PERSPECTIVE ON MODULAR DEMONSTRATION OF OIL SHALE TECHNOLOGY

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As the costs of individual projects continue to increase, and the ability of energy companies to generate capital decreases, energy investment alternatives must be analyzed more carefully than ever to determine where to invest the limited funds available. First generation shale oil plants will have major economic risks associated with the construction and operation of new technology at commercial scale. Industry has historically taken this type of risk, but shale oil plants have substantial added risks in the form of major future product price uncertainties and uncertainties related to future government policies regarding energy pricing and environmental regulations. In order to justify the allocation of capital to synthetic fuels plants, it appears essential that government share these risks with industry.

Federal support for modular demonstration of oil shale technology has been proposed as one means of risk sharing by the government. Current proposals call for the construction of modular facilities at federal expense. A modular plant is one containing a single retort producing 6,000 to 10,000 barrels of shale oil per day. By comparison, a commercial plant would produce about 50,000 or more barrels of shale oil per day and would incorporate several parallel retort trains operating in concert with mining, upgrading, and support facilities. Extent of the reserves, project life, and many other factors are considered when sizing a commercial plant.

An engineering contractor's estimate, prepared in September 1975, indicated that total capital cost for a commercial plant producing 48,000 barrels of upgraded shale oil per stream day would be about $829 million. Annual operating costs were estimated to be $75 million per year. Since then, no additional estimates have been undertaken; however, monitoring of equipment and manpower cost escalation since then indicate that these costs would be about 11 percent higher now. In contrast, a one-train modular plant producing 8,000 to 10,000 barrels per day at the same location might cost $250 million with annual operating costs of $20 million. A breakdown of these capital costs is given in table 1.

Considering these economies of scale, it is reasonable to ask why an oil shale developer might choose to undertake a modular demonstration program before full scale commercial plant construction and operation. There are both advantages and disadvantages to modular development, and we believe that a federal government synthetic fuels program should provide incentives for both modular plants and first-generation multiple retort commercial plants. Selection between these alternatives should be based on the specific next step requirements of the developer and the state of the technology to be employed in the project.

Modular Alternatives

If a modular oil shale demonstration plant is to be built, the developer has some

Table 1. - Comparison of commercial and modular plant costs.

September 1975 Dollars

	Commercial	Modular
Product Oil, BPSD	48,000	8,000
Capital, $ Million		
Mining, Crushing, Disposal Equipment	118	28
Pyrolysis, Oil Recovery	244	50
Upgrading	103	41
By-product Recovery	54	13
Utilities, General Facilities	159	50
Mine Pre-development Costs	9	11
Catalysts, Chemicals, Spare Parts	15	3
Project Management, Plant Staffing	25	12
Community Assistance Expenses	28	10
Other Miscellaneous Capital Costs	74	32
	829	250
Operating Costs, $ Million/Year (excluding by-product credits)	75	20

Note: Above numbers exclude any cost for reserves.

significant alternatives to consider. Will he produce raw shale oil or will he upgrade on site? Will the module be designed for expansion to a full scale commercial plant at some future date, or will it be a "one-shot" plant to be shut down and possibly dismantled once the modular demonstration is completed? Other decisions, such as plant location, water supply, product transportation mode, and product testing depend heavily on the upgrading alternative selected and the intended long-term disposition of the module.

Scope

Table 2 enumerates some of the factors to be considered in establishing the scope of a modular demonstration program. How soon does the developer want to begin, when will the results be needed? What are the technology questions to be answered, what information is needed on environmental and socioeconomic impacts? How large must the demonstration project be to satisfy these information needs? What constitutes a successful demonstration? How and when will the program terminate?

Table 2. - Planning and implementation of a modular demonstration program.

Factors influencing program scope

- Desired project timing
- Mining, retorting, upgrading, product testing needs
- Environmental, socioeconomic impact information needs
- Number and size of facilities to be tested
- Criteria for deciding that a demonstration has been successful

Questions concerning technology demonstration needs are not limited to retorting alone. The entire process of producing synthetic fuels from oil shale can be broken down into four categories: mining, retorting, raw shale oil processing, and product utilization. Evaluation of technology in each of these categories must be made if the commercial feasibility of oil shale development is to be truly evaluated.

If a modular demonstration project is not performed on a large enough scale, it may not provide the desired data to answer questions about the impacts of shale oil development. We believe it takes a large-scale demonstration project employing economies of scale in design, incorporating all aspects of shale oil production, by-product recovery, product transportation, and environmental control to provide answers for the environmental, socioeconomic, and marketplace questions which have been raised about oil shale development.

The question of what constitutes a successful demonstration of technology is very difficult to answer. Each solution will raise several new questions. There will always be some unanswered questions. The developer must clearly establish the criteria he will accept as proof of a successful demonstration before undertaking such a program.

Selection of Technology - Table 3 outlines the considerations affecting selection of technology.

To reap maximum benefit from a modular

Table 3. - Planning and implementation of a modular demonstration program.

Factors influencing the selection of technology to be demonstrated
Applicability of process to general industry use
Degree of present technical development
Scale-up limitations
Probability of success
Downstream processing or end use testing requirements

demonstration project, the technology to be demonstrated should be that which can be used by a maximum number of developers, has already had some development work, and has a reasonable chance of successful operation at commercial scale.

Mining - In mining, the most well-developed technology is the room and pillar technique which has been tested by the federal government, Mobil Oil Corporation and others at Anvil Points, and by Colony Development Operation at its Parachute Creek facilities. Colony Development Operation has mined at rates up to 2,300 tons per day and removed over 1.3 million tons of oil shale from its mine since it was opened in 1965. Today, Colony is continuing a modest rock mechanics program in the mine to determine long-term pillar load-carrying capabilities, and stress distribution in the mine. We have found that there is much more to be learned about optimizing pillar size and orientation for increased resource recovery and improved mine safety.

Even though room and pillar mining is generally accepted as well-developed technology, uncertainties concerning underground haulage and ventilation would be removed by operation of a large-scale underground mine.

Modified in situ, in situ, mechanical miner, retreat chamber, and other oil shale mining techniques are in various stages of research and development or subcommercial scale demonstration. Based on published information on the mining aspects of in situ and modified in situ recovery techniques, it appears that schemes developed by Occidental Petroleum, Shell Oil Company, Equity Oil Company are the most advanced oil shale recovery technologies other than room and pillar mining. These techniques appear to us to be promising complementary recovery schemes to be used in conjunction with room and pillar mining and surface retorting for increased recovery of the overall oil shale reserve.

Retorting - No two potential commercial oil shale retorts are at the same state of development and there are significant differences in scale-up limitations for the various retorts. Table 4 lists some, but not all, oil shale retorting processes receiving some current interest. None of these retorts has been built and operated on oil shale at a commercial scale. Benefits would result from modular scale demonstration of any of these retorts.

From a process design standpoint, there are two general categories into which the previously mentioned retorting techniques fall. For discussion purposes, we shall call them "segmented" and "combined"; in both cases, the retorting sequence is the same: preheating, retorting, product recovery, and waste cooling. The difference is in the degree of independence or physical separation between individual steps during the retorting process.

Retorting processes, such as TOSCO II, Lurgi-Ruhrgas, Superior, and the Galoter process, fall into the segmented category. As illustrated in figure 1, each stage of retorting is performed in an individually controlled system within the overall process. These processes are generally complex from a mechanical standpoint, but are more amenable to modification if actual operating conditions fail to match design conditions. Conservate design can be used to guarantee operation more readily in segmented processes, and scale-up is not too difficult in the 10:1 size ratio range. Too conservative an approach, however, can lead to high capital costs.

Combined processes, on the other hand, perform the necessary unit operations in as

Table 4. - Oil shale retorting schemes.

Process Developer	Process	Demonstrated Throughput, T/D	Announced Consideration of Its Use by U.S. Oil Shale Developers
Petrobras and Cameron Engineers	Petrosix	2,000	None
Development Engineering, Inc.	Paraho	280	White River Shale Project Rio Blanco Oil Shale Project
Lurgi	L-R	15	None
Occidental Petroleum Corporation	Oxy Modified In Situ	(500 B/D)	C-b Shale Oil Project
Superior Oil Company	Superior Multi-Mineral Process	100	Superior Oil Company
Tosco Corporation	TOSCO II	1,000	Rio Blanco Oil Shale Project Colony Development Operation C-b Shale Oil Project
Union Oil Company of California	Union A Union B	1,200 5	Union Oil Company of California
U.S.S.R.	Galoter Kiviter	550 275	None None

few vessels as possible. Usually one vessel is sufficient for all operations. Examples of what we call combined processes are the Paraho, Union, Petrosix, and Kiviter retorts. Figure 2 presents a simplified concept of combined processing. A combined process is characterized by continuous flow of shale through a single vessel in which preheat, retorting, and product recovery are achieved in adjacent zones. The integrity of these zones is maintained through injection of combustibles, air and inert gases, by controlling shale feed rate, and maintaining a specific feed particle size range. In situ and modified in situ retorts also fit the combined process category. In these processes, as in the old NTU oil shale retort, the shale does not move but the preheat and retorting zones progress through the bed. Integrity of the moving zones is maintained by injection of combustibles, air and inert gas, or other fluids to control the rate of combustion underground.

Combined processes are mechanically simpler and should be cheaper to build than a segmented unit of equivalent capacity. They do not have as much "fix-up" flexibility and the operator has fewer independent variables to use in controlling the retorting process. Successful operation is therefore more dependent on the correlation between design assumptions and actual operating conditions and scale-up is probably more difficult than for segmented processes.

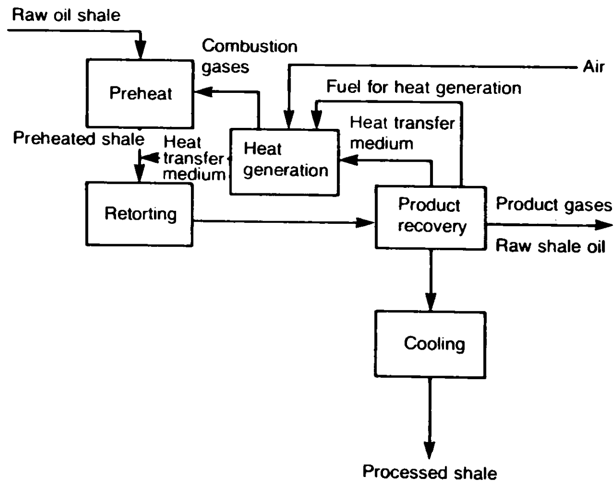

Figure 1. - Conceptual flow for segmented oil shale retorting processes.

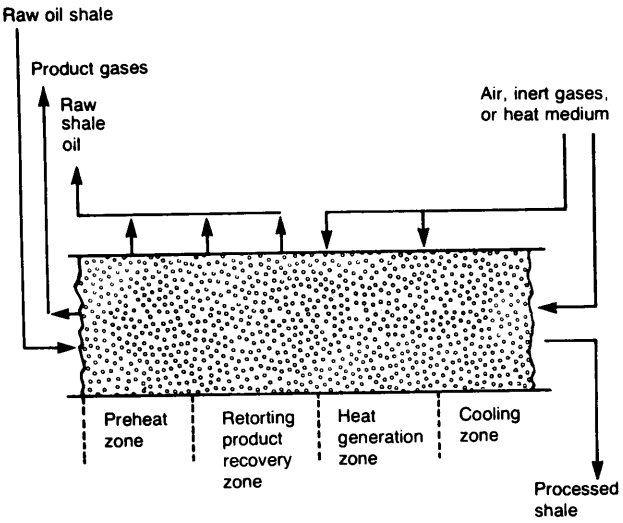

Figure 2. - Conceptual flow for combined oil shale retorting processes.

Upgrading - As mentioned earlier, incorporation of upgrading into a modular demonstration program must be considered. Conventional petroleum refining industry experience would support the position that there is little risk in designing such facilities using no more than pilot plant data. Our experience in completing the process design for the commercial Colony shale oil plant shows that this is not so.

Atlantic Richfield Company has performed large numbers of bench scale upgrading tests on shale oil and has developed sophisticated design parameters for construction and operation of commercial scale shale oil upgrading facilities. Our bench scale tests have indicated that there are benefits to be gained from tests on facilities built and operated in a manner comparable to commercial upgrading. The bench scale tests have also shown that because of high nitrogen levels, trace metals, and other factors, raw shale oil cannot be readily processed in conventional petroleum refineries. This is a very important reason for incorporating upgrading into a modular program.

If the oil product is upgraded, it can probably be handled in existing petroleum processing plants or used for large scale end-product tests. If raw shale oil is produced, however, the processing alternatives are severely reduced and may not reflect the markets which a commercial shale oil product might serve.

Considering the long-term projections for energy consumption in the U.S., it appears obvious that shale oil's long-term contribution to this country's energy demand will be to augment the supply of middle distillate fuels such as diesel, jet, and No. 2 fuel oil. The need to demonstrate the technology for upgrading shale oil to a level from which such fuels may be readily produced is just as great as the need to demonstrate retorting technology.

Information to be Obtained

In establishing the scope of his program and selecting technology, a developer must look at the effect a modular demonstration project might have on commercial scale economics. Can the module provide information which will allow reductions in overall plant cost? Will it provide the information necessary to make certain process decisions? The cost of undertaking modular development before proceeding with full scale commercial development will likely be greater than building the commercial plant initially and modifying it as necessary during the start-up phase of operation. Each oil shale developer must weigh this cost against the possible benefits of increased chance of technical success.

Another factor to be considered is the extent to which a modular plant can be used to provide information for a better understanding of environmental and socioeconomic impacts of a full scale plant. Can air and water quality predictions be confirmed? Can effects on wildlife, vegetation, and humans be measured and extrapolated to a full scale plant? What levels of employment are required? Will new community services be needed?

What is to be done with the products from a modular plant? Oil production would probably range from 5,000 to 10,000 barrels per day. Depending on the facilities installed, there may also be significant quantities of sulfur and ammonia by-products. At this scale, it would be possible to conduct product transportation and performance tests previously impossible because of an insufficient supply of sample.

What data can a developer expect to obtain from a modular program?

One obvious advantage of a modular program is demonstration of retorting technology on a commercial scale. Since a commercial retorting facility is by definition a combination of modules, design uncertainty is minimized. In theory, a developer would need only to duplicate the demonstrated design several times over when building a commercial plant.

Beyond this, the usefulness of data obtained from a modular demonstration facility becomes a function of the scope of the program.

Several questions concerning the impact of oil shale development will be only partially answered or left unanswered by operation of a modular facility of limited scope. Data can be collected on ambient air quality, but the degree, location, and duration of construction activity may not represent full scale commercial construction. Good data can be obtained from mining and waste disposal activities, but water supplies and consumption patterns will not necessarily be the same as those for the commercial plant. A small modular program might use local wells as water supply rather than piping river water to the plant.

Socioeconomic impacts of a modular demonstration program could be far different than those from construction and operation of a commercial facility. The demand for housing and other services would last only as long as the demonstration project continued. This would inhibit development of major capital items such as sewer and water systems, communications, and other utilities. It could also place a heavy burden on remaining residents if such services are not paid for before tax sources related to the modular program are depleted.

Colony's proposed commercial plant, on the other hand, would employ about 1,100 permanent employees. Total direct and indirect employment generated by Colony would be about 2,500 jobs. A population increase resulting from this number of jobs does require socioeconomic impact mitigation such as that proposed by Colony Development Operation. Rio Blanco oil shale project, C-b shale oil project, White River shale project, and others have similar plans. Conclusions drawn by the BLM in Colony's draft environmental impact statement are that the long-term socioeconomic impact of a commercial plant is positive. A stable community is established, an adequate tax base provides long-term income to pay for the cost of sewer, water, school, and other permanent facilities.

Logistics

Table 5 presents some logistic factors a developer must consider. There are a large number of permits required, environmental and socioeconomic baseline data needs to be met before development can begin. At last count, Colony had more than sixty permits, licenses, or approvals to obtain before work could begin on the plant, staging area, and community development. Starting from scratch, a delay of several years or more will occur before actual construction of commercial facilities can begin.

Plant water supply is critical. The developer can obtain water supplies by purchasing water from storage, diverting surface runoff under the Colorado water-right priority system, or developing groundwater supplies. Each of these alternatives is a time-consuming task and none is without its own peculiar problems.

How is disposition of the modular plant products to be handled? Pipeline, truck, and rail transportation are all possible. The selection depends upon the size of the demonstration plant and resultant quantity of product. Again, planning and implementing

Table 5. - Planning and implementation of a modular demonstration program.

Logistics factors

Permit requirements

Water supply

Disposition of plant products

Availability of support facilities

Taxes or other funds available to local governments

Disposition of modular facilities following a demonstration program

the product transportation system would add significantly to lead time and cost of a modular demonstration program.

Power must be available. If existing distribution lines with adequate capacity are not located nearby, the developer is faced with the cost and permitting process delays of bringing adequate electricity to the modular plant site.

If the project is to be located on federal land, how will local governments obtain money equivalent to property taxes that would be paid if the project were located on private lands? Are there other impact mitigation funds available?

The best way to evaluate these and similar questions is to look at decisions by developers of projects already underway. This strongly suggests that a developer take full advantage of work which has been done already by meshing his plans with those of a project where these questions have already been addressed.

Conclusion

In conclusion, we believe that modular demonstration of oil shale technology is useful and that it is appropriate for the federal government to undertake a risk-sharing program with industry. We believe, however, that the scope of a demonstration program must be large enough to provide the necessary information on all aspects of commercial oil shale technology, including mining, retorting, upgrading, and end-use tests, and to provide the scale and detail of information needed for adequate assessment of environmental impacts.