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N O T I C E

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SOCONY MOBIL OIL COMPANY, INC.

RESEARCH DEPARTMENT

# M O N T H L Y  P R O G R E S S  M E M O R A N D U M

(Covering July 16 to August 15, 1964)

ANVIL POINTS OIL SHALE RESEARCH CENTER

Rifle, Colorado

August 17, 1964

CONTRIBUTORS:

Mechanical Engineering
Retorting Section
Analytical Laboratory Section
Engineering Analysis

Signed by:

RH Cramer

R. H. Cramer
Program Manager

## NOTICE

The primary object of the Anvil Points Oil Shale Research Center MONTHLY PROGRESS MEMORANDUM is to advise authorized personnel employed by the Participating Parties(1) that various activities are in progress or that certain significant data have been obtained within the Research Center.

These MONTHLY PROGRESS MEMORANDA have been prepared to provide rapid, on-the-spot reporting of research currently in progress at Anvil Points. The conclusions drawn by project personnel are tentative and may be subject to change as work progresses. The PROGRESS MEMORANDA have not been edited in detail.

(1)Socony Mobil Oil Company, Inc. and Humble Oil & Refining Company

MONTHLY PROGRESS MEMORANDUM

(Covering July 16 to August 15, 1964)

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CONFIDENTIAL

MONTHLY PROGRESS MEMORANDUM
Anvil Points Oil Shale Research Center
(Covering July 16 to August 15, 1964)

## I. ADMINISTRATION

Staffing of the Anvil Points Facility by the Research Foundation is almost complete. As of August 14, their personnel on site totaled about 71 out of a projected 76. Three of the four non-technical crews necessary for pilot retort operation and the analytical laboratory technicians were added on or about August 3. The fourth pilot retort operating crew will be added, when necessary, to maintain seven-day shift operation.

Technical staffing by the Participating Parties is complete, with the exception of mining personnel. No definite reporting date has yet been established for the mining engineers.

## II. MECHANICAL ENGINEERING (W. S. Bergen)

Reconstruction of the No. 1 Retort has progressed to the point of testing shale flow from the storage bins through the retort, weigh bin, and spent shale discharge system. Flow control systems for the various gas streams were tested for operability. Final adjustments will be made when the unit is put on stream.

Engineering assignments and responsibilities during this period have included:

1. Field engineering the construction of the No. 1 Retort.
2. Testing of various components of the No. 1 Retort for operability as they were installed.
3. Design and selection of equipment to reconstruct the No. 2 Retort for shale mass flows up to 750 lbs/(Hr)(Ft$^2$).
4. Discussion of initiation of Mechanical Model study program and initial equipment needs.
5. Discussions and establishment of equipment needs for the mist formation study program.
6. Coordination and direction of the rehabilitation of the plant to an operational status.

### Summary

1. The No. 1 Retort is approximately 90% complete with respect to reconstruction. Completed systems include:
   a. The spent shale discharge system.
   b. The stand pipe shale level control system above the retort.
   c. The gas piping and recovery equipment.
   d. Liquid piping and tankage at the retort.
   e. Control systems for gas flows.

2. Equipment tested for operability was included:
   a. The recycle compressor.
   b. The flow control equipment.
   c. The spent shale table feeder.
   d. Spent shale conveyors and weigh bin.
   e. Fresh shale conveyor system.

3. Design of the No. 2 Retort has progressed to the completion of the gas piping drawings, the flow diagram, and the demister recovery equipment. Most of the piping materials have been ordered and received. The mist recovery equipment has also been selected, ordered, and received.

4. Discussions were held with T. C. Lyons to review initial Mechanical Model study needs. No further work has been done in this area.

5. Discussions were held with K. I. Jagel, Jr. concerning mist recovery equipment and testing systems. Selection of test equipment was made and the equipment will be ordered shortly.

6. Daily meetings are being continued between the Research Foundation supervisory staff and W. S. Bergen, R. H. Cramer, and J. E. Lawson to discuss the progress of the completed day's work, the work schedule for the next day, and to iron out manpower and material problems.

Other problems and manpower needs such as shale sampling, housing rehabilitation, plant maintenance, and analytical laboratory needs were also discussed daily at these meetings.

Weekly meetings are also being continued to review over-all progress and problems associated with the rehabilitation and operation of the Research Center.

Discussion

A. Construction of the No. 1 Retort

The shale level control system and the stand pipe above the retort were installed and the control system adjusted. Initial indications are that the Gamm-o-tron radiation level sensing system will control the shale level. At the present time, level variations of five inches in the stand pipe are being experienced but with the installation of the rate control system within the next two weeks this variation should be eliminated.

The spent shale discharge system was completed during this period. This included considerable modification to the table feeder to even out its discharge to the star feeder. Modifications were made to the star feeder and conveyor system to the four-hour spent shale bin to accommodate movement of shale without loss. These changes were effective and shale now moves from the retort to the four-hour weigh bin in a fairly evenly distributed manner.

All gas piping and recovery equipment has been installed. Most of the piping was pre-cut in the shop and its installation proceeded in an orderly manner. Initial tests of the gas piping indicated that it was a tight system.

The liquid piping, sight glasses, two and four hour liquid tanks, and weigh scales for these tanks have all been installed.

The flow control system for various gasses has been checked for controlability. All systems are in an operational condition subject to final adjustment when the unit is put on stream.

B. Testing of Equipment

Tests have been made and are being made of the operation of the Gamm-o-tron. The Gamm-o-tron shale level controller controls the level at the top of the retort by varying the speed of the table feeder at the bottom of the retort. Adjustments have been made in sensitivity of the control equipment and the system now appears fairly stable.

Modifications were needed to even out the discharge flow of the table feeder to the star feeder. The existing system had batched the shale discharge on a revolution bases. Eight arms or rakes were installed under the table feeder to even out the discharge from the bottom of the retort. Tests of the discharge system indicate that approximately 1,300 pounds per hour of fresh shale can be moved through the unit. It will be necessary to revise the table feeder slightly to raise this amount to approximately 1,800 pounds per hour. This change will be made when the unit is emptied of shale.

Early tests of the conveying system from the star feeder to the four-hour bin showed considerable loss of shale from the conveyor due to the change of direction of shale flow from the star feeder to the belt. It was necessary to slow the belt down in order to retain the shale. These changes and the installation of a retaining surge section for the shale on the belt were effective.

The recycle blower was tested and adjustments required made to two of the bearings. These adjustments were effective and no over heating of the bearings is apparent. A flow test for this compressor for capacity is needed and will be made as early as possible.

C. Design of No. 2 Retort

The piping installation drawings for the gas system and recovery equipment have been completed. All piping materials have been ordered and delivered. The use of Victaulic type fittings and piping systems are being employed again for the No. 2 Retort. The recovery systems have been designed and the Buell cyclones and the York demisters have been received. As soon as manpower is available, dismantlement of the No. 2 piping and associated equipment will begin. Repiping of the No. 2 unit will then follow in an orderly manner. The new design condition for this unit will increase shale throughput from 25 tons per day to approximately 100 tons per day. Present plans will incorporate the

use of all existing panel board equipment, the retort as it exists and existing shale handling equipment. All piping and recovery equipment will be discarded and replaced. All blowers and pumps will require revisions for these new flow rates.

D. Mechanical Model Studies

Structural and equipment needs for the Mechanical Model study program were discussed with T. C. Lyons. Tentative site and structures were agreed upon. Action in this matter has been delayed in favor of reactiviation of the No. 1 Retort. Priority will be given to this work as the No. 2 Retort is revised.

E. Mist Formation Study Program

Equipment needs for this program were developed with K. I. Jagel, Jr. Initial equipment has been selected and orders will be placed as soon as possible. This equipment is scheduled to be in operation for early studies of the No. 1 Retort.

F. Plant Rehabilitation

Rehabilitation of the plant facility is continuing. The boiler plant rehabilitation was completed by Research Center personnel during this period at an out-of-pocket cost of about $7,300. This compares with the bid price of $12,000 from Stearns-Roger Corporation. Most of the vehicles needed for the Program's initial needs have been rehabilitated. All housing required for Participating Party personnel have been assigned, rehabilitated and painted. The analytical laboratory will be complete within the next two weeks to coordinate with the operation of the No. 1 Retort. Shop facilities have been rehabilitated and are in operation. The milling machine ordered for the machine shop has been received and will be installed as early as possible. All office equipment needs have been fulfilled and contracts consummated with Olivetti in line with Socony Mobil National Accounts policy.

A copy of the latest PERT diagram is attached.

III. RETORTING SECTION (J. E. Lawson)

A. Staffing

L. J. Skowronek reported on August 5 and Irvin A. Jefcoat reported on August 6, for assignment in the Retorting Section. These assignments complete the proposed engineering manpower requirements for this section.

Duties performed by the above individuals during this period included:

1. Instruction of operating personnel in the use of the Ty-Lab tester and recording of the data obtained.

2. Familiarization of operating personnel with the product tank farms and associated piping and transfer pumps.

3. The preparation of five gallons of shale painted red to be used during the cold operations of Retort No. 1 to determine the average hold-up time for various particle sizes.

4. Familiarization with the facilities at the Anvil Points Research Center with particular emphasis on the No. 1 Retort and its associated equipment.

5. Direction of the activities of the operator crews in cleaning and repair of product tankage systems.

During the previous month a total of nine retort operating personnel and a crusher operator were hired. This crew will be sufficient to support a continuous operation on one retort for five days per week. It is planned to add some three or four additional operators at a later date when it becomes desirable to begin a seven day per week continuous operation.

B. Operating Manual and Operator Training (T. C. Lyons and P. H. Gifford)

The nine men who will make up the retort operating crew reported for work on August 3 and the training program began immediately. A crusher operator who had been hired earlier also participated making a total of 10 trainees. The Operator's Instruction Manual covering the No. 1 Retort has been completed, and it was used as a textbook for the operator training program.

The first two days of the course consisted of classroom instruction dealing with such areas as the general objectives of the project, characteristics of the gas-combustion retort process, safety considerations, and familiarization with instruments and automatic control. The process flow diagram was discussed in detail and special emphasis was placed on explaining the purpose and operating characteristics of the basic pieces of equipment. Start-up and shut-down procedures were outlined as were test run and sampling details. A written examination at the conclusion of the classroom instruction indicated that the lecture series had accomplished its objective.

A laboratory program followed the classroom portion to round out the week. In the laboratory portion, the trainees were exposed to the actual equipment and had an opportunity to operate it wherever it did not conflict with the current construction work. A familiarization course in the slide rule was also included in this phase of the program.

At the conclusion of the week's instruction, the operators (shift leaders) were selected and the helpers were assigned to make up three crews of three men each. These crews are currently being used to inspect and rehabilitate storage tanks, transfer pumps and lines, and other equipment associated with the retort.

Cold circulation of shale in Retort No. 1 was begun toward the end of the week of August 10 and operator training commenced in regard to familiarization with the raw and spent shale handling facilities and data recording.

## C. Shale Analysis and Preparation (C. W. Tyson)

Objective: To determine the quantity and quality of raw shale stockpiles available for the first phase of retorting research.

### 1. Background

#### a. Raw Shale Inventory and Sampling

Seven piles of raw shale have been located at the Anvil Points facilities. The location and description of each pile are shown in Table 1 along with the available Fischer Assay results. All mine run shale piles have to be or will have to be crushed to three-inch minus before representative samples can be obtained. Pile "A", therefore, is the only pile which does not have to be run completely through the crushing and screening facilities.

TABLE 1

Location, Description and Analyses of Raw Shale Stockpiles

| Pile | Location | Shale Size | Estimated Amount, Tons | Fischer Assay gal/ton | Fischer Assay 95% Conf. Limits | Sampling Procedure |
|---|---|---|---|---|---|---|
| A | West of mine road gate | -3", +¼" | ca. 1000 | 27.8 | ±2.1 | Perimeter & 2 diagonal trenches 4 assays run |
| B | Above Crusher Bldg. | -3", +¼" | 225 | 26.3 | ±2.7 | Total pile through Crusher 4 assays run |
| C | Above Crusher Bldg. next to pile "B" | Mine Run | ca. 1400 | 24.8 | ±0.8 | Total pile through Crusher 14 assays run |
| D | East of mine road gate | Mine Run | ca. 1000 | 40 to 50 | -- | Total pile through Crusher |
| E | Behind pile "D" and probably part of it originally | -3", +¼" | 60 | 50.8 | -- | Total pile through Crusher 1 assay run |
| L | East of mine road gate next to pile "D" | Mine Run | ca. 1000(1) | 10 to 15 | -- | Total pile through Crusher if required |
| M | In 7th cross cut of mine | Mine Run | ca. 2000 | 28 to 30 | -- | Total pile through Crusher |
| | | | ca. 6700(1) | | | |

(1) Use of Pile "L" may not be feasible except for solids flow studies.

b. Sample Processing

The flow of shale through the crushing, screening and sampling facilities is described below. A minimum amount of crushing to obtain minus three-inch shale was desired in order to retain the maximum flexibility of shale utilization in the retorting program.

1. The shale entered through the primary crusher which had its jaws set at five inches.
2. The shale was sorted on the primary screens. The oversize (+ 3 inch) was recrushed in the secondary crusher and returned to the primary screen. The fines (- $\frac{1}{4}$ inch) were dumped over the cliff. The proper size (- 3 inch, + $\frac{1}{4}$ inch) was conveyed to the sampler.
3. The sample was taken by cutting across the stream of shale at regular time intervals. The sample was then crushed to minus $\frac{1}{2}$ inch and passed through a seven stage splitter. About 20 pounds of sample was obtained from each 80 tons of shale processed.
4. After sampling, the remaining shale was returned to its original location.

2. Status of Program

Piles "A", "B", "C", and "E" have been processed to three-inch minus and assayed for oil content.

One hundred tons of minus one-inch shale of unknown assay was prepared for cold operation and initial start-up of the retort.

3. Future

Plans are presently being made to process either the pile "D" as a rich blending stock or pile "M" as a retort feed stock. The decision as to which pile will be prepared next will depend on the schedule of heavy equipment availability.

D. Evaluation of Mist Formation and Recovery (K. I. Jagel)

The critical role of oil mist formation and recovery in successfully operating the gas-combustion retort is well-known. In order that these phenomena may be studied in the oil shale research program, several steps are being taken or planned. The first step is the design and purchase of analytical tools to permit determination of liquid concentration and droplet size distribution in the retort vapors and at each point in mist recovery system.

The equipment for obtaining the above determinations has been decided upon and its purchase will be initiated in the near future. The key unit in the proposed scheme is a Cascade jet impactor which, coupled with appropriate sampling tubes, filters, a rotameter, and a rotary vacuum pump, will permit the desired analyses of the mists to be obtained. The total cost of the proposed equipment will be about $2,000.

The above equipment will permit precise determination of the efficiency of the various mist recovery devices that are to be evaluated in the retorting program. In addition to the aspect of mist recovery, some study of the phenomena of mist formation in the process is to be undertaken. To aid in the latter, a theoretical analysis of the operation of mist formation zone has been started. This work is expected to culminate in the design of a test series for execution on the pilot retort which will permit evaluation of the use of nucleation agents in retorting and the effect of gas cooling rate on mist formation and recovery.

## IV. ANALYTICAL LABORATORY SECTION (B. L. Beck)

### Summary

An additional three technicians have joined the analytical laboratory during the past month; this completes the staffing with a supervisor, a chemist, and four laboratory technicians. The technicians are now going through a training program consisting of lectures and extensive laboratory work. About half of the initial tests are ready; all but two or three of them should be ready by August 21. A sample request form has been prepared and the general operation of the laboratory has been published. An improvement in our sample treatment procedure before analysis has significantly increased the results on the Fischer Assays of the first two shale piles sampled.

### Discussion

### A. Personnel

Both of the technical laboratory people (B. L. Beck, Humble and D. Liederman, Socony) have moved their families to Anvil Points and are permanently living here. During the week of August 3rd, R. J. Aldrich, E. G. Bosier, and R. E. Poundstone joined A. W. VanArsdale as laboratory technicians. The staffing of the analytical laboratory with a supervisor, a chemist, and four laboratory technicians is now complete.

### B. Training Program

The technicians were acquainted with the work here at Anvil Points through part-time attendance at the two day lecture portion of the retort operators' training program, and through the training program prepared by the Analytical Section. This latter training program consisted of a day of lectures by the supervisor and chemist followed by a minimum of two weeks of laboratory work becoming familiar with the various tests.

The technical staff from the laboratory participated in the lecture part of the retort operators' training program.

C. Tests

Initially the following tests are being set up in the laboratory:

Fischer Assay
Mineral $CO_2$
Ash Content - Shale
Ignition Loss
Moisture
Carbon/Hydrogen
Nitrogen
Gravity
Viscosity
Ramsbottom Carbon
Water and Sediment in Oil
Pour Point
Ash (Oil)
Distillation
Gas Chromatography
Water in Gas

About half of these tests are ready; with the exception of the Carbon/Hydrogen and Distillation all of them should be ready or nearly ready by August 21. Except for the ASTM tests, procedures are being written for each test as it is being performed in this laboratory.

D. Laboratory Operation

A notegram has been issued describing the operation of the analytical laboratory with regard to incoming samples, analysis request sheets, result reporting, and log books. A blue 8" x 11" form (OSRC-12, LABORATORY ANALYSIS REQUEST) has been designed and prepared that is to be used with all samples submitted to the laboratory. Sample tags and suitable containers are being made available to those submitting samples.

E. Shale Assay

Since the Fischer Assay equipment is not quite ready, the laboratory has been forwarding the samples of various shale piles to the Colorado School of Mines Research Foundation at Golden for assay. A revision in the riffling and sieving procedure before sending the samples has increased the assays to that more representative of the entire sample. The distribution of richness of shale samples with a wide distribution of particle size is much greater than was initially anticipated. The assay of the first two shale piles sampled is greater than had first been reported; the recent revised assays of these piles and those of more recently sampled piles are now believed to be representative of the entire laboratory sample.

## V. ENGINEERING ANALYSES (P. W. Snyder and J. E. Burchfield)

### A. Rehabilitation

Objective: Establish communications link with Socony Mobil Computer Center.

Discussion

The Socony Mobil Engineering Department has completed the programing of our pilot retort material balances and it has been tested satisfactorily on our Teletype. Table 2 shows the result of the material balance calculation for a 24 hour record of the Bureau of Mines ten day demonstration run. About five minutes were required to type in the input and get the balance back. An input data sheet has been prepared and the system is ready to use.

### B. Engineering Analyses

Objective: (1)Establish the retort conditions which need further experimental definition by means of a process variable study with the math model. (2)Develop guidelines for interrelating the economics of mining, crushing, and retorting.

#### 1. Process Variable Study with Math Model

Analysis of the initial process variable runs revealed that the heat balances were running about 90% for calculations on one-inch shale particles and 120% for three-inch particles. One program error was found and corrected; however, there is still a significant heat balance error for calculations on three-inch particles. Heat balance calculations have been incorporated into the program and are being used to locate the source of the error.

Even though the heat balance error is not completely corrected the gross effects of process variables should be significant. Therefore 24 or 30 process variable runs were completed. These runs indicated that water addition will be a significant factor in controlling the off-gas temperature particularly for the larger shale particles. Runs on three-inch particle diameter shale which were inoperable because of excessive off-gas temperatures were operable with 75 pounds water/ton addition and produced off-gas temperatures below 2000 F. These runs were also made operable by increasing retort length from 12 to 20 feet.

The significant effects of the process variables, including the effect of water addition, will be included in correlations to be developed and presented in next month's report.

#### 2. Development of Economic Guidelines

Preliminary economic bases are being prepared to appraise and guide mining, crushing and retorting development. The bases are for general or guideline type economic analyses. The base case will be patterned

TABLE 5/o

029, RUN NO 282 D [illegible] JAN 20 1992

INPUT DATA

A. RUN TIME 2.4000000E+01

B. CHARGE MATERIALS

| | | | | | |
|---|---|---|---|---|---|
| RS | 1.2315000E+01 | WRS | 1.0000000E+02 | CLRS | 1.0000000E-01 |
| PA | 2.0000000E+01 | CRS | 2.0000000E-02 | CCRS | 1.0700000E-01 |
| ASRS | 6.7000000E-01 | CRS | 1.7100000E-01 | HRS | 1.7900000E-02 |
| U | 0.0000000E 00 | | | | |
| A | 1.5900000E+01 | WA | 3.0000000E-02 | | |

C. PRODUCTS

| | | | | | |
|---|---|---|---|---|---|
| SS | 9.9860000E+03 | WSS | 5.9000000E-03 | | |
| CLSS | 5.0000000E-02 | CSS | 1.0000000E-03 | CCSS | 1.5900000E-01 |
| ASSS | 6.2400000E-01 | CSS | 5.0000000E-02 | HSS | 1.9000000E-03 |
| L | 1.5160000E+03 | WL | 1.4900000E-01 | CLL | 8.5100000E-01 |
| CCL | 8.3700000E-01 | HCL | 1.1200000E-01 | BCL | 7.7600000E+00 |
| G | 2.4200000E+01 | WG | 6.9000000E+00 | CG | 1.0000000E-01 |
| HHG | 4.2000000E+00 | CCG | 4.0000000E+00 | CHG | 4.0000000E+00 |
| CCCG | 2.7400000E+01 | HG | 5.0900000E+01 | CC | 1.2000000E+01 |
| HG | 7.9200000E-01 | | | | |

CALCULATIONS

A. MATERIALS IN, lbs

| | | | | | |
|---|---|---|---|---|---|
| WH($H_2O$) | 2.2055000E+02 | CH (C) | 2.0000000E+03 | HH ($H_2$) | 2.1000000E+02 |
| OH($O_2$) | 2.0000000E+03 | ASH(Ash) | 8.2570000E+03 | HH(Total) | 1.8960000E+04 |

B. MATERIALS OUT, lbs

| | | | | | |
|---|---|---|---|---|---|
| BS($Z_n$) | 3.0700000E+01 | WO($H_2O$) | 4.7700000E+02 | | |
| CO ($CO$) | 1.9900000E+03 | HO ($H_2$) | 2.3400000E+02 | CO ($O_2$) | 2.2000000E+03 |
| ASO(Ash) | 7.8500000E+03 | HO(Total) | 1.3700000E+04 | | |

C. YIELDS

| | | | | | |
|---|---|---|---|---|---|
| | | By Gas | | Carbonate Decomp, % | |
| Dry Feed FAY | 9.8800000E-01 | GY dry/ft | 5.0200000E+03 | CD | 2.7500000E+01 |
| Water, g/ft WY | 8.8000000E+00 | CL dry/ft | 6.7700000E+02 | | |

D. MATERIAL BALANCES, Fraction Material Out / Material In

| | | | | | |
|---|---|---|---|---|---|
| Solvent CVHB | 9.8800000E-01 | CHB ($C$) | 9.8700000E-01 | HHB ($H_2$) | 1.0000000E+00 |
| Ash ACHB | 9.8100000E-01 | CHB ($O_2$) | 1.0000000E+00 | | |

END OF RUN

after a general industry when necessary. Restricted [illegible] or Humble data will not be used and refining considerations will be maintained. Our base case will use coking to produce a pumpable synthetic crude. Bureau of Mines coking data will be used. The additional bases as developed to date are shown below. These bases are under review currently and some changes or additions are expected.

a. Plant

The plant as envisioned in the base case will have a mining, crushing, retorting and coking complex located at the mine site. 84,000 ton/day of 30 gal/ton oil shale will be mined.

b. Products and Disposition

The coker products and approximate yields are as follows:

| Stream | Wt. % | Vol. % |
|---|---|---|
| Shale Oil (Coker Feed) | 100.0 | 100.0 |
| $C_2$ and Minus | 3.6 | 4.9(1) |
| $C_3$ | 1.6 | 2.9 |
| $C_4$ | 0.9 | 1.4 |
| $C_5$ - 180° F. | 2.9 | 4.1 |
| 180 - 380° F. | 18.5 | 22.1 |
| 380° F. + | 56.1 | 59.0 |
| Coke | 16.4 | 12.8(1) |
| Coker Distillate ($C_4$+) | 78.4 | 86.6 |

(1)FOE bbls

For evaluation purposes a constant volume of 46,900 B/D of coker distillate product will be maintained by purchasing, and charging crude oil to the coker when necessary. The coker distillate will be pipelined as a synthetic crude into the Four Corners or Rangely area.

c. Investments, M$

| | Onsites | Utilities & Offsites | Total |
|---|---|---|---|
| Mining | 8.3 | 3.2 | 11.5 |
| Crushing | 14.4 | 0.6 | 15.0 |
| Retorting - 230#/(Hr)($Ft^2$) Shale Rate | 23.0 | 8.5 | 31.5 |
| 500#/(Hr)($Ft^2$) Shale Rate | 12.5 | 8.5 | 21.0 |
| Coking | 7.5 | 4.7 | 12.2 |
| Total - 230#/(Hr)($Ft^2$) Shale Rate | 53.2 | 17.0 | 70.2 |
| 500#/(Hr)($Ft^2$) Shale Rate | 42.7 | 17.0 | 59.7 |

d. Direct Manpower, Men (Ex Supervision)

| | Operating | Maintenance | Total |
|---|---|---|---|
| Mining | 540 | 115 | 655 |
| Crushing | 54 | 27 | 81 |
| Retorting - 230#/(Hr)(Ft$^2$) | 25 | 27 | 52 |
| 500#/(Hr)(Ft$^2$) | 21 | 25 | 46 |
| Coking | 21 | 45 | 66 |
| Total - 230#/(Hr)(Ft$^2$) | 640 | 214 | 854 |
| 500#/(Hr)(Ft$^2$) | 636 | 212 | 848 |

e. Utilities

| | Mining | Crushing | Retorting | Coking | Total |
|---|---|---|---|---|---|
| Power, MKWHr/D | 150 | 130 | 5.5 | 0.4 | 285.9 |
| Explosives, #/D | 42,000 | -- | -- | -- | 42,000 |
| Cooling Water Makeup, MGPD | -- | -- | -- | 1,500 | 1,500 |
| Boiler Water Makeup, MGPD | -- | -- | -- | 30 | 30 |
| Fuel, MBtu/hr. | -- | -- | -- | 492 | 492 |
| Steam, M#/hr. | -- | -- | -- | 150 | 150 |

f. Operating Costs

| | | |
|---|---|---|
| Labor - Operating Labor $/Hr. | 3.00 | |
| Supervision, % Operating Labor | 10.00 | |
| Benefits, % Direct Labor | 30.0 | |
| Fuel, ¢/MBtu | 25.0 | |
| Electric Power, ¢/KWHr. | 1.0 | |
| Water, Cooling - Investment | M$ = 0.035 x W | (W = MGPD Water Circulation) |
| Power | KWHr/D = 0.8 W | |
| Treating - Investment | M$ = 0.015 (T + 0.02S + 0.014W) | |
| | | T = MGPD Treated Water |
| | | S= M#/Hr. Steam |
| Maintenance, % Investment/Year | | |
| Labor (if not included) | 3.0 | |
| Material | 3.0 | |
| Plant Overhead, % Investment/Year | 1.5 | |
| Insurance and Taxes, % Investment/Year | 1.5 | |
| Miscellaneous Supplies | 1.0 | |

g. Product - Raw Material Value

| | |
|---|---|
| Crude $/B (well-head) | 2.84 |
| Coker Gas, ¢/MBtu | 25.0 |
| Retort Gas, ¢/MBtu | 15.0 |
| Coke, $/Ton | 12.0 |
| Propane, $/B | 2.0 |

h. Taxes, Capital Costs

| | |
|---|---|
| Federal Income Tax | 50% |
| Depletion on $1/Ton oil shale | 15% |
| Depreciation: Sum of years digits | 10% |
| Cost of Capital, DCF | 10% |