steel lined with refractory brick. During direct-mode operation, shale is fed to the top through the rotating "pants-leg" distributor. The shale passes down along with retort axis and encounters a rising stream of hot combustion gases. Kerogen decomposes to oil, gas, and residual carbon. Oil and gas are drawn from the retort through collecting tubes near the top of the retort. As retorted shale approaches the burner bars, oxygen in the gas-air mixture ignites residual carbon to yield

*Draft Oil Shale Environmental Development Plan Department of Energy. June 1979.

**The two types of Paraho retort operation are "direct-mode" and "indirect mode." In the former operation, a portion of the retort off gas is combusted with the residual carbonaceous content of the spent shale in the combustion zone of the retort to furnish the heat required for retorting. In the "indirect mode" operation, there is no combustion zone in the retort. The off gas has a much higher heating value (800 Btu/scf as compared to 100 Btu/scf for direct-mode off-gas). The indirect-mode off-gas is heated externally and then used to pyrolyze the shale in the retort. The Paraho process developers prefer direct-mode operation for various engineering reasons.

the heat required for additional kerogen pyrolysis. Heat is recovered from spent shale by the recycle-gas stream which is injected into the bottom of the retort. Cool shale exits the retort through a discharge grate. Temperature in the retort is controlled by adjusting the compostion of the gas streams fed to each set of burner bars and by adjusting the composition of the recycle gas stream.

2. Union Oil Shale Process

History of Technology Development

The Union Oil Company of California (Union Oil) has been involved in oil shale activities for more than fifty years. All of their research has been conducted on privately owned lands with the majority of funds coming from the company itself. Several variations of a vertical kiln retorting process, with upward flow of shale and counter current downward flow of gases and liquids, have been developed by Union. Two variations are known as Retort A and the Retort B. The first concept, the Retort A process, has been carried through 2 tons per day and 50 tons per day pilot plants. This was followed by the construction and operation of a large demonstration plant in the late 1950's. An imporved version of the Union Oil process, the Retort B process, was developed in subsequent work in response to the increasing energy demands and shortage of fuel supplies, and has been carried through pilot plant stage. It is the Retort B process that Union Oil now proposes to construct and demonstrate at the 10,000 tons per day rate along with all necessary auxilliary facilities.

PROCESS TECHNOLOGY

A simplified schematic of the Retort B process is shown in Figure A-3. Crushed oil shale flows through two feed chutes to a solids pump in the bottom of the retort. As shale is moved upward through the retort by the upstroke of a piston, it is met by a downward flowing stream of 950° to 1000°F recycle gas from the recycle gas heater. The rising oil shale bed is heated to retorting temperature by countercurrent contact with the hot recycle gas, resulting in the production of shale oil vapor and fuel gas. This mixture of shale oil vapor and fuel gas is forced downward by the recycle gas, and cooled by contact with the cold incoming shale in the lower section of the retort.

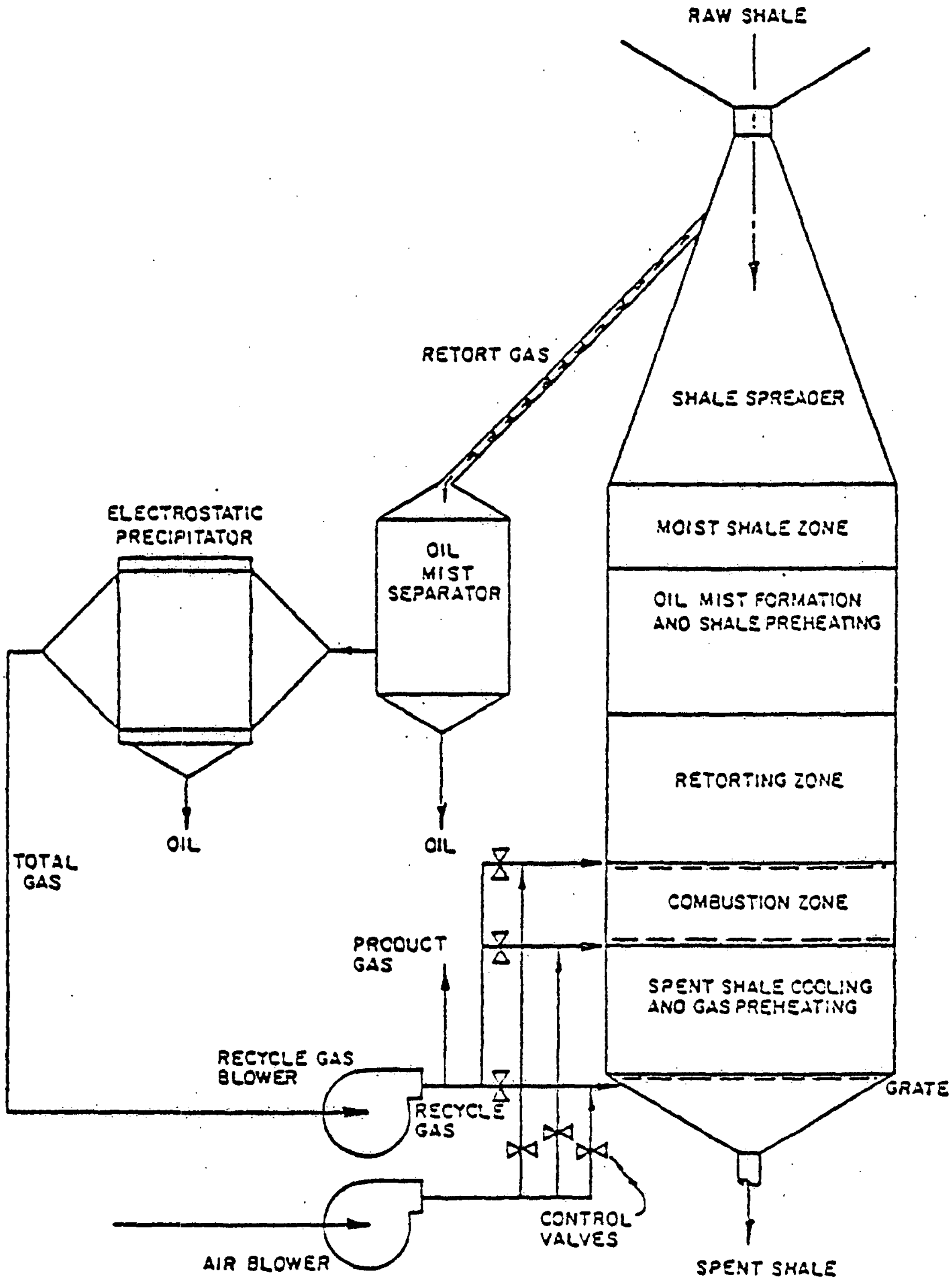

FIGURE A-2. PARAHO DIRECT MODE RETORT FLOW DIAGRAM

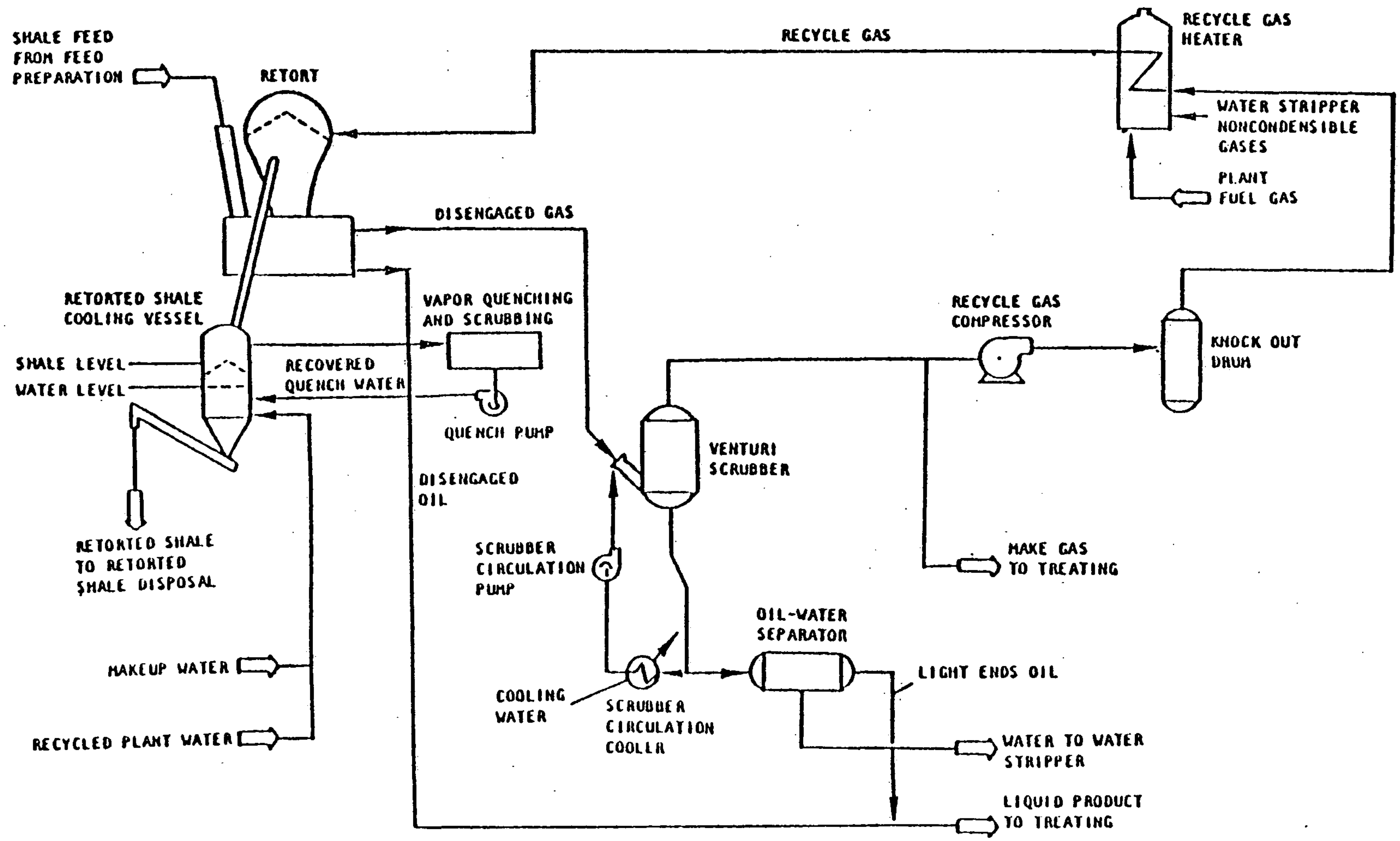

FIGURE A-3. Flow Diagram for Retort System in Union Oil Retort B Prototype Plant

The fuel gas is first sent to a scrubber for cooling and particulate removal. That portion of the fuel gas not to be recycled is then processed by compression and oil scrubbing to remove additional naphtha and heavy ends, followed by a Stretford unit to remove hydrogen sulfide. The sulfur-free fuel gas is used as plant fuel. The remaining gas, taken off after the scrubber, is recycled to the retort through the recycle gas heater to provide the heat for oil shale retorting.

The raw shale oil from the retort is treated sequentially for solids, arsenic, and light ends removal. The dearsenated shale oil is sent to a stripping prior to shipment. This partially upgraded shale oil may now be marketed as a low sulfur burner fuel in various locations in the United States, and is also a suitable feedstock for refineries that have adequate hydrotreating capacity. At the present time, however, Union Oil does not envision additional upgrading of the crude shale oil on-site.

3. TOSCO II Oil Shale Process

History of Process Development

TOSCO II is a process developed by The Oil Shale Corporation (TOSCO). Initial development work (1955-1966) was conducted under TOSCO sponsorship by the University of Denver Research Institute in a 24 ton/day pilot plant. In 1964, a joint venture of Standard Oil Company of Ohio, Cleveland Cliffs Iron Company and TOSCO was formed. A 1,000 ton/day plant was constructed on 8,500 acres of privately owned land on upper Parachute Creek near Grand Valley, Colorado. When Atlantic Richfield joined the venture in 1969, the venture name was changed to Colony Development Operation. The plant and associated pilot room and pillar mine were operated until 1972.

A full scale 66,000 tons/stream day commercial plant which would produce 47,000 bbl/day of low sulfur fuel oil and 4,300 bbl/day of liquefied petroleum gas (LPG) has been designed. Plans for commercialization have been dormant since 1974 pending initiation of a federally-sponsored synfuels commercialization program.

Process Technology

Unlike other proposed U.S. oil shale processes, the TOSCO II/Colony commercial plant is designed not only to produce shale oil, but also to upgrade it on-site to produce synthetic crude oil and LPG, with ammonia, sulfur, and coke as by-products. In addition, a treated fuel gas, a C_4 liquid stream, fuel oil, and diesel oil are obtained for internal plant use. The simplified schematic flowsheet for the raw shale oil production portion of this process is shown in Figure A-4.

The raw shale is first fed to a dilute phase fluidized bed, where it is preheated to about 500° F with flue gases from the ceramic ball heater. The preheated shale is fed to a horizontal rotating retort (pyrolysis drum), together with approximately 1.5 times its weight in hot ceramic balls from a ball-heater in order to raise the shale to pyrolysis temperature (900° F) and convert its contained organic matter to shale oil vapor. The mixture of balls and denuded shale are discharged through a trommel, in order to separate the emerging warm balls from the processed shale. The warm balls are purged of dust with flue gases from a stream preheater. The dust-free warm balls are returned to the ball heater via the ball elevator. In the ball-heater they are reheated to about 1300° F, using in-plant fuel, and recirculated to the pyrolysis drum.

4. Modified In-Situ (MIS) Processes

The modified in-situ process involves mining about 10 to 30 percent of the shale to increase the void volume for in-situ retorting. The remaining oil shale (directly above the mined zone) is fractured and retorted in place. Retorting in the modified in-situ process can be accomplished by forcing the combustion zone to move horizontally for this shale deposits or vertically for thick deposits. The mined shale may be processed in a surface retort.

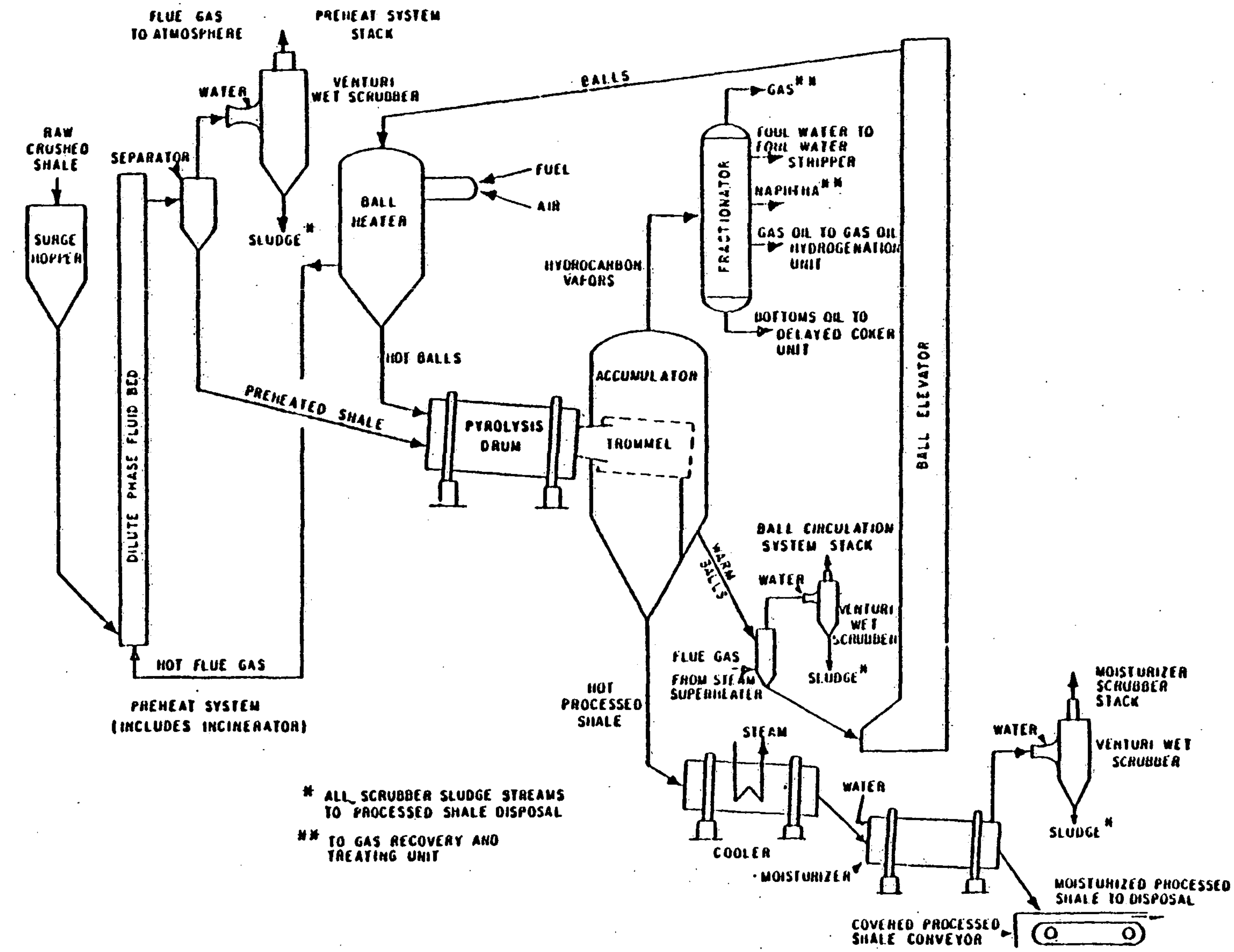

FIGURE A-4. Pyrolysis and Oil Recovery Unit TOSCO II Process

The advantages of in situ over surface processing include the reduction of shale mining and shale transport, reduction of shale disposal problems, and substantial reduction of surface installations and manpower requirements. Oil recovery is lower, however, because particle size and void distribution cannot be well controlled, and because the fracturing of shale deposits is not well understood.

The Occidental Petroleum Corporation is the principal domestic developer of the MIS process, their vertical type retort is presently based at a federally leased tract in Colorado.

The Occidental process involves three basic steps. The first step is the mining of approximately 20 to 25 percent of the oil shale deposits. This is followed by drilling long holes from the mined-out space into the shale, loading with an explosive, and detonating it with appropriate time delays so that the broken shale will fill both the volume of the mined-out space and the volume of the shale column before blasting. Connections are made to both the top and bottom of the prepared retort and retorting is carried out. Figure A-5 shows the finished retort and connections.

Retorting is initiated by heating the top of the rubblized shale column with a flame from compressed air and oil, propane, or natural gas. After several hours, the flame is turned off, and the compressed air flow is maintained, utilizing the carbon in the retorted shale at the top to sustain combustion. The hot gases from the combustion zone move downwards to pyrolize the shale just below that zone, producing gases, water vapor, and shale oil mist which collects in trenches at the bottom of the rubblized column. Oil production precedes the advancing combustion front by 30 to 40 ft. The shale oil and some byproduct water are collected in a sump and pumped to storage. The off-gas consists primarily of gases from shale pyrolysis, carbon dioxide and water vapor from the decomposition of organic carbonate (primarily dolomite and calcite), and hydrogen from the water gas reaction as well as N_2. This off-gas, after being discharged through gas blowers is cooled and passed through a Stretford-type hydrogen sulfide removal system, and part through a thermal oxidizer and steam generation system, where steam needed for the retorting

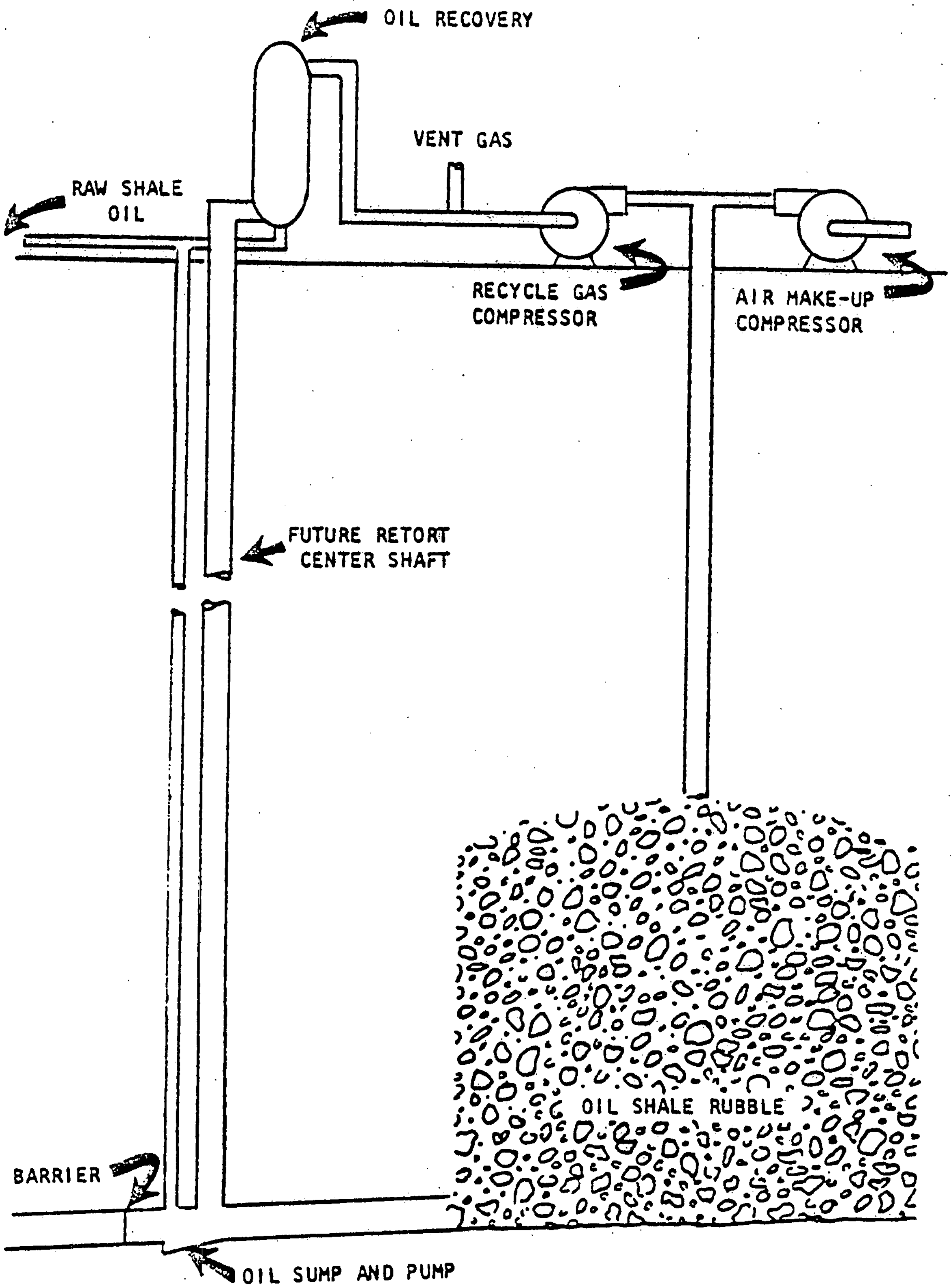

FIGURE A-5. Schematic of the Occidential Modified In Situ Process operation and perhaps other plant uses may be generated by the combustion of the treated off-gas.

The first commercial size MIS retort, with 120 ft. by 120 ft. cross section and 250 ft. height, was ignited by Occidental from the top on December 10, 1975. The ignition was successful, with oil being recovered from a sump at the bottom of the column and sustained combustion and temperature control achieved by recycle of a portion of the retort gas. A total of 27,500 barrels of oil was produced. A second test was unsuccessful in that voids distribution was poor and bad channeling of the flame front developed, causing poor oil yield. Another test is presently in progress.

The other modified in situ processes are similar to the Occidental process. The Geokinetics project involves relatively shallow, thin shale beds, and produces a surface disturbance (upheaval) following fracturing. The Equity Oil project involves injection of super heated steam into thick, deep, and leached shale beds, and may include recovery of other minerals.