

NOTICE

15/06/001/004

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SOCONY MOBIL OIL COMPANY, INC.

RESEARCH DEPARTMENT

MONTHLY PROCESS MEMORANDUM

(Covering August 16 to September 15, 1964)

ANVIL POINTS OIL SHALE RESEARCH CENTER


Rifle, Colorado

September 17, 1964

CONTRIBUTORS:

Mechanical Engineering
Retorting Section
Analytical Laboratory Section
Engineering and Economic Analyses

Signed by:


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 August 16 to September 15, 1964)

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MONTHLY PROGRESS MEMORANDUM
Anvil Points Oil Shale Research Center

(Covering August 16 to September 15, 1964)

I. TECHNICAL ADVISORY COMMITTEE

The second meeting of the Technical Advisory Committee was held September 3 and 4, 1964 at Anvil Points.

The Committee approved the 1964 expense budget of \$910,000 covering the period May 1 to December 31, 1964 which had been presented at the June 30, 1964 meeting. The Committee received and took under advisement the 1965 expense budget of \$1,090,000 covering the period January 1 to November 30, 1965.

Each member of the Participating Parties' professional staff at the Research Center reported to the Committee on his activities - past, present and planned - during the meeting.

The next meeting of the Technical Advisory Committee will be held on October 30, 1964 at the Socony Mobil Building in New York City.

II. ANVIL POINTS OPEN HOUSE

On September 13, 1964, an Open House was held at the Research Center to commemorate the reactivation of the Facility. The Open House was attended by about 500 people, representing Socony Mobil, Humble, the Research Foundation, national, state and local governments, the press and surrounding communities. Secretary of the Interior Udall and his Oil Shale Advisory Board, the Colorado Congressional delegation and Governor Love of Colorado were among the dignitaries present.

III. ADMINISTRATION

Auditors, representing Socony Mobil and Humble, examined the accounts and records of the Research Center as contractually required on August 24 and 25, 1964. The accounts and records were found to be in order.

IV. MECHANICAL ENGINEERING (W. S. Bergen)

The No. 1 Retort was put into operation during this period. Essentially all construction planned for this unit has been completed.

Summary

1. The No. 1 Retort was put into operation August 28. All planned equipment has been installed except the Syntron shale rate controller.

2. All equipment and systems have been tested, adjusted, or revised to insure operability.

3. Design of the No. 2 Retort has progressed to include the liquid piping and the line burner in addition to the systems reported previously. Most materials and equipment have been selected and ordered. Construction is scheduled to start September 21, 1964

4. Design of equipment for the initial Mechanical Model study program is complete. Drafting is in progress and orders have been issued to the shops to relocate an existing steel tower for the models. Materials for construction have been ordered.

5. All initial equipment needs for the most study program have been ordered and partial deliveries have been received.

6. The rehabilitation of the Research Center is about complete. (See PERT schedule of September 14, 1964 attached.)

Discussion

A. Construction and Startup of No. 1 Retort

Considerable effort was put into the completion of the unit and subsequent startup. All instruments and motor valves were adjusted for service conditions. The star feeder on the discharge of the retort was revised and finally discarded in favor of a larger unit. Clinkers and uneven shale feed to the eight-inch feeder proved the need for the twelve-inch feeder that is serving as its replacement.

The table feeder was redesigned to effect a greater discharge rate. The maximum discharge capacity of the existing feeder was unknown until tested. The table feeder will now handle approximately 2,000 pounds per hour of spent shale which is equivalent to a $1200 \text{ lb}/(\text{Hr})(\text{Ft}^2)$ fresh shale mass flow.

A considerable amount of fine dust is formed during the retorting process. The spent shale conveyor was covered with an exhaust system installed. Additional exhaust systems are needed and will be installed.

The liquid product tank piping and pipe heaters outside of the building had deteriorated during the last eight years. The retort operators assisted in its replacement and reinsulation.

The Syntron shale rate control system has not arrived as yet. It is now six weeks overdue. An interim feeder was installed over the Labor Day weekend. This unit is considerably more effective than the Utah unit that it replaced.

Tests are being made by the retort operator staff to determine the effectiveness of the recovery equipment. These results will be reported when the tests are completed.

All systems are operating, permitting a five-day operating schedule. Changes, additions, and repairs are being made during the weekends.

B. Testing of Equipment

The weighing systems for the fresh shale, the spent shale, and the liquid product have all been tested for accuracy. Orifices have been checked by the retort operating staff for calibration.

Startup of the retort is accomplished by the use of the line burner. This unit was tested and adjusted. Its use for the startup is proving to be very effective. Readjustment of this burner has been necessary from time to time. A determination is being made of the cause of the need for readjustments.

Tests were made of the rate of discharge of the table feeder as indicated earlier.

Tests of the Gamm-o-tron shale level indicator-controller show it to be very accurate as a shale level measuring device. Its control function will permit only a small deviation in the shale standpipe above the retort.

The use of sight glasses in the flowing gas stream indicates the effectiveness of the recovery train.

C. No. 2 Retort Redesign

Drafting is about completed for the liquid piping and product tank system. Equipment selected and ordered include the shale level control, all hardware such as thermocouples, pressure gauges, pipe heaters and controllers, insulation, product scales, stainless steel piping and fittings for the line burner, sight flow indicators, and motor valves.

Reconstruction will start September 21 with a complete demolition of all equipment except the retort vessel, the panel board and blowers. Present scheduling will complete the No. 2 Retort by about October 30. Operational testing will begin about November 2.

D. Mechanical Model Studies

Work has begun for the construction of the first Mechanical Model unit. An existing structure will be relocated and wood and plexiglass bins constructed. All materials have been ordered. The first unit will be a non-pressurized system to study flow capacities through pipes and bins.

E. Mist Formation Studies

Equipment has been ordered for the first study using the jet impactor.

F. Research Center Rehabilitation

The plant and facility rehabilitation is complete except for the steam distribution system. Housing still has work requirements in excess of manpower availability.

The plant air and propane systems are now operable. A new air compressor was purchased and installed for the instrument air.

All vehicles required are in working condition and the shops are fully equipped for current needs.

V. RETORTING SECTION (J. L. Lawson)

The primary objective of the Retorting Section during the past month has been the initiation of operation of Retort No. 1. Highlights of these efforts are presented in the following discussion.

Cold circulation of shale in Retort No. 1 was begun in mid-August at the conclusion of the classroom portion of the operator training program. This provided an opportunity to familiarize the operating crews with the raw and spent shale handling facilities and to correct mechanical problems in the system. During this period, the uniformity of shale flow through the retort was checked and found to be satisfactory. In order to check the flow pattern, a 50 pound sample of shale was painted red and charged to the retort through the normal feed system. Thus, any maldistribution of flow in the rotary feeder (gas seal) or in the top of the retort would be included in the overall flow pattern. This tracer procedure was carried out at total shale flow rates of 300 and 600 lb/(Hr)(Ft²).

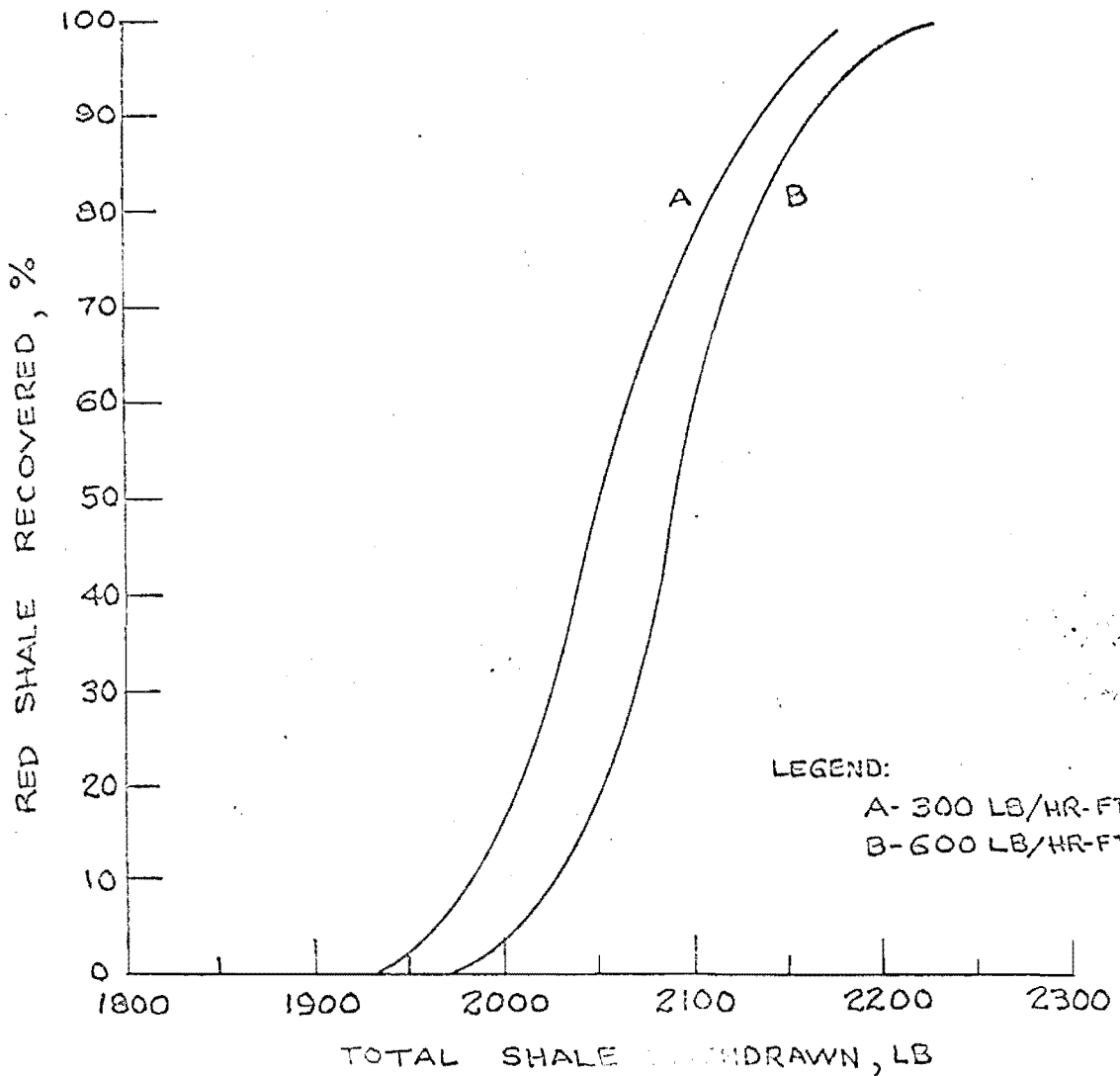
As expected, the smaller particles passed through the retort faster than the larger particles. (The original 50 pound sample was diluted in 350 pounds of unpainted material when it reached the discharge system.) However, for both flow rates, 50 percent of the tracer sample was recovered after roughly 2,000 pounds of shale was withdrawn from the unit. Since this is approximately the inventory of the unit, it was concluded that the entire retort volume was being utilized. The average breakout curves for both flow rates are illustrated in Figure 1. As a result of these studies, it is now possible to calculate the average residence time of various particle sizes at any total flow rate.

Following the completion of the cold circulation studies the unit was fired on August 28 for the first time. Round-the-clock technical coverage began at that time and is continuing at present. During the ensuing hot shakedown runs particular emphasis was placed on evaluating the startup and shutdown procedures. After some minor modifications to the startup procedure, it has been possible to line the unit out from a cold start in a matter of four to six hours. On the other hand, the shutdown procedure is not entirely satisfactory at this time. When the combustion air is turned off during the shutdown sequence, a slight vacuum develops in the retort. As a result, air is drawn into the retort through the gas seals and sustains the burning in the bed. We are currently investigating the use of steam or nitrogen to aid in the shutdown process.

The retort has also been operated under lined-out conditions for periods up to several days. In addition to evaluating the mechanical aspects of the unit, checks were made on the sampling methods, data recording, and material balance procedures. The preliminary material balances have been in the order of 90 percent and the primary source of loss appears to be gas leakage through the top and bottom seals. Corrective measures are being taken to improve the balance.

Figure 1

BREAKOUT CURVES FOR RED-MARKED ONE-INCH
SHALES FLOWING THROUGH THE No. 1
RETORT AT RATES OF 300
AND 600 LB/HR-FT²



A series of demonstration runs are now underway in which we hope to duplicate key runs which were made by the Bureau of Mines. However, exact duplication will not be possible because of minor differences in the air distributor design and the product recovery train. It is believed, however, that the latter factors will not cause sufficient deviation to interfere with reproduction of Bureau of Mines data with reasonable accuracy.

Thus far, in some yield periods, yields approaching 90 percent of Fischer Assay have been achieved under conditions similar to those used by the Bureau of Mines. Hopefully, during the next few days of operating experience, yields in excess of the 90 percent level can be achieved on a consistent basis.

VI. ANALYTICAL LABORATORY SECTION (B. L. Beck)

All of the initial laboratory tests with the exception of distillation, carbon/hydrogen, and water in gas are now in operation. The latter two should be ready in another week; equipment delivery problems have held up the carbon/hydrogen test.

Six Fischer Assay units are now in operation. A first look at the Fischer Assay cross-check program among the Bureau of Mines at Laramie, the Colorado School of Mines Research Foundation at Golden and our laboratory shows good agreement. The complete data on this program will be available in the near future.

For the past two weeks the laboratory has been in operation five days a week 24 hours per day; this coincides with the schedule of the retorting section. All of our effort has gone towards analyzing the samples from the No. 1 Retort. To date the work load has exceeded our capacity. We expect this to be remedied shortly through revision of the analyses required and delivery of some time saving equipment, some of which has been on order for three months. We intend to increase the capacity of two tests - the carbon/hydrogen from one unit to two or three units, and the mineral CO₂ from one unit to two units.

As soon as the procedures, samples, and testing levels out, a quality control program will be added on various tests.

VII. ENGINEERING AND ECONOMIC 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.

A. Engineering Analyses (P. W Snyder)

1. Debugging Program

a. Correction of Heat Balance Error

The heat balance error in the math model of the Gas Combustion Retort, which was discussed in the August report, has been found and corrected.

The sensible heat required when mass was transferred from the shale at its temperature to the gas phase at its temperature was neglected. This resulted in as much as 20 percent error in overall heat balance for calculations with three-inch particles where the temperature difference between the solid phase and the gas phase was the greatest. However this missing heat requirement did not appear to have a major effect on results as shown in Table 1. The only significant effect of correcting this error was to reduce the gas cooling rate in the mist forming zone.

b. Comparison with Bureau Run

The corrected model results still appear to simulate the actual measured Bureau data for Run No. 334E as also shown in Table 1. The calculated carbonate decomposition is still lower than that measured which may be due to the 70° F. lower calculated peak temperature. We suspect that we are using too high of a net heat requirement for the combined carbonate decomposition - metal silicate formation reaction. Since very little is known about the form of silicate produced the estimate net heat required is only approximate.

2. Process Variable Study

Although the process variable runs were made before correcting the heat balance error we are analyzing the results for trends to guide our appraisal of significant process variables. Figures 2 - 4 show the effect of shale rate and particle size on conditions in the mist forming zone, the combustion zone and the shale cooling zone. The significant observations from these analysis are:

a. Effect of Shale Rate

- (1) Kerogen can be completely decomposed in a 12-foot retort through shale rates of 750 lbs/(Hr)(Ft²); in fact a run, made at 2300 lbs/(Hr)(Ft²) resulted in complete decomposition of the kerogen. (Pressure drop would put a severe economic penalty on operating at 2000 lbs/(Hr)(Ft²) rate, as it would be about 80 psi)
- (2) Gas cooling rate increases with increasing shale rate; thus mist formation should improve with increasing shale rate. However, mist impingement on shale particles at high velocity may present a problem.
- (3) Kerogen entering the combustion zone increases with increasing shale rate; this may cause cracking of the oil as it passes out of the particles.
- (4) The oxygen used to burn coke is reduced by increasing shale rate which should reduce the surface temperature of the shale in the combustion zone.
- (5) The spent shale temperature increases only 40° F. in going from 300 to 750 lbs/(Hr)(Ft²).
- (6) Preheat was required to operate at 750 lbs/(Hr)(Ft²).

b. Effect of Shale Size

- (1) The kerogen is completely decomposed when retorting three-inch shale; even at the high throughput rates most of the kerogen is decomposed before the combustion zone.

Table 1

EFFECT OF CORRECTING 10% ERROR IN HEAT BALANCE ON
MATH MODEL RESULTS

Run: Simulation of Bureau of Mines Run No. 334E
 Shale Rate: 290 lbs/(Hr)(Ft²)
 Shale Size: 3/4 inch
 Recycle Rate: 15120 SCF/T
 Air Rate: 4300 SCF/T
 Dilution Gas/Air: 0.35 V/V
 Brine Addition: 15 lbs/T
 Water Reflux: 30 lbs/T

<u>Run</u>	<u>Before Correction</u>	<u>After Correction</u>	<u>Bureau of Mines Experimental Data</u>
<u>Results</u>			
<u>Mist Forming Zone</u>			
Offgas Temperature, °F.	140	139	140
Gas Cooling Rate, °F./Sec.	2500	1500	1300
<u>Combustion Zone (1)</u>			
Kerogen Entering Comb. Zone, %	70	76	--
Peak Shale Temp. °F.	1230	1270	} 1340
Peak Gas Temp. °F.	1290	1220	
Oxygen Used to Burn Coke, %	57	--	--
Length of Comb. Zone, Ft.	0.8	0.8	--
<u>Shale Cooling Zone</u>			
Spent Shale Temperature, °F.	380	365	200 (2)
Carbonates Decomposed	18	16	35
Kerogen in Spent Shale, %	0	0	0.6

(1) Region between air inlet and where 90 percent of oxygen has been consumed.

(2) Surface temperature

MATHEMATICAL SIMULATION
EFFECTS OF PROCESS VARIABLES ON CONDITIONS IN THE MIST FORMING ZONE

Retort Height - 12-16 Ft. Shale Part. Size - 1-3 inches Tot Recycle Gas - 16,000 SCF/T
 Air Inlet to Top - 6-10 Ft. Shale Rate - 300-750 lbs/(Hr)(Ft²) Air Rate - 4000 SCF/T
 Wet Add. & Reflux - 45-90 lbs/T Raw Shale Temp. - 60°F Dil. Gas/Air - 0.4 V/V

Air-Dilution Gas Temp - 120-1800°F

x ——— x 1-inch shale (6 feet from air inlet to top & 45 lbs water/T)
 o - - - o 3-inch shale (10 feet from air inlet to top & 90 lbs water/T)

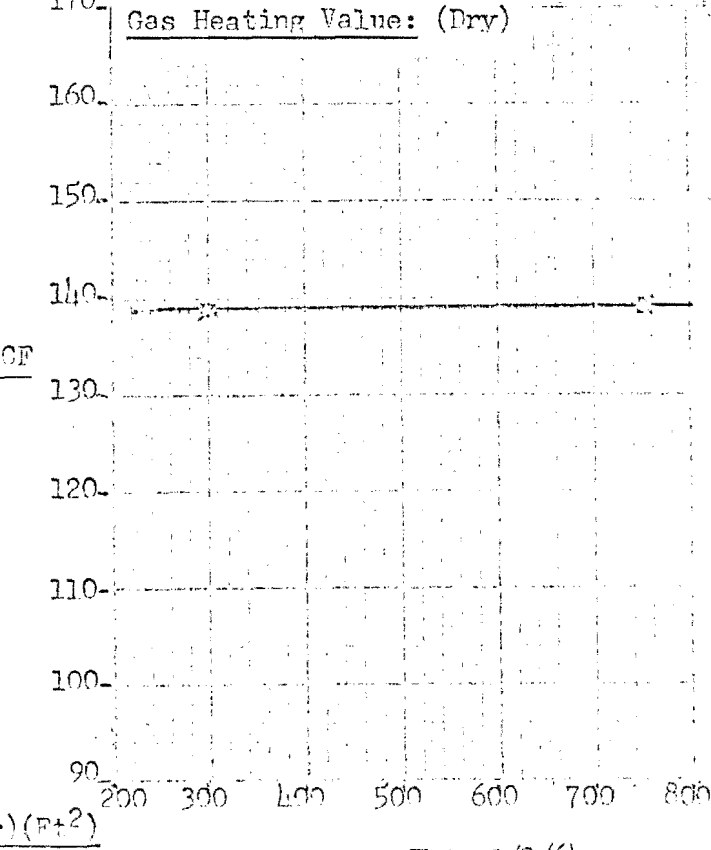
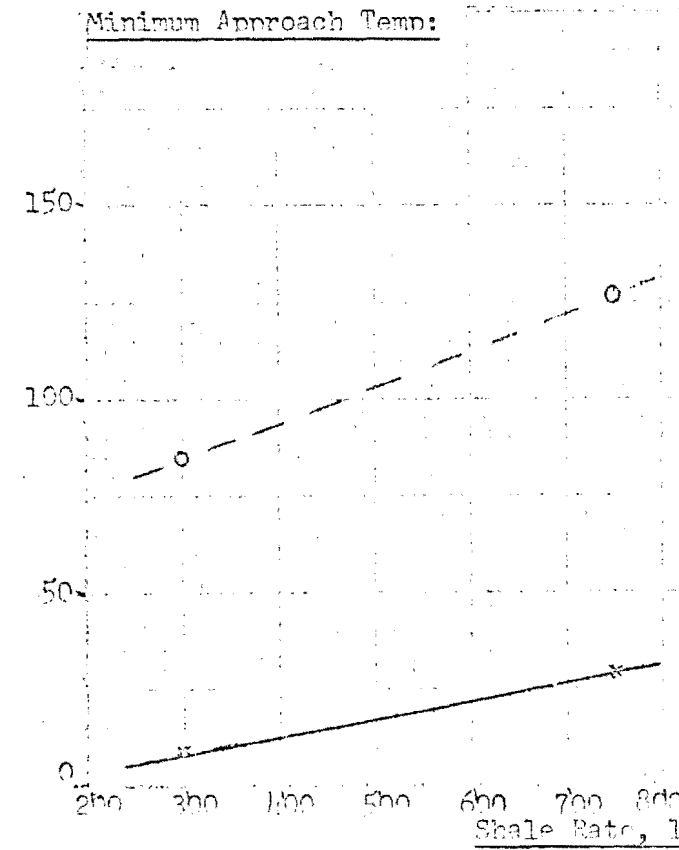
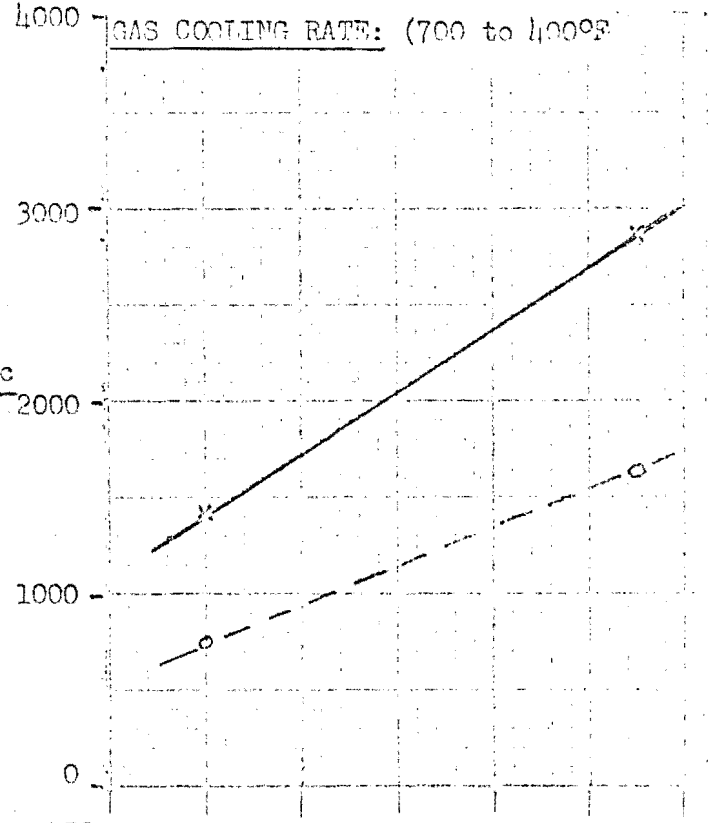
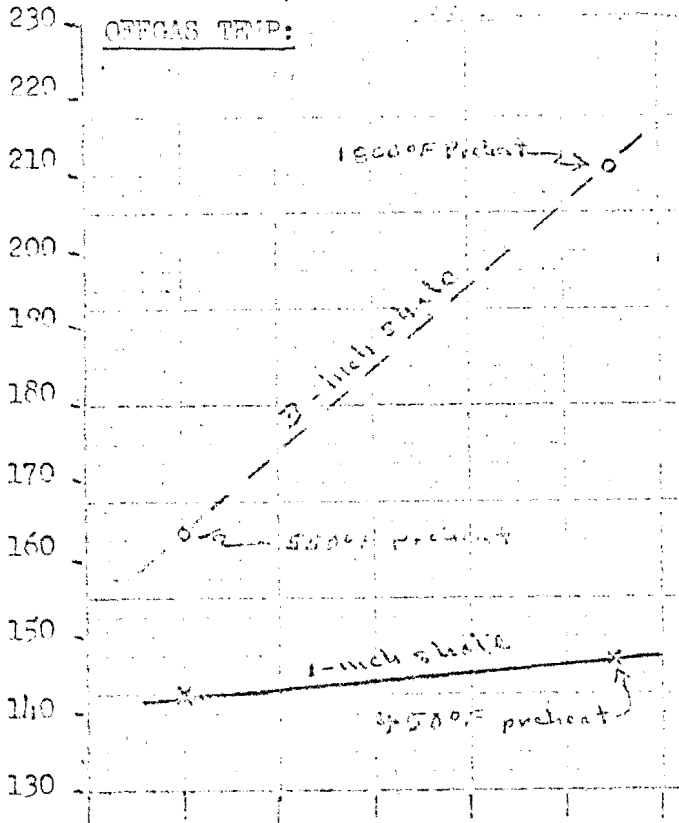


Fig. 3
MATHEMATICAL SIMULATION
EFFECT OF PROCESS VARIABLES ON CONDITIONS IN COMBUSTION ZONE

Potent Height - 12-16 Ft. Shale Part. Size - 1-3 inches Tot Recycle Gas - 16,000 SCF/P
 Air Inlet to Top - 6-10 Ft. Shale Rate - 300-750 lbs/(Hr)(Ft²) Air Rate - 4000 SCF/T
 Water Add. & Reflux - 45-90 lbs/T Raw Shale Temp. - 600°F Dil. Gas/Air - 0.4 V/V

Air-Dilution Gas Temp - 120-1800°F

x ——— x 1-inch shale (6 feet from air inlet to top of 45 lbs water/T)
 o ——— o 3-inch shale (10 feet from air inlet to top of 90 lbs water/T)

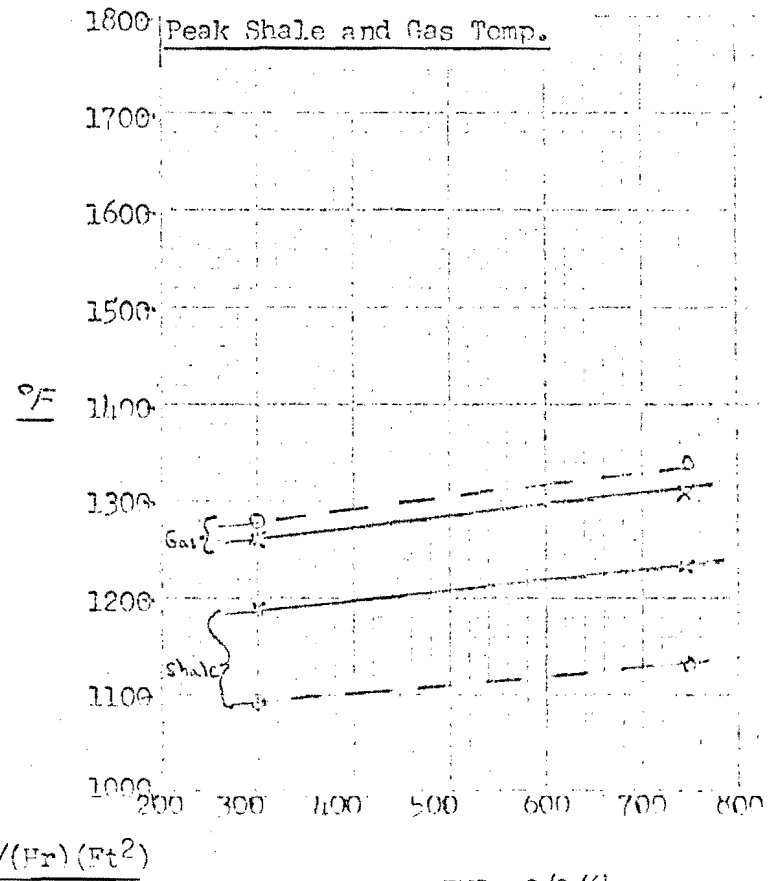
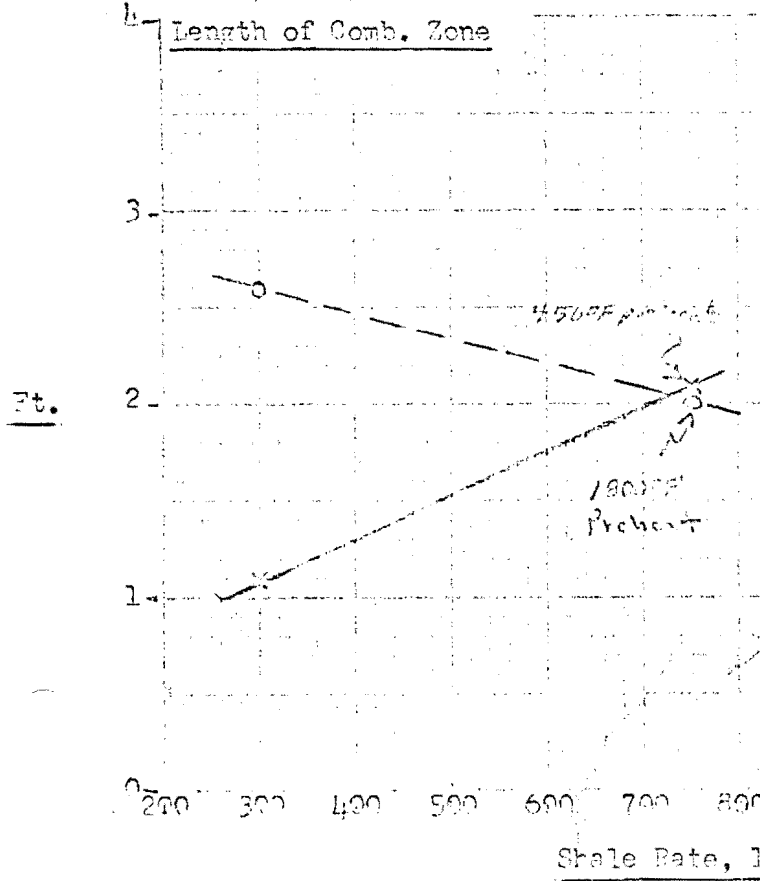
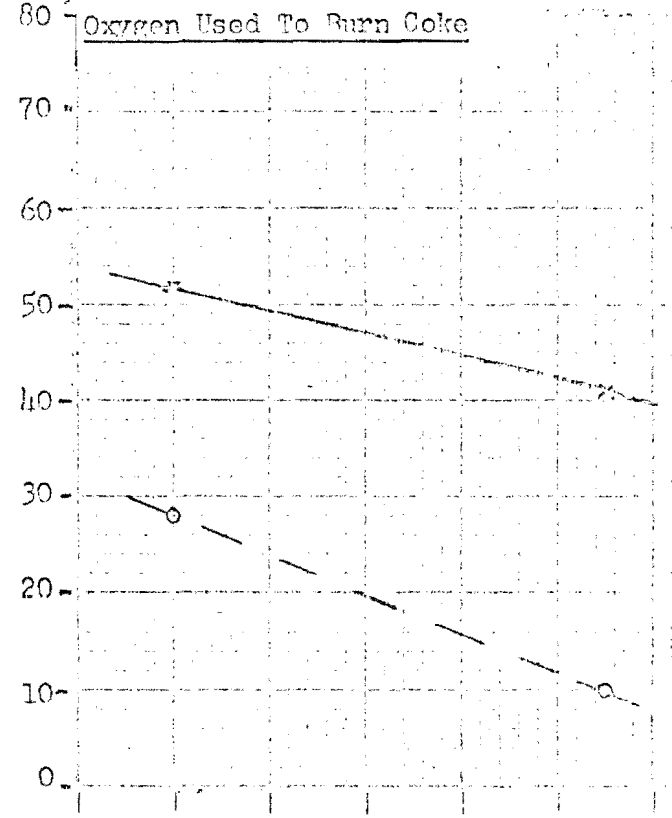
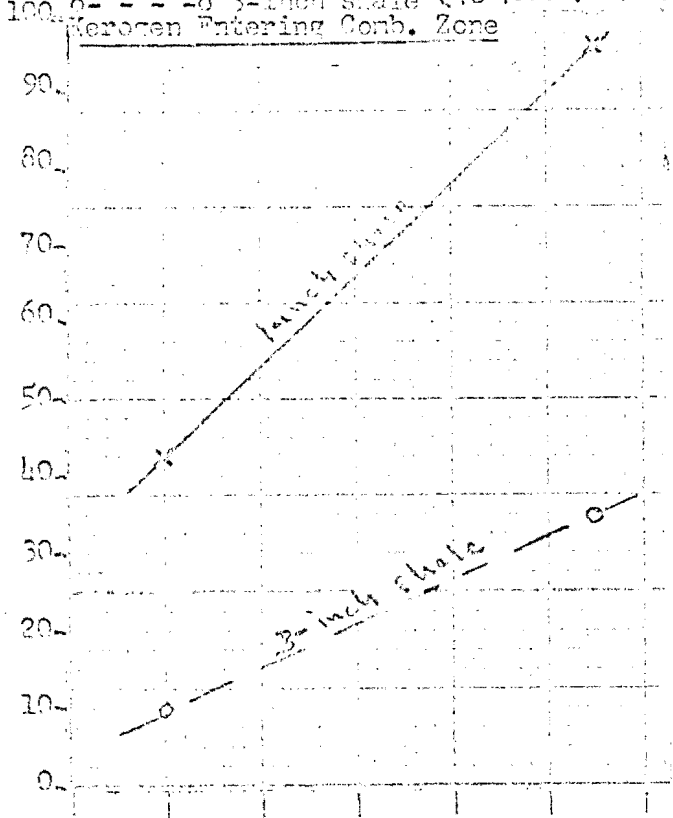
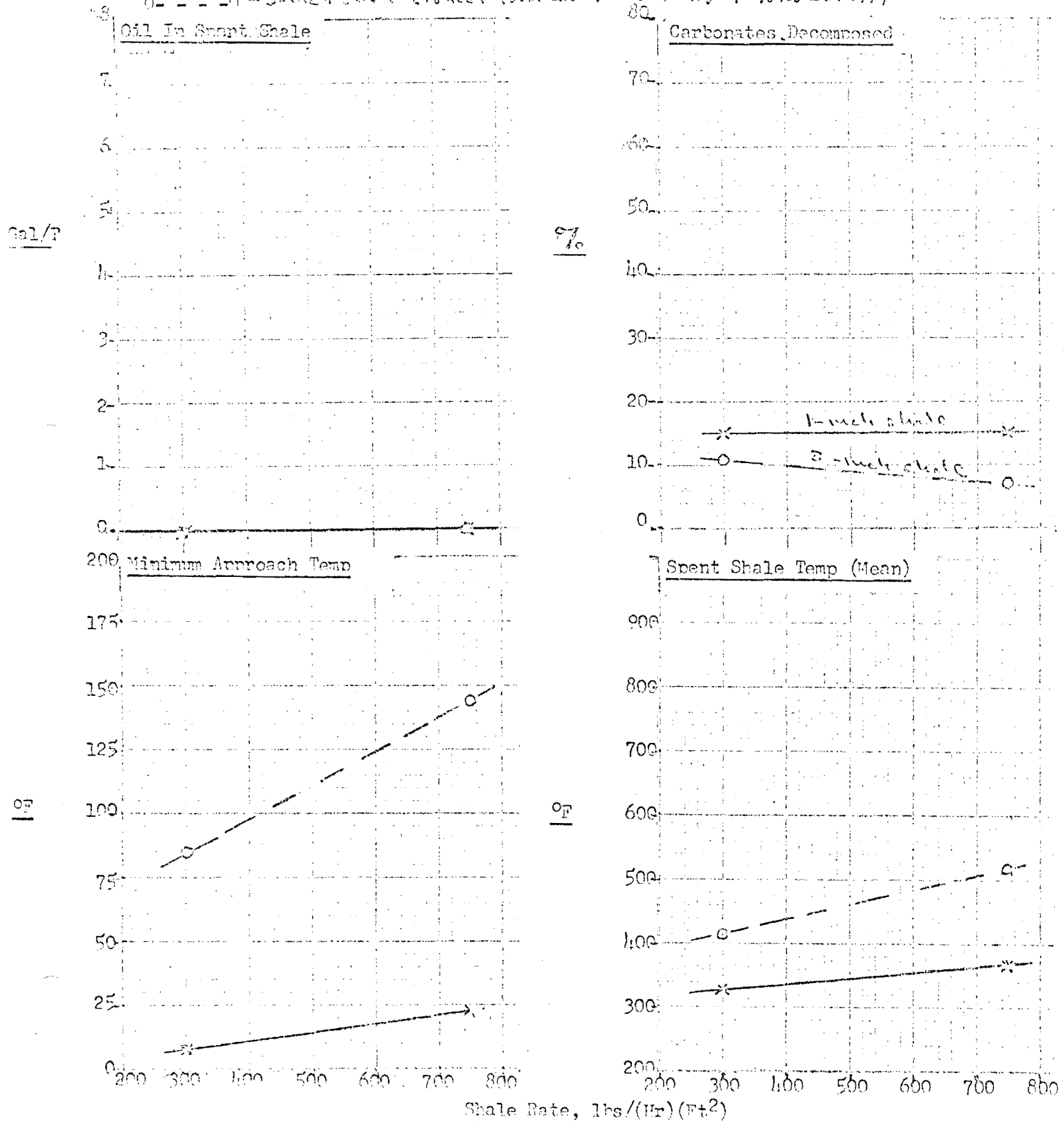


Figure 4
 MATHEMATICAL SIMULATION
 EFFECTS OF PROCESS VARIABLES ON CONDITIONS IN THE SHALE COOLING ZONE

Retort Height - 12-16 Ft. Shale Part. Size - 1-3 Inches Tot Recycle Gas - 16,000 SCF/T
 Air Inlet to Top - 6-10 Ft. Shale Rate - 300-750 lbs/(Hr) (Ft²) Air Rate - 4000 SCF/T
 Wat. Add. & Reflux - 45-20 lbs/T Raw Shale Temp. - 60°F Dil. Gas/Air - 0.4 V/V

Air-Dilution Gas Temp - 120-1800°F

x ——— x - 1-inch shale (6 feet from air inlet to top @ 45 lbs water/T)
 o — — — o - 3-inch shale (10 feet from air inlet to top @ 20 lbs water/T)



(2) Increasing shale size from one to three inches cut the gas cooling rate in the mist forming zone nearly in half and significantly increased offgas temperatures. This will hinder mist formation.

(3) The minimum approach temperatures increased 75 to 100° F. even though retort length was increased from 12 to 16 feet. For optimum heat transfer and temperature profile retort length should be increased to about 20 feet. This increased length should reduce offgas and spent shale temperatures.

(4) Preheat of the air-dilution gas was required to obtain operable solutions for three-inch shale, 550° F. at 300 lbs/(Hr)(Ft²) and 1800° F. at 750 lbs/(Hr)(Ft²). (This excessive preheat at the high rate reduced the length of the combustion zone making it appear that with three-inch shale increasing rate reduces the length of the combustion zone.)

(5) Peak shale temperatures are reduced 100° F. going from one to three inch shale.

(6) Spent shale temperatures are increased about 100° F. to temperatures above 400° F. going from one to three inch shale. Since there is a 100° F. minimum approach temperature for the three-inch shale increasing the length of the bottom zone should reduce the temperature below 400° F.

In summary, retorting one-inch shale at shale rates of 750 lbs/(Hr)(Ft²) appears achievable, if cracking of the shale oil in the combustion zone is not excessive. Processing three-inch shale at high throughput rates does not look achievable at the conditions run because of the excessive preheat required, unless increasing retort length permits operable solutions without excessive preheat.

The remainder of the process variable runs will be analyzed and conditions recommended for operating the 6 T/D at 500 lbs/(Hr)(Ft²).

The following additional studies will be made with the model:

1. Study the effects and develop a mechanism for water refluxing in the top section of the retort.
2. Introduce the slightly higher gas burning rates obtained in experimental studies at Paulsboro.
3. Determine the effect of varying the heat of the carbonate decomposition - metal silicate formation reaction.

B. Development of Economic Guidelines (J. E. Burchfield)

Proposed bases for preliminary economic analyses to guide retort development have been reviewed and revised. As originally proposed, mining, crushing and retorting rates were held constant and shale oil production was varied with changes in process variables. Crude oil was to be purchased and introduced with shale oil into a coking operation to produce constant coker products. These bases created the following problems:

1. Determining coker yields and optimum operating conditions on shale oil versus crude oil.
2. Finding suitable non-proprietary coker correlations.
3. Using product values rather than costs.

Because of these problems, the bases have been modified as follows:

1. Coking has been eliminated.
2. Shale oil production rate is to be held constant by varying mining, crushing and retorting.
3. Depletion allowance is not being used in the current evaluations to avoid the problems associated with the manner in which depletion allowance might be determined. Furthermore depletion allowance will not have a major effect on retorting optima.
4. Mining costs have been approximated from earlier studies updated for technological improvements, to be in the order of $40\phi/\text{Ton}$. More thorough and detailed economic studies are planned on mining later. However, for our purposes at this time this approximate cost of $40\phi/\text{Ton}$ is satisfactory because the cost of mining has only a slight effect on retorting optima as shown later.
5. Crushing costs likewise have been approximated from earlier studies. The cost of crushing is in the order of $18\phi/\text{Ton}$ mined. This cost will also be used in current evaluations.
6. Retorting costs were calculated using the attached revised bases.

With the above changes and the following revised bases for retorting shown in Table 2, costs were calculated for shale oil at various retort mass rates and yields (as percent of Fischer Assay). These costs are shown in Table 2 as the cost difference (from a base of $230 \text{ lbs}/(\text{Hr})(\text{Ft}^2)$ and 90 percent of Fischer Assay yield) versus mass rate and percent yield.

This plot illustrates that mass rate has a significant effect on cost. It also illustrates the degree by which yield may be sacrificed to achieve higher mass rates.

The same plot also shows that the effect of increased mining costs on differential retorting costs is small. However, higher mining cost does increase total shale oil cost by an additional $6.5\phi/\text{Bbl}$ over that shown in Figure 5 when mining cost is $44\phi/\text{Ton}$ instead of $40\phi/\text{Ton}$.

Close cooperation will be maintained with the retorting section to develop the relationship between yield or yield loss and mass rate through the retort. This relationship when combined with the above cost relationships will indicate the optimum mass rate and yield for the bases indicated.

Other factors will also be studied for their effect on costs. These factors include shale particle size, air rate, air preheat, retort length, recirculation gas rate, external line burners and other appropriate variables which later development indicate to be significant.

Table 2

Preliminary Economic Bases for Determining Guidelines for Retort Development
Revision 1

Cost of Shale Oil = $\frac{\text{Cost of Capital} + \text{Operating Costs} - \text{By Product Value}}{\text{Bbls of Shale Oil Recovered}}$

Cost of Mining = 37 - 43¢/Ton

Preliminary Base 40¢/Ton
Depletion Allowance not Credited
No Cost Taken for Land

Cost of Crushing = 17 - 19¢/Ton

Preliminary Base 18¢/Ton

Cost of Retorting
Cost of Capital
General

7% Federal Income Tax Investment Credit
15 Yr. SYD Depreciation
15 Yr. Project Life
10% D.C.F. Return on Investment

Retort Investment*	230 lb/(Hr)(Ft ²), M\$	31.5
	500 lb/(Hr)(Ft ²), M\$	21.0
	800 lb/(Hr)(Ft ²), M\$	17.1

<u>Operating Costs</u>	<u>Operating</u>	<u>Maintenance</u>	<u>Total</u>
Direct Manpower 230 lb/(Hr)(Ft ²), Men	25	27	52
500 lb/(Hr)(Ft ²), Men	21	25	46
800 lb/(Hr)(Ft ²), Men	17	23	40
Power, MKWhr/D			550
Labor Wages, \$/Hr.			3.00
Cost of Electricity, ¢/KWhr.			1.00
Maintenance Material, % of Invest/Yr.			2.5
Plant Overhead, 50% Wages (Oper. + Maint. + Sup'r) + 0.75% Invest/Yr.			
Benefits, 30% of Wages (Oper. + Maint. + Sup'r)			
Insurance and Taxes, % of Invest/Yr.			1.5
Miscellaneous Supplies, 1¢/Ton of Retort Feed			
Escalation, 0.5% of Material/Yr. + 1.0% of Wages/Yr.			
Federal Income Tax, 50%			

By Product Values

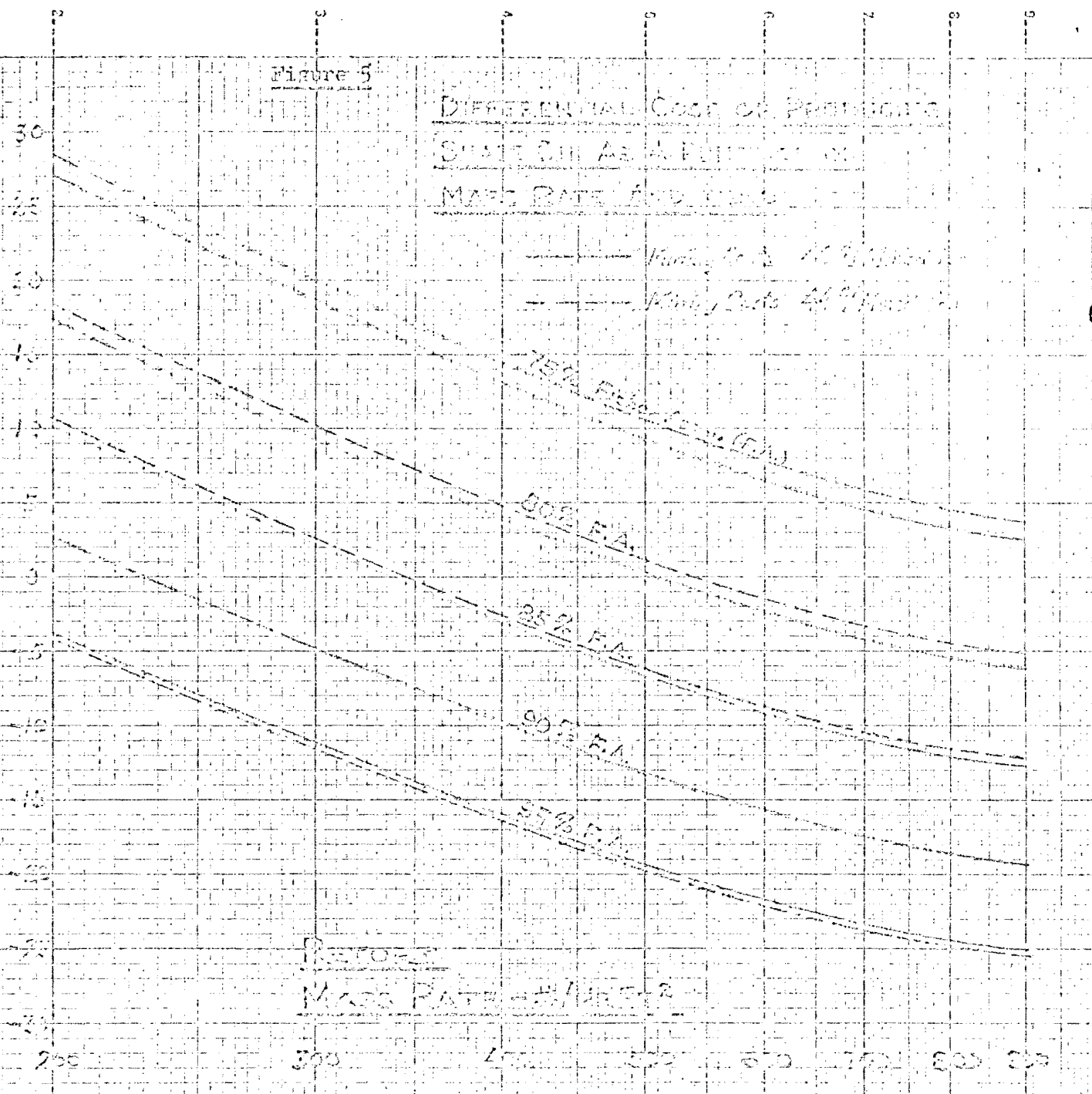
Retort Gas	16¢/M ³ Tu
Raw Shale Fines	No Value

*Mining Rate of 84,000 T/D is used for 90 percent yield on retorting. For higher or lower rates due to yield differences, investment is to be prorated by 0.6 power of the ratio of the mining rate to 84,000 T/D.

Figure 5

DIFFERENTIAL COST OF PRODUCTION
 SUSTAIN AS A FUNCTION OF
 MASS RATE AND FUEL RATE

MASS RATE OF FUEL CONSUMPTION
 PER UNIT OF PRODUCTION



- Process
- Mining Cost 40% of Total
 - 50% of Total
 - 50% of Total
 - 10 Year Project Life, 15 Year S.M. Term
 - 10% DCF Factor
 - 50% Interest
 - No credit for the 5% Fine Product in Crushing
 - Product has value of 15¢/M.T.U.
 - Crushing Cost Proportional to Rate of 12¢/M.T.U.
 - Mining Cost Proportional to Rate of 4¢/M.T.U.

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