MODIFIED-IN-SITU TECHNOLOGY COMBINED WITH ABOVEGROUND RETORTING AND CIRCULATING FLUID BED COMBUSTORS COULD OFFER A VIABLE METHOD TO UNLOCK OIL SHALE RESERVES IN THE NEAR FUTURE

J. HULSEBOS (Occidental Oil and Gas Corp.*), B. P. POHANI (Bechtel, Inc.), R. E. MOORE (Consultant), R. L. ZAHRADNIK (Occidental Oil Shale, Inc.)

*Address: Box 300, Tulsa, Oklahoma 74102, U.S.A.

ABSTRACT

This paper describes the technology and economics of producing syncrude from oil shale using Occidental's Modified-In-Situ (MIS) process combined with Aboveground Retorting (AGR). Electricity is produced from shale fines, retort offgases and spent shale using Circulating Fluid Bed Combustors (CFBC). This combination of technologies increases extraction of heat and chemical values from the shale, thereby improving the economics of shale oil.

Most of the technologies utilized in this process arrangement have been proven on a commercial scale. MIS retorts have been demonstrated since 1972, with five retorts of commercial size. A full-scale AGR has been in operation at Parachute Creek in Colorado for the last four years. Its remaining problems appear to be solely mechanical in nature and should be resolved before another commercial-size unit is built. CFBC technology is also well proven, although the effects on combustion stability and sulfur capture of shale fines and spent shale in combination with MIS retort offgas need to be demonstrated.

Economic analyses indicate that a 20 percent internal rate of return on a commercial plant at the C-b site in Rio Blanco County, Colorado, would require a syncrude price in 1987 dollars between \$23 and \$35 per barrel (0.159 m^3), depending on the plant capacity and real oil price growth.

1. INTRODUCTION

The largest oil shale reserves in the world are found in the U.S.A., Brazil, the Soviet Union, and China. The quantities of oil recoverable from shale in these four countries alone far outweigh the proven world reserves of petroleum. A substantial increase in world oil reserves would result if portions of the shale resource could be tapped in an economical manner.

In the U.S.A., interest in oil shale has declined from the early 1980s due to the sharp drop in crude oil prices. The only currently active oil shale project is Unocal's 10000 barrels-per-day (BPD) facility at Parachute Creek, Colorado. This project utilizes AGR technology developed by Unocal. If production of oil from shale is to become more prevalent in these times of lower oil prices, ways must be found to lower production costs significantly.

Since the cost of mining shale is a significant portion of the direct operating cost, roughly 40 percent, project economics would improve by minimizing mining requirements, as in Occidental's MIS technology. In addition, by utilizing more of the heat and chemical values of the mined-out portion of the shale in AGR combined with CFBC, the operating costs per barrel of oil are reduced.

2. TECHNOLOGY

MIS retorts, approximately 50 m wide x 50 m deep x 85 m high, are constructed as shown in Figure 1. Three retort void rooms (upper, intermediate and lower) are mined in this interval to provide expansion space for the oil shale during explosive rubblization. Product level drifts are located 15 m below the retort floors and are connected to the lower void level by draw ports through which the liquid and gaseous products flow.

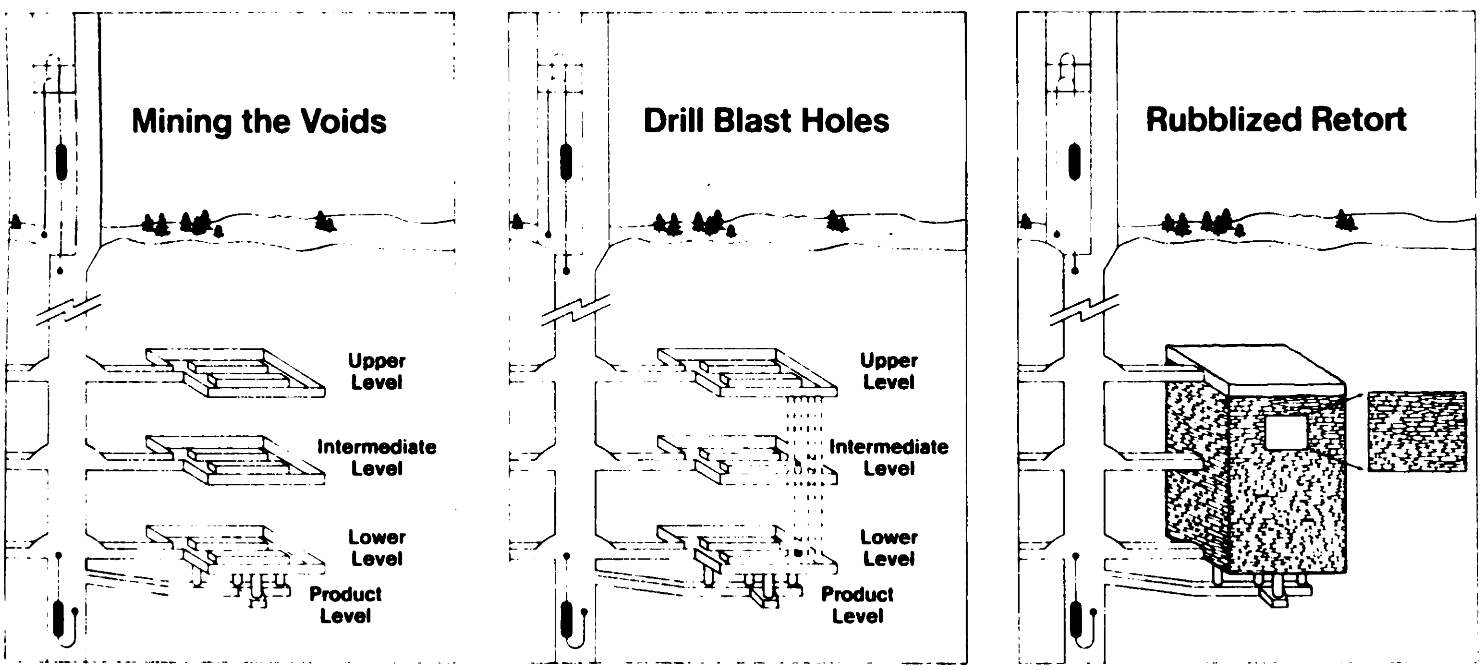

Figure 1. Construction of MIS Retorts

MIS retorts are developed in clusters or rows of eight with new clusters added as older ones are retorted. The walls are 15 m between retorts in a cluster and 46 m between clusters. This design maximizes resource recovery, consistent with safe working practices. Conventional drill-blast-muck methods are used to construct the access drifts and retort void rooms. The resulting oil shale muck is transported to the surface, where it is crushed and screened to provide the necessary size requirement for the AGR, as shown in Figure 2. Fines produced during this preparation step are fed to the CFBC.

After ignition of the top of the rubblized column with a proprietary hot inert gas generator, a combustion front is established by drawing air downwards through the retort. This front moves in a downward direction driving oil and gases ahead. Oil recovered from the retorts is pumped to the surface for further processing. MIS retorts can accommodate a wide range of shale grades, and steady-state MIS operations will produce various quantities of raw shale oil depending on the number of retorts and the shale grade involved.

Offgas from the MIS retorts is a low-joule fuel gas which contains water, condensible hydrocarbons, ammonia and sulfur bearing constituents. Condensible hydrocarbons and water are recovered by processing the offgas through water-contact condensers and sponge-oil scrubbers in the gas processing system. The water is stripped of ammonia and sulfur-bearing components and is used elsewhere in the process.

For cost estimating purposes, the AGR unit is assumed to be similar to the one in operation at Unocal's facility. This unit uses a rock pump to move the shale in an upflow design. Hot recycle gas flows countercurrent to the shale and provides heat to retort the kerogen from the shale. The AGR yields raw shale oil and significant quantities high-joule gas.

Cooled, spent shale from AGR, shale fines, and offgas from MIS, AGR, and other units are fed to the CFBC. In this unit, superheated steam is generated at 10440 kPa and 783°K. The superheated steam is fed to steam turbine generators to produce power as well as steam at various pressure levels required within the facilities. The shale, which contains considerable calcium and alkali values, captures sulfur dioxide remaining in the offgases.

The raw shale oil from the MIS retorts and from AGR and the light condensed oil are further processed in fractionation and deashing units. and are hydrotreated to produce a high quality crude which meets pipeline and conventional refining feed specifications.

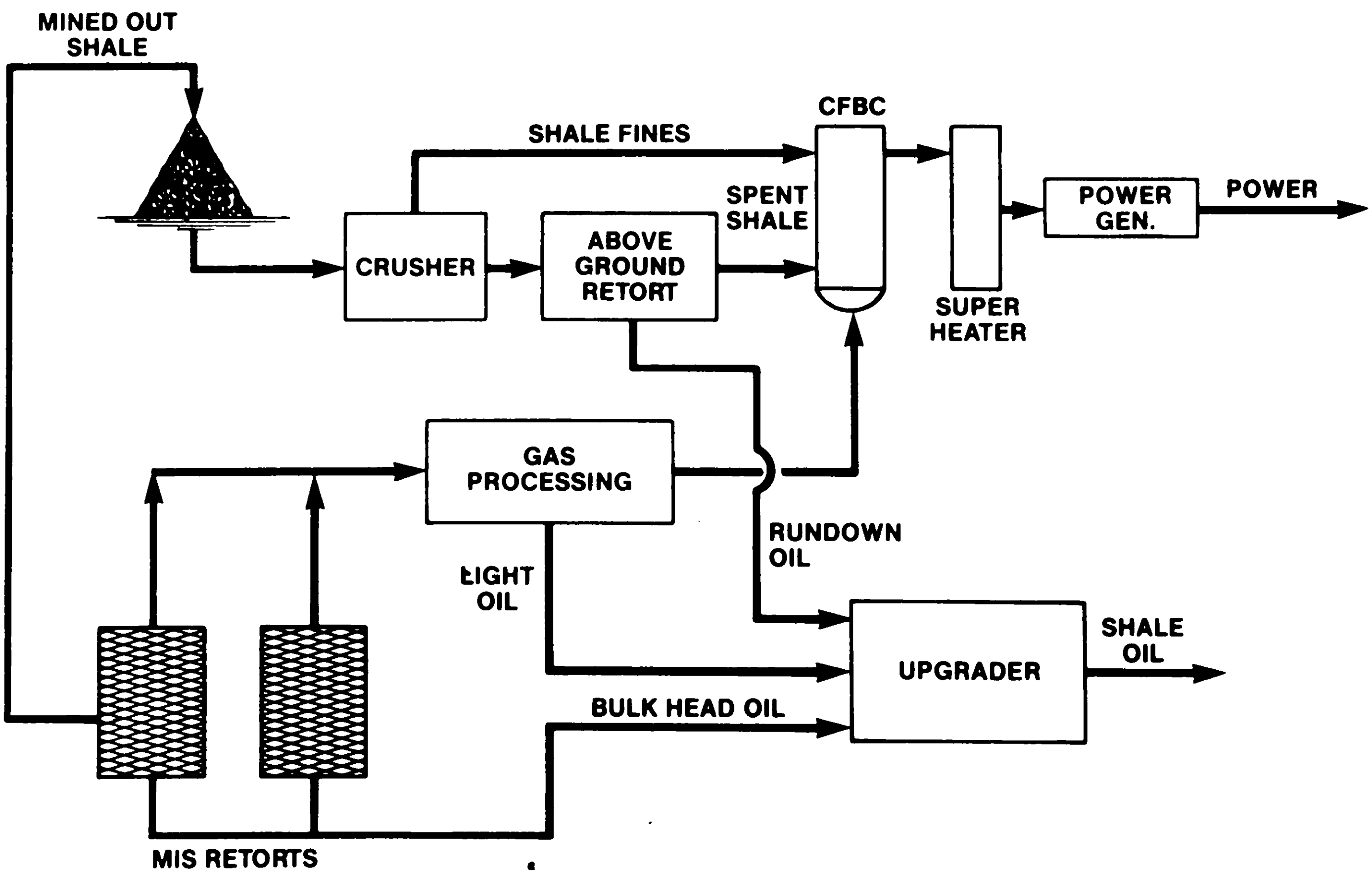

Figure 2. Oil Shale Processing Facility

3. ENVIRONMENTAL

Some of the environmental challenges in shale oil production are associated with generation of large quantities of spent shale, shale fines, and gases containing sulfur and nitrogen compounds.

The process described above should substantially reduce these environmental problems. The use of MIS retorts reduces the need for spent-shale disposal and hence the scope of spent-shale revegetation. The CFBC very efficiently uses shale fines to generate steam for power production and spent shale tc remove SO_2 from gases, without sludge formation. Thus added advantages are gained over and above effieient utilization of low-joule gas from MIS retorts.

4. COSTS AND SCHEDULES

Construction of a commercial facility should be preceded by: (1) testing of the proposed fuel mix in a CFBC and establishment of the design basis; (2) construction and operation of a semi-commercial facility which demonstrates integrated operation of MIS retorts and a CFBC.

It is estimated that two years and approximately $2 million will be sufficient for the CFBC tests and for development of the CFBC design basis.

A demonstration plant would consist of two MIS retorts operating simultaneously, aboveground MIS gas processing, and a CFBC. The facility would produce 1206 BPD of raw shale oil and 33 megawatts of power to the grid. Such a facility can be built for an estimated $203 million in 1987 dollars. Annual operating costs are estimated at $33 million before tax or $15 million after credits for oil and power sales. Construction and start-up of such a facility would require a total of four years.

Construction of additional modules to bring the plant capacity to commercial and profitable size could be done in stages and would require an additional six years.

The capital requirements and operating costs for two commercial production levels at Tract C-b were determined. Federal lease C-b comprises a 20.6 km^2 tract of land in Rio Blanco County, Colorado. It contains some of the richest shale in the world with an average oil content of 0.71 barrels per metric ton, in seams more than 90 m thick. This tract is leased from the U.S. Department of Interior by the Cathedral Bluffs Shale Oil Company, of which Occidental Petroleum Corporation is a 50 percent partner and the operator. The current mine shafts give access to reserves capable of 88800 BPD of syncrude production for 60 years.

The cases analyzed involve production of 22200 and 88800 BPD of syncrude. These cases would yield the following by-products: 51.4 and 206 megawatts power to the grid, 69 and 276 metric tons per day ammonia, 41 and 165 metric tons per day sulfur. The first case would require 22

MIS retorts, 1 AGR, and 4 CFBC. The larger one would require 88 MIS retorts, 4 AGR, and 16 CFBC.

The capital requirements are shown in Table 1.

Table 1. CAPITAL COST SUMMARY
($ Millions 1987)

Description	Capacity (BPD) 22200	88800
Mine	74	298
Utilities	15	35
Power Distribution	14	39
Interconnecting Pipeways	15	45
Buildings	19	21
Site Preparation and Development	15	19
Mobile Equipment	6	7
Offsites (less pipeline)	7	18
Aboveground Retorting Facilities	94	370
Materials Handling Facilities	18	72
Control System	4	9
Oil Upgrading Facilities	108	432
Syncrude Pipeline	10	27
MIS Process Facilities	152	608
CFBC/Power Generation	204	694
Total Direct Field Cost	755	2694
Indirect Field Cost/Home Office Costs	291	884
Spare Parts, Taxes, Royalties	139	427
Total Project Cost	1185	4005

The capital costs, amounting to $53000 and $45000 per daily barrel, respectively, do not include the sunk costs already expended in developing the C-b tract.

The operating costs for the C-b site, excluding capital related charges, federal royalties and incomes taxes, are shown in Table 2.

Table 2. ANNUAL OPERATING COSTS
($ Millions 1987)

	Capacity (BPD) 22200	88800
Natural Gas	10.1	40.4
Diesel Fuel	0.8	3.2
Raw Water	1.1	4.4
Catalyst and Chemicals	8.3	33.2
Operating Labor	14.1	42.2
Maintenance Material and Labor	20.0	77.2
Spent Shale Disposal	0.3	1.2
Retort Construction	29.8	119.1
Mining Cost	100.2	328.0
Administrative Costs	14.9	37.9
Total Annual Costs	199.6	686.8

The operating costs per barrel are grade dependent and amount to $24.63 and $21.19 per barrel in 1987 dollars. These estimated costs compare with a 1986 direct operating cost of $11.50 per barrel, reported for the 130000 BPD Syncrude Canada Ltd tarsand operation.(1)

5. ECONOMICS

The economic analysis consisted of determining oil prices (in 1987 dollars) which would generate reasonable returns on investment. The following economic parameters were assumed:

Table 3. ECONOMIC PARAMETERS

Debt/Equity Ratio	75/25	Plant Start-up	1993
Inflation, %	5	Operating Life, Yrs	25
Interest on Debt, %	10	By-product Credits:	
Federal Income Tax Rate, %	34	Power, ¢/KWH	3.5
State Income Tax Rate, %	5	Sulfur, $/metric ton	55
Depreciation Tax Life, Yrs	7	Ammonia, $/metric ton	110
Depreciation Option: Double Declining		Carbon Dioxide, $/1000 m^3	23

Figure 3 shows oil price requirements as a function of internal rate of return.

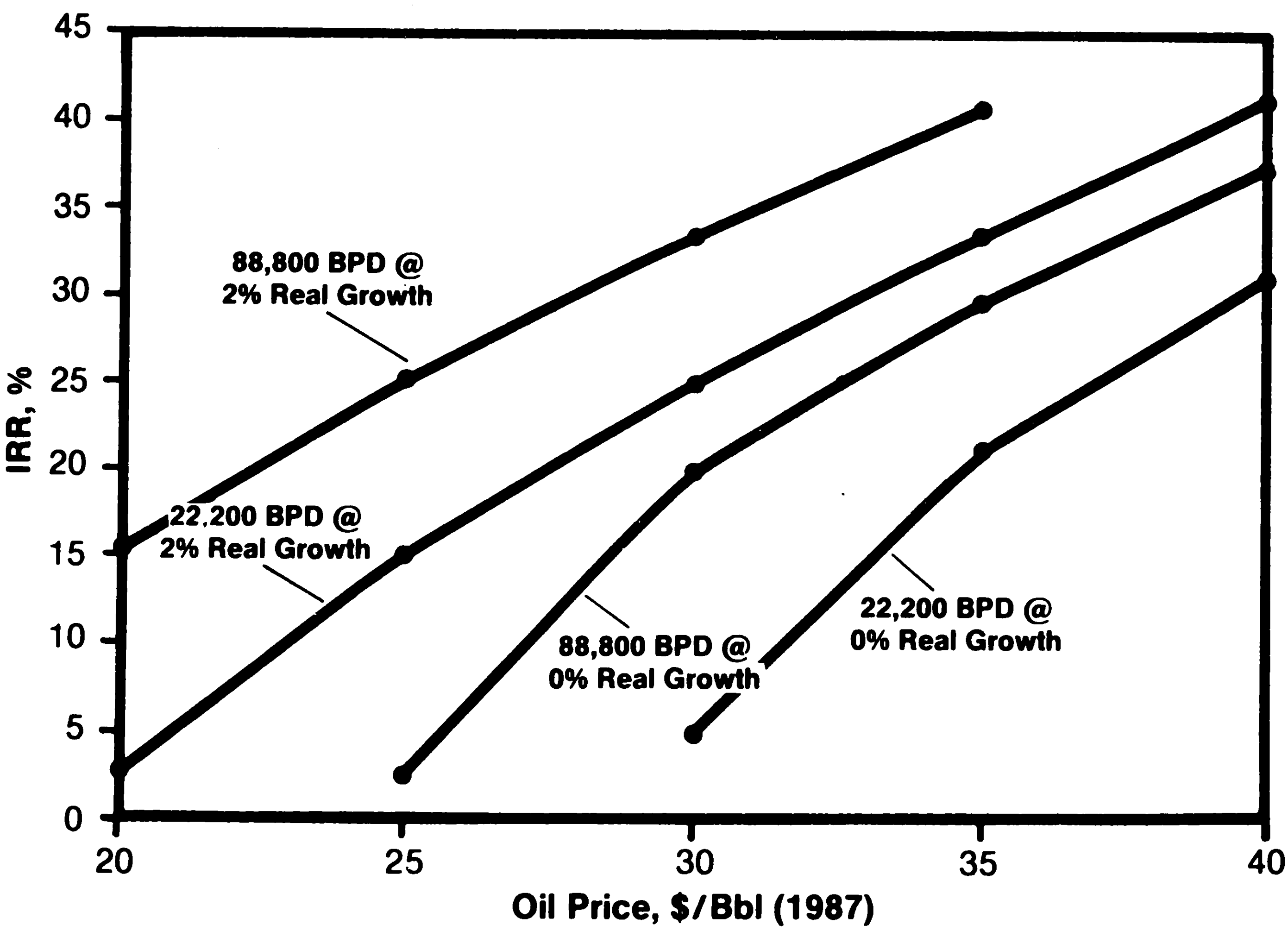

Figure 3. Shale Oil Economics at Tract C-b

Table 4 lists oil price requirements to generate a 20 percent return on equity under the assumptions outlined above.

Table 4. PRICE OF OIL TO GENERATE 20% ROE

	Oil Price (1987 $)	
Plant Capacity (BPD)	0% Real Growth	2% Real Growth
22200	35	28
88800	30	23

Sensitivities to power rate, CO_2 recovery as a by-product and increase in base capital are shown in Figure 4 for a production capacity of 22200 BPD and 0 percent real growth in oil price (i.e., oil price escalates with inflation of 5 percent per year).

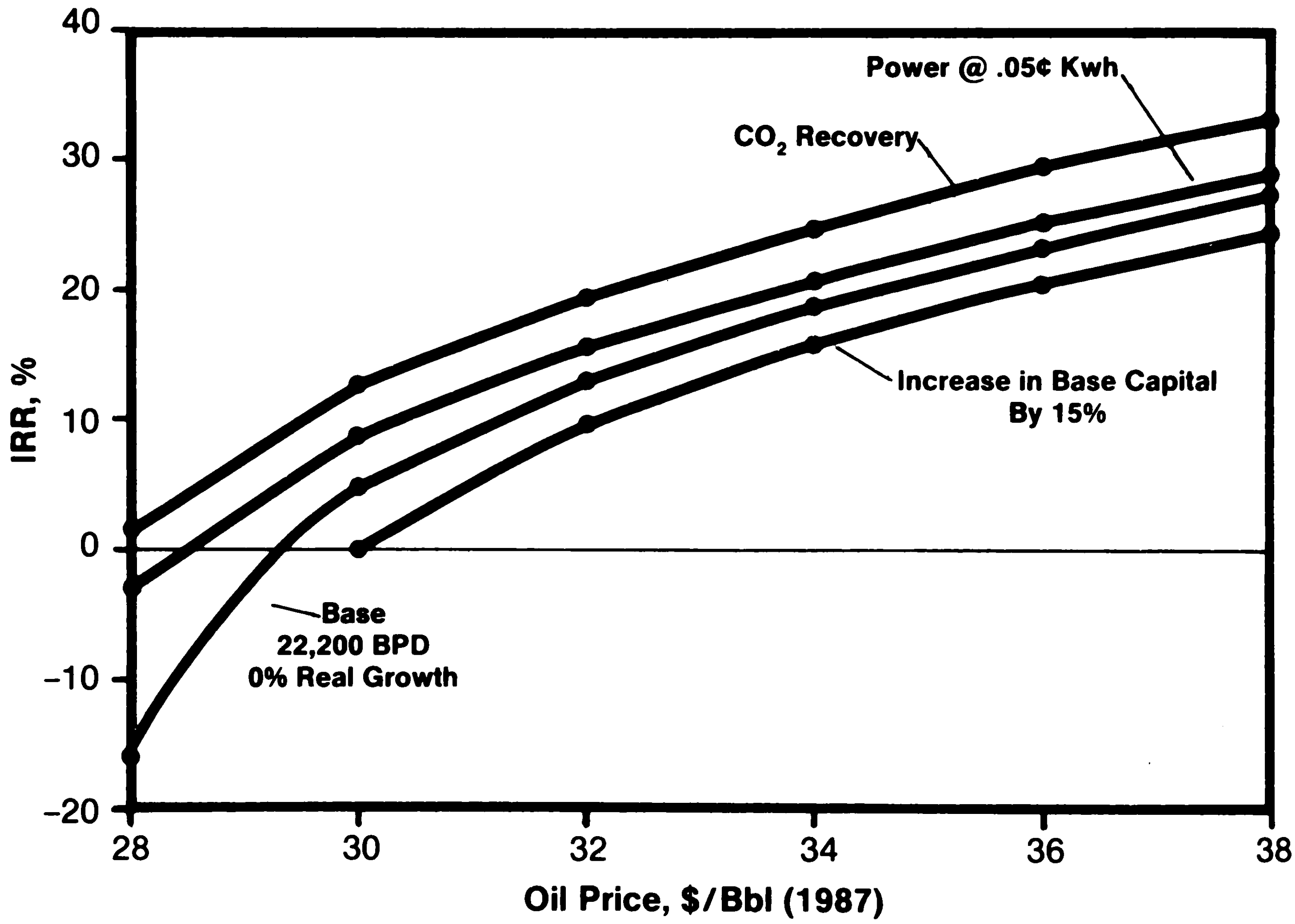

Figure 4. Sensitivities of Shale Oil Economics at Tract C-b

5. CONCLUSIONS

1. The use of MIS retorts combined with AGR and CFBC will result in efficient use of the heat and chemical values of shale, resulting in production of syncrude at costs not too far from those prevailing at the present time, assuming energy prices increase 2 percent or more above general inflation.
2. The facilities can be built in modules to minimize initial capital outlay. Other benefits from a modular construction include gaining

experience on a small scale to achieve significant reductions in capital requirements and operating costs in subsequent modules.

3. The essential parts of the processing scheme: MIS, AGR, CFBC and Oil Upgrading, have been in operation on a commercial scale or have been tested on a large scale. However, the proposed fuel combination of shale fines, spent shale, MIS retort offgas and AGR offgas has not been tested. Tests will be required to prove the feasibility of the fuel mix and to determine the need for supplementary firing of higher grade fuels such as natural gas, coal or oil.
4. Integrated operation of the various technologies can be demonstrated in a semi-commercial facility producing approximately 1200 BPD of raw shale oil and 33 megawatts of power.
5. A demonstration program would not only result in confirmation of design bases, but would allow quicker implementation of a commercial facility with lower capital requirements and operating costs due to the experience gained on a smaller scale.
6. The process envisioned extracts more values from shale, utilizes off-gas streams and shale fines, and results in an environmentally acceptable manner to clean offgas as well as generate power.

ACKNOWLEDGEMENT

The assistance of Mr. T. Angelosante and other Bechtel personnel involved in these studies is gratefully acknowledged.

REFERENCES

(1) "Syncrude 'Inexpensive' SCL Experience Shows," Hydrocarbon Processing, 15, June 1987.