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GLOSSARY

bpd	barrels per day
Btu	British thermal units
efo	equivalent fuel oil
gpm	gallons per minute
MBH	million Btus per hour
M lb/h	million pounds per hour
Mscfd	million standard cubic feet per day
scfd	standard cubic feet per day
psig	pounds per square inch (gauge)
tpd	tons per day

EFFECTS OF INJECTION GAS COMPOSITION
ON MODIFIED *IN SITU* SHALE RETORT ECONOMICS

by

J. W. Barnes

ABSTRACT

The effects of injection gas composition on the performance and economics of a Modified *In Situ* oil shale retort have been examined. The injection of air could produce oil at a slightly lower price than steam-air injection. Retort systems using steam-oxygen or carbon dioxide-oxygen are economically unattractive. A system using water and air could be economical if water addition can be controlled. Approximately one-quarter of the energy is produced as a retort off-gas that has a very low heating value.

I. EXECUTIVE SUMMARY

The effects of injection gas composition on the performance and economics of an oil shale plant using the modified *In Situ* (MIS) process for production of shale oil have been examined. The results of this study are shown in Table I.

All costs are in January 1980 dollars. Costs include those facilities required to (1) upgrade the raw shale oil to a quality suitable for pipeline transport, (2) treat plant waste and effluent streams, and (3) provide utilities and plant support services. Oil yields are given as a percentage of Fischer Assay oil in the MIS retort recovered after an allowance for internal plant consumption to meet process energy requirements. Yields (and costs) are based on laboratory experimental data; full-scale field experiments have produced much lower oil yields.

The following conclusions can be drawn from this study.

TABLE I

EFFECTS OF INJECTION GAS COMPOSITION
ON SHALE OIL PRODUCTION COSTS

Case	Net Oil Recovery (% of Fischer Assay)	Cost ($/bbl)
Steam-air Injection		
Air only	82	18.40
25/75 Steam/Air	87	19.00
50/50 Steam/Air	93	20.40
75/25 Steam/Air	70	30.30
Water-Air Injection		
29/71 Water/Air	87	17.50
Steam-Oxygen Injection		
10/90 Oxygen/Steam	81	26.30
14/86 Oxygen/Steam	77	26.80
18/82 Oxygen/Steam	75	27.00
Carbon Dioxide-Oxygen Injection		
10/90 Oxygen/Carbon Dioxide	81	30.40
14/86 Oxygen/Carbon Dioxide	83	30.[illegible]0
18/82 Oxygen/Carbon Dioxide	82	31.20

- The simplest systems are the most economical systems. Injection of air produces oil at a lower price than any steam-air system. However, steam injection may be required for system control in commercial operation. Oxygen enrichment of injection gas or carbon dioxide recovery for reinjection are both much more expensive than the air-only system.
- The injection of liquid water into the retort will improve both oil production economics and off-gas quality slightly in comparison with the air-only case. However, control of water distribution to prevent local reaction quenching in the retort may present a major problem in commercial operation.

II. INTRODUCTION

The MIS process for extractin of oil from shales offers long-term potential for becoming the most economical means for production of petroleum.

Processes for retorting oil shale above ground have been demonstrated at the scale of about 1000 tpd throughput. Commercial-scale retorts (10 000 tpd) may be economically competitive with conventional petroleum as a source of refinery feed at present market prices. The MIS process offers the potential for producing oil at a lower cost because of a reduction in shale handling and surface equipment requirements. However, the ability to adequately control a MIS retort and obtain satisfactory oil recovery has not been demonstrated and still requires considerable engineering research.

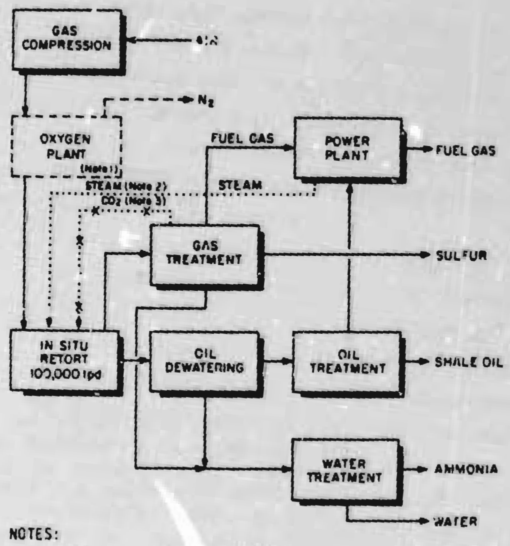
There are many parameters that are important to the operation of a MIS retort, such as rubble size, size distribution, and retorting rate. Injection gas composition has an effect on total resource recovery, oil yield, gas yield, and gas quality. These factors, in turn, affect the energy efficiency of a shale oil complex and the requirements for surface processing and support systems. The study evaluates the effect of variations in injection gas composition on shale oil production economics.

The economics of MIS retorting, in combination with several alternative methods for processing mined shale removed to the surface, was evaluated in a previous study.[1] That study showed that MIS retort gas yield and quality have a major effect on total system economics. This study focuses specifically on operation of the MIS retort and the effects of variable injection gas composition on the economics of a MIS retort system.

III. PROCESS DESCRIPTION

A. The MIS Retort System

Figure 1 illustrates the MIS retort system developed for use with this study. The MIS process involves (1) mining a fraction of oil-rich shale (10-30 volume per cent) from an underground shale bed to create voids, (2) rubblization of the remaining oil-bearing shale to create passages for subsequent flow of gas and oil, (3) ignition of the rubblized shale with injection of an oxidizer (air or oxygen) to maintain combustion and a moderator (steam or carbon dioxide) to control the reaction, and (4) collection of oil and fuel gases that are driven from the shale by the retorting reaction.



NOTES:

1. Oxygen plant not required with water-air or steam-air systems.
2. Steam not required with water-air or carbon dioxide-oxygen system.
3. Carbon dioxide recycle required only with carbon dioxide-oxygen system.

Fig. 1. Process flow sheet shale oil production.

The MIS retorting operation is assumed to process 100 000 tpd of oil shale with an oil content of 24 gal/ton by Fischer Assay. The retorts are assumed to be at a depth of 1500 ft and are constructed using room-and-pillar mining techniques. Approximately 0.4 lb of oil shale is mined and brought to the surface for each pound of oil shale retorted in the MIS retort. The mined shale would probably be retorted by one of several surface retorting processes. However, for this study, we have assumed that no further processing is required of mined shale transferred to the surface, and no allowance has been made for further handling or disposal of the mined shale.

The MIS retort development costs and production parameters were obtained from Ref. 2, and have been escalated to January 1980 dollars. Capital investment costs include all necessary mining equipment and operations for initial development of the mine and retorts. The development costs for subsequent retorts, including rubblization and removal of shale, are included in the operating costs. These costs are shown with each process case, and are held constant for all cases studied.

B. Product Treatment and Upgrading

The crude oil products of the MIS retorting process and off-gas condensates must be treated to separate the shale oil hydrocarbons and water. The dewatered, crude shale oil product of this plant has a high pour point and is not suitable for pipeline transport. The minimum upgrading plant would contain equipment to vacuum-fractionate the raw shale oil and dewax the heavy residuum. The vacuum fractionation split at 800°F true boiling point would produce an overhead of acceptable pour point for pipeline transport. The heavy residuum is dewaxed to lower the pour point and is blended with the fractionator overhead to yield a pipelinable product. The high-wax extract is used as power plant fuel.

The cool gaseous product stream of the MIS retort is cleaned to remove hydrogen sulfide in the gas purification plant and produce elemental sulfur (a marketable by-product). The purified gas stream is used as fuel in the power plant. All aqueous effluents from the complex are processed to remove dissolved hydrocarbons, hydrogen sulfide, and ammonia. The hydrocarbons and acid gases are returned to the gas purification plant. Ammonia is steam-stripped from the deacidified bottoms, concentrated, and marketed.

C. Plant Utilities and Services

The shale oil complex will have its own internal steam generation and power plant, cooling water system, and water supply system. The power plant will contain gas-turbine-driven generator sets and steam boilers that will be fired by low-Btu gas from the MIS retort and shale oil fractionator residuum. Turbine exhaust heat recovery boilers will also be included. If the total amount of gas from the MIS retort exceeds the requirements of this plant, the excess will be marketed at the plant boundary.

D. Injection Gas Supply

Injection gas will be supplied from systems within the plant as required to meet injection gas needs. Where air is used as the oxidizer, large air compressor systems will provide air for injection to the MIS retort. The air will be compressed and blended with steam before injection. All cases studied assume a pressure of 50 psig at the injection gas source. Where oxygen is used as the oxidizer, a cryogenic air separation plant is included as part of the complex.

Moderator gas, which is required to control the reaction, may be steam or carbon dioxide. Steam will be provided as incremental capacity from the complex's power plant. Carbon dioxide will be extracted from the MIS retort product gas. A larger gas treatment plant will be required for the carbon dioxide cases. However, the fuel gas from these cases will have a higher heating value as a result of the carbon dioxide removal.

IV. CASE STUDIES

A. Data Sources

Data from field tests have shown poor yields of gas and oil.[3,4] Gas quality has been of such low heating value that its use as a fuel is questionable. These poor results are primarily a result of the inability to provide a uniform rubble size throughout the retort. Further experimentation and study are required to develop adequate control techniques and demonstrate commercial feasibility.

Laboratory tests in pilot retorts of several tons' capacity have produced data that are both more extensive than the large-scale field tests and more reproducible. These data are more representative of conditions that must be obtained for commercial operation, and should also approximate conditions to be expected in the field if further research and development efforts are successful. For these reasons, we have used the data from computer models developed by Lawrence Livermore National Laboratory (LLNL).[5,6] These models accurately predicted the results of tests conducted in the LLNL 6-ton pilot retort.

B. Design Calculations

Process flow sheets were developed for each of the basic injection gas systems. Material balances were developed for variations in each system to search out optimum compositions. The plant capacities were defined for each unit in a total MIS shale oil complex. Estimates of capital and operating costs were then prepared for each system and the variations, in each case using the methods and sources discussed in Ref. 1. Capital and operating cost summaries for the individual cases are presented in the discussions that follow.

Product costs were calculated using a simplified formula for discounted cash flow calculations.[7] A conservative approach was used to determine the necessary inputs for the calculations. The life of the plant was assumed to be 20 yr, with a 16-yr period for depreciation by the sum-of-year digits method. The capital structure assumed was 100 per cent equity financing, and the required return on equity was set at 12 per cent. A 48 per cent federal income tax rate was assumed. No investment tax credit was allowed, no carry-forward scheme for tax losses was used, and negative income tax was not allowed. These factors decrease the cash flow significantly and increase the final product price.

The results for the systems evaluated are on a consistent basis with regard to input data for the calculations. The numerical results are considered most significant in a relative sense. The absolute numerical result is questionable because of the conservative approach used for calculating unit costs, the conceptual nature of the process design, and the unit-capacity capital-costing methods.

C. Steam-Air Injection

Results for the steam-air injection case are plotted in Fig. 2. The price of product oil increases slowly as the steam fraction increases to 55 per cent steam. At higher steam-air ratios, production costs climb rapidly because a fraction of the oil produced must be consumed to produce injection steam, resulting in lower net oil production.

This plot would indicate that injection of air without steam addition is more economical than steam-air injection in any combination. However, the ability to control a commercial-scale operation without the use of steam to control retort operation has not been proven. The air-only case also produces a fuel gas of lower heating value than that obtained in the steam-air cases. As the higher heating value fuel gas can be burned more easily and efficiently, a premium should be placed

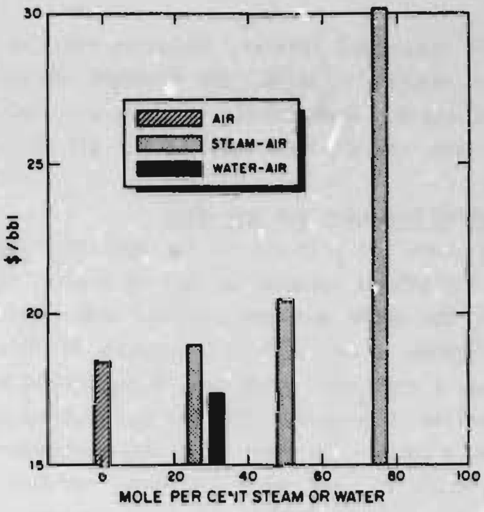


Fig. 2. Shale oil cost for steam-air injection.

on the higher value product, especially if sold off-site.

The data presented in Fig. 2 assume an equal value for all excess fuel gas produced of $2.00 per million Btu and exact no cost penalties for burning lower Btu fuel gas in the power plant. Furthermore, as field tests and large-scale retort tests have yielded very low-quality gas (typically 20-40 Btu/scf with air only and 40-70 Btu/scf with steam injection), steam addition may be necessary if this gas is used as plant fuel.

Capital and operating costs for the three steam-air cases and air-only case are summarized in Table II. Capacities of the individual plants making up a shale oil production complex are also presented to allow comparison. The cost summary indicates that *in situ* retort development and operation are the major contributors to the cost of oil production. At high steam-air ratios, the cost of the power plant (required for steam production) also becomes significant.

Table III summarizes both gross and net energy production rates for the four cases evaluated. Oil production costs are presented for alternatives in which excess fuel gas is valued at $12.00 per barrel equivalent fuel oil and $24.00 per barrel equivalent fuel oil. A third case is also presented in which the fuel gas is assumed to have no value (as internal fuel or as a marketable product) and all plant energy requirements are met by diversion of a portion of the shale oil produced.

TABLE II

CAPITAL AND OPERATING COSTS
STEAM-AIR INJECTION

Capital Costs	Air		25/75 Steam/Air		50/50 Steam/Air		75/25 Steam/Air	
Plant	Capacity	10^6 \$	Capacity	10^6 \$	Capacity	10^6 \$	Capacity	10^6 \$
In situ retort	100 000 tpd	300.0	100 000 tpd	300.0	100 000 tpd	300.0	100 000 tpd	300.0
Gas cooling	1 895 Mscfd	14.1	1 658 Mscfd	12.4	1 339 Mscfd	10.0	1 063 Mscfd	7.9
Gas purification	1 895 Mscfd	45.5	1 658 Mscfd	39.8	1 339 Mscfd	32.1	1 063 Mscfd	25.5
Oil dewatering	1.06 M lb/h	7.0	1.79 M lb/h	11.8	2.83 M lb/h	18.7	5.10 M lb/h	33.7
Oil treatment	47 100 bpd	19.1	51 025 bpd	20.7	53 380 bpd	21.6	52 595 bpd	21.3
Waste water	845 gpm	3.6	2 190 gpm	6.7	4 212 gpm	15.3	8 786 gpm	31.8
Power plant	1 420 MBH	27.2	2 535 MBH	48.6	3 955 MBH	75.9	7 315 MBH	140.4
Cooling water	140 000 gpm	8.7	149 000 gpm	9.2	161 000 gpm	9.9	210 000 gpm	13.0
Water supply	2 655 gpm	9.2	3 085 gpm	10.7	3 330 gpm	11.5	4 570 gpm	15.8
Gas compression	1 387 Mscfd	12.5	1 196 Mscfd	10.6	911 Mscfd	8.2	696 Mscfd	6.3
Support facilities 10.5%		46.9		49.4		52.8		62.5
Total Direct Capital		493.8		520.1		556.0		658.2
Other Capital 21.5%		106.2		111.8		119.5		141.5
Total Capital		600.0		631.9		675.5		799.7
Annual Costs								
Raw materials		3.3		3.3		3.3		3.3
Mine labor		168.7		168.7		168.7		168.7
Process labor		15.0		15.8		16.9		20.0
Supplies		3.9		4.1		4.4		5.2
Total Operating		190.9		191.9		193.3		197.2
By-product Credit		59.1		35.1		7.5		1.0
Net Operating		131.8		156.8		185.8		196.2

TABLE III

ENERGY PRODUCTION SUMMARY
STEAM-AIR INJECTION CASES

	Air	25/75 Steam/ Air	50/50 Steam/ Air	75/25 Steam/ Air
Oil production, bpd				
Gross	47 100	51 000	53 400	52 600
Net	46 700	50 600	53 000	39 800
Fuel gas production				
Gross, bpd-efo	20 400	18 800	17 500	16 900
Net, bpd-efo	14 700	8 700	1 600	0
Btu/scf	65	68	78	95
Oil cost, $/bbl				
Fuel gas at $2.00/MBH	18.40	19.00	20.40	30.30
Fuel gas at $4.00/MBH	14.60	16.90	20.00	30.30
No fuel gas use				
Net oil production, bpd	41 000	40 500	37 100	22 600
Oil cost, $/bbl	25.30	26.90	29.70	53.50

This table illustrates the effect of retort off-gas use on shale oil economics. Approximately one-third of the total energy produced is a low-Btu gas. This gas must be used and must be of a quality that will allow its use if the *in situ* retorting process is to realize its maximum potential.

D. Water-Air Injection

A case can be made for the injection of water directly instead of steam, if water distribution and retort operations can be adequately controlled. This approach may recover a greater fraction of the residual sensible heat left in the retort, allows *in situ* generation of steam, and significantly reduces the steam plant size and the fuel requirement for that steam plant.

The results for the water-air case are shown in Fig. 3 with the previously discussed steam-air cases. For the one case calculated, the cost of oil produced is lower than that for the air-only case, and the quality of the fuel gas is improved. The injection of water into an *in situ* retort appears economically attractive. However, proper control and distribution of water will be essential to efficient operation. The problems that can arise from uncontrolled water addition have been demonstrated during *in situ* coal gasification tests.

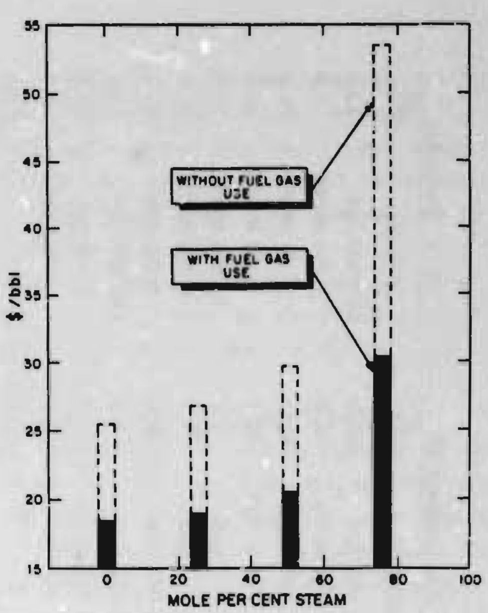


Fig. 3. Shale oil cost for water-air injection.

Table IV presents a summary of capital and operating costs for the water injection case. Comparison with Table II illustrates the reduced

TABLE IV

CAPITAL AND OPERATING COSTS
WATER-AIR INJECTION CASE

Capital Costs		
Plant	Capacity	$10^6$$
In situ retort	100 000 tpd	300.0
Gas cooling	1 610 Mscfd	12.0
Gas purification	1 610 Mscfd	38.6
Oil dewatering	1.97 M lb/h	13.0
Oil treatment	49 850 bpd	20.2
Waste water	2 587 gpm	9.4
Power plant	1 455 MBH	27.8
Cooling water	149 000 gpm	9.2
Water supply	960 gpm	3.3
Support facilities 10.5%		45.5
Total Direct Capital		479.0
Other Capital 21.5%		103.0
Total Capital		582.0
Annual Costs		
Raw materials		3.3
Mine labor		168.7
Process labor		14.6
Supplies		3.8
Total Operating		190.4
By-product Credit		54.9
Net Operating		135.5

capital requirement when compared with a system injecting the equivalent amount of water as steam.

Table V presents gross and net energy production rates for the water injection case. Comparison with Table III illustrates that, although gross oil and fuel gas production are roughly equivalent for similar water-steam inputs, net production of fuel gas is improved for the water injection case.

E. Steam-Oxygen Injection

An obvious route for improving fuel gas quality to assure its usability is to inject oxygen rather than air into the retort. Figure 4 presents the results for several steam-oxygen injection cases.

These results are not in full agreement with those shown in Figs. 1 and 2 because the computer program used to calculate yield data for the steam-air and water-air cases was revised and improved before the steam-oxygen calculations were made.* Steam-oxygen injection is not economically competitive with the steam-air injection base cases presented in Fig. 2. However, in the case where fuel gas from the steam-air system is not usable, as might happen with poor gas quality, the steam-oxygen alternative might be beneficial.

TABLE V

ENERGY PRODUCTION SUMMARY
WATER-AIR INJECTION CASE

Oil production, bpd	
Gross	49 900
Net	49 500
Fuel gas production	
Gross, bpd-efo	19 500
Net, bpd-efo	13 700
Btu/scf	73
Oil cost, $/bbl	
Fuel gas at $2.00/MBH	17.50
Fuel gas at $4.00/MBH	14.20

*Computations for the steam-air and water-air cases were for 20 per cent void volume in the retort. Computations for the steam-oxygen and carbon dioxide-oxygen cases assumed a 30 per cent void volume. On the basis of new, as yet unpublished, data obtained from LLNL, using the revised computational methods and a 30 per cent retort void volume, the shale oil product price would be increased by approximately $0.50 per barrel for the steam-air and water-air systems.

Table VI summarizes capital and operating costs for the four cases presented in Fig. 4. This table shows that the oxygen plant addition results in a large capital cost increase.

Table VII shows gross and net energy production for the four cases. The oil production decreases with increasing oxygen content. This decrease is offset by an increase in fuel gas production so that the overall oil cost does not vary much.

F. Carbon Dioxide-Oxygen Injection

Retort gas can also be upgraded by removal of carbon dioxide to improve the heating value. The gas product is of good heating value (400-500 Btu/scf) and can be consumed in conventional industrial boilers or turbines. The extracted carbon dioxide can also be used instead of steam as a reaction moderator for the *in situ* retort. The results for several carbon dioxide-steam cases are presented in Fig. 5.

The carbon dioxide-steam systems are not cost competitive with any of the other options covered in this study, primarily because of the high capital cost of CO_2 extraction. Capital and operating costs for the three cases studied are summarized in Table VIII. To make this concept competitive with other systems studied, a more cost-effective means of CO_2 recovery is needed. It is possible that a less efficient, more economical system is available for CO_2 recovery. Additional review in this area is warranted before the concept is rejected.

Table IX presents gross and net energy production information for carbon dioxide-oxygen injection. Internal energy requirements of the carbon dioxide systems are high, so no excess fuel gas is produced for external sale. The systems are, however, approximately in balance with respect to energy needs and fuel gas availability. Only a small amount of the shale oil produced need be diverted to satisfy the energy balance deficit.

ACKNOWLEDGMENT

The economic analysis in this report is based on process models developed by R. L. Braun of the Lawrence Livermore National Laboratory. The source of these data is gratefully acknowledged.

TABLE VI

CAPITAL AND OPERATING COSTS
STEAM-OXYGEN INJECTION

Capital Costs	10/90 O_2/Steam		14/86 O_2/Steam		18/82 O_2/Steam	
Plant	Capacity	$10^6$$	Capacity	$10^6$$	Capacity	$10^6$$
In situ retort	100 000 tpd	300.0	100 000 tpd	300.0	100 000 tpd	300.0
Gas cooling	732 Mscfd	5.5	815 Mscfd	6.1	829 Mscfd	6.2
Gas purification	732 Mscfd	17.6	815 Mscfd	19.6	829 Mscfd	19.9
Oil dewatering	3.3 M lb/h	21.8	2.9 M lb/h	19.1	2.6 M lb/h	17.2
Oil treatment	46 450 bpd	18.8	44 480 bpd	18.0	43 300 bpd	17.5
Waste water	6 500 gpm	23.5	6 000 gpm	21.7	5 000 gpm	18.1
Power plant	4 775 MBH	91.6	4 215 MBH	80.9	3 700 MBH	71.0
Cooling water	147 000 gpm	9.1	140 000 gpm	8.7	130 000 gpm	8.0
Water supply	1 755 gpm	6.1	~1 200 gpm	4.2	1 300 gpm	4.5
Oxygen plant	0.46 M lb/h	110.4	0.56 M lb/h	134.4	0.62 M lb/h	148.8
Support facilities 10.5%		63.5		64.3		64.2
Total Direct Capital		667.9		677.0		675.4
Other Capital 21.5%		143.6		145.5		145.2
Total Capital		811.5		822.6		820.6
Annual Costs						
Raw materials		3.3		3.3		3.3
Mine labor		168.7		168.7		168.7
Process labor		20.3		20.6		20.5
Supplies		5.3		5.3		5.3
Total Operating		197.6		197.9		197.8
By-product Credit		2.3		15.6		23.3
Net Operating		195.3		182.3		174.5

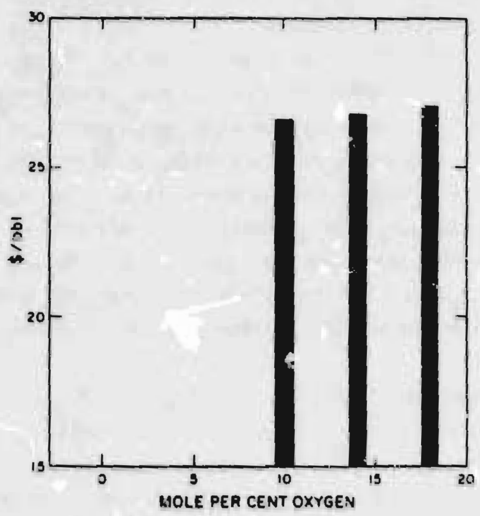


Fig. 4. Shale oil cost for steam-oxygen injection.

TABLE VII

ENERGY PRODUCTION SUMMARY
STEAM-OXYGEN INJECTION CASES

	10/90 O_2/Steam	14/86 O_2/Steam	18/82 O_2/Steam
Oil production, bpd			
Gross	46 400	44 500	43 300
Net	46 100	44 100	42 900
Fuel gas production			
Gross, bpd-efo	19 400	20 600	20 500
Net, bpd-efo	300	3 700	5 700
Btu/scf	134	128	128
Oil cost, $/bbl			
Fuel gas at $2.00/MBH	26.30	26.80	27.00
Fuel gas at $4.00/MBH	26.20	25.80	25.40

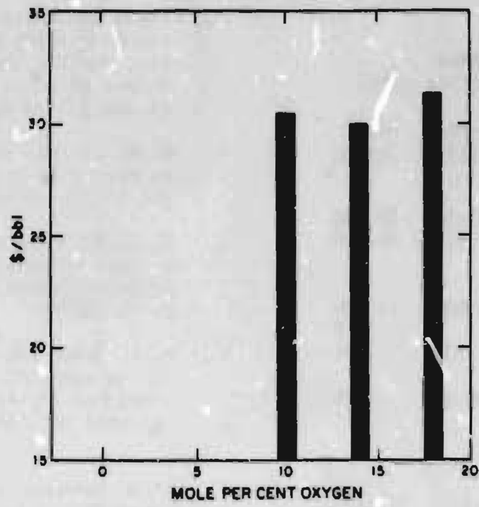


Fig. 5. Shale oil cost for carbon dioxide-oxygen injection.

TABLE VIII

CAPITAL AND OPERATING COSTS
CARBON DIOXIDE-OXYGEN INJECTION CASES

Capital Costs	10/90 O_2/CO_2		14/86 O_2/CO_2		18/82 O_2/CO_2	
Plant	Capacity	10^6\$	Capacity	10^6\$	Capacity	10^6\$
In situ retort	100 000 tpd	300.0	100 000 tpd	300.0	100 000 tpd	300.0
Gas cooling	1 697 Mscfd	12.6	1 614 Mscfd	12.0	1 580 Mscfd	11.8
Gas purification	1 697 Mscfd	224.0	1 614 Mscfd	213.0	1 580 Mscfd	208.6
Oil dewatering	0.91 M lb/h	6.0	0.93 M lb/h	6.1	0.94 M lb/h	6.2
Oil treatment	48 420 bpd	19.6	48 020 bpd	19.4	47 630 bpd	19.3
Waste water	~500 gpm	1.8	~550 gpm	2.0	~600 gpm	2.2
Power plant	3 950 MBH	75.8	3 360 MBH	74.1	3 890 MBH	74.6
Cooling water	135 000 gpm	8.3	132 000 gpm	8.2	130 000 gpm	8.0
Water supply	2 900 gpm	10.0	2 850 gpm	9.9	2 640 gpm	9.1
Oxygen plant	0.47 M lb/h	112.1	0.58 M lb/h	138.7	0.73 M lb/h	175.4
Support facilities 10.5%		80.9		82.3		85.6
Total Direct Capital		851.1		865.7		900.8
Other Capital 21.5%		183.0		186.1		193.7
Total Capital		1 034.1		1 051.8		1 094.5
Annual Costs						
Raw materials		3.3		3.3		3.3
Mine labor		168.7		168.7		168.7
Process labor		25.9		26.3		27.4
Supplies		6.7		6.8		7.1
Total Operating		204.6		205.1		206.5
By-product Credit		1.0		1.0		1.0
Net Operating		203.6		204.1		205.5

TABLE IX

ENERGY PRODUCTION SUMMARY
CARBON DIOXIDE-OXYGEN INJECTION CASES

	10/90 O_2/CO_2	14/86 O_2/CO_2	18/82 O_2/CO_2
Oil production, bpd			
Gross	48 400	48 000	47 600
Net	46 300	47 400	46 900
Fuel gas production			
Gross, bpd-efo	14 000	15 200	15 200
Net, bpd-efo	0	0	0
Btu/scf	565	535	530
Oil cost $/bbl	30.40	30.00	31.20

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