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NOTICE

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SOCONY MOBIL OIL COMPANY, INC.

RESEARCH DEPARTMENT

MONTHLY PROGRESS MEMORANDUM
(Covering May 16 to June 15, 1965)

ANVIL POINTS OIL SHALE RESEARCH CENTER

Rifle, Colorado

June 21, 1965

CONTRIBUTORS:

Mining Section
Mechanical Engineering
Retorting Section
Analytical Laboratory Section
Engineering and Economic Analyses

Signed by:

R H Cramer

R. H. Cramer
Program Manager

NOTICE

The primary objective 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., Project Manager

Humble Oil and Refining Company

Continental Oil Company
Pan American Petroleum Corporation
Phillips Petroleum Company
Sinclair Research, Inc.

MONTHLY PROGRESS MEMORANDUM

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MONTHLY PROGRESS MEMORANDUM

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MONTHLY PROGRESS MEMORANDUM
(Covering May 16 to June 15, 1965)

I. MINING SECTION (G. R. Haworth and J. B. Sellers)

A. Planning

The Humble mining engineer, Dr. Barry Sellers, arrived at Anvil Points on June 4. During the past month, much of the time was spent reviewing literature and past practices concerning the Anvil Points Mine.

As part of the Scoping Study for Stage II initial construction requirements, all existing equipment and plant facilities were examined to determine needs for the required mine production. The results of this study indicated that with the exception of haulage trucks the existing facilities were adequate. A considerable amount of overhaul work will be necessary on the equipment, and rehabilitation work has to be done on roads and service facilities. To supplement the haulage truck fleet it is proposed to purchase some light trucks suitable for handling the yard work.

Work is proceeding on the preparation of the Mine Plans for Stage II. In view of the length of time which the mine workings have been standing open and after a thorough examination of roof conditions, a series of alternative mining plans, with recommendations are being prepared. The main purpose being to provide safe working conditions and at the same time keep mining costs at a minimum.

In line with maintaining production and safe working conditions it will be necessary to set up a continuing program of roof and pillar control. Sag pins will have to be installed in the roof, periodic sag readings and stratascope investigations should indicate roof conditions and the nature of any parting of the bedding planes above. It is recommended that further testing be carried out on roof bolt design and installation practices, in the light of recent developments in this field.

B. Production

The second round which was fired in "Charlie" haulageway has been cleaned out and hauled to the crusher plant. The compressors have been installed and work has started on scaling the face and roof bolting in preparation for drilling the third round in "Charlie".

Operating practices are being reviewed from a cost and safety standpoint.

The road to the mine is being graded and the ditches are being cleaned out to prevent washouts.

C. Mining Research

Very little time has been spent on research at this point beyond setting down a few basic ideas on the type of research to be carried on. It is intended to prepare a research program after completion of the Stage II mining plan.

II. MECHANICAL ENGINEERING (W. S. Bergen)

Retort No. 2 was put into operation the evening of May 20. Many changes have been made since in an effort to increase mist recovery efficiency and improve liquid product-water separation. Scoping for Stage II was completed and copies of the memorandum sent to all participating parties.

Summary

Retort No. 2

After startup of Retort No. 2 it became evident that the precipitator was malfunctioning, affecting mist recoveries. This was corrected. The air cooled condenser was also piped in series and ahead of the precipitator to increase the recovery system efficiency potential. Problems have also occurred in separating and sampling the water content of the liquid product. This system is being revised to effect a higher degree of separation of water from the oil, and sampling procedures changed.

Changes were also made to the gas takeoff product to minimize the effect of the large void volume above the shale bed.

The air distributors appear to be effective in producing flat temperature profiles.

Stage II Scoping

Scoping for Stage II was completed. Three development plans were projected. Plan I was to develop Stage II facilities by November 1, 1965 but found to impose a January 15, 1966 completion date (authorization required to proceed by July 15). Plan II will complete designs and order long range delivery equipment by November 1, 1965. Construction will begin after that date. Plan III schedules design and construction to start after November 1, 1965.

It is our recommendation to adopt the Plan III program. Details and reasoning are in the discussion of this report and the special memorandum forwarded to Technical Advisory Committee Members.

Discussion

1. Retort No. 2

Since starting operation of Retort No. 2, it has become apparent that operational problems still exist in

a. Recovery equipment efficiency
b. Oil and water separation in the liquid product
c. Continuity of shale flow to the unit
d. Gas metering

All systems have been altered and improved. Some problems are still to be solved.

The electrostatic precipitator was shorting out in service when Retort No. 2 began operation. A Research Cottrell service technician was flown to Rifle and the problems finally corrected. It is now operating at expected efficiencies.

Throughputs of gas to the precipitator were approximately 2,000 ACFM. The efficiency at this rate is 90%. To raise this efficiency, piping changes were made to the bypass gas line to reroute its passage around the low pressure recovery equipment. At the 500 lbs/(hr)(ft^2) shale mass rate, the efficiency of the precipitator should now be 98% plus.

The air cooled condenser was repiped to be in series with the precipitator. Approximately 40 - 50 pounds of water-oil mixture per ton of shale is being collected from the air cooled condenser.

The recovery train now appears to be operationally efficient. Plans are to bypass the air cooled condenser at an early date. Data will also be available shortly with a breakdown of oil and water recoveries from

a. The Surge drum, cyclone, demister combination
b. The air cooled condenser
c. The precipitator

With the incorporation of the air cooled condenser in the recovery train, problems have occurred in separating the large amount of water make from the oil. The product from the condenser is now pumped continuously to the decanter. This emulsifies the mixture preventing good decanting operation. Changes have been made to the decanter and its efficiency has improved greatly. However, it will be necessary to decant the condenser effluent prior to pumping if further improvement is to be obtained. This design is in progress.

Sampling of Tank D-3 has been a problem due to the large amounts of water collected. The stirrer appears to adequately mix the product. A special test was made of the product during one pump-down to test the water concentration at 200 pound intervals. This was compared with the normal sample taken during the pump-down. This test resulted in a change of the sampling procedure. A continuous stream sample is now obtained during the D-3 pump-down.

Liquid decanting of the product from the precipitator will also be studied to improve the procedure.

Shale flow controls have been revised to upgrade its reliability of operation. The raw shale dumping mechanism at the Richardson actuates approximately 300 times daily. Problems have generated with the probe occasionally preventing the dumping of shale to the Syntron. A second probe has been installed paralleling the first probe. Either probe will actuate the dump mechanism. An alarm has also been installed in this system. It will function if the dump gate does not open within 30 seconds after it is electrically actuated.

Changes will also be made to the roll feed discharging retorted shale. Overriding maximum and minimum settings will be imposed on the system. These changes should insure shale flow continuity short of a drive failure.

Gas metering equipment was ordered and installed on the last shut-down. A Rootsmeter #38M125 was purchased. Precalibrated meter accuracy is 99.78% at 3,700 CFH and 100.20% at 38,000 CFH. The vent and all air orifices are to be calibrated.

The raw shale sampling system has been changed. Sampling time was changed from two to one minute intervals. Breakers in the sample crusher were also replaced. A bolt in the crusher casing had broken out and was replaced. This bolt opening permitted crushed dust to escape from the system.

The Utah feeders are failing under the high throughput service. Repairs are being made to revitalize these units. The effectiveness of the repairs will be determined in service.

The Toledo scale to weigh spent shale has been partially delivered. It will be installed when all parts on are site.

The void volume above the shale bed in the retort is variable from 5 to 14 feet. At the lower bed heights, a large amount of wall is exposed permitting condensation or mist agglomeration on this surface. Internal extensions were added to the gas drawoff pipes at the top of the retort. These extensions pick up the retort offgas about 18 inches above the top of the bed. The extended drawoff chutes should prevent or minimize this problem.

The retort was shut down June 14 for repairs. Inspection of the retort showed a clinker on the south wall extending to the center distributor and across the full bed width. A partial clinker had formed in the NE corner of the wall distributor blocking two ports.

The remaining ports on all air distributors were free from debris or buildup.

A considerable amount of oil and coke was found in the recycle gas distributor. Many ports were plugged or partially plugged - mostly in the north half. The distributor was cleared of coke and all ports opened. An inspection will be made on the next shutdown to ascertain if there is a recurring condition.

The retort wall aside from the clinker was clean.

No inspection was made of the precipitator.

Facilities to meter air into the recycle gas piping were added.

B. Stage II Scoping

The Scoping Study for Stage II was completed.

A special memorandum titled "Scoping Study for Stage II Initial Construction Requirements" was sent to all participants on June 1, 1965. The following are the conclusions and recommendations of this report.

1. Mining - Crushing - Retorting - Plant Facilities

Existing mining, crushing, retorting, and plant facilities are adequate to support the Stage II program. Extensive revisions and repairs will be required but nothing of a serious nature. A new transformer is needed for the recycle blower on Retort No. 3.

The mine will be rehabilitated and a mining plan submitted to the U. S. Bureau of Mines for approval. Much of the existing mining equipment will be utilized.

The crushers will be reconditioned for full time operation. Preliminary tests have shown the crushing plant capacity to exceed retort needs.

The retort shell, its structure, and controls are in excellent condition and will be put into operation with a minimum of cost. Blowers, piping, pumps, recovery equipment and retort internals will be replaced.

A review of the tank farm indicates storage capacity adequate for 30 days full operation. Means of disposing of product will have to be found. In previous operations, many communities were given this oil for road surfacing programs. This may be a feasible method of disposal.

2. Planning of Construction

The PERT diagram for Plan I shows that the November 1, 1965 completion data for construction cannot be met. The earliest possible date for the completed retorting, mining and crushing plant construction would be January 15, 1966 even if approval to proceed were given by July 15, 1965. Plan I now represents the shortest design and construction time from July 15.

Plan II and III are as originally projected.

In all cases, it will be necessary to prepare the mine road and mine water supply by September 20, 1965 with an expenditure of $38,000.

Costs for the three plans are as follows:

		Plan I	Plan II	Plan III
Decision Required By:		7-15-65	7-15-65	7-15-65
Complete Facilities By:		1-15-66	3-7-66	5-1-66
Program Time Remaining After Completion of Construction (1)		15 1/2 mo.	14 mo.	12 mo.
Total Expenditures or Committments for the Stage II Program Construction				
Retort A	7-1-65 to 11-1-65	$ 521	$ 287	$ 38
	11-1-65 to Completion Date	150	414	663
	Total	$ 671	$ 701	$ 701
Retort B	7-1-65 to 11-1-65	558	304	38
	11-1-65 to Completion Date	155	439	705
	Total	$ 713	$ 743	$ 743

(1) Sufficient time and money should be available to complete Stage II, even if Plan III is selected.

Construction will be contracted on a cost-plus basis as would drafting, engineering, crushing plant and plant electrical requirements. A $30,000 penalty has been included in Plan II and Plan III for winter time construction.

Plant labor will be used for most of the mining rehabilitation.

3. Recommendations

We recommend that Plan III be implemented.

Plan III has several advantages over Plan I and II. Much of the present experimental program will not be completed until late summer. Decisions resulting from these experimental programs will have a direct bearing on shale feed and discharge systems and the retort itself. Design criteria for Plan I must be developed by August 13, Plan II by September 3 and Plan III by November 26. Plan III permits completion of experimental programs before designs are required.

Plan I and Plan II require a considerable cash investment prior to authorization of Stage II The PERT shows a two month time advantage of Plan II over Plan III at a cost risk of $249,000 during Stage I. It is possible to narrow the time differential between Plan III and II to five weeks if authorization were given three weeks before Stage II is authorized. The cash risk would be small in comparison to the gain in time.

Both Plan II and Plan III contemplate winter time construction with no relative advantage for either. Plan I is best from a construction weather viewpoint but risks $521,000 during Stage I.

Plan I and Plan II will impose a heavy additional work load upon our engineering personnel at a time when the experimental program is at its height. Plan III will alleviate this condition.

For these reasons, we recommend Plan III for the establishment of Stage II.

III. RETORTING SECTION (J. E. Lawson)

A. Retorting Operation

1. Retort No. 1

Demonstration runs at a 600 lbs/(hr)(ft^2) rate using 1/4 to 3/4-inch shale have been completed on Retort No. 1 with the results shown on Table 1. The yields were calculated on a raw shale basis, with one exception. The yields from this series are surprisingly low (85.6% FA) which makes us suspect that the large void volume above the shale bed (6 feet of shale above the air distribution in a 9 foot retort) may have adversely affected mist product take-off. This work may have to be repeated after mechanical changes to the unit.

Demonstration runs were attempted at a 300 lb/(hr)(ft^2) rate using 3/4 to 1 1/2-inch shale at the nominal conditions of BOM Run 334E in Retort No. 1, as shown on Table 1. The low yields and skewed temperature profiles indicated internal refluxing. Brine addition was attemped on two occasions (Runs 602 and 604) without alleviating the refluxing. Inspection of the unit upon shutdown revealed the presence of a large clinker covering one half the cross sectional area of the retort, located about three feet below the top of the shale bed. This clinker varied from six inches to one foot in thickness. It is our best judgment that the clinker was formed during the transition from 1/4 to 3/4-inch to 3/4 to 1 1/2-inch shale feed. Because of the clinker and the possible effect of void volume at the top of the retort, this work will have to be repeated.

2. Retort No. 2

a. Current Results

Recently a series of runs at identical conditions have been accomplished at Retort No. 2 in order to determine the problems which exist in measurement techniques and operating procedures. Results from a preliminary analysis of these runs are presented in Table 2 attached. These data indicate an average yield of 85.5% at these operating conditions. Accounting of water in the precipitator liquid product for Runs 614 to 623 was not proper since it was assumed the oil was dry. The effect of this factor on the above series could be to lower yield of Run 623 by at most 4% which would lower the average yield by at most 1%.

Detailed analyses of these data is still being made. However, some areas of interest are immediately apparent.

(1) Ash balance is less than satisfactory. As mentioned elsewhere in this report, it is believed that the inaccuracy is due to poor spent shale weight accounting and will be materially reduced when the spent shale weigh scale is installed.

(2) Water balances are also not accurate to a desirable degree. Work on this problem is continuing and may result in improved yields and balances.

(3) Although it is not readily apparent from these data, the Fischer Assay of raw shale is somewhat higher than expected. These assays averaged 30 gal/ton RS whereas samples obtained at the crushing plant over the same period averaged about 29 gal/ton RS. This result is believed to be due to inaccurate sampling at the retort. Steps are being taken to improve this situation.

Full analyses of these data may reveal other promising leads for improvement of measurements and operations.

TABLE 1

RETORT NO. 1 DEMONSTRATION RUNS

Run Nos.	596-600	601,603[1]	602,604[1]
Shale Feed Size, inches	1/4 - 3/4	3/4 - 1 1/2	3/4 - 1 1/2
Operating Conditions			
Mass Rate, lb/hr-ft^2	589	295	286
Air Rate, SCF/Ton RS	6070	4330	4460
Recycle Rate SCF/Ton RS	10440	12860	13470
Bed Height, ft	6	6	6
Off Gas Temp., °F	124	189	184
Raw Shale FA, gal/Ton RS	27.3	28.6	29.2
Brine Added, gal/Ton RS	0	0	2.8
Yields and Quantities			
Oil Yield, Vol % RSFA	85.6	85.0	81.2
Gravity, °API	20.7	20.0	20.3
Gas Make, SCF/Ton RS	8050	5440	5390
CO_2 Content, Vol %	27.2	22.0	20.0
Htg. value, BTU/SCF	95	127	148
Spent Shale, wt % RS	77.4	81.5	82.4
Organic Carbon, wt %	1.78	2.40	2.54
FA, gal/Ton	0.0	0.0	0.0
Mineral CO_2 Decomp., %	42.9	22.0	19.8
Balances, %			
Ash, as measured	97.8	99.0	99.7
Overall	100.4	99.7	99.0
Organic Carbon	100.9	95.9	97.1
Basis for Calculation	4 as meas. 1 spent shale	2 as measured	2 as measured

[1] see discussion for comments on large clinker formed between Runs 600 and 601.

TABLE 2

CURRENT RESULTS ON 3/4 TO 1 1/2-INCH SHALE - RETORT NO. 2

Run Nos.	B623	B624	B625	B626	Avg B623-626
Operating Conditions					
Mass Rate, lbs/(hr)(ft^2)	508	511	507	505	508
Air Rate, SCF/Ton RS	5,720	5,700	5,620	5,670	5,680
Recycle Rate, SCF/Ton RS	11,250	11,190	11,200	11,330	11,240
Bed Height, ft	8	8	8	8	8
Offgas Temp., °F	126	127	129	126	127
Raw Shale, FA, gal/ton RS	29.1	31.0	30.2	29.8	30.0
Yields and Quantities					
Oil Yield, Vol % RSFA	88.7	82.8	83.7	86.7	85.5
Gravity, ° API	21.6	21.1	21.0	21.0	21.2
Gas Make, SCF/ton RS	7,260	7,050	7,140	7,240	7,170
CO_2 Content, Vol %	23.7	22.5	23.5	23.2	23.2
Htg. Value, Btu/SCF	110	125	117	120	118
Spent Shale, Wt % RS	79.3	79.0	80.0	80.4	79.7
Organic Carbon, Wt %	2.33	2.56	2.47	2.51	2.47
FA, gal/ton RS	0	0	0	0	0
Mineral CO_2 Decomp., %	34.9	32.9	31.4	32.9	33.0
Balances					
Ash, as measured	94.3	91.0	98.7	94.7	94.7
Overall	100.6	100.0	100.8	101.8	100.8
Organic Carbon	101.1	98.4	100.7	104.1	101.1
Water	125.5	118.3	137.4	146.1	131.8

b. Review of Operations

Retort No. 2 was fired on the 12-8 shift on May 21, and brought on stream at the conditions of Runs 507 - 509, the 500 lbs/(hr)(ft^2) demonstration from Retort No. 1. Initially mechanical difficulties with the Utah shale feeders caused problems; this was cleared up by the night of May 22. Results of the first four runs (B605 - B608) are shown in Table 3. Unit operability was good and temperature profiles reasonably uniform. The high oil product API gravity indicated internal refluxing, probably due to the void volume at the top of the retort (7 feet of shale above the distributor in a 14 foot retort). The unit was shut down on May 26 and the product take-off lines were extended to within six inches of the bottom of the shale feed chute. This change succeeded in reducing the oil product API gravity to a reasonable level and slightly increased yield.

During the period of these tests, the electrostatic precipitator was not adequate to recover product from the recycle gas stream. Therefore, the air cooled condenser was used for product recovery on Runs B605 - B608.

The Toledo spent shale scales, which had been delayed because of tornado damage to the manufacturer's plant, had been promised for shipment May 14. However, to date the entire shipment of parts has not been received. Because of the uncertainties in spent shale weights, all results will be reported on a raw-shale-forced-ash-balance basis until the scales can be installed. At present, the spent shale is weighed on truck scales and the weights used for guidance only.

An inordinate amount of difficulty was encountered on start-up May 27. The unit was shut down and inspected in detail by the technical staff on the night of May 28. No mechanical anomalies were encountered. A detailed account of this inspection is given elsewhere in this report. An improved startup procedure was developed and the unit started up smoothly on the 12-8 shift May 29 under technical supervision.

The unit was operated for Runs B609 - B614 using either the air cooled condenser or the air cooled condenser and electrostatic precipitator in parallel in the recovery system. During this period it became quite evident that the mist recovery system was not functioning adequately. The unit was shut down on June 2 to pipe the air cooled condenser and electrostatic precipitator in series and to reduce the gas volume flowing through the low pressure gas recovery system. These changes succeeded in increasing the mist recovery efficiency. At the same time, the product take-off lines were made adjustable to provide flexibility on bed height.

B620-B621
500
5,300
11,440
8
127
29.0
85.1
20.7
6,700
23.2
113
80.0
2.29
0.0
32.5
92.6
99.9
98.0
RS

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TABLE 3

RECENT RESULTS FROM RETORT NO. 2

Run Nos.	B605-B608	B609-B612	B613	B614	B615	B617-B618	B619
Shale Size, in	←		3/4 to 1 1/2				
Operating Conditions							
Mass Rate, lb/(hr)(ft^2)	498	488	496	500	493	490	498
Air Rate, SCF/T	4,960	5,460	5,350	5,650	5,240	5,370	5,290
Recycle Rate, SCF/T (1)	12,380	13,410	11,400	11,250	11,460	13,400	13,100
Bed Height, ft	7	7	7	7	7	7	8
Offgas Temperature, °F	140-210	162	140	134	129	146	135
Raw Shale FA, gal/T	29.1	30.7	30.1	28.8	30.6	30.0	29.2
Recovery System	A/C Condenser	A/C Condenser and ESP in parallel →			A/C Condenser and ESP in series →		
Yields and Quantities							
Oil Yield, vol % RSFA	79.4	79.9	84.9	83.6	82.0	82.3	83.3
Gravity, ° API	21.4	20.4	20.2	21.2	21.3	22.5	22.6
Gas Make, SCF/T	6,150	6,870	6,890	7,010	6,610	6,850	6,720
CO_2 Content, vol %	21.1	21.7	23.0	22.0	21.8	24.7	24.3
Gross Htg. Value, BTU/SCF	132	120	122	121	92	86	78
Spent Shale, wt % RS	81.4	78.6	79.0	80.4	79.9	79.1	79.0
Organic Carbon, wt %	2.63	2.45	2.47	2.43	2.61	2.43	2.25
FA, gal/ton	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineral CO_2, Decomp. %	27.2	36.1	33.7	30.8	30.5	34.8	35.4
Balances, %							
Ash as Measured	95.0	96.7	88.1	97.0	95.5	94.2	97.7
Overall	99.6	100.2	101.7	100.3	100.6	100.7	99.6
Organic Carbon	94.2	93.9	97.7	99.9	92.8	92.6	89.7
Calculation Basis (2)	RS	RS	RS	RS	RS	RS	RS

(1) Recycle gas reported is the measured recycle only. Measured gas losses from the star feeders are add make as measured. Minimum interference with the veracity of the recycle measurement is expected due

(2) Calculations are on a forced ash balance basis assuming the raw shale rate is more accurately measure shale rate.

The unit was started up on June 3 to undertake a limited study of the effects of recycle gas rate and bed height, starting with Run B615.

The unit was shut down on June 14 to install the Roots Connverville gas flowmeter for calibrating gas orifices and for inspection. During the inspection it was found that parts on the north end of the recycle gas distributor had become plugged, which probably occurred during periods when the electrostatic precipitator was not in service. This may account for the slightly lower temperatures which have consistently been noted on the north side of the unit. It may also account for some of the operating stability problems encountered. Calibration tests of the various orifice meters made during this shutdown are included under a separate topic of this report.

The unit has shown a tendency to form clinkers when shale feed is interrupted. We had had a momentary power interruption and some problems with the Richardson feed system (failure to dump) which have caused feed interruptions.

Recycle gas rate appears to be much more critical than on Retort No. 1. If the recycle gas rate is increased to about 13,000 SCF/T, the product API gravity tends to increase to about 22.5, indicating internal refluxing. If the recycle gas rate is decreased to about 10,000 SCF/T it is difficult to maintain a stable combustion zone and the fire goes out. This has probably been aggravated by recycle gas maldistribution, due to the plugged ports found on June 14.

The offgas temperatures encountered on Retort No. 2 are considerably higher than on Retort No. 1. When bed height was increased from seven to eight feet these temperatures were reduced to an acceptable level. Increasing the bed height to nine feet did not reduce temperatures further. The increase in bed height probably compensates for minor differences in configuration.

Separating water from the oil product has continued to be a problem. Several decanter modifications have been made and none has worked well. When the water-concentrations are measured to be low, yields are generally improved and carbon balances are good. When the water-concentrations are high, the converse is true. Apparently the large amount of water recovered in the air cooled condenser has aggravated the problem. Work is continuing on this item. Some efforts along these lines are reported elsewhere in this memorandum.

In an attempt to improve yield and operability on Retort No. 2 we plan to try injection of about 1% oxygen as air into the recycle gas stream. There are some indications that this will be effective in alleviating incipient recycle gas channeling, because of burning below the combustion zone. This directionally has the tendency to make recycle gas channeling self-correcting rather than self-aggravating.

The recycle gas stream is abnormally dry, due to the large amount of water collected in the air cooled condenser. The lack of moisture in the retort may have a fundamental effect on the water gas shift reaction and on certain combustion reactions. We plan to try operation without the air cooled condenser, if the electrostatic precipitator will adequately recover product with the reduced gas loading. If not, steam injection into the recycle gas stream will be attempted to evaluate the effect of moisture concentration.

B. Retort No. 2 Inspection and Startup Procedure (J. H. Haddad and J. G. Mitchell)

On May 26 the retort was shut down due to clinker formation in the bottom heat-recovery zone and above the air distributors in the south-east corner of the retort. During the subsequent period May 26, 27, and 28 the unit was clinkered two more times on the south side during startup attempts. During this period the following observations and tests were made:

1. The uniformity of shale flow throughout the retort was verified by observing the level of the surface of the shale bed while drawing shale out the bottom of the retort in a normal manner. This test did deviate from normal retort operations due to the fact that the shale inventory throughout the unit during the test was raw shale.

2. The south gas outlet from the top plenum of retort contained considerably more deposits than the north outlet. It also was noted during the previous Runs B605 through B608 that the top south gas outlet was hotter than the north outlet. These factors, plus the fact that clinkers occurred in the south section, caused concern about the combustion-air and recycle gas distribution.

3. Inspection of the air distributor indicated that all orifice ports were open.

4. Inspection of the recycle distributor orifices would have required considerably more down-time. Therefore a smoke bomb test was made on the recycle distributor

with a shale level about one foot above the distributor. Smoke appeared to rise out of all areas of the bed.

It was concluded that special care should be taken in starting up the unit, observing retort temperatures and controlling shale rate very closely. The startup procedure was accordingly revised and the ensuing startup proceeded smoothly. Subsequently, an air distributor skin thermocouple and a combustion zone thermocouple immediately adjacent the air distributor pipes were connected to the temperature recorder.

C. <u>Investigation of Mixing in Retort No. 2 Liquid Product Tank</u> (J. W. Hasz)

A number of liquid product samples were taken at Tank D-3, the main liquid product tank, to determine if the samples obtained by the routine sampling procedure were truly representative of the contents of the tank, particularly with respect to water. The results of these samples are summarized below. Note that two sets of samples were obtained. One set was obtained from the pump discharge as the tank was pumped out, a sample being obtained at increments of 200 pounds weight loss from D-3. The second set of samples was obtained by a thief from the north side, south side, and center of the tank.

Summary of Analyses for Water of Liquid Product in D-3

Sample No.	Product Tank D-3, wt	Water	Sediment
Special 1	1,700	18.2	0.4
2	1,500	18.6	0.4
3	1,300	17.0	0.4
4	1,100	18.1	0.45
5	900	18.7	0.40
6	700	18.6	0.40
7	500	19.0	0.40
8	300	19.4	0.40
9	100	15.6	0.55
North Side - D-3 Thief	--	17.6	2.30
South Side - D-3 Thief	--	18.9	1.70
Center D-3 Thief	--	18.1	1.35

The pump-out samples averaged 18.1% water and the thief samples averaged 18.2% water. The sediment values for the thief samples are higher than those for the pump-out samples. This is believed to be because the thief picked up dirt from the bottom of the tank.

It therefore appears that present liquid product handling procedures are adequate to produce a good mixture in the liquid product tank.

As a result of the study it was decided to continue current procedures and to obtain a composite sample of the tank contents by sampling continuously during pump-out of D-3.

D. Calibration of Retort No. 2 Orifice Meters (P. M. Gifford)

The air, dilution, and vent orifices have been calibrated against the new Roots Connersville positive displacement meter. The results of this calibration are given in Table 4. Based on these results it is recommended that no changes be made in the meter factors presently being used.

In addition to the results shown in the table, a 12-hour check on the air meter during the regular operations showed 223 SCFM by the Roots meter versus 228 SCFM calculated for the orifice meter. It thus appears that no correction factors are warranted at this time for orifice meter factors on Retort No. 2.

E. Preliminary Correlation of Retorting Yield Data (K. I. Jagel)

In last month's Progress Memorandum, a correlation of the oil yield data obtained with 3/4 to 1 1/2-inch shale was presented. A slight improvement in correlation has now been obtained by correlating yield in terms of air flow ratio and recycle gas flow ratio rather than total gas flow ratio and oxygen entering the combustion zone. This is shown in the following tabulation:

Standard deviation of data before regression	± 3.12
Correlation with total gas flow ratio, T, and oxygen concentration entering the combustion zone, O.	
Standard error about regression	± 2.62
Correlation coefficient	0.62
F ratio	4.66
Correlation with recycle gas flow ratio and air flow ratio	
Standard error about regression	± 2.60
Correlation coefficient	0.63
F ratio	4.94

This new correlation has the following form:

$$Y = Bo+B_1X_1+B_2X_2+B_3X_3+B_{11}X_1^2+B_{22}X_2^2+B_{33}X_3^2+B_{12}X_1X_2+B_{13}X_1X_3 +B_{23}X_2X_3$$

TABLE 4

ORIFICE CALIBRATION - RETORT NO. 2
JUNE 15, 1965

Time	Roots Meter Reading ft^3	Pressure in H_2O	Temp ° F	Flow Rate SCF/M	Orifice Reading	Pressure in H_2O	Temp ° F	Flow Rate (1) SCF/M
					VENT ORIFICE			
0750	104200	60	123	--	5.3	40	110	--
0900	130000	59	128	312	5.47	38	118	292
0929.5	141000	57	131	309	5.55	37	120	299
1000.5	153000	57	137	310	5.65	37	124	303
1033.5	165000	57	135	310	5.65	37	125	303
					DILUTION ORIFICE			
1244	175000	125	164	--	7.98	124	146	--
1316	177300	123	168	66.4	7.95	124	150	65.4
1349	179600	123	168	64.3	7.94	124	152	65.4
					AIR ORIFICE			
1532	190200	93	158	--	6.0	90	152	
1600.5	195300	93	158	156	6.0	90	151	154

(1) This rate includes an estimated 13 SCF/M leak which occurred during the vent orifice calibration.

Where

B_n = Empirical coefficient
X_1 = Recycle gas flow ratio, SCF/Ton RS
X_2 = Air flow ratio, SCF/Ton RS
X_3 = Residence time parameter defined as (Bed height above air distributor/raw shale mass velocity, ft^3 - hr/lb RS) X 10^2

The stationary point of this correlation is at a recycle gas flow ratio of 10,000 SCF/Ton RS, an air flow ratio of 4,600 SCF/Ton RS and a residence time parameter of 1.79. In order to obtain a geometrical interpretation of the response surface it is helpful to consider the surface obtained with the independent variables considered two at a time.

Recycle gas flow ratio, Air flow ratio - Minimax (Saddle)

Recycle gas flow ratio, Residence time - Maximum (Surrounded by elliptical contours of yield)

Air flow ratio, Residence time - Minimax (Saddle)

A plot of the response surface obtained at a recycle gas flow ratio of 10,000 SCF/Ton RS is shown in Figure 1. The empirical coefficients of this correlation are:

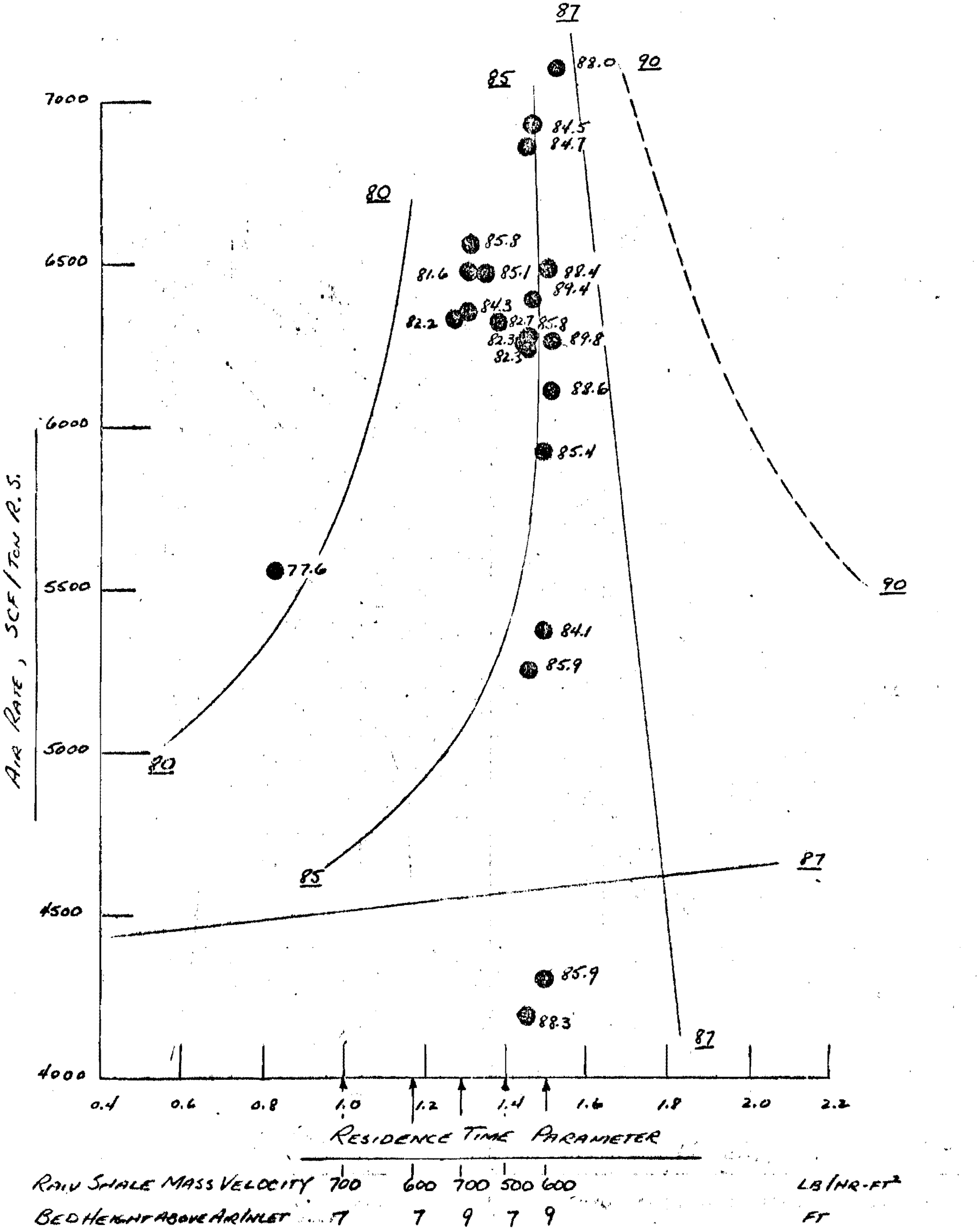
Bo	7.0068×10^{1}
B_1	1.06×10^{-2}
B_2	-2.24×10^{-2}
B_3	1.7483×10^{1}
B_{11}	-3.79×10^{-7}
B_{22}	9.35×10^{-7}
B_{33}	-5.380
B_{12}	3.26×10^{-7}
B_{13}	-2.53×10^{-3}
B_{23}	5.87×10^{-3}

In order to evaluate the relative importance of the three independent variables considered in this correlation, the yield data have been correlated in terms of each of the variables taken singly. The following results have been obtained:

Correlation with recycle gas flow ratio only	
Standard error about regression	± 3.17
Correlation coefficient	0.11
F ratio	0.43
Correlation with air flow ratio only	
Standard error about regression	± 3.09
Correlation coefficient	0.25
F ratio	2.41

FIGURE 1

EFFECT OF RESIDENCE TIME & AIR RATE ON OIL YIELD AT 10,000 SCF/TON RS RECYCLE



Correlation with residence time parameter only	
Standard error about regression	± 2.64
Correlation coefficient	0.56
F ratio	17.1

The low value of the F ratio for the first two of these correlations compared to the third indicates the overriding significance of the third variable. Some work is now going on to develop a method of correlation which will reduce the sensitivity to this residence time parameter.

F. Mist Simulation Studies (K. I. Jagel)

One of the key parts of an oil mist simulation apparatus is the mist generator. When this study was undertaken it was felt that an oil mist lubricator made by C. A. Norgren & Co. would be a suitable mist generator. Subsequent evaluation has indicated that it is not suited for this service. An atomizing nozzle made by Astrosonics, Inc. which appears to be usable for this purpose has been ordered on a rental basis so that it may be evaluated. The performance characteristics of this nozzle as described by the manufacturer are shown in Figure 2.

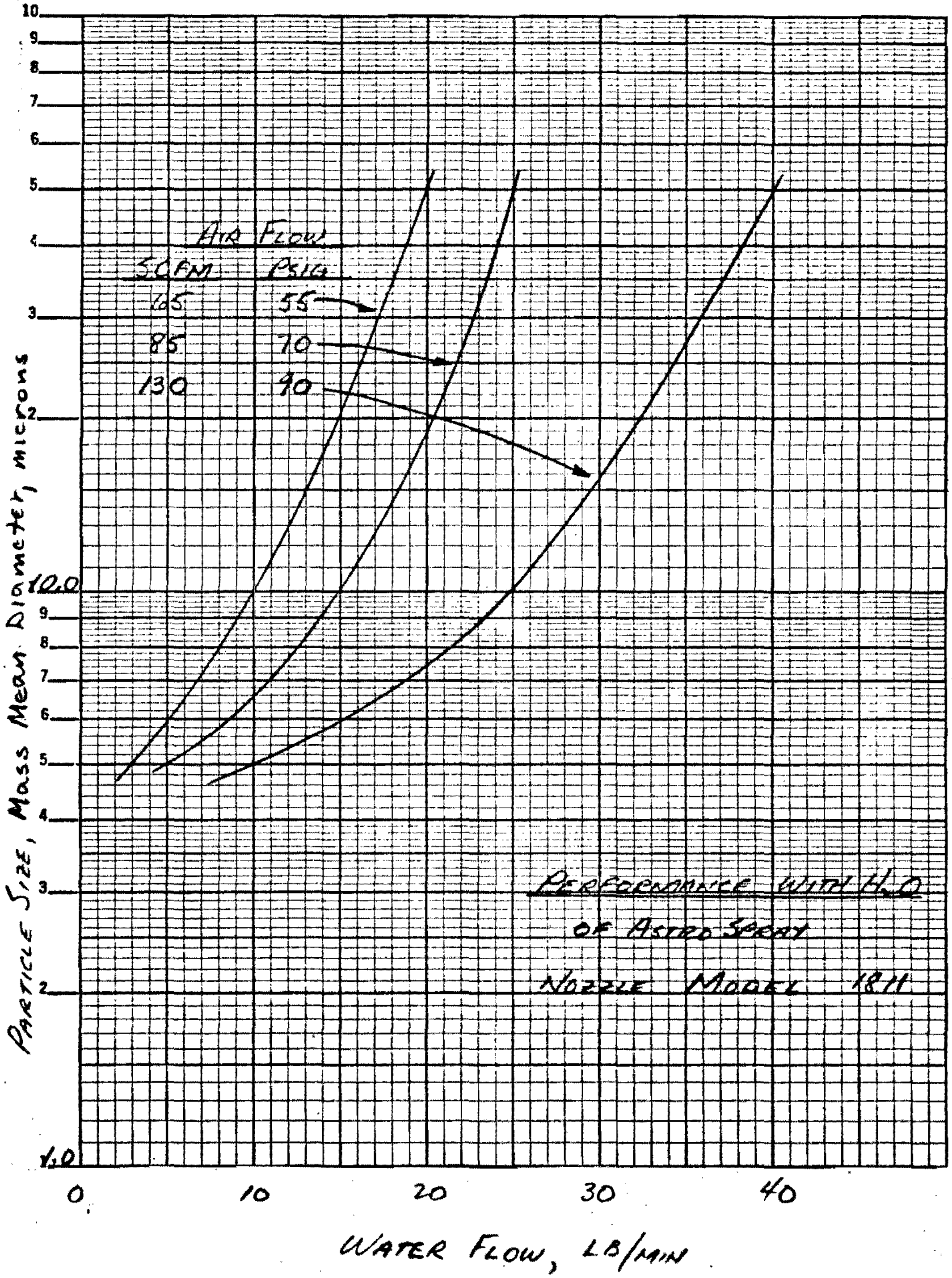
G. Commercial Mist Recovery Equipment (J. H. Haddad and J. G. Mitchell)

Discussions with Research-Cottrell, Inc. personnel at Boundbrook, New Jersey, and subsequent confirmation by letter indicate that the use of an electrostatic precipitator for the recovery of oil mist will be economical commercially. Operational problems at full oil loading and high dust loads are not anticipated. The estimated cost for a commercial size unit of 460,000 SCFM (to service a 16,000 to 19,000 T/D retort) is $0.54 per ACFM. In contrast, the cost of an experimental precipitator to service Retort No. 3 (12,000 SCFM) is $4.76 per ACFM

Quotations from Research-Cottrell were requested for the following conditions.

Efficiency	= 99.5%
Operating Pressure	= 3 inches water gage
Oil Loading of Gas	= Full (.0058 lbs per ACF) and Half (.0029 lbs per ACF)
Gas Temperature	= 140° F
Gas Density	= .079 lbs per cu ft at Std conditions
Oil Pour Point	= 85° F
Oil Specific Gravity	= 0.8
Oil Viscosity	= 130 SUS at 130° F
Dust Content	= 20 - 40 grains per cu ft of gas
Oil Size	= 20% less than 1 micron

FIGURE 2



Air Flow
SCFM PSIG
65 55
85 70
130 90
Performance with H_2O
of Astro Spray
Nozzle Model 1811
Particle Size, Mass Mean Diameter, microns
Water Flow, LB/MIN
0
10
20
30
40
1.0
10.0

Preliminary quotations for the two unit sizes requested are summarized below:

Case Number 1 - 12,000 cfm For Retort No. 3

One (1) precipitator, one (1) unit, nine (1) ducts with duct spacing to be 9" by 12'-0" high by 18'-0" long with the length divided into two 9'-0" electrical sections. This unit will be powered by two 70 KVp, 250 ma silicon type electrical sets. The approximate weight of the equipment is 22 tons. The approximate prices are:

Material---------------------	$36,000
Erection Labor---------------	14,500
Freight to Jobside-----------	1,600
Supervision of Erection------	5,000

Case Number 2 - 460,000 cfm

One (1) precipitator, two (2) units, thirty-seven (37) ducts with duct spacing to be 9" by 24'-0" high by 27'-0" long with the length divided into three 9'-0" electrical sections. Equipment will be energized by four 70 KVp, 750 ma silicon electrical sets. See drawing SK-14386-L for general dimensions. The erected weight of this equipment is about 220 tons. Prices are as follows:

Material---------------------	$167,300
Erection Labor---------------	60,700
Freight to Jobsite-----------	7,600
Supervision of Erection------	13,600

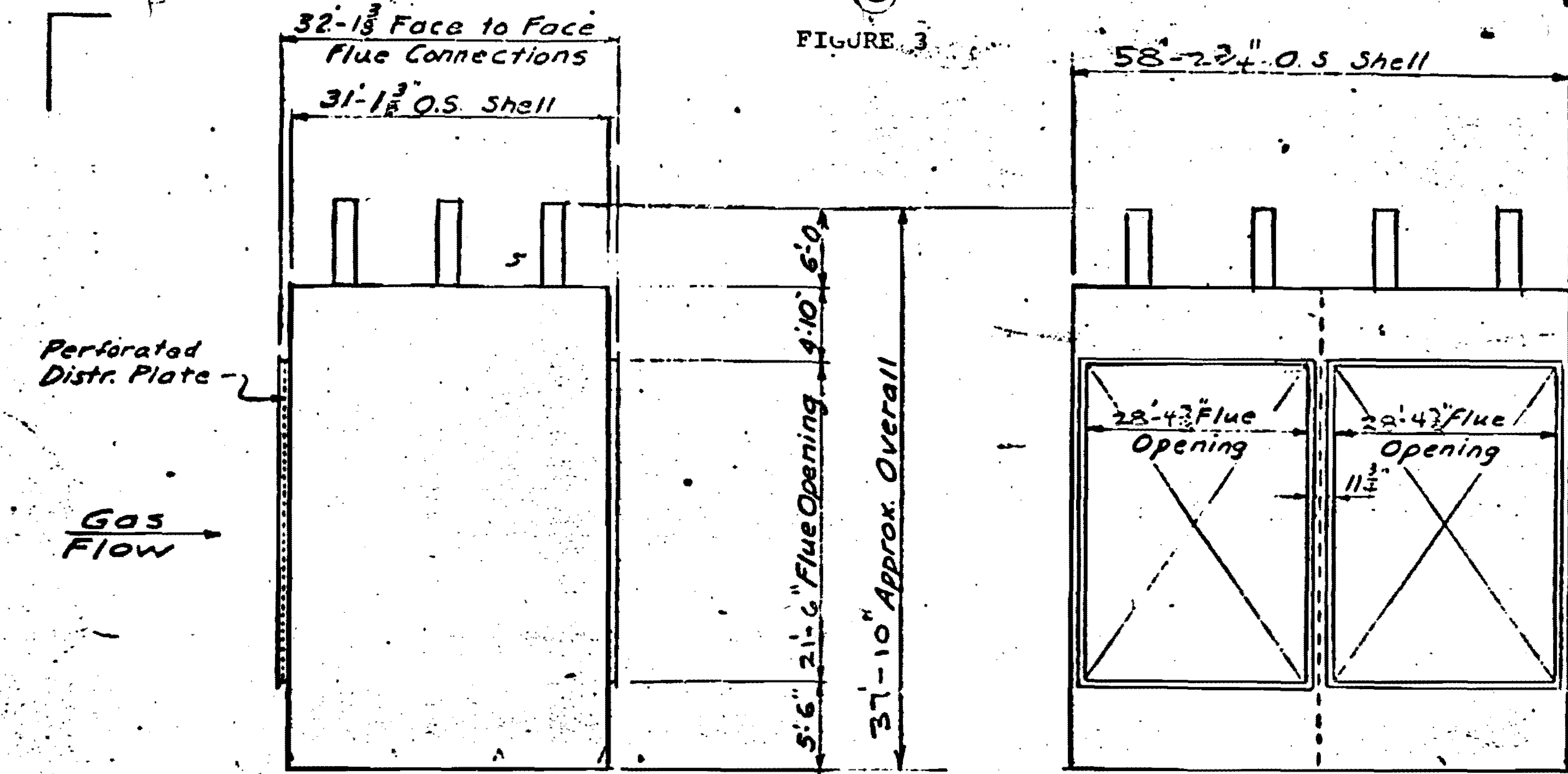
It is anticipated that electrostatic precipitators, preceeded by primary cyclonic recovery equipment, will provide the most economical and efficient mist recovery arrangement.

H. Effect of Shale Segregation (J. H. Haddad and J. G. Mitchell)

Preliminary calculations have been made to estimate the effects of segregation at the top of the retort on the gas distribution throughout the retort, and on the operation.

Run 454 which was made with 1/4 to 3/4-inch shale was used as the basis for the calculations. It was assumed that the shale

FIGURE 3



N-3564

Note: Dimensions & Construction Details are Subject to Change

NO.	REVISION	BY	DATE	NO.	REVISION	BY	DATE

RESEARCH – COTTRELL, INC.
BOUND BROOK, N.J.

OPZEL PLATE PPTR.
2U,37D 9" x 24'0 x 27'0' (9'-0 PLS.)

DRN. RWS | DATE | SCALE:
CH'K. | APP.

SK-14386-L

Form No 615

★ 100M-28

in part of the retort was at the average particle size of the feed (0.41 inch APD, Old Basis), part of the retort contained a smaller size shale (0.305 inch APD), and the shale in the remainder of the retort was larger than average (0.55 inch APD). It was also assumed that the pressure at each elevation in the retort were isobaric. Quench Run 509 was used as the basis for estimating the size reduction in the shale down through the retort, assuming the percentage reduction of each size range was constant.

The pressure drop equations used in the estimates are summarized on Table 5. The basis for the effect of gas rate in these equations was presented in May 21, 1965 Monthly Progress Memorandum, Figures 18 and 19. The basis for the effect of APD in the heat recovery and the combustion zone equations was estimated from the Ergun equation. The basis for the effect of APD in the retort and shale preheat zone equation was estimated from Figure 21 of the May 21, 1965 Monthly Progress Memorandum. The constants in the heat recovery and combustion zone equations vary to account for the different operating temperature levels.

The estimated effect of segregation on gas distribution through each section of the retort is summarized in Table 6. It was assumed that segregation does not affect the combustion air distribution as the air distribution is controlled by restricting orifices. It is noted that the calculated total retort pressure drop (17.63 inches water) through the average particle size shale checks the measured pressure drop for Run 454E (18.5 inches water).

The calculations indicate that:

(1) Segregation has a big effect on recycle distribution through the heat recovery zone

(2) The recycle distribution becomes worse in the combustion zone

(3) Segregation has little effect on gas distribution throughout the shale preheat and retort zones - i.e. the gases would tend to redistribute. However the calculations do not take into account the heat or temperature effects due to the recycle maldistribution below.

The above effects have a detrimental effect on the heat balance and retorting results throughout the unit and might even influence the stability of the operation.

Further analysis of this type will require additional knowledge with regard to pressure gradient relationships, and the effect of shale feed size on particle size deterioration.

TABLE 5

PRESSURE DROP EQUATIONS USED FOR PRELIMINARY SEGREGATION ESTIMATES

A. Bottom 3.3 Feet of Heat Recovery Zone

$$\Delta P/L = 0.55\left(\frac{SCFH/FT^2}{2290}\right)^{1.47}\left(\frac{0.16}{APD}\right)^{1.42}$$

$\Delta P/L$ = inches water/ft

$SCFH/FT^2$ = Recycle Rate

APD = Average Particle Diameter, inches
= 0.243 (APD) shale feed

B. Top 2.2 Feet of Heat Recovery Zone

$$\Delta P/L = 0.75\left(\frac{SCFH/FT^2}{2290}\right)^{1.47}\left(\frac{0.46}{APD}\right)^{1.42}$$

$\Delta P/L$, $SCFH/FT^2$, APD = Same as under A

C. Combustion Zone

$$\Delta P/L = 0.835\left(\frac{SCFH/FT^2}{2290}\right)^{1.47}\left(\frac{0.16}{APD}\right)^{1.42}$$

$SCFH/FT^2$ = Recycle + Air Rates

$\Delta P/L$, APD = Same as under A

D. Retort and Shale Preheat Zone

$$\Delta P/L = 0.28\left(\frac{SCFH/FT^2}{4590}\right)^{6.5}\left(\frac{0.56}{APD}\right) \text{ for APD} \leqq 0.62''$$

$$= 0.28\left(\frac{SCFH/FT2}{4590}\right)^{6.5}\left(\frac{0.62}{APD}\right) \text{ for APD} > 0.62''$$

$SCFH/FT^2$ = Air + Recycle + Gas Make
= Air + Recycle + 2830 SCF/Ton RS

APD = 0.85 (APD) Shale Feed, inches

$\Delta P/L$ = Same as under A

TABLE 6

SUMMARY OF ESTIMATED EFFECT OF SEGREGATION
ON GAS DISTRIBUTION THROUGHOUT RETORT

Shale Feed	Small Segregated	Average Size	Large Segregated
APD inches	.305	0.41	.55
Preheat + Retort Zone			
APD, inches	.259	.35	.467
ΔH, ft	4.3	4.3	4.3
ΔP, " H_2O	4.01	4.01	4.01
$\Delta P/L$, " H_2O	0.935	0.935	0.935
Offgas:			
$SCFH/FT^2$	4900	5145	5380
(Gas Make-	720	720	720
Air-	1305	1305	1305
Recycle-)	2775	3120	3355
Combustion Zone			
APD, inches	.074	.10	.134
ΔH, ft	0.7	0.7	0.7
ΔP, " H_2O	3.0	3.0	3.0
$\Delta P/L$, " H_2O/ft	4.28	4.28	4.28
$SCFH/FT^2$:			
Air	1305	1305	1305
Recycle	2005	3120	4555
Total	3310	4425	5860
Heat Recovery Zone			
APD, inches	.074	.10	.134
ΔH, ft	5.5	5.5	5.5
ΔP, " H_2O	10.62	10.62	10.62
$\Delta P/L$, " H_2O/ft	1.93 Avg 1.69 Bottom 3.3 ft 2.3 Top 2.2 ft	1.93	1.93
$SCFH/FT^2$			
Recycle	2330	3120	4140

I. Mechanical Models (T. C. Lyons and L. J. Skowronek)

Shale Flow Studies

1. Calming Height Determinations

Calming heights are being measured for various shale sizes in circular pipes and rectangular ducts. Calming height was explained in the Progress Memorandum of May 21, 1965, however, the schematic diagram is repeated in Figure 4 to aid in analyzing the results. Briefly, calming height is the length of pipe or duct required to obtain uniform shale flow even though the draw-off at the outlet is non-uniform.

The calming heights observed to date are summarized in Table 7. These data reveal that:

(1) The 1/4 to 3/4-inch and 3/4 to 1 1/2-inch shales have about the same calming height in a given pipe or duct.

(2) A rectangular duct has a greater calming height than a circular pipe.

(3) The calming height increases as the rectangular duct width increases. This increase is not apparent in the circular pipes over the range studied (7 1/2 to 16-inch I.D.).

(4) Velocity in the range of 0.1 to 5.0 ft/min has very little effect on calming height.

Further studies will be made with larger shale sizes and spent shale will also be investigated.

2. Segregation Studies

The model which will be used to investigate particle segregation in shale beds has been completed and studies are in progress. This model is a rectangular box 8-feet wide, 10-feet high, and 1-foot deep. Shale is fed to one side of the model and the particles are allowed to flow unconfined to the other side (up to 8-feet away). Thus, it is possible to simulate feeding a shale pile up to 16-feet wide from a central point. A movable trough is used to draw shale slowly and uniformly across the bottom of the entire model. The trough is compartmented so that samples can be taken which are representative of material passing down through vertical cores (6-inches wide in the bed).

The initial studies have been directed toward investigating the effect of pile size. The widest size range (1/4 to 3-inch) has been used since this material would have the greatest tendency

Figure 4

CALMING HEIGHT OF OIL SHALE

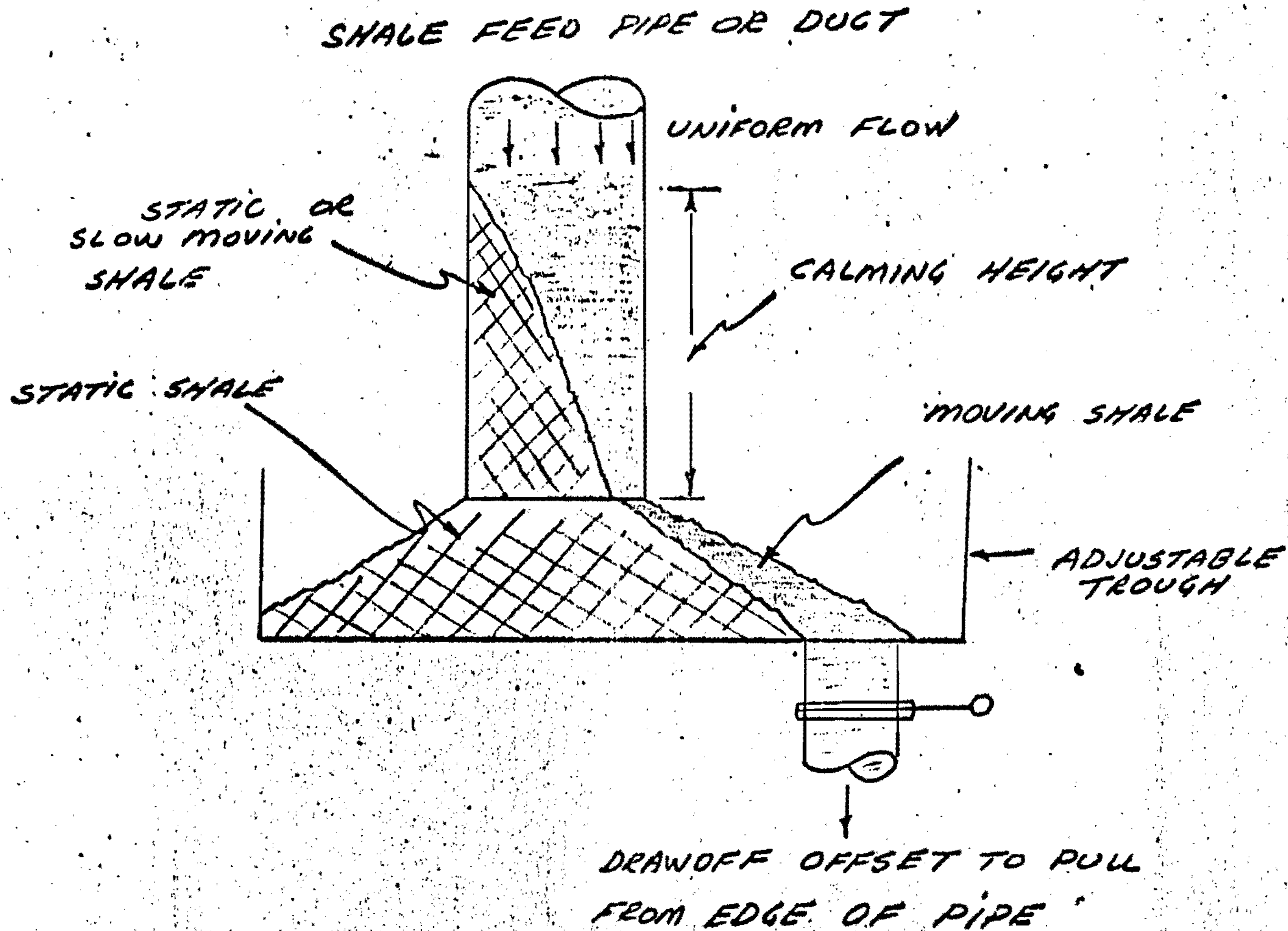


TABLE 7

CALMING HEIGHT OF RAW OIL SHALE

Shale Size / Configuration	Calming Height(1)	
	1/4 to 3/4-Inch	3/4 to 1 1/2-Inch
7 1/2 in. I.D. Pipe	1.2 - 1.6 Pipe Diam.	No Flow
11 1/2 in. I.D. Pipe	1.2 - 1.5 Pipe Diam.	1.2 - 1.5 Pipe Diam.
16 in. I.D. Pipe	1.4 - 1.6 Pipe Diam.	Not Available As Yet
12 in. Rectangular Duct	1.9 - 2.4 Widths	1.9 - 2.1 Widths
15 in. Rectangular Duct	2.8 - 3.0 Widths	2.8 - 3.0 Widths
18 in. Rectangular Duct	3.0 - 3.1 Widths	2.9 - 3.1 Widths

(1) Shale velocity was varied from 0.1 to 5.0 ft/min in each case

to segregate. The first runs have revealed that the segregation is extremely severe. For example, in a 16-foot pile, the average particle diameter (APD) ranged from 0.2-inches in the core beneath the feed point to about 1.0-inch at the wall 8-feet away. The APD's at intermediate points are shown in Figure 5.

These data also give some insight as to the reproducibility of the runs. In these studies, the shale is charged to the unit and circulated until the entire inventory has been rotated completely. Thus, the distribution of particle sizes at the bottom of the model is the result of the segregation that took place as the pile was formed at the top. Runs 1 and 2 are back-to-back samples. The inventory was then circulated completely once again and Runs 3 and 4 were made to get a second set of back-to-back samples.

The segregation was equally severe in 12 and 8 foot piles as shown in Figures 6 and 7. These runs were made by the same procedure as that described previously. It should be pointed out that the increase in the composite particle size in these runs is the result of discarding the material smaller than 1/4-inch. This is being done to clean up the inventory.

Work is continuing with 1/4 to 3-inch shale and smaller piles. Studies will also be made with the narrower shale size ranges in light of the severe segregation that has been observed to date. Following this, efforts will be made to reduce segregation by various techniques.

IV. ANALYTICAL LABORATORY SECTION (B. L. Beck and D. Liederman)

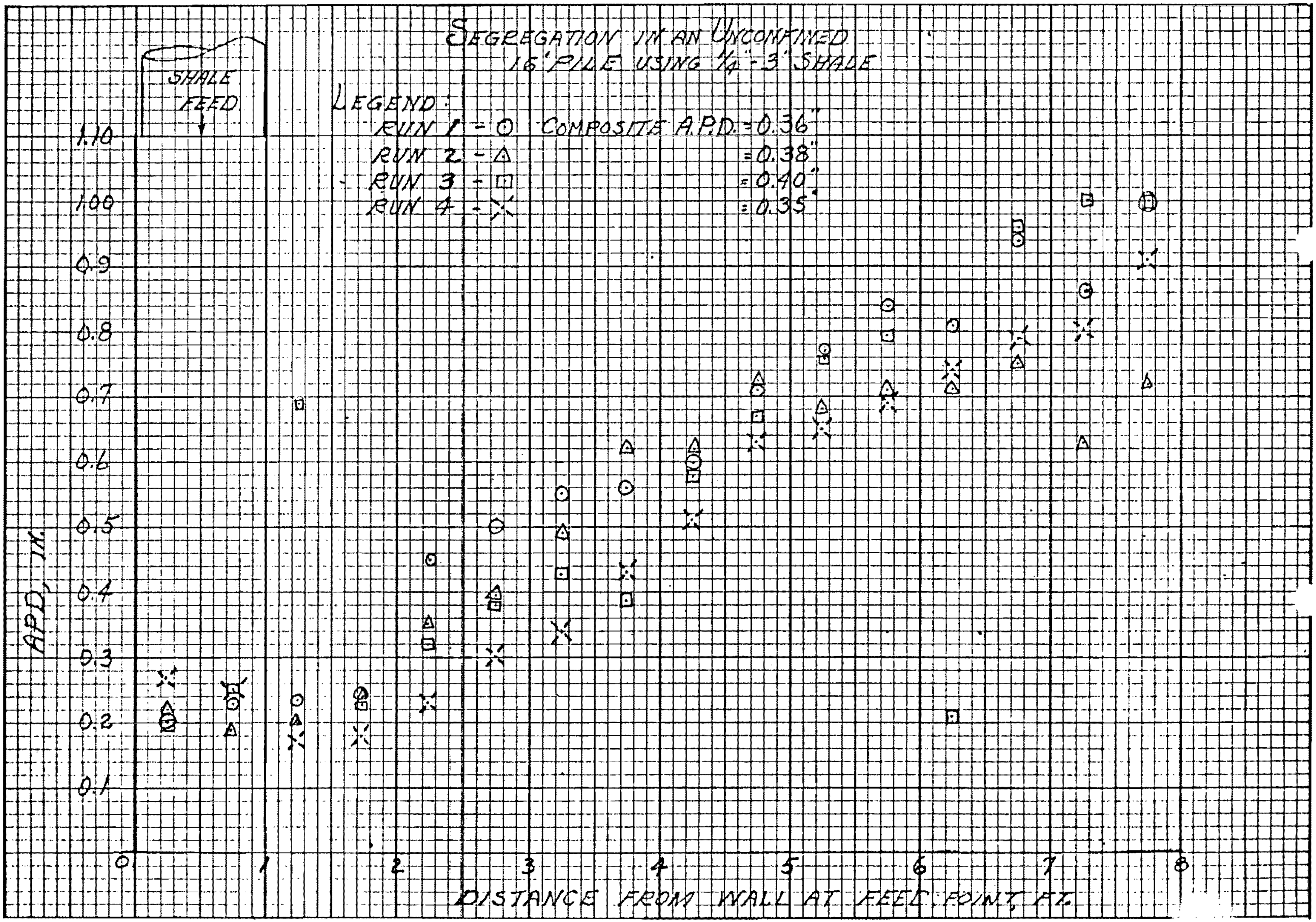
A. Progress on Determination of "Others" in Recycle Gas

The Chronofrac gas chromatograph which has a catalytic combustion detector, has been delivered. Initial problems of voltage and gas flow stability are in the process of being remedied. A regulated power supply and a gas sampling valve has been ordered to help improve the instrument's performance.

Initial experiments with a 12-foot HMPA (hexamethyl phosphoramide) column verified that it can separate C_2 through C_5 but, unfortunately, the liquid phase slowly "bled" into the detector where it partially polymerized and rendered the detector inoperative. In addition, CO_2 still presents an interference problem. However, two methods are being considered to circumvent this.

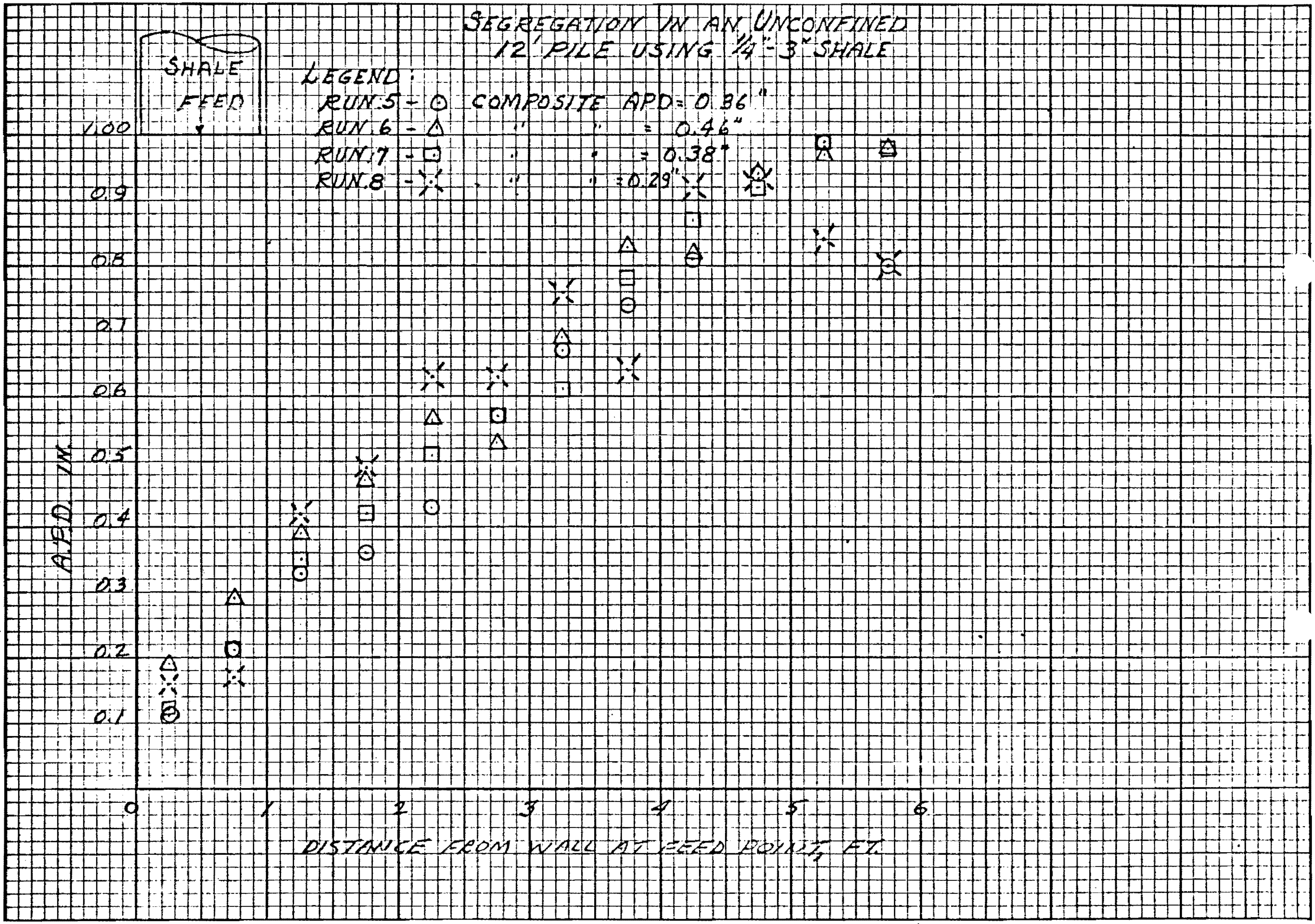
One involves using a dibutyl phithalate column, which has just been delivered. This column ought to perform the required separation, and it is reported that the liquid phase does not "bleed" as the HMPA does.

FIGURE 5

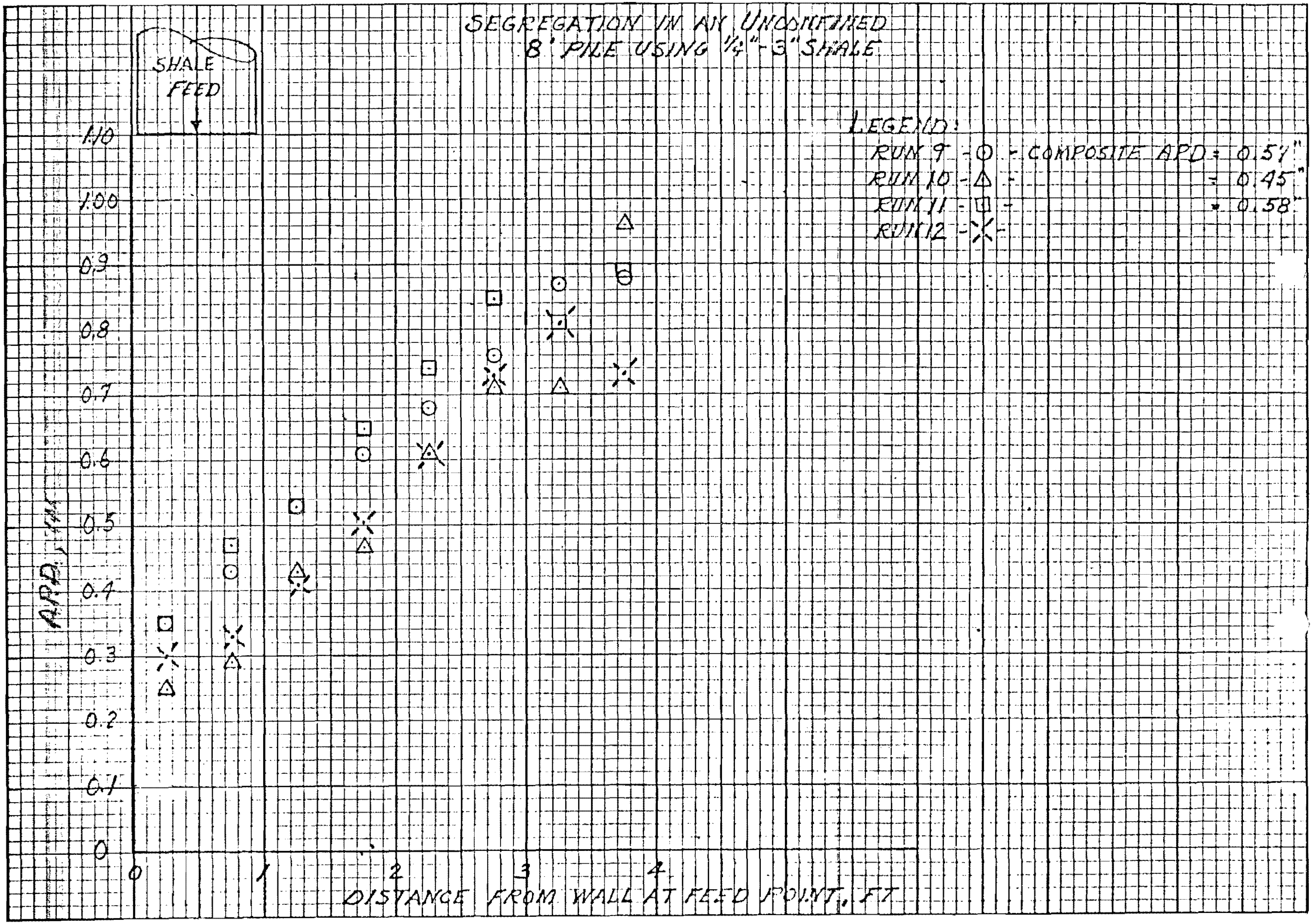


SEGREGATION IN AN UNCONFINED 16' PILE USING 1/4"-3" SHALE
SHALE FEED
LEGEND:
RUN 1 - ⊙ COMPOSITE A.P.D. = 0.36"
RUN 2 - △ = 0.38"
RUN 3 - ⊡ = 0.40"
RUN 4 - ⁙ = 0.35"
APD, IN.
1.10
1.00
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
DISTANCE FROM WALL AT FEED POINT, FT.

FI RE 6


SEGREGATION IN AN UNCONFINED
12' PILE USING 1/4"-3" SHALE
SHALE FEED
LEGEND:
RUN 5 - ⊙ COMPOSITE APD = 0.36"
RUN 6 - △ " " = 0.46"
RUN 7 - □ " " = 0.38"
RUN 8 - ✳ " " = 0.29"
1.00
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
A.P.D. IN.
0
1
2
3
4
5
6
DISTANCE FROM WALL AT FEED POINT, FT.

F JRE 7



SEGREGATION IN AN UNCONFINED
8' PILE USING 1/4"-3" SHALE
SHALE FEED
LEGEND:
RUN 9 - ⊙ - COMPOSITE APD = 0.51"
RUN 10 - △ - = 0.45"
RUN 11 - ⊡ - = 0.58"
RUN 12 - ⁝ -
1.10
1.00
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
APD, IN.
0
1
2
3
4
DISTANCE FROM WALL AT FEED POINT, FT

The other is the use of an Ascarite absorber to remove the CO_2 and thus eliminate its interference. However, there is a question of possible absorption of organic components that will have to be investigated.

The aim at the present time is to determine the concentrations of ethane-ethylent (together), propane, propylene, butanes and, possibly, pentanes. Feasibility should be demonstrated within a week or two.

B. Distillation of Crude Shale Oil

The apparatus for distillation by ASTM D-1160-61 procedure has been assembled and is now in operation. Several crude shale oil samples have been distilled at 10 mm and corrected to 760 mm using chart number 53-12. So far the shale oils distilled have about the same distillation curves; a typical curve is shown in Figure 8.

The initial samples are being run in duplicate in order to obtain precision data. So far it appears the precision is within the limits given in the ASTM method.

C. Analytical Laboratory Methods

An "Analytical Laboratory Methods" book presenting the details of all procedures and equipment in use in the analytical laboratory is now in preparation. This publication, which is about 80% complete, should be issued next month.

V. ENGINEERING ANALYSES (P. W. Snyder, J. E. Burchfield and K. I. Jagel)

A. Retorting Time-Temperature Profiles for Cross Section of Pilot Retort No. 1 Runs

The shale temperature and kerogen decomposition profiles were calculated from the average temperature probe profiles for nine runs from Retort No. 1. The average profiles were assumed to be gas temperatures and the shale temperatures were then calculated using the math model with these profiles and input. The resulting retorting time-temperature patterns are shown on Figure 9. The inclusion of more runs and using a more precise method of calculating mean shale temperature from gas temperature shows that we have obtained longer shale retorting residence time than indicated in last month's Progress Memorandum. However, the general conclusion that 10 to 40% of the kerogen is decomposed above 930° F (maximum Fischer Assay temperature) in the Gas Combustion Retort is still true.

FIGURE 8

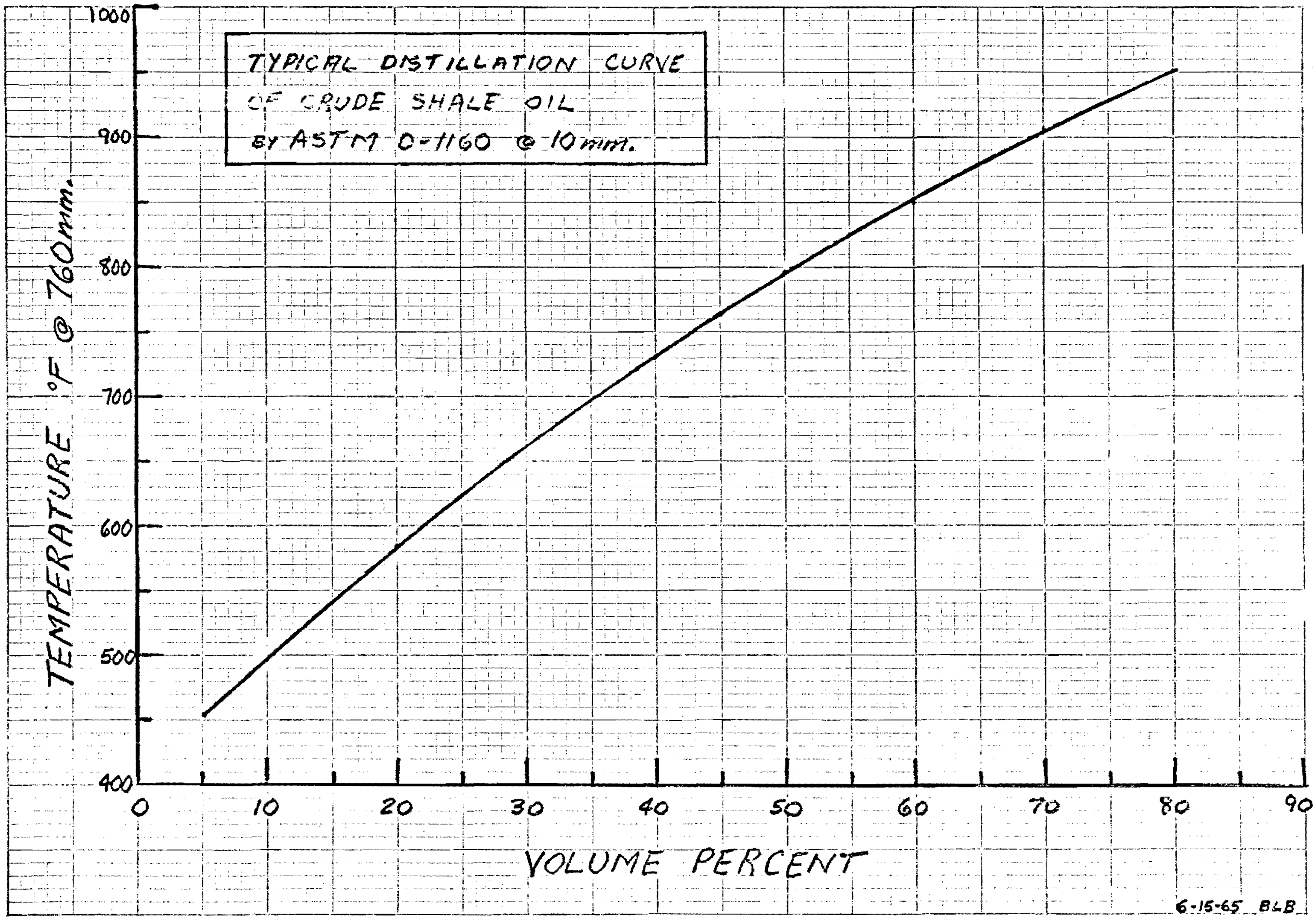
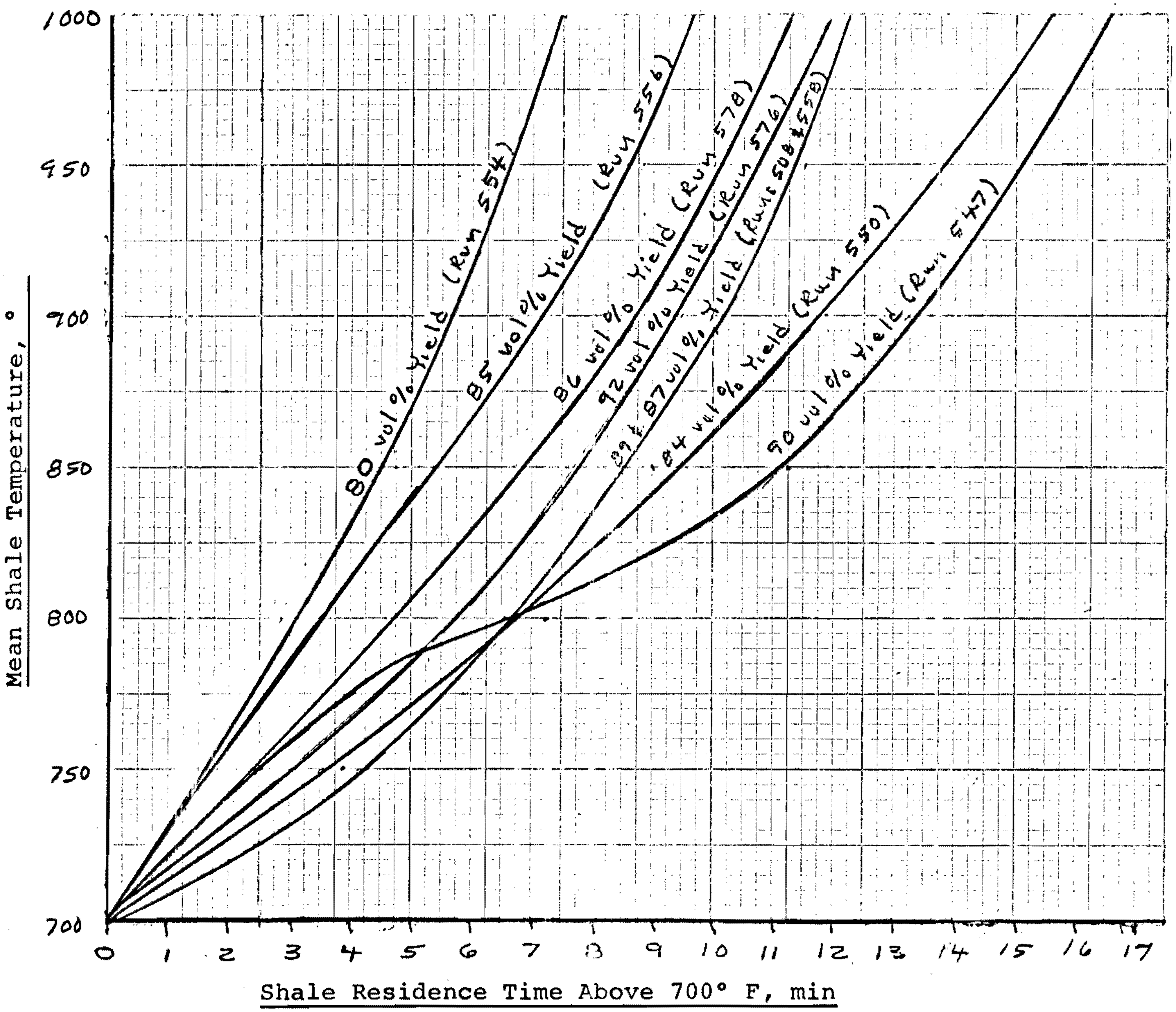

TYPICAL DISTILLATION CURVE
OF CRUDE SHALE OIL
BY ASTM D-1160 @ 10 mm.
TEMPERATURE °F @ 760mm.
1000
900
800
700
600
500
400
0
10
20
30
40
50
60
70
80
90
VOLUME PERCENT
6-15-65 BLB

FIGURE 9

CALCULATED SHALE RETORTING TIME-TEMPERATURE PROFILES FROM MEASURED TEMPERATURE PROFILES

Calculated From Measured Temperature Profiles by the Math Model



PWS 6-14-65

Although only nine runs were evaluated in this procedure, the following preliminary conclusions may be drawn:

1. Retorting residence time of less than 10 minutes in the 700 to 1,000° F zone reduces yield.

2. Longer retorting residence time does not always increase yield. This indicates that there are other factors operating such as refluxing of oil.

The operating conditions, yield, retorting residence time, and calculated kerogen remaining at 900 and 950° F are shown for these runs in Table 8. There is no clear trend in operating variables with retorting residence time; again indicating some other variable is affecting yield. Increasing total gas rate via air or recycle theoretically increases retorting residence time. However, as can be seen by comparing Runs 558 with 550 and Runs 556 with 554, sometimes increasing recycle does increase retorting residence time and sometimes it does not.

These data indicate that as far as retorting severity is concerned there is not much flexibility in the Gas Combustion Retort within the range that retorting severity is controlling the yield.

B. Experimental Proposals to Increase Yield on Retort No. 1

Last month's Progress Memorandum showed that the severe retorting conditions of the Gas Combustion Retort result in lower yields than are obtained in Fischer Assay, Royster, Gas Flow and TOSCO retorts. Oil yield from the Gas Combustion Retort should increase if retorting severity is decreased and shale residence time is increased in the 850 to 950° F temperature zone. Four schemes to accomplish this have been considered. They are:

1. Extension of the low air rate operation with preheat to stabilize the combustion zone.

2. Two level hot gas-air distributor.

3. Increase heat capacity of the gas.

4. Reduced peak temperatures in the combustion zone.

The bases and estimated operating conditions for evaluating these proposals are summarized in Table 9. Discussions of these propositions are as follows:

1. Low Oxygen Variable With Preheat

The regression analyses that have been carried out with the 3/4 to 1 1/2-inch shale have indicated that a high yield region

TABLE 8

EFFECT OF PROCESS CONDITIONS ON RETORTING ZONE

Run No.	Bed Height Feet	Shale Rate lbs/(hr)(ft^2)	Air Rate SCF/T	Recycle SCF/T	Yield Vol % RSFA	Shale Residence Time Minutes	Retorting Zone (700-1000°F)(1) Kerogen Remaining % at 900° F	at 950° F
547	9	570	6,600	11,400	90	16 1/2	28	8
578	9	690	6,600	10,700	86	11	40	14
556	9	610	5,900	10,200	85	9 1/2	45	15
554	9	620	5,900	12,700	80	7 1/2	52	18
576	9	610	5,300	12,800	92	12	35	13
550	9	600	5,400	12,500	84	15 1/2	33	10
558	9	620	5,900	11,100	87	12	48	16
508	7	500	5,500	12,800	89	12	44	15
530	7	640	6,200	12,500	84	12	--	--

(1) Calculated from average temperature profiles by means of the math model

TABLE 9

SUMMARY OF PROPOSED MODIFICATIONS TO THE OPERATION OF RETORT NO. 1 FOR INCREASING YIELD

Modification:	Minimum Air	Two Level Hot Gas - Air Distr	Increase Heat Capacity of Recycle Gas	Reduce Peak Temperature by Consuming Part of Air Externally
Bases for Optimism	Regression Analyses	Maximize Retorting Residence Time, and Reduce Temperature Gradient Across Particle	Permit the High Recycle Rate Indicated By the Regression Analyses Without Excessive Liquid Loading	Minimize Peak Shale Temperature and Minimize Combustion Zone
Operating Conditions				
Shale Rate, lbs/(hr)(ft^2)	500	500	500	500
Bed Heights, ft				
Air Dist. To Top	6	7 - 8	6	6
Hot Gas Distr. to Top	--	6	--	--
Hot Gas Distributor				
Total Hot Gas Rate, SCF/T	--	4000-9000	--	--
Hot Gas Temp., ° F	--	1200-1300	--	--
Air Distributor				
Air Rate, SCF/T	5,000(1) 3,900(1)	4000-3000	750 of Pure O_2(1)	4,000(1)
Dilution Gas, SCF/T	-- --	--	9,000	9,000
Air-Dil. Gas Temp. ° F	1,000 1,200	--	1,300	1,300
Air Burned Internally, %	~50 ~	60-80	10	10
Recycle Rate, SCF/T	9,500 16,000	1200-9000	11,000	11,000

(1) Assumes adiabatic heaters on line burner transfer line to eliminate heat loss.

may exist at relatively low air rates. A number of attempts to operate Retort No. 1 at low air rates have met with mixed success. Sustained operation for eight or so hours have been observed in which high yields were obtained. External observations indicated that the unit was lined out, when suddenly, the operation would deteriorate rapidly. Tentatively, this has been attributed to a metastable condition in the combustion zone. This proposed program is intended to investigate the possibility of increasing the stability of the combustion zone by preheating the air. An attempt has been made to find conditions which would give the same values of total gas flow, $\underline{T}$, and oxygen concentration in the combustion zone, $\underline{O}$, which regression analysis had indicated would give 90+ $\bar{o}$il yields.

In order to do this it was necessary to develop a relationship between and propane flow rates with temperature and oxygen concentration of the line burner product. This has been done in approximate manner by making a number of simplifying assumptions and by recognizing that the maximum allowable heat release in the No. 1 line burner is 120,000 Btu/hr. It has been assumed in this analysis that the heat loss from the line burner is 16,400 Btu/hr and that this heat loss is constant and independent of line burner feed rates of propane and air. It is probably a good assumption when the temperature of the line burner product is near 1,000° F and the propane flow rate is 20 SCFH or greater. The relationship between air and propane flow rates and line burner product temperature and oxygen content which was developed is shown in Figure 10.

The proposed run conditions which are designed to evaluate the effect of air preheat on combustion zone stability are shown in the following table:

Raw Shale Mass Velocity: 500 lbs/(hr)(ft^2)
Size Range: 3/4 to 1 1/2-inch
Bed Height: 6 Feet Above Air Distributor
Preheat Runs: Line Burner Product Temperature - 1,000° F

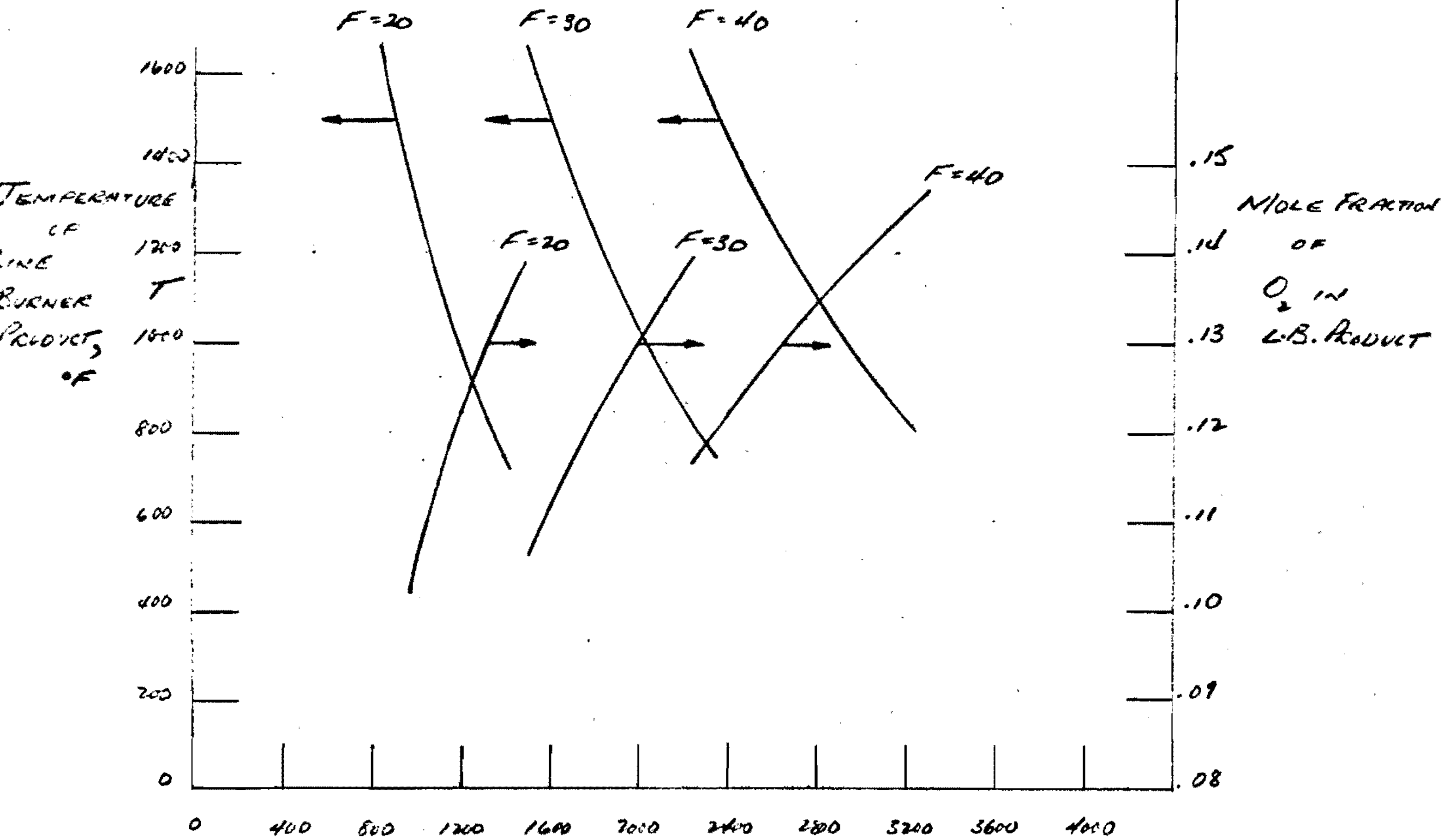
Gas Rates (In SCF/Ton PS			T(1)	O(1)
Air	Recycle	Propane		
5400(2)	9500	73	15	5.0
4800	10100	68	15	4.5
Blank Runs: Air Inlet Temperature - Ambient				
3900	11100	0	15	5.5
4300	10700	9	15	6.0

(1) $\underline{T}$ = (Recycle + Air) 10^3 MSCF/Ton PS
$\bar{O}$ = 21 x (Air)/(Recycle + Air)
(2) Approximately 400 SCF/T required to satisfy heat losses.

FIGURE 10

Relationship Between Air & Propane Flow Rates and Temperature & O_2 Content of Line Burner Product

(F = Propane Rate, SCFM)



Air Rate SCFM (Stoichiometric + Dilution Air)

(L.B. Product Rate = Air Rate + 2 × Propane Rate)

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The operability of the preheat runs should be satisfactory. It is expected, however, based on previous operating experience that the low air rate of 4,800 SCF/Ton RS is about a practical minimum. The operability of the blank runs are more questionable although it is felt that the second condition should probably be operable based on previous experience. A 1,200° F preheat run with 16,000 SCF/Ton of recycle and 3,900 SCF/Ton of air is also proposed to establish the minimum air rate.

2. Two Level Hot Gas-Air Distributor

Injection of oxygen-free hot gas above the air distributor into the retorting zone should increase retorting residence time. This scheme is being evaluated with the retorting math model. The conditions specified in Table 9 are preliminary bases and will be changed as necessary.

Attempts on the math model to inject hot gas three feet above the air distributor to complete 80% of the kerogen decomposition resulted in quenching the fire at the air distributor. However, math model calculations have been successfully completed with only one foot between the distributors. In addition, most of the heat input in this case went in the air distributor.

The effects of (1)distance of separation and (2)heat apportionment for the distributors are now being evaluated on the math model. The major problem with this scheme appears to be in maintaining a stable combustion zone at the air distributor.

3. Increased Heat Capacity of the Recycle Gas

Regression analyses and the fundamental consideration of retorting residence time indicate yield should be improved by increasing recycle rate. Retorting residence time is influenced by temperature profile which is in turn influenced by the heat content and hence the rate of recycle gas. However, raising gas rate increases pressure drop very rapidly in the top of the retort (May Progress Memorandum, p. 22) thereby increasing liquid loading. Thus, the potential for yield gain with increasing gas rate due to residence time may very well be lost by cracking or refluxing.

Another way to increase the gas heat content without increasing gas rate, is to increase the molal specific heat of the gas stream. Components with high molal specific heats are CO_2, CH_4, and H_2O. Those with low molal specific heat include O_2, N_2 and CO. Hence, gas heat capacity and temperature profile along with their influence on retorting residence time can be changed by increasing the concentration of CH_4 and CO_2 and/or decreasing O_2, N_2 and CO. Commercially this may be done through providing a portion of the heat input via an indirect heater or direct combustion of spent shale and heat recovery.

Either of these methods applied to the Retort No. 1 for test purposes would require extensive revisions. However, conditions could be approached by providing a part of the oxygen required as pure oxygen and mixing it with recycle for burning in the line burner or shale bed. This would reduce the large nitrogen dilution effect on specific heat and increase the heat capacity of the gas. Although probably not attractive commercially some indication of the effect on retorting residence time, temperature pattern, and yield would be obtained.

4. Reducing Peak Shale Temperatures

Reducing peak shale temperature has the advantages of potentially improving yield and decreasing carbonate decomposition. Peak shale temperatures can be reduced by externally consuming a part of the oxygen required for heat input.

A test to determine the significance of such a process change must be large enough to be discernable. Consequently, a proposal was investigated in which 90% of the air was to be externally and 10% of the air was to be burned in the retort bed.

The total heat required at 500 lbs/(hr)(ft^2) and 10% carbonate decomposition is about 435 MBtu/Ton RS or 4,500 SCF Air/Ton RS. The external heat release in consuming 90% of the oxygen is 211 MBtu/hr. No. 1 Retort line burner can tolerate a heat release of only 120 Btu/hr. Hence a test in which part of the air is burned externally requires either that (1) less oxygen be consumed externally, i.e. about 40 to 50%, or (2) a larger line burner be provided.

Another consideration for such a test is the temperature of the gas from the line burner. The theoretical flame temperature of the undiluted burned gas is too high for the materials normally used and is undesirably high insofar as retorting is concerned. Therefore the gas/air mixture burned to release the required 211 MBtu/hr must be quenched with about 9,000 SCF/Ton RS of dilution gas to reduce the inlet gas temperature to a reasonable 1,300° F.

Recycle rate for heat recovery in the bottom of the retort will be limited to about 11,000 to 12,000 SCF/Ton RS because gas rate appears to be limited by pressure drop in the top part of the retort. This limiting gas rate is about 6,500 SCF/hr ft^2 or 26,000 SCF/Ton RS (for 500 lbs/(hr)(ft^2). However, pressure drop in some section other than the top, and economics may conceivably impose a lower gas rate limit. With the 26,000 SCF/Ton limitation, minimum air rate about 4,500 SCF/Ton, dilution gas 9,000 SCF/Ton, and some carbonate decomposition, recycle rate must be limited to about 12,000 SCF/Ton. In heat requirement calculations 11,000 SCF/Ton of recycle was assumed giving a spent shale temperature of 500° F.

Another consideration for this case is the large volume of gas going through the air distributor, 13,500 SCF/Ton RS. Since this gas is at an elevated temperature and reduced pressure the actual volume per unit of time is unusually large relative to normal operations. Hence, a new air/gas distributor must be provided for this proposed operation.

Because of the major revisions required for the line burner and air distributor this proposal will not be investigated at this time.

C. Minimum Air Requirement for Retorting

1. Estimated Minimum Air at 500 lbs/(hr)(ft^2)

Heat requirements for kerogen decomposition, and water desorption are fixed, but heat recovery diminishes with reduced recycle rate. Since gas velocity is limited, recycle rate has to be reduced as shale mass rate increases. Thus minimum air requirement per ton of raw shale increases as mass rate increases. Air requirements have been estimated below for a mass rate of 500 lbs/(hr)(ft^2) and assuming 10% carbonate decomposition. The heat balance is the same as those used in the material balance program and the reference is raw shale at 60° F.

Heat In	MBtu/Ton RS	Heat Out	MBtu/Ton RS
Recycle	13.9	Carbonate Decomposition	55.1
Condensing Oil	24.1	Water Desorption	38.0
		Spent Shale Sensible Heat	149.6
		Kerogen Decomposition	107.2
		Oil Sensible Heat	13.1
		Gas Leak Sensible Heat	3.7
		Offgas Sensible Heat	40.2
		Heat Loss	18.3
Total	38.0	Total	425.2

Net Heat Requirement	387.2 MBtu/Ton RS	
Heat Loss from New Line Burner, if Used		43.3 MBtu/Ton RS
Air Required, No Line Burner	96 Btu/SCF Air	4,100 SCF/Ton RS
Air Required, With Line Burner		4,500 SCF/Ton RS

The heat loss in spent shale was calculated assuming an 11,000 SCF/Ton of recycle and 500° F spent shale. Estimates of heat loss in spent shale were reported in last month's Progress Memorandum. This estimate of spent shale temperature with recycle is preliminary but is probably in the right range. As discussed in the foregoing topic recycle and heat recovery from spent shale may be improved only slightly. A difference of 100° F in spent shale temperature changes air requirement by about 300 SCF/Ton RS and about 2,000 SCF/Ton of recycle is required to lower shale temperature by 100° F.

Carbonate decomposition, was assumed to be 10%. Math model runs indicate that carbonate decomposition will probably be higher than this. A change of 5% changes air requirement by about 300 SCF/Ton RS.

Heat losses via the gas were estimated at 150° F top temperature. Heat losses from the shell were estimated to be about 10,000 SCF/hr.

This is believed to be a fairly good approximation of minimum air requirement for 500 lbs/(hr)(ft^2). The calculation is supported by operating data on the Retort No. 1. Runs made at 4,200 SCF/Ton have been unstable.

2. <u>Minimum Air Estimated on the Math Model</u>

Runs were made on the math model to estimate minimum air rate. At 500 lbs/(hr)(ft^2), 12,000 SCF/Ton of recycle and 3,500 SCF/Ton of air the computer could arrive at a solution only by adding preheat to 1,500° F - equivalent to an additional 1,000 SCF/Ton RS of air. At 16,000 SCF/Ton of recycle and 3,500 SCF/Ton of air, preheat equivalent to an additional 400 SCF Air/Ton was needed for a solution. The spent shale temperature calculated by the model was higher than the retort correlation developed in last month's Progress Memorandum. This accounts for the higher stated air requirement by the model at 12,000 SCF/Ton of recycle. The correlation of spent shale temperature with recycle rate will be improved as additional data become available.

Carbonate decomposition for the math model runs was 15% and 14% respectively. Thus it appears that the minimum air requirement calculated by heat balance and math model runs is in the range of 4,000 to 4,500 SCF/Ton and is dictated by combustion stability.

D. <u>Allis-Chalmers Crushing Information</u>

Last fall Allis-Chalmers Manufacturing Company agreed to prepare a proposal for crushing equipment for a 50,000 B/D operation. However, unusually heavy committments on other work have delayed their work. Last month Allis-Clamers sent their proposal for crushing equipment. It includes an 1,800 ton/hour primary single roll crusher and a 300 ton/hour secondary single roll crusher. The primary crusher will reduce a scalped feed with an average size of 36" x 28" x 10" to a 14" minus product at a 12 1/2-inch setting. The secondary crusher will reduce a feed of 8" x 2" to 80 - 85% 2" minus. Power consumption is estimated to be 0.09 to 1 KWHr/Ton of material crushed for each crusher.

The proposal covers the crushing equipment and does not include the associated equipment such as feeders, conveyors, ventilation, tunnels and other miscellaneous equipment. Much of this equipment will be dependent upon terrain, location and other considerations which will vary with each company's situation.

However this information may be helpful to participants in their plans therefore the Allis-Chalmers letter and attachments have been forwarded to all Technical Advisory Committee members. A large drawing of the 48 X 72 Fairmount (4872) crusher was omitted from the letter because of difficulty in duplication but can be made available upon request.