CONCEPTUAL DESIGN OF COMBINED IN SITU AND SURFACE RETORTING OF OIL SHALE

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INTRODUCTION

The Rio Blanco Oil Shale Project was formed in 1974 after Standard Oil (Indiana) and Gulf Oil Corporation were the successful bidders on the first 5,100 acre (2,040 ha) federal prototype oil shale lease. This lease is located in Colorado and is known as Tract C-a. In the first three and one-half years after acquiring this lease, we have spent about $160 million, mostly for lease payments, environmental baseline measurements and engineering studies and plans. We submitted a revised detailed development plan in May, 1977, which described a 40-year plan for developing the oil shale resource on Tract C-a. This includes a 10-year modular development phase and a 30-year commercial phase. Conceptual designs of modified in situ retorting, combined with surface retorting of shale actually mined and brought to the surface, is the subject of today's paper.

MODIFIED IN SITU DEVELOPMENT PLAN

We received approval of the modified in-situ development plan from the Department of the Interior in September, 1977. In October of 1977, we received authorization from Gulf and Standard to proceed with a 4-year modular development program, costing $93 million. During this 4-year period, we plan to burn five underground retorts of increasing size, beginning with a 140 ft. high (42 m) retort in 1979 and ending with two retorts of 400 ft. height (120 m) in 1981. If this development work is successful, we will then make the decision to proceed with commercial development of at least 50,000 barrels (7,990 m^3) a day capacity and requiring about five years to build. Total time, from purchase of the lease to commercial production in 1987, thus would be about 13 years; total expenditures will be more than $1 billion.

Advantages and Disadvantages

Before making the decision to submit a plan calling for modified in situ development, we looked at the advantages and disadvantages of this method, compared with the surface retort (table 1).

Table 1. Modified In Situ Oil Shale Retorting Process

Advantages

- Less mining and rock transport
- Less environmental disturbance
- Less water required
- Less front-end investment
- More economical

Disadvantages

- Large gas circulation
- Low BTU gas utilization
- Less resource recovery
- Subsidence

The advantages include less mining and rock transport. In the case of modified in situ, we believe about 20 percent of the rock is all that needs to be mined and brought to the surface. The remaining rock will be rubblized in place and then retorted without ever leaving the ground. Consequently, there is less environmental disturbance insofar as surface disposal of processed shale is concerned. The process requires less water - our calculations indicate about one-half as much, compared with surface retorting. Finally, we foresee a lower investment requirement resulting in a more economical process.

The disadvantages include large gas circulation rates required per barrel of oil produced and the subsequent need to find a method to use all of the low BTU gas produced. The process will recover less resource compared to the open-pit mining method. Finally, there may be some subsidence of the surface, depending on spacing of underground retorts.

Major Problems of Method

The modified in situ oil shale retorting process requires the marriage, for the first time, of mining and processing activities underground. We are currently working on the mining and processing designs so that they are compatible (table 2).

Table 2. Modified In Situ Oil Shale Retorting Process

Major Problems

- Mining methods and optimization
- Rubble size and distribution
- Retort stability
- Flame front control
- Gas recovery and utilization
- Water disposal
- Site restoration

The major mining problem is the development of methods to produce a rubble size, small enough and well distributed enough to enable retorting to be most efficient. Secondly, retort pillars and spent shale must be strong enough to provide retort stability. In the processing area, the problems include development of flame front control to prevent the big retorts from becoming channelized, thus resulting in less recovery of oil. Recovery and use of the low BTU gas produced will be a major processing problem. Methods to dispose of sour water and leachate which may be coming from the retorts will be a major area of research. Finally, at the conclusion of all operations, it will be necessary to restore the site.

Operations

Figure 1 is a schematic view of a modified in situ retort which has been about half-burned. The upper part of the rubble zone has already been burned and is in the process of being cooled by incoming air and steam. The combustion zone represents the point where residual carbon on spent shale is being burned by the incoming oxygen. Immediately below this is a shale preheating zone. Below that is the retorting zone where the oil shale is being retorted in the temperature range between about 370^{o} and 480^{o}C. The bottom zone of the retort represents the area where the gas is being cooled and oil is condensed. Oil and gas then pass out of the bottom of the retort at about 70^{o}C, which is the water dew point.

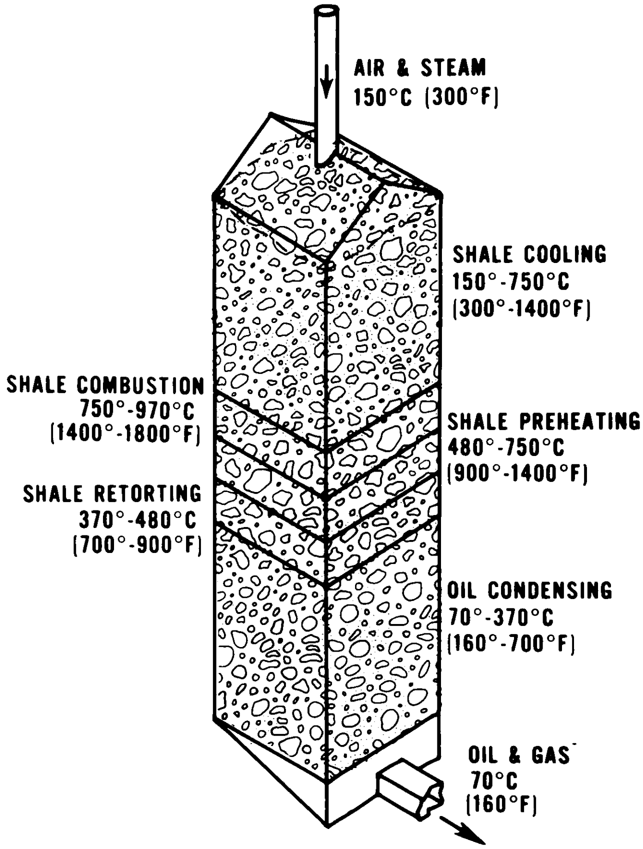

Figure 1. MIS retort schematic.

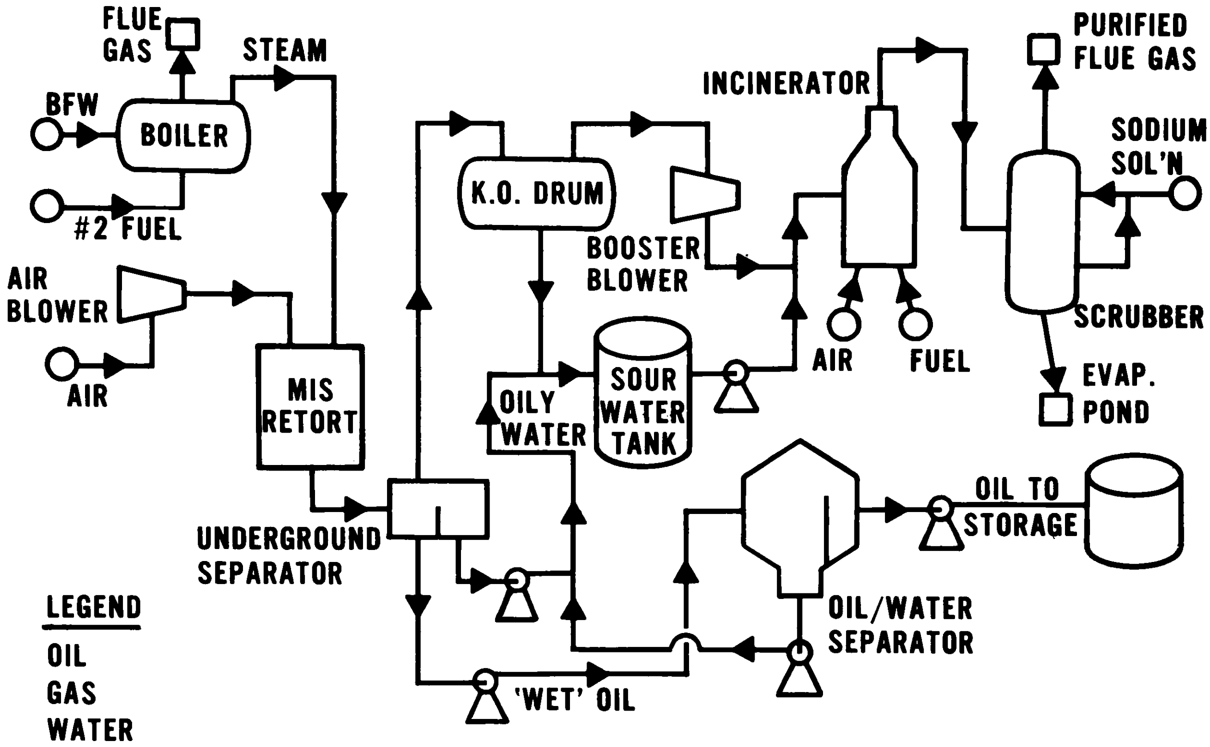

Figure 2. MDP simplified flow diagram.

Figure 2 is a simplified flow diagram of operations during the modular development phase. After heating the top layer with hot inert gas, a mixture of air and steam under pressure will be supplied to the underground retort to move the combustion and retorting zones through the retort, as just described. Oil and low BTU gas flow out of the bottom of the retort to an underground oil/water separator. The low BTU gas flows to the surface through a knockout drum to a booster blower which then supplies the gas to a conventional incinerator. Sulphur dioxide will be removed from flue gas by an alkali scrubber designed to remove 90 percent of the sulphur from the flue gas before it is emitted to the atmosphere. A side stream of low BTU gas will be studied in a pilot plant preparatory to designing the Commercial Phase gas utilization equipment. Going back to the underground separator, sour water from the retort is pumped to the surface to a sour water tank where it is stored before incineration after the MIS retort has been shut down. Some of the sour water will be sent through a pilot plant to develop a process for conserving this water during the Commercial Phase. We expect to produce during the modular development phase about 150,000 barrels (23,970 m^3) of shale oil. The five retorts will be burned intermittently.

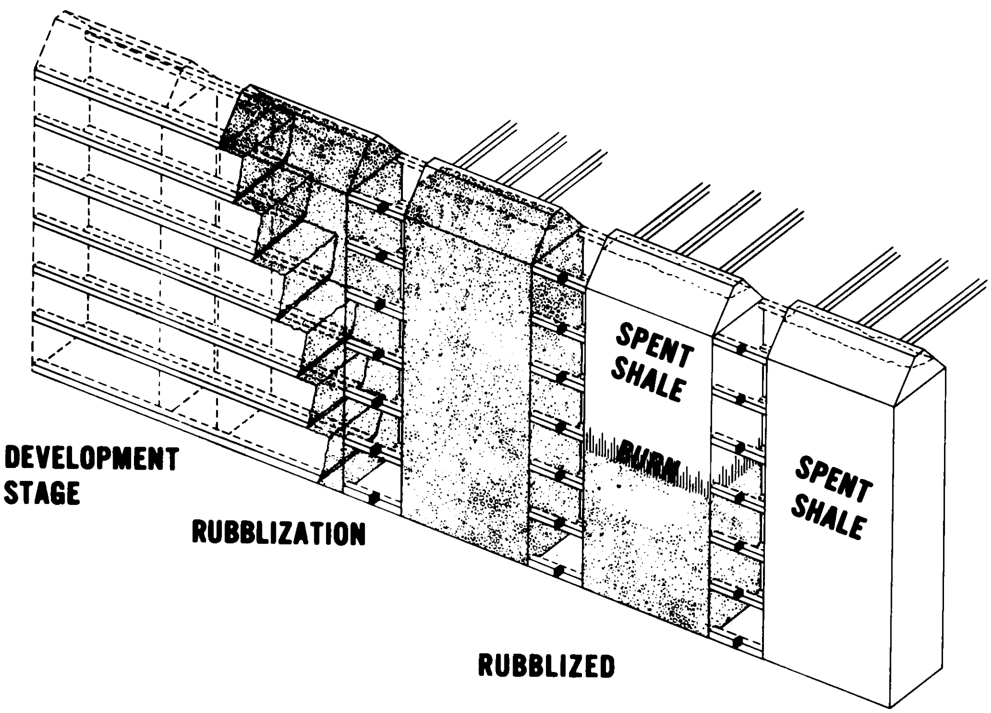

Figure 3. Sequence of development: commercial modified in situ retorts.

The down time between each retort burn will allow time for study of the results and revision of equipment and operating procedures between burns.

COMMERCIAL RETORTING

Figure 3 shows the sequence of development of a line of commercial retorts, each 150 ft. x 300 ft. (45 x 90 m) in cross-section, by 700 ft. (210 m) in height. We plan to use a modification of sublevel caving as a means to rubblize the 700 ft. (210 m) high retorts. A series of sublevels, about 100 ft. (30 m) apart, will be used to achieve uniform rubblization. Sublevel drifts are seen in the development stage on the extreme left side of figure 5. The next retort shows the achievement of rubblization in the top level, followed by various stages of development in succeeding lower levels. About half of the shale to be removed will come from the drifts and slots required for development of each level. The other half will be removed by drawing each of the levels to loosen up the shale and provide more uniform distribution of the void space. The next retort (middle, figure 5) has been

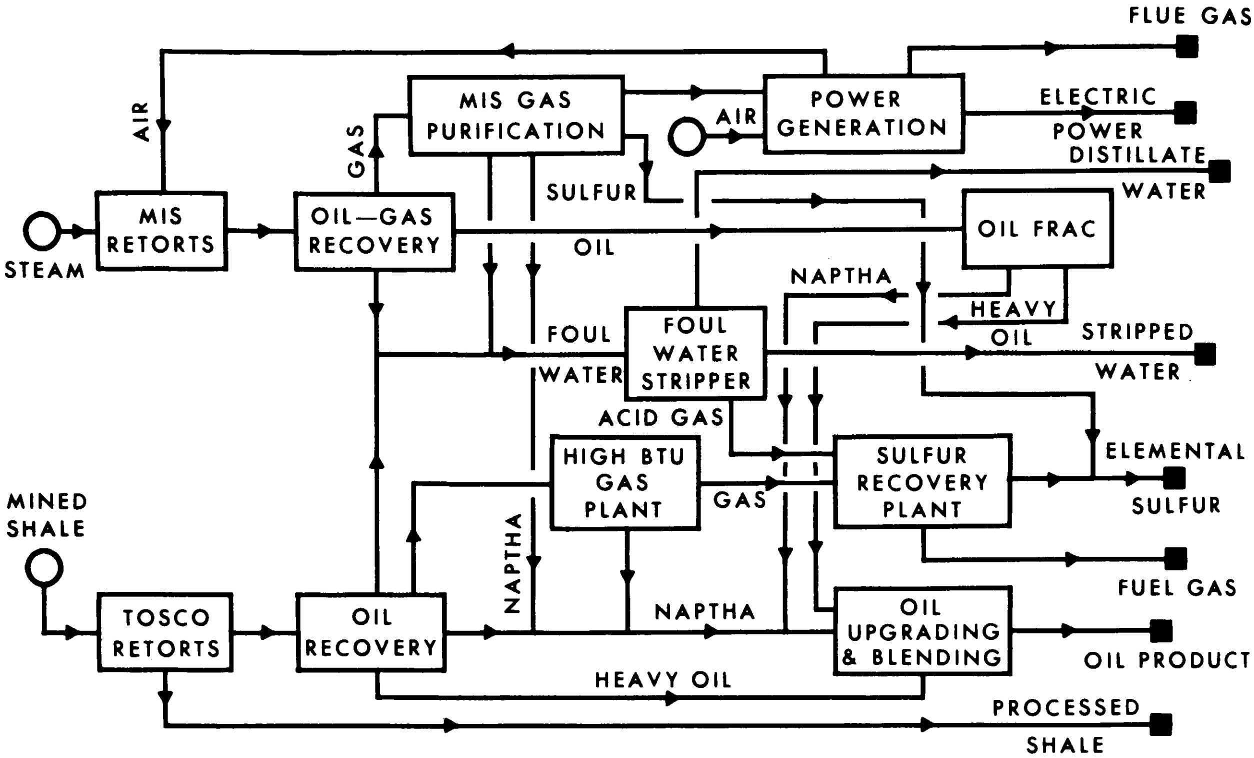

Figure 4. Commercial phase, processing facility.

fully rubblized and will be kept under pressure to prevent gases from leaking from the burning retort to the mine workings. The next one is about half way burned. Finally, the last retort (lower right, figure 5) has been fully retorted and is now filled with spent shale.

Commercial Processing Facility

Figure 4 is a simplified block flow diagram of the Commercial Phase processing facility. The low BTU gas will be purified before it is used to generate electric power. The purification and power generation blocks will be described later. The oil will be fractionated into light and heavy streams before being recombined with products from the surface retorting here shown as Tosco retorts. Pour point depressants will be added to the combined oil as necessary in order to make a pipeline quality oil product.

Gas Purification

Figure 5 depicts the gas purification block on the previous flow diagram. Again, it is a simplified diagram. The low BTU gas is first sent through a multi-stage compressor to compress the gas to about 150 lbs. per sq. inch (1.05 MPa). Condensed light oil and water are sent to the oil recovery section. After extracting fuel for the Tosco retorts, the main body of the low BTU gas, now under 150 lbs. per sq. inch pressure (1.05 MPa), flows through a Stretford unit for removal of sulphur. Purified fuel gas is supplied to conventional gas turbines to generate electric power.

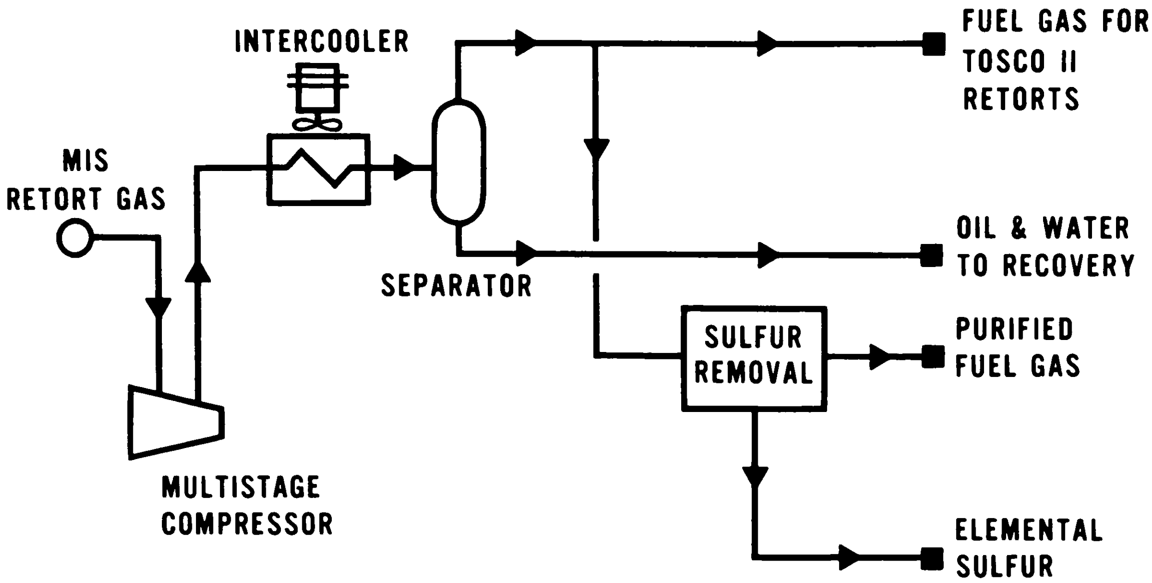

Figure 5. Flow diagram, MIS gas purification plant.

Low BTU Gas Turbine. - Figure 6 shows the low BTU gas turbine which will need to be developed during the modular development phase. Purified fuel gas will flow to a specially designed combustion chamber. This chamber will have to be designed to adequately burn the low flame-speed gas expected to be produced from the modified in situ retorts. The combustor is hooked to a conventional high BTU gas turbine which generates electric power. The reason that a high BTU gas turbine can be used in this process has to do with the amount of air required for burning the low BTU gas. Normally, excess air is supplied to the combustor of a high BTU gas turbine in order to control the temperature so as not to overheat the turbine blades. In the case of low BTU gas, only about half of the air normally required will burn the low BTU gas. No excess air will be needed to temper the flame and the same volume of gas flows into the power turbine. The other half of the air will be sent through an air expander to generate additional electric power before supplying compressed air to the modified in-situ retorts.

USE OF RESOURCE

Figure 7 shows that the 30-year plan described in our detailed development plan will exhaust about one-half the resource on Tract C-a at a production rate of 76,000 barrels (948.8 m^3) per day. The Tosco retorts, together with the gas compression and gas turbine equipment,

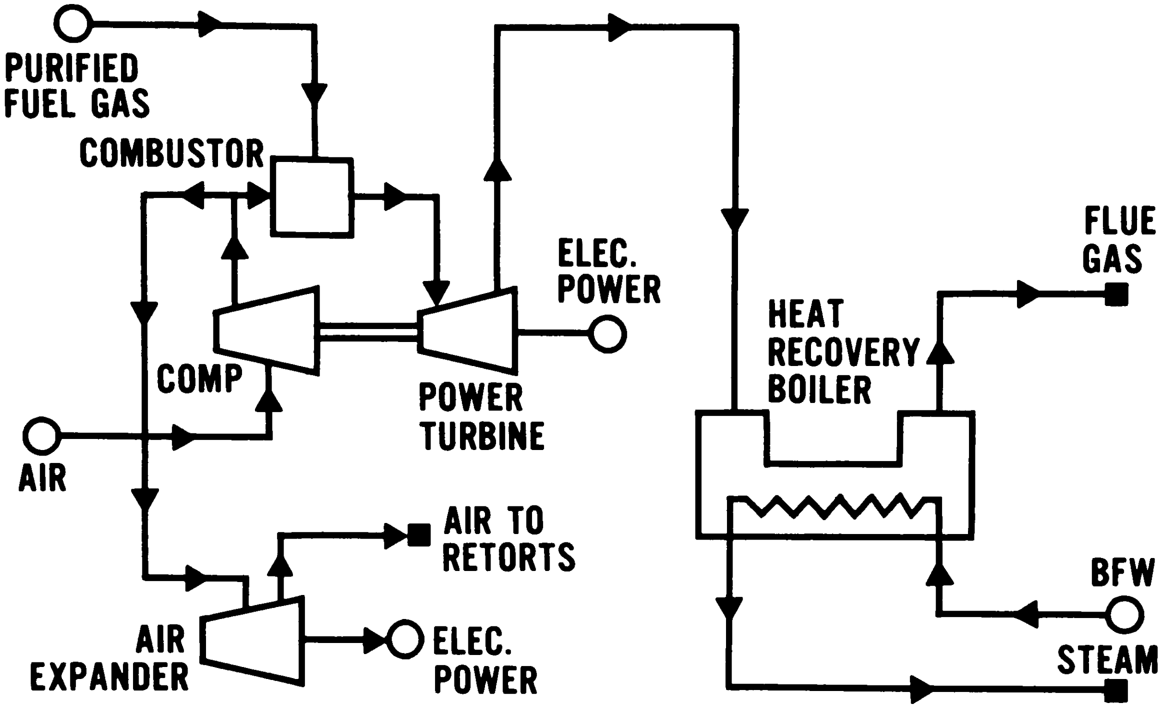

Figure 6. Low BTU gas turbine.

will be located along a ridge pillar not subject to potential subsidence. The spent shale disposal area for the Tosco retorts is located in the southeast portion of the lease. We are currently working on a research program to form slurries of spent shale with cement-like qualities which would be reinjected into the burned out retorts. The object would be to prevent invasion of underground aquifer waters and also to reduce subsidence of the area. In this case, the processed shale disposal area would be reduced in size and, perhaps, not even be needed.

Raw shale, removed during the modular development phase, will be disposed of in a mine stock pile which will be revegetated. We do not plan to do any surface retorting during the modular development phase. A second raw shale disposal area, called the crushed ore stock pile, results from mine development taking place while the surface retorts are being constructed.

ENERGY BALANCES

Table 3 is a comparison of the net energy ratios for making gasoline from petroleum, oil shale and coal. Data shown in this figure (except for the in situ retorting) came from the Colorado Energy Research Institute Report entitled: "Net Energy Analysis"; An Energy Balance Study of Fossil Fuel Resources, April 1976. We used the same methods to calculate net energy ratios from modified

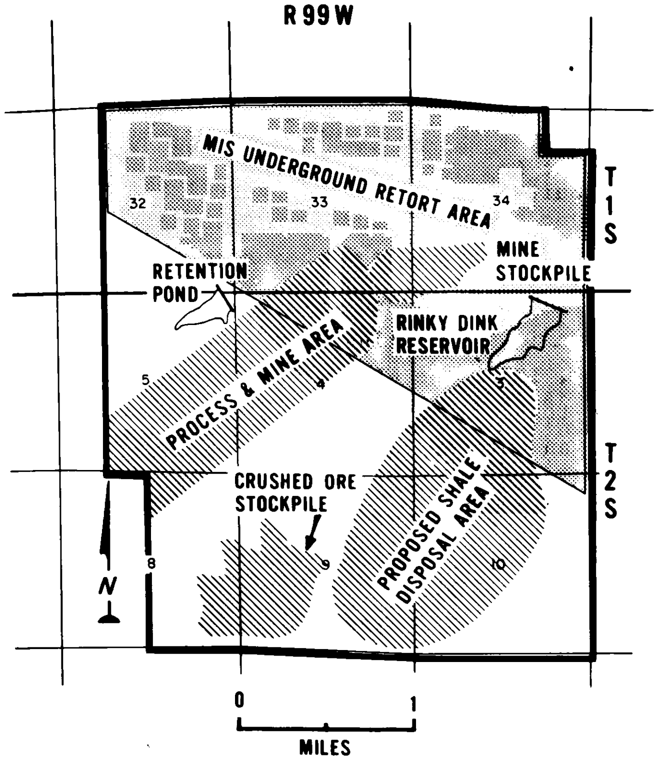

Figure 7. MIS general layout.

in situ retorting with and without surface retorting. Modified in situ retorting has a slightly higher net energy ratio than when combined with surface retorting. However, it is misleading to be guided entirely by the external net energy ratio which is all that is shown here. Process ratio and the resource yield ratios both would favor the combined in situ and surface retorting. Of course, the most important factor to be used in guiding the decision to proceed with commercial operations is projected economics. Our studies indicate that the combination of surface retorting with modified in situ will improve the economics but we must wait for results from our 4-year program before we can make the decision to proceed with commercial development.

Table 3. Net Energy Ratio (Gasoline as Final Product)

Petroleum	9.6
Oil Shale:	
Open pit	6.1
Room and pillar	6.3
Modified in situ	8.5
MIS + surface retorts	6.8
Coal:	
Surface mining	6.4
Underground mining	6.5