J R Conley

15\06\005\001

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MOBIL OIL CORPORATION

RESEARCH DEPARTMENT

MONTHLY PROGRESS MEMORANDUM

(Covering June 16 to July 15, 1967)

ANVIL POINTS OIL SHALE RESEARCH CENTER

Rifle, Colorado

July 21, 1967

CONTRIBUTORS:

Mining Section
Mechanical Engineering
Retorting Section
Retort Operability Task Force
Engineering and Economic Studies

Signed by:

R H Cramer

R. H. Cramer
Program Manager

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] Mobil Oil Corporation

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

MONTHLY PROGRESS MEMORANDUM

(Covering June 16 to July 15, 1967)

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MONTHLY PROGRESS MEMORANDUM
(Covering June 16 to July 15, 1967)

I. TECHNICAL ADVISORY COMMITTEE MEETING

The Nineteenth Regular Technical Advisory Committee Meeting was held at Anvil Points on July 13, 1967.

After much discussion, it was decided to test the Anvil Points Task Force concept of liquid oil removal to improve operability and yields from Retort No. 3 as soon as possible.

No date was set for the next Committee meeting.

II. ADMINISTRATION

Ralph Bernheimer returned to Esso Research and Engineering, effective July 1. He will not be replaced.

III. MINING SECTION (G. R. Haworth, J. B. Sellers and F. W. Brackebusch)

A. Mining Production

1. Progress

During the past month, heading operations in Rooms 2, 3 and 4 have been completed. As far as the heading rounds are concerned, we are left with three rounds to take in Room 1 and two simultaneous rounds to establish Crosscut 12H. This is shown in Figure 1.

As described in the drilling and blasting section we created Crosscut 23J by blasting two simultaneous rounds, one drilled from Room 2 and the other from Room 3. We experienced severe shattering of the northwest side of Pillar 23H and much scaling and secondary blasting was required to remove dangerous loose rock. A survey of the area revealed that 10 feet of the pillar was lost. To compensate for this we plan to make Crosscut 23G narrower. When driving crosscuts from the rooms using our normal blasting techniques we have always experienced a severe rounding off of the pillar corners. This rounding off is particularly marked in the center of the mining horizon, i.e. around the mahogany marker. This tends to give the pillar an hour-glass shape and removes rock which is needed for roof support. Plans are being made to experiment with smooth-wall blasting techniques to achieve more precisely formed pillars. Should our efforts be successful the technique might also be applicable to standard heading rounds to achieve smoother ribs in the mining headings.

Benching is proceeding at the southeast end of Room 2. Figure 1 shows the area benched out. Conclusions on the benching reached so far are as follows.

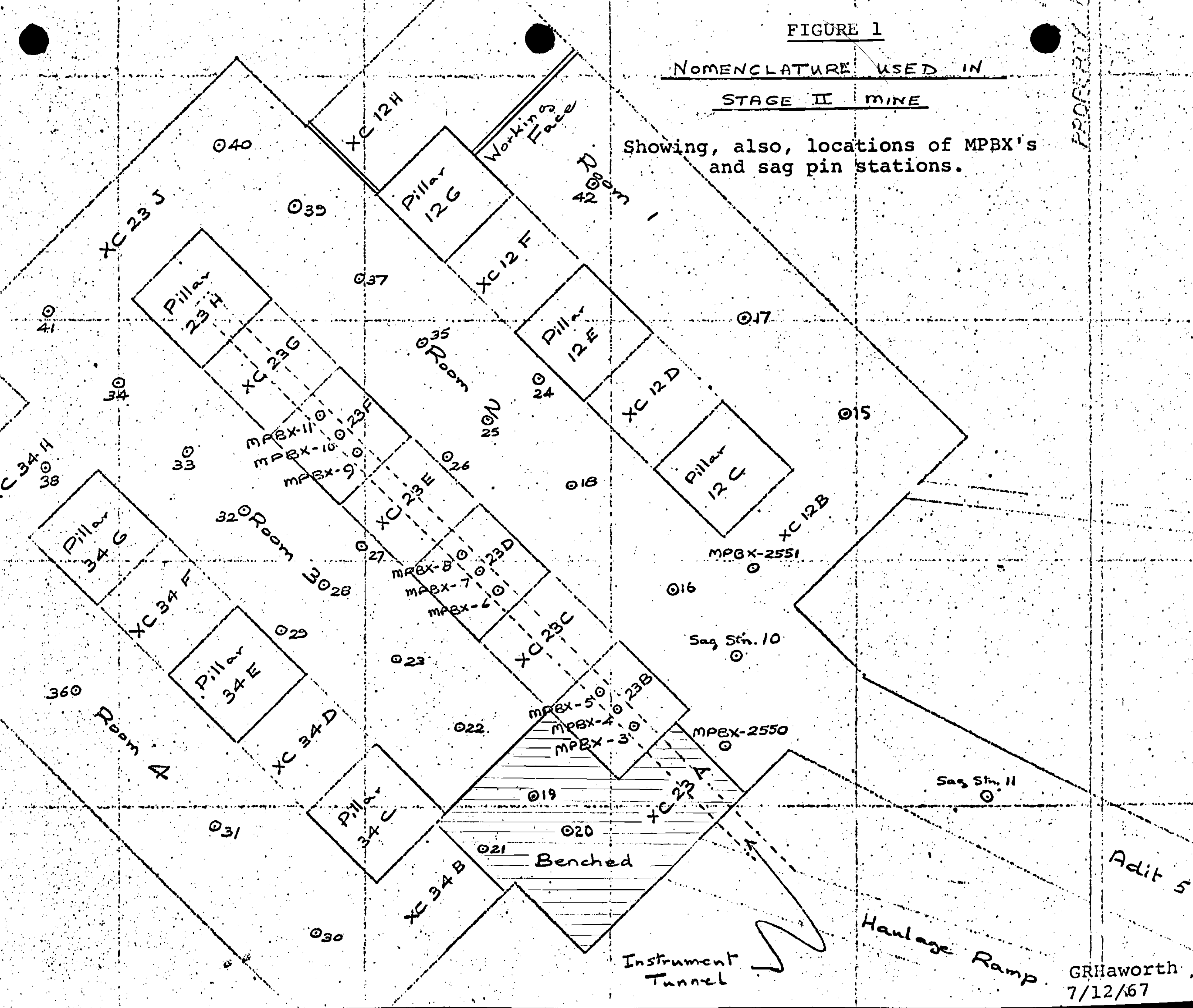
1. The floor of the bench is exceedingly smooth. This promotes less wear and tear on the loading and hauling equipment and should result in less tire wear. The Skooper performs very well on this floor.

2. The same difficulty is noted in the bench as in the headings, namely the rounding off of pillar corners. In the case of the bench this has resulted in the undermining of the southern corner of Pillar 23B. While this has not seriously impaired the strength of the pillar (as shown by MPBX readings) it has left a series of overhangs which will be removed by drilling and blasting so as to improve the appearance of the pillar.

FIGURE 1

NOMENCLATURE USED IN STAGE II MINE

Showing, also, locations of MPBX's and sag pin stations.



GRHaworth
7/12/67

3. Benching has not adversely affected roof conditions.

4. The walls of the bench are generally quite smooth requiring little scaling. However there may be a tendency for the old walls of the mining headings to loosen despite the fact that they were scaled well before benching below them. This could develop into a difficult problem because it is not easy to scale at heights of 60 to 73 feet above the floor of the bench. The scaling crews do not work as well at this height and there is a greater danger of a scaled off piece of rock falling and hitting the scaling rig. A mechanical scaler would be most beneficial in these areas.

5. Drilling and powdering the bench is a simple matter and reduces mining costs quite dramatically. Time studies will show that the objectives of the mining cost study, as related to benching, will be achieved and surpassed.

6. Large amounts of backbreak have been noted, that is to say, the bench face, instead of breaking cleanly from hole to hole along the last row of the round, breaks beyond this and closer to the unloaded holes behind the face. The situation is aggravated by joints which run in a northeast - southwest direction, parallel to the rows of drill holes. Although the overbreak, which might amount to 7 or 8 feet, does not damage the next row of holes (rows are spaced at 15 feet) it does produce coarse fragmentation

In order to provide maximum protection for the loading and hauling crew, the brow of the haulage ramp where it enters Room 3 has been thoroughly bolted and covered with wire mesh.

As the benching proceeds it automatically puts the upper half of the crosscuts out of reach of the heading jumbo. Therefore it is necessary to have the crosscuts drilled off before the benching reaches them. Accordingly all the crosscuts between Rooms 3 and 4 have been drilled off and also the halves of the crosscuts between Rooms 2 and 3 which are drillable from Room 3.

It is imperative to have the walls of the headings well scaled before the benching passes below them. The first scaling, performed when the walls of the heading are still close to the mining faces on the headings is not sufficient to ensure safe conditions. The walls continue to loosen for a period of about one month following their formation.

Thus it is necessary to repeatedly check the walls for unsafe loose rock and remove it as required. Both pillar walls in Room 3 have been scaled afresh.

2. Ventilation

Ventilation conditions in the mine have been bad. The results of a dust survey conducted March 27-31, by the Bureau of Mines Health and Safety Activity are summarized in Table 1.

Based on a free silica content of 11%, the threshold limit value for Anvil Points mine oil shale airborne dust is 16 million particles per cubic foot of air. Samples showing a high concentration are shown bracketed and indicate operations making excessive amounts of dust. However, dust conditions have improved since this survey was taken.

Loading blasted rock into trucks is a particularly dusty operation. A system of continuously wetting down the muck pile is required. Air conditioning of the loader operators cab is necessary. The problem here is to preserve intact the windows of the cab. The windows on the present cab were very quickly shattered by rocks dropping from the bucket. Correct design would solve this problem.

Drilling heading round holes can produce dust very rapidly if the water to the drill bit is shut off for a short period of time. Otherwise dust conditions are acceptable. A safety interlock to prevent operation of the drill with the water off is required.

Scaling can produce harmful dust clouds. All faces should be wet down before and during scaling. The scaling rig should have a water tank, pump and hose specifically for this purpose.

Diesel fumes are an obvious problem. It was hoped that the creation of a breakthrough between Rooms 2, 3 and 4 would result in a circulation of air through these headings. This was not the case. An attempt was made to force air down Room 2 using a 25,000 cfm axial flow fan and 30 inch tubing. This was unsuccessful and only caused turbulence at the end of Room 2.

It will be necessary to cause the entire 75,000 cfm of air passed by the main fan in the ventilation crosscut, to flow down Room 2 and back down Room 3 and out of the haulage ramp. To do this two brattice cloths will be erected; one across Adit 5 and the other across Crosscut 23A. The one across Adit 5 has been erected and was most successful in promoting good ventilation conditions.

TABLE 1

(Taken By Bureau of Mines Health and Safety Activity)

APPENDIX I - Midget Impinger Sample Data

Sample number	Date, start of sampling	Operation, location, remarks	Number concentration mppcf 7/
	Mar. 29, 1967		
AP-61	8:10 a.m.	Outside air; mine yard in vicinity of portal, in part represents intake air.	0.9
AP-62	9:50 a.m.	Outside air; same as above.	2.5
	March 28		
AP-1	8:05 a.m.	Going into mining area, along Adit No. 5; BZ 8/ of miner.	1.3
	March 29		
AP-13	8:05 a.m.	Going into mining area, along roadway from changehouse to adit, through adit to working place; BZ miner.	1.8
	March 28		
AP-2	8:25 a.m.	Wetting down muckpile; room 1 at face; BZ miner.	4.9
AP-3	8:35 a.m.	Same	4.9
	March 29		
AP-14	8:25 a.m.	Same	1.9
	March 28		
AP-4	8:50 a.m.	Loading muck into trucks with Skooper; room 1 at face; BZ Skooper operator.	23
AP-5	9:10 a.m.	Same. Ventilation fan reversed during sampling.	24
AP-6	9:25 a.m.	Same. Ventilation fan reversal effects noted during sampling.	71
AP-7	11:00 a.m.	Operating 20-ton truck during loading, tramming and dumping cycle; from room 1 at muckpile to outside dump; BZ truckdriver. Truck loaded by Cat 966B front-end loader.	8.4
AP-8	11:15 a.m.	Same. Interrupted sample; truck loaded by Skooper.	13
	March 29		
AP-15	9:05 a.m.	Same. Truck loaded by Skooper.	5.2
AP-63	10:25 a.m.	Operating 40-ton haul truck during loading, tramming and dumping cycle; from room 1 at muckpile towards crusher; BZ truckdriver.	4.5

7/ Millions of particles per cubic foot of air.

APPENDIX I - Midget Impinger Samples
(continued)

Sample number	Date, start of sampling	Operation, location, remarks	Number concentration mppcf
AP-64	10:40 a.m.	Operating 40-ton haul truck; along access road towards crusher; BZ truckdriver	1.4
AP-65	11:00 a.m.	Operating 40-ton haul truck; along access road to crusher, dumping ore, returning along access road; BZ truckdriver.	3.3
AP-19	2:30 p.m.	Scaling rib and back from aerial platform; room 2 near face; BZ two miners.	9.1
AP-20	2:45 p.m.	Same.	5.9
AP-21	3:05 p.m.	Same.	4.4
AP-67	2:25 p.m.	General atmosphere near scaling operation; room 2 right rib, floor.	6.5
AP-68	2:50 p.m.	Same.	5.0
AP-69	3:15 p.m.	Same.	2.3
	March 30		
AP-75	1:20 p.m.	Rockbolting back (drilling holes and installing bolts); room 2, near face, on 80-foot aerial platform; BZ miner.	25
AP-76	1:35 p.m.	Same.	18
AP-77	1:50 p.m.	Same.	8.6
AP-28	1:25 p.m.	General mine atmosphere during rock-bolting; room 2 near face.	3.7
AP-29	1:45 p.m.	Same.	3.2
AP-30	2:00 p.m.	Same.	4.7
	March 28		
AP-10	1:10 p.m.	Drilling 29-foot holes, with water mist; room 3 at face, in cab of drilling machine 37 feet off the bottom; BZ miner.	7.0
AP-11	1:30 p.m.	Same. Drilling 27 feet off the bottom.	15
AP-12	1:50 p.m.	Same.	13
	March 29		
AP-16	10:25 a.m.	Drilling 17-foot holes, with water mist with detergent added; crosscut 34B, in cab of drilling machine 37 feet off the bottom; BZ miner.	7.7
AP-17	10:45 a.m.	Same.	9.2
AP-18	11:00 a.m.	Same, but 32 and 21 feet off the bottom	4.7

APPENDIX I - Midget Impinger Samples
(continued)

Sample number	Date, start of sampling	Operation, location, remarks	Number concentration mppcf
AP-22	7:10 p.m.	Charging holes with AN/FO; crosscut 34B at face on 80-foot aerial platform; BZ two miners.	2.1
AP-23	7:30 p.m.	Same.	2.9
AP-24	7:45 p.m.	Same.	2.6
AP-70	7:20 p.m.	Operating pressurized AN/FO prill machine; crosscut 34B near face, on mine floor; BZ helper.	2.6
AP-71	7:35 p.m.	Same.	2.1
	March 28		
AP-9	12:00 m.	Eating lunch; changehouse on surface; BZ miners.	2.3
	March 29		
AP-66	12:05 p.m.	Same.	1.8
	March 30		
AP-25	8:55 a.m.	Operating crusher; crusher building, main floor at control panel; BZ operator; ore mixed with snow going into primary crusher.	6.1
AP-26	9:15 a.m.	Same.	3.2
AP-27	9:35 a.m.	Same.	3.8
AP-72	8:55 a.m.	General atmosphere in crusher building; along walkways and vicinity of primary and secondary crushers, of screens. Ore is mixed with snow.	5.9
AP-73	9:05 a.m.	Same.	4.4
AP-74	9:30 a.m.	Same.	3.3
	March 31		
AP-31	7:35 a.m.	Operating crusher; main floor at control panel; BZ operator. Ore still wet, in part, from previous snowfall.	13
AP-32	8:20 a.m.	Same. Helper swept floor during sampling.	25
AP-33	8:45 a.m.	Same. Local dust exhaust system in operative midway during dust sampling.	150
AP-78	7:40 a.m.	General atmosphere in crusher building; along walkways and vicinity of primary and secondary crushers, at screens. Ore is wet from previous snowfall.	10
AP-79	8:00 a.m.	Same.	12
AP-80	8:20 a.m.	Same.	10
AP-81	8:45 a.m.	Same location. Hydro Filter dust collecting system inoperative during sampling.	80

3. Equipment Availability

The 40 ton Mack truck was received from Timpte after extensive modifications to the aluminum bed made under the direction of Alcoa engineers. Figure 2 shows a sketch of the modifications made to the bed to strengthen it. After two weeks of satisfactory operation, during which time no visible signs of damage to the bed were seen, the Mack truck was again out of service due to a frozen transmission. The transmission has been sent to Denver for repairs and the Mack truck will be out of commission for one to two weeks. This presents a problem of hauling shale to the crusher. Using the 20 ton Darts on the down hill haul results inevitably in much repair to these old vehicles. Consequently the crusher is being supplied from the stockpiles down by the plant area using the front-end loader and Darts. It may be necessary to contract the haul from mine to crusher if the Mack truck cannot be put into operation within the next few days.

It is becoming increasingly difficult to keep the Dart trucks running. We can achieve our mining objectives only if we can ensure the removal of 3,000 tons per day from the benching operation. It will not be possible to do this given the increasingly unfavorable availability of the Dart trucks. Consequently we are inviting bids to contract out the hauling of the benching work from the mine to dump over the cliff edge.

The availability of the remainder of the mining equipment has been good.

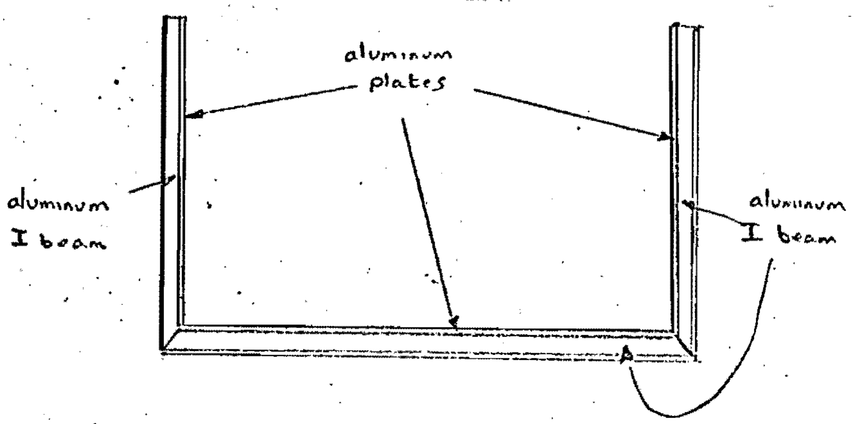
4. Condition of the Roof in the Mining Area

Figure 1 shows the location of the various sag rod stations. Roof conditions during the period are summarized in Figures 3 and 4 which show the movements at the two horizons of concern.

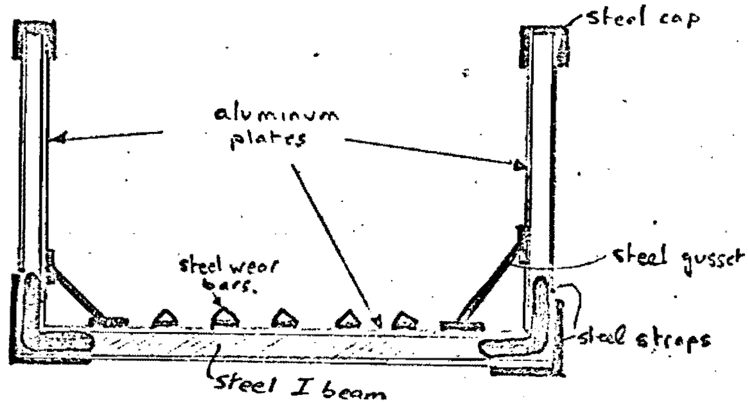
In the 0 to 5 foot horizon a sagging of 0.004 inch has been noted throughout the mine at points undisturbed by mining. These same movements occurred in the period covered by the last Monthly Progress Memorandum. This may be a temperature effect similar to the one in the roof of the old mine. At locations close to the working faces movements have been greater. Movements at locations near crosscuts are not appreciably larger than movements at points remote from crosscuts. This indicates that a 6 foot by 6 foot roof bolt spacing is effective in holding up the two feet thick slab no matter what the roof span.

FIGURE 2

TRUCK BED ON MACK SHOWING STEEL REINFORCEMENT



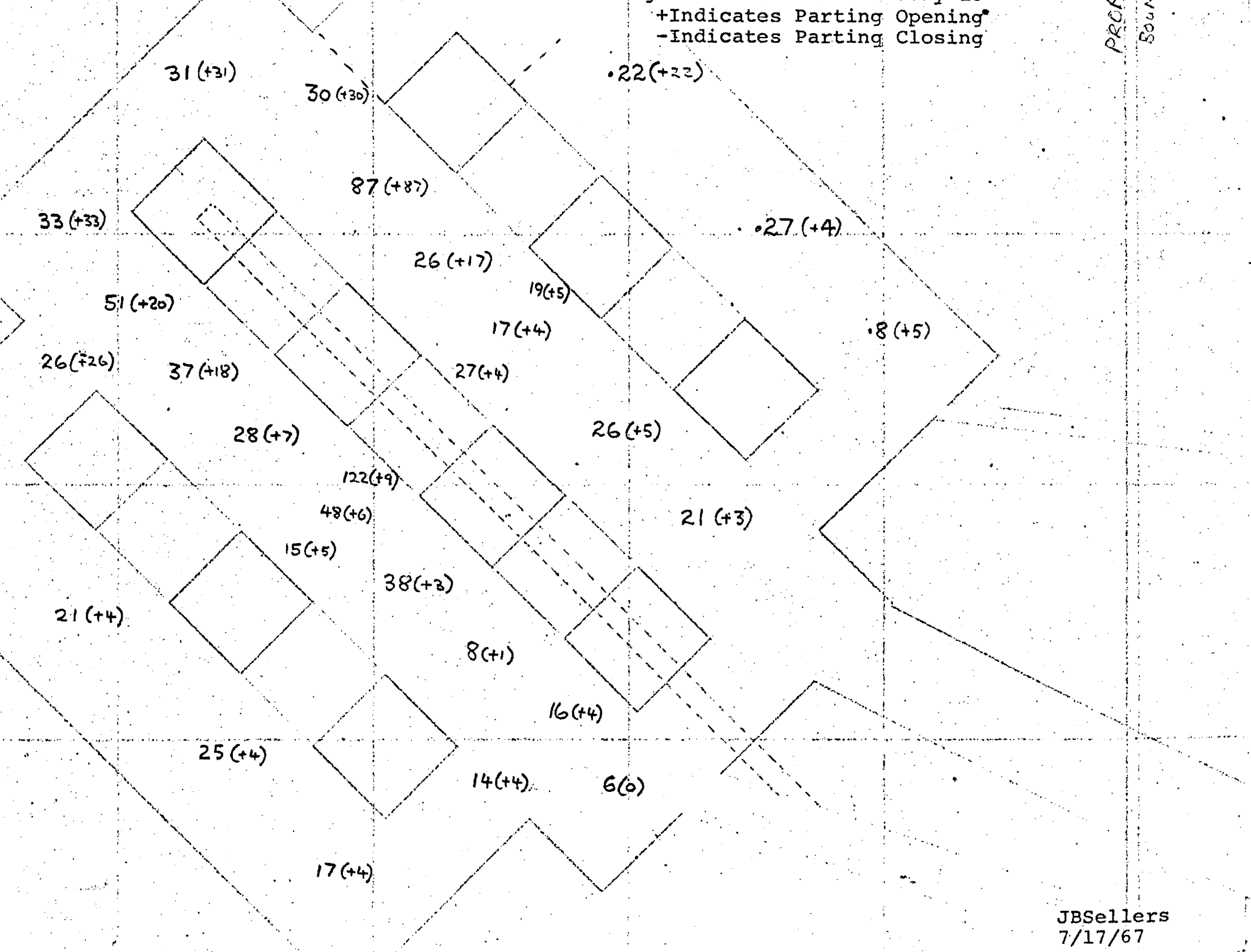
Old Design



New Design

FIGURE 3

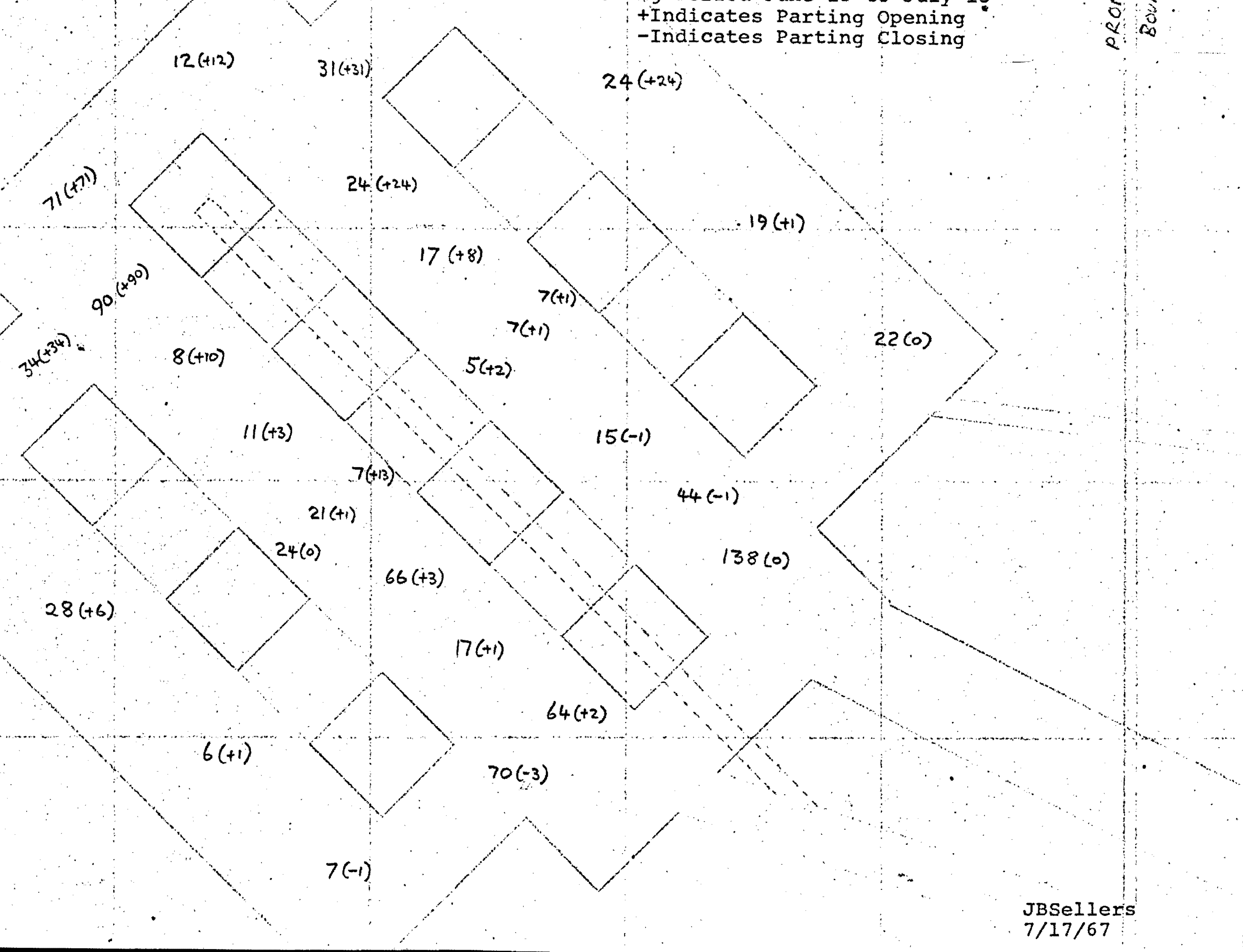
SHOWING SAGGING IN 0 TO 5 FOOT ZONE ABOVE ROOF IN MINING AREA
First Number is Absolute Sag (In Thousandths of an Inch)
Number in Parenthesis is Movement During Period June 15 to July 15
+Indicates Parting Opening
-Indicates Parting Closing



JBSellers
7/17/67

FIGURE 4

SHOWING SAGGING IN 5 TO 15 FOOT ZONE ABOVE ROOF IN MINING AREA
First Number is Absolute Sag (In Thousandths of an Inch)
Number in Parenthesis is Movement During Period June 15 to July 15
+Indicates Parting Opening
-Indicates Parting Closing



JBSellers
7/17/67

At Station 37 in Room 2, 0.087 inch movement was detected but the movement has since decelerated and the area is stabilizing.

In the 5 to 15 foot horizon at locations remote from the working faces, the roof has remained practically static. At points close to Crosscuts 34H and 23J quite large amounts of sag were detected, similar to the movements observed around crosscuts at the southeast end of the rooms. Thus the formation of crosscuts and wider roof spans does definitely induce greater roof sagging. The movements although moderately large are decelerating and the area appears to be stabilizing.

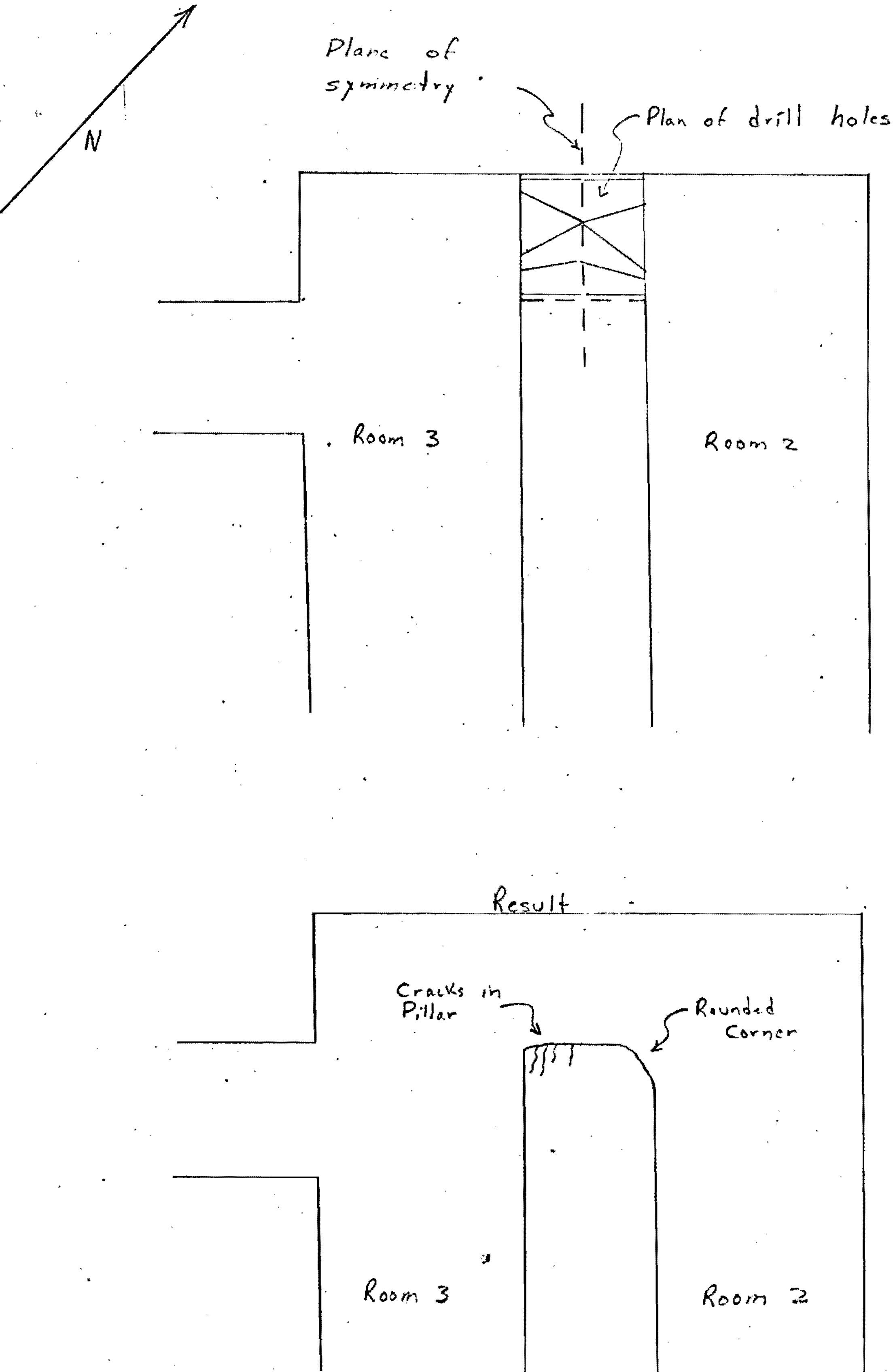
B. Drilling and Blasting Development

In the March 16 to April 15 Monthly Progress Memorandum, a tentative conclusion was made that collar priming, which has definite cost advantages, would not produce successful blasts in a 40 foot by 60 foot heading with the standard 28 four-inch hole configuration. During this period a heading round in Room 1 was taken using collar priming. This latest round using collar priming was powdered similarly to successful rounds except the dynamite primer was installed in the hole after loading the ANFO. The results of this round were: tonnage blasted - 3,300 tons, footage advanced - 20 feet, throw - 170 feet. It is concluded that collar priming produces less than satisfactory results because of lower detonation pressures at the bottoms of the holes and because of a tendency for misfires to occur.

The last operation of this mining program is the removal of seven 40 feet by 40 feet by 73 feet crosscuts. Because of the planned high stress levels in the 40 feet by 40 feet by 73 feet pillars, each crosscut must be removed in one blast, rather than two or more blasts, to provide safety to the miners. Therefore, a round has been designed to accomplish such a blast, and has been tried out. Crosscut 23J was selected for the test. Figure 5 shows a general plan of the round. The configuration is symmetrical to an axis running parallel to Rooms 2 and 3. Half of the round was drilled from Room 3 and half was drilled from Room 2. Each hole was detonated at the same time as its counterpart. The round pulled well, but also resulted in the rounding of the corners of Pillar 23H. To reduce this rounding effect when blasting the 40 feet by 40 feet by 73 feet crosscuts, the rib holes will be powdered in such a way to reduce the intensity of the stress wave generated by the rib holes. The stress wave intensity can be reduced by using a salt formula ANFO, or by using cardboard tubes to provide a hollow space in the ANFO column, or by using explosives packaged in containers that are considerably smaller than the hole bore.

FIGURE 5

A ROUND TO BLAST A 40' X 40' X 40' CROSSCUT



The method of breaking rock for the benching operation is shown in Figure 6. In benching blasts taken to date fragmentation has been coarser than for heading rounds. A considerable amount (6 to 8 feet) of back break (breakage in the direction of advance beyond the line of holes) has been observed. The powder factor in rounds to date has averaged 0.40 and has been as low as 0.32 pounds per ton. The coarser fragmentation is probably caused by the alignment of the holes with the strong N 45° E joint system. Lower powder factors and the ease of moving rock when two free faces are available may contribute to the coarser fragmentation. Future plans are to obtain better fragmentation by decreasing the delay period between detonation of holes, and to reduce the footage drilled per ton of broken rock by increasing the spacings of blast holes.

Figure 7 and Table 2 show the results of the bit factorial experiment completed recently. Analysis was by K. I. Jagel.

The experiment was designed and carried out as a complete $3^3 2^1$ factorial experiment without replication. The order in which the holes were drilled was set up so that any effects on the results due to shale richness or bit life would be confounded with the three factor and higher interactions and the experimental error.

The analysis of variance presented in Table 2 indicates that the significant variables determining penetration rate are the direct effects of the clearance angle of the drill and the thrust applied to the drill. Bit hardness and rake angle probably are not significant direct efforts.

The two factor interactions indicate that although rake angle and hardness are not significant effects, in themselves, they may affect the clearance angle effect. The interaction between clearance angle and thrust is not surprising considering the importance of each of these variables. A regression equation will be developed from these data which will assist in predicting the penetration rate that can be achieved with a given bit design and drill thrust.

C. Pillar Research

Figure 8 shows pillar strains measured over the section opposite the mining headings. Pillar 23F shows small amounts of convergence due to the removal of Crosscuts 34H and 23J. Pillar 23D has remained static. Pillar 23B shows the effects of benching close by. The MPBX No. 4 showed further roof-floor convergence. Surprisingly enough, little convergence was measured in Pillar 23B in the section opposite the benching. It was to be expected that the removal of the bench from around the lower half of the pillar would have caused much more convergence in the lower half of the pillar than actually occurred.

FIGURE 6

DRILLING PATTERN
12' X 15' Burden

Map View

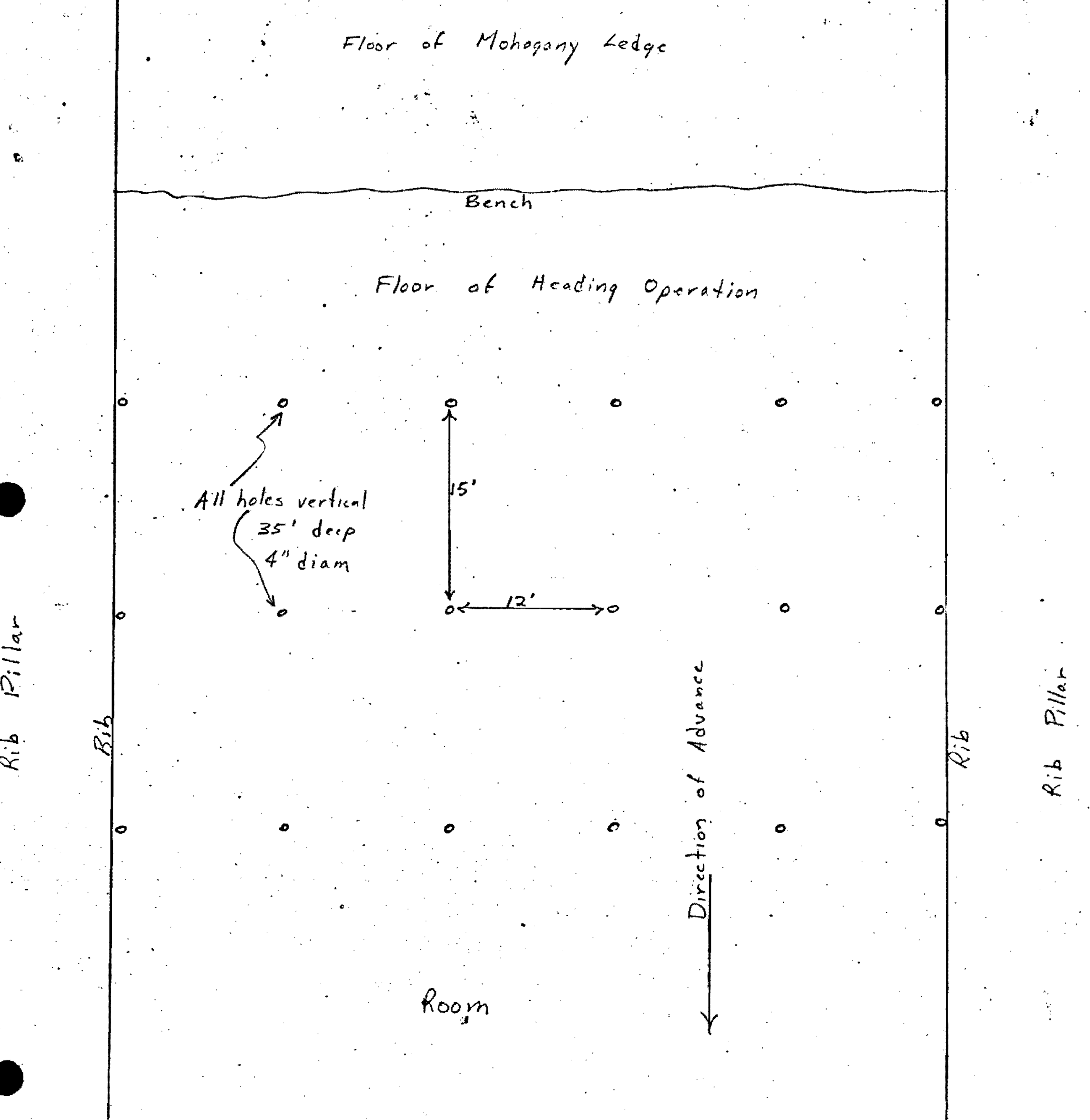
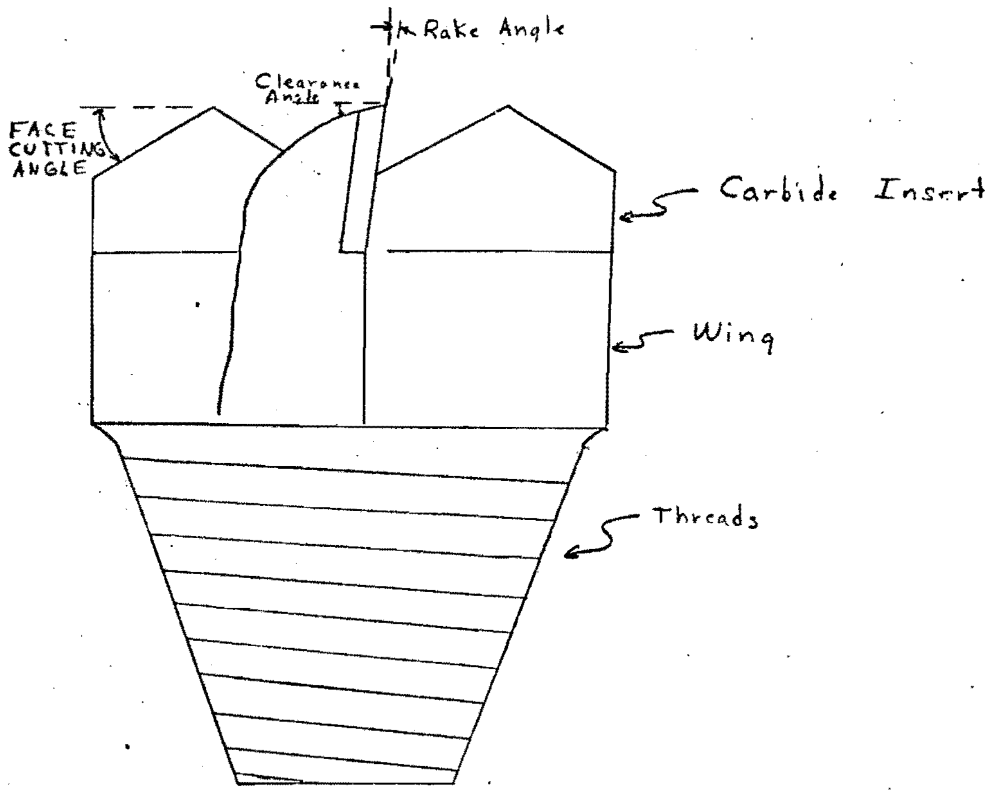
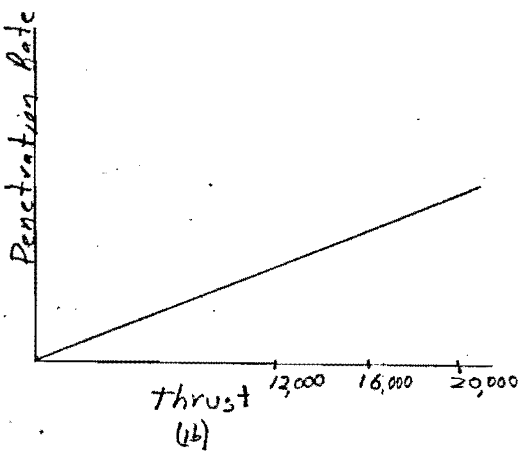


FIGURE 7

SKETCH OF TYPICAL DRAG BIT





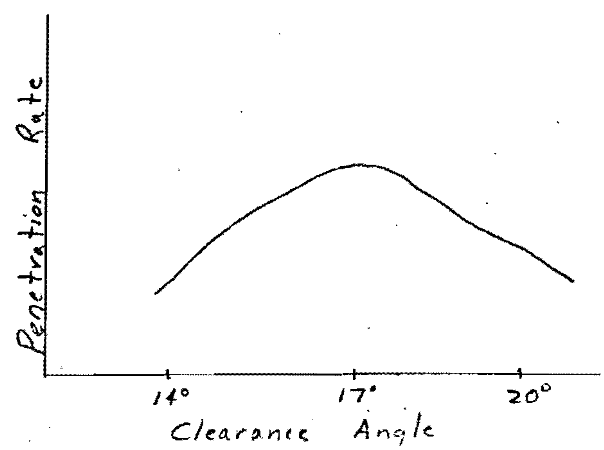


TABLE 2

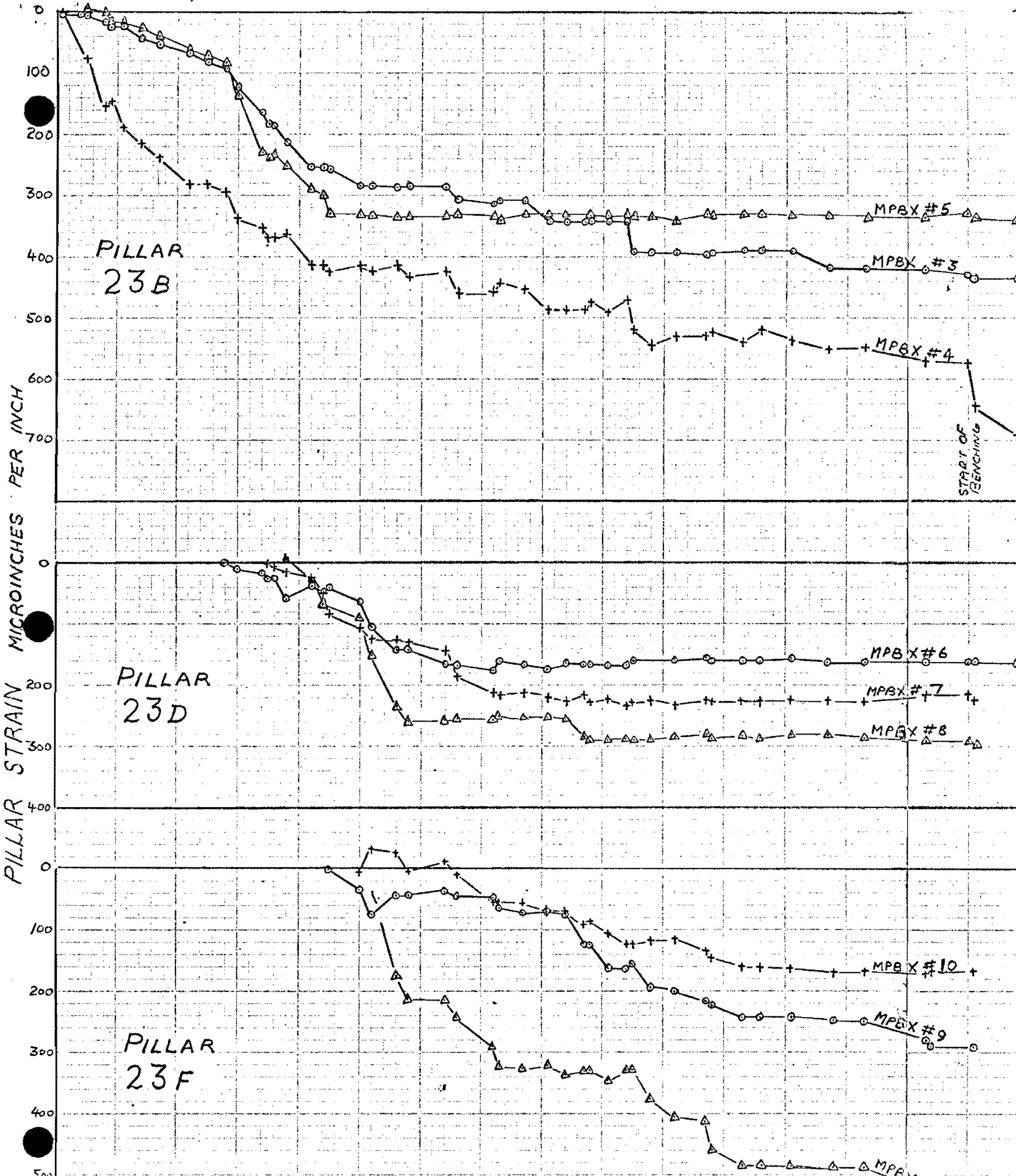
OIL SHALE DRILLING STUDIES
ANALYSIS OF VARIANCE

Variables	Sum of Squares	d.f.	Significance P[1]
Drill Design Parameters			
Rake Angle, R			
Linear	1.258	1	Not Significant > 10%
Quadratic	0.371	1	Not Significant > 10%
Clearance Angle, C			
Linear	1.388	1	Not Significant > 10%
Quadratic	17.690	1	Highly Significant < 1%
Bit Hardness, H			
Linear	3.745	1	Not Significant > 10%
Thrust, T			
Linear	11.742	1	Significant 1% < P < 5%
Quadratic	0.001	1	Not Significant > 10%
Two Factor Interactions			
$R \times C$	16.368	1	Highly Significant < 1%
$R^2 \times C$	15.143	1	Significant 1% < P < 5%
$R \times C^2$	17.072	1	Highly Significant < 1%
$R^2 \times C^2$	0.034	1	Not Significant > 10%
R,H	19.018	2	Significant 1% < P < 5%
R,T	4.532	4	Not Significant > 10%
C,H	6.600	2	Not Significant > 10%
C,T	4.420	1	Not Significant > 10%
$C^2 \times T$	0.728	1	Not Significant > 10%
$C \times T^2$	0.294	1	Not Significant > 10%
$C^2 \times T^2$	35.381	1	Highly Significant < 1%
T,H	10.996	2	Possibly Significant 5% < P < 10%
Remainder	58.564	28	
Total	225.345	53	

(1) Probability that observed effect is due to experimental error.

FIGURE 8

PILLAR STRAINS MEASURED OVER SECTION OPPOSITE MINING HEADINGS.



IV. MECHANICAL ENGINEERING (W. S. Bergen, R. E. Smith and J. J. McAleer)

Retort No. 3 tested 1/4 to 2 1/2 inch and 1/4 to 1 inch shale, both with dilution gas and preheated combustion air, each shale range with a different air distributor arrangement.

Major conclusions of a mechanical nature are:

1. Serious firing problems are created using the existing line burner with dilution gas with the present installation configuration.

2. Thermowells must not extend into the combustion zone of the retort.

3. The liner design as used in Retort No. 3 appears to be stable under adverse conditions such as high temperatures and clinkering.

Discussion

A. Secondary Crusher

Data on crushing plant output and power requirement versus secondary roll tooth maintenance is now being assembled for transmission to Allis-Chalmers as per our original agreement.

Recently some screening tests were made where the wear or service of two additional hardfacing materials were compared with the Amsco 60 rod which we have been using routinely for secondary roll tooth hardfacing. It should be emphasized that these tests were screening and short term to evaluate any obvious difference in wear characteristics. Each material was applied to seven teeth each, and a period of two weeks elapsed prior to comparison.

The materials were Stoody #2134 and Eutectic 61 which were compared with Amsco 60. Based on this test, the Stoody rod was inferior in that it lacked resistance to impact and shock and failed to a greater extent from brittle fractures. The Eutectic and Amsco rods seemed to be essentially comparable in quality except that the Eutectic rod may have more resistance to wiping or plastic deformation. The test techniques employed would not provide a definitive answer to this question however.

We will continue to use the Amsco 60 rod in future maintenance however, since it will provide better continuity of data over the remaining project time. We are having to perform extensive rebuilding of the tooth shape with high manganese rod at present, and we will want to determine the feasibility of this technique without extraneous factors

B. Weigh Bin Area

No changes have been made in this area.

C. Retort No. 3

1. Air Distributors

Testing of 1/4 to 2 1/2 inch shale was performed using a three header - 36 riser configuration. Air headers were on 21 inch centers and the risers from the headers on 12 inch centers.

Testing of 1/4 to 1 inch shale was performed using a two header - 36 riser horizontal yoke system. Air headers were on 36 inch centers, yokes on 12 inch spacings and risers on a 12 inch by 18 inch rectangular pattern. See Figure 9. Supporting gussets for the yokes were from below rather than between the risers as had been previously used. No serious riser distortions were encountered during Run C1050.

2. Air Distributor Internal Insulation

A new internal insulated system was installed during the July 6-9 turnaround. This was installed to minimize temperature differences of the air from riser to riser. Temperature differences will cause variable air flows from each riser. Calculations have shown a 166 F temperature difference along the header using cold air at the 400 shale mass conditions. The following indicates temperature and air flow variations:

Shale Mass Rate	ΔT	Air Flow From Mean
300	200 F*	± 7%
400	166 F	± 6%
500	135 F*	± 5%

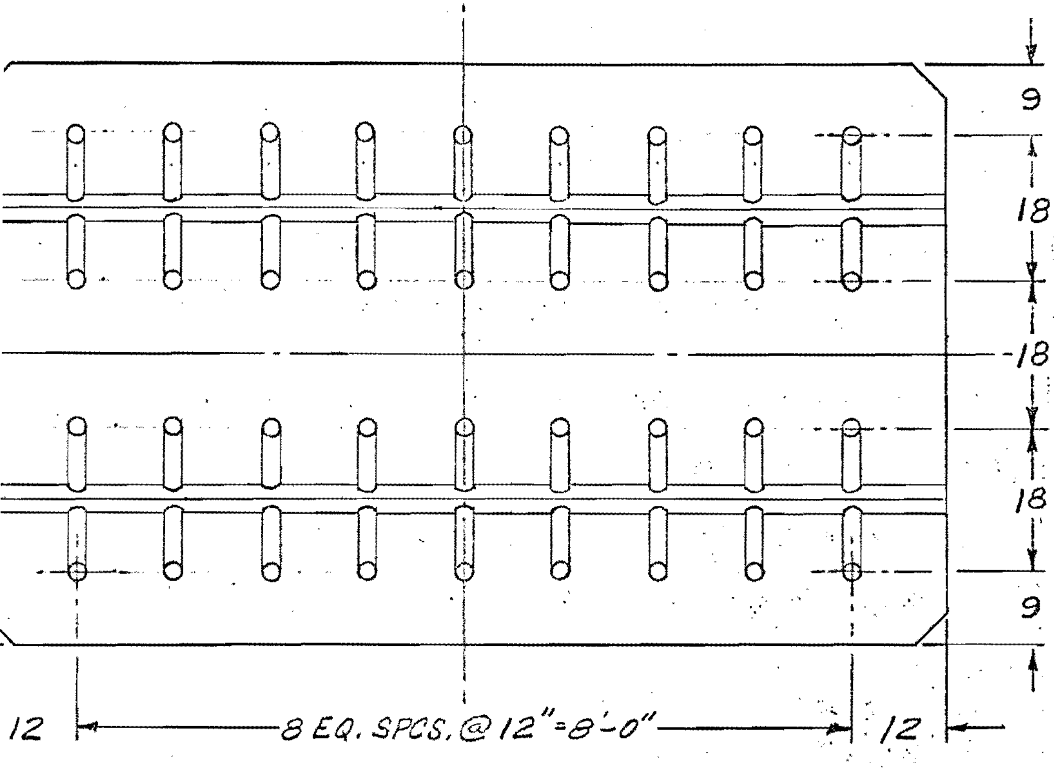
*Estimated from less rigorous calculations.

The original design was for 150 F for the 400 to 500 mass operation.

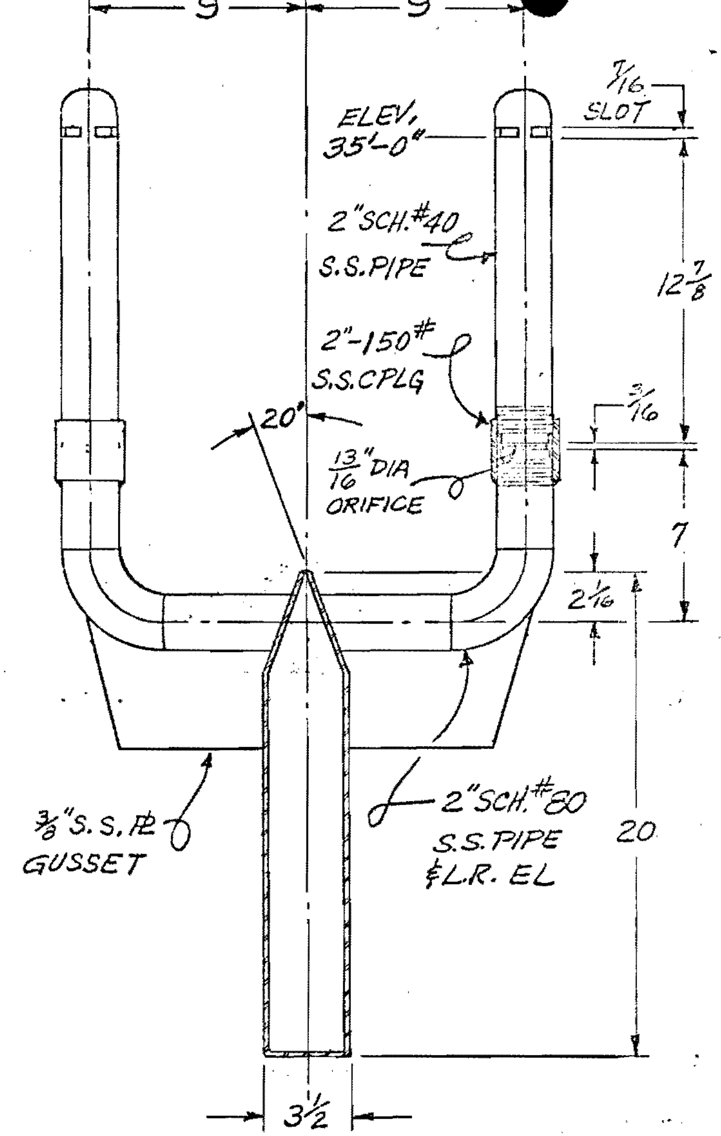
The temperature gradient along the header will be measured when cold air is tested. The gradient is expected to be between 25 F and 40 F with an air flow differential less than ± 2%.

3. Roll Feeder

During the startup of Run C1046 with 1/4 to 2 1/2 inch shale a serious knocking occurred. After careful analysis



PLAN
SCALE: 1/2" = 1'-0"



RISER ASSY
SCALE: 1 1/2" = 1'-0"

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OIL SHALE RESEARCH CENTER
RIFLE, COLO.
PROJECT MANAGER-SOCONY MOBIL OIL CO., INC.

JOB NO. | CHARGE
APPROVED | PROCESS | DESIGN | SAFETY

SCALE: NOTED
DRAWN BY: [illegible signature]
STARTED: 7-7-69
COMPLETED: 7-7-69
DIMENS.

AIR DISTRIBUTOR SPACING
2 HEADER - 36 RISER
RETORT NO. 3
FIGURE 9

LOCATION
DRAWING NO. RE 85

feeding shale to the north roll was interfering with the ribs on the roll. No change in operation was deemed necessary. Following the test of 1/4 to 2 1/2 inch shale, inspection verified the conclusion reached earlier. There had been concern at the time that the shaft on the north roll might have broken.

During the raw shale circulation tests preceeding Run C1046, the rolls had been opened to 2 1/2 inches for operation. The raw shale flow tests showed slow flow in the southwest corner. The south roll was opened 1/4 inch at the west end to adjust this condition.

4. Raw Shale Inlet

Jamming of shale at the inlet to No. 1 star feeder occurred when first testing the 1/4 to 2 1/2 inch range. Pieces of shale 6 inches by 8 inches by 2 inches were found. The rubber tongue in the feeder was removed with no further problems.

5. Retort Liners

The liners have remained in good condition with no warping. A deposit has built up on the wall under the liner edge forming a taper at this point. This formation is similar to that found in Retort No. 2 at the lower end of the liner.

D. Vibratory Feeder

No problems have occurred with the No. 6 vibratory feeder. A replacement belt conveyor has been fabricated and is ready for installation if needed.

E. Zero Speed Switches

No failures have been noted with the zero speed switches. The mechanism to speed up the input to the spent shale roll "O" speed switch has been installed to make it fully operative.

F. Multiclone

Cleaning is required on each shutdown. This will be replaced with a conventional cyclone if future operations are indicated.

G. Screw Conveyors

The replacement flights for the No. 2 screw conveyor were installed on the July 6-9 turnaround.

H. Gas Sampling System

This system has been revised. The condenser from the Retort No. 2 sampling system was installed as well as the new after-cooler. On a subsequent startup, the line at the compressor outlet was found plugged with coke. It was replaced.

I. Vertical Thermowells

The bottom six inches of the thermowells were seriously damaged during the 1/4 to 2 1/2 inch shale tests. The 330 stainless steel sheath had melted or burned through. This section was cut out and the lowest point is now 18 inches above the air inlet.

J. Electrostatic Precipitator

The latest test of the precipitator shows the efficiency still to be at the 99% plus level.

K. Recycle Blower

No problems have occurred with this unit.

L. Raw Shale Accounting

The raw shale accounting system has had few problems. The weigh bin switches on the Hardy scale will be replaced on the next turnaround.

M. Line Burner

Since we began hot air and hot dilution gas testing we have experienced line burner difficulties. These have primarily been burner flame failures and heavy pressure surges. It was believed that these pressure surges could cause flame failures, and that the pressure surges were caused by back firing at the point where dilution gas is introduced into the burner scroll.

In an attempt to remedy this situation an orifice was installed at the point of dilution injection to insure a gas velocity in excess of the flame velocity. This improved the operation to a degree in that pressure surges were reduced, however, the burner operation was still not satisfactory.

We again experienced line burner cut outs during Run C1050 which was our first attempt at hot dilution gas operations with 1/4 and 1 inch shale and the current two header - 36 riser air distributor. It was difficult to determine the exact cause of these burner failures after the fact, so a complete survey of the equipment was performed prior to the start of Run C1051.

A Brown instrument service representative examined the controller. No defects were found in the controller but on the chance that it might be an intermittent problem, a new amplifier was installed in the unit.

All gas and air pressure regulators in the burner system were examined and adjusted to conform with the recommended values. It was found that the pilot light gas pressure was approximately seven inches of H_2O instead of the recommended five inches. A leak was found in the main gas pressure regulator diaphram adjusting spring closure. This leak resulted from an "O" ring failure subsequent to installation prior to Run C1050 and may have been the cause of burner failure. A leak in this regulator diaphram closure has the effect of unloading the diaphram and upsets the system balance. Experimentation showed that a leakage from either the pilot or main gas regulator diaphrams caused the burner to go out.

After completion of the burner maintenance, the burner was operated for a four hour test period without any difficutly.

N. String Data

No mechanical difficulties have been experienced with the string measuring equipment. It can be assumed therefore, that all data obtained during this report period are accurate and comparable with previous data.

O. Spent Shale Riffler

A new spent shale sample riffler was installed on the spent shale system. This equipment is a bar in tube riffler employing the same design as the new raw shale sample riffler installed during the previous report period. Drawings RB452 and RB453 show the construction details.

This equipment appears to be performing satisfactorily based on data to date. Its primary advantages are simplicity, and the elimination of possible sample bias as evidenced by raw shale sample errors observed with original raw shale riffler which was of the same design as the original spent shale riffler.

P. Air Blower

During this report period, we experienced our first and minor mechanical problems with the air blower. The gas seals at both the suction and discharge end of the blower began to throw sealing water. These seals employ water in a slinger ring and labyrinth to effect a seal. Leakage began after a water main failure and repair, during which it was assumed that considerable solid material may have been introduced into the seals.

New seals have been ordered, and the blower is presently being operated without sealing water. Air leakage in this unit is of no concern either from a mechanical or accounting standpoint. It was considered undesirable to allow water to be injected into the retort air supply, and evidence indicated that this was happening since considerable condensed water was found in the line burner during a turnaround inspection.

Q. Liquid Disengagement

Engineering, procurement, and construction is in progress for the installation and testing of the liquid disengagement equipment in Retort No. 3. Figure 10 shows the disengagement tray which will be installed in the retort, while Figure 11 shows the flow diagram for the oil circulating and accounting system which will be used during the tests.

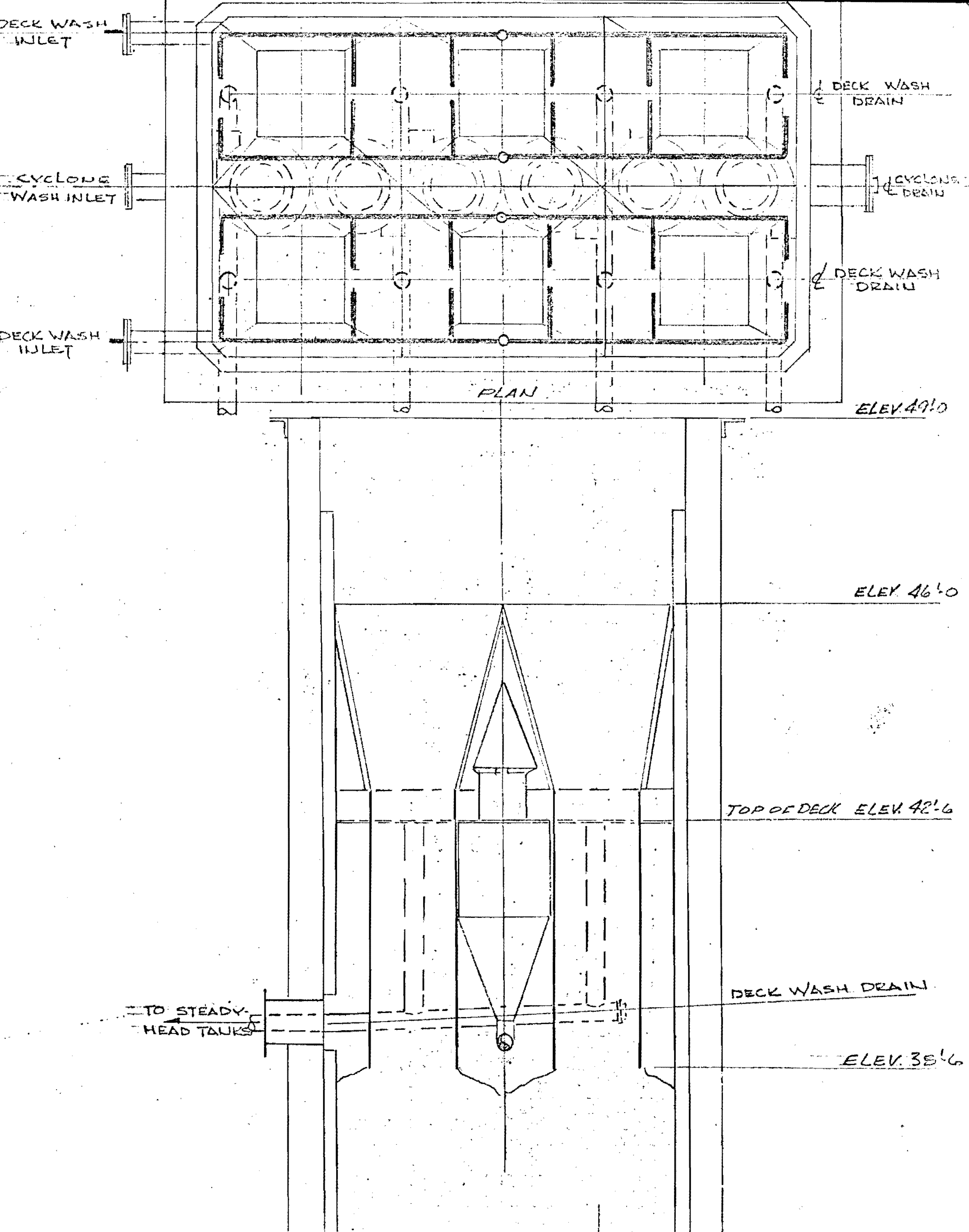
Briefly, shale passing through the retort will flow over inclined grates which have 1/8 inch wide open spacing between the bars. Liquid oil will drain from the shale through the grates, and be collected on the oil deck where it will flow through drain pipes to the product recovery system. Since it is anticipated that some fine shale will also accumulate on the deck, a flush stream of oil will be recycled continuously to the deck to prevent accumulation and plugging.

In addition, gas from the shale-gas disengagement zone created by the shale chutes will flow up through six cyclones, up through the grates, and into the upper shale bed. In the cyclone, some oil mist and dust will be removed. In order to keep these lines free of plugging, a flush oil stream will also be circulated to the drain lines continuously.

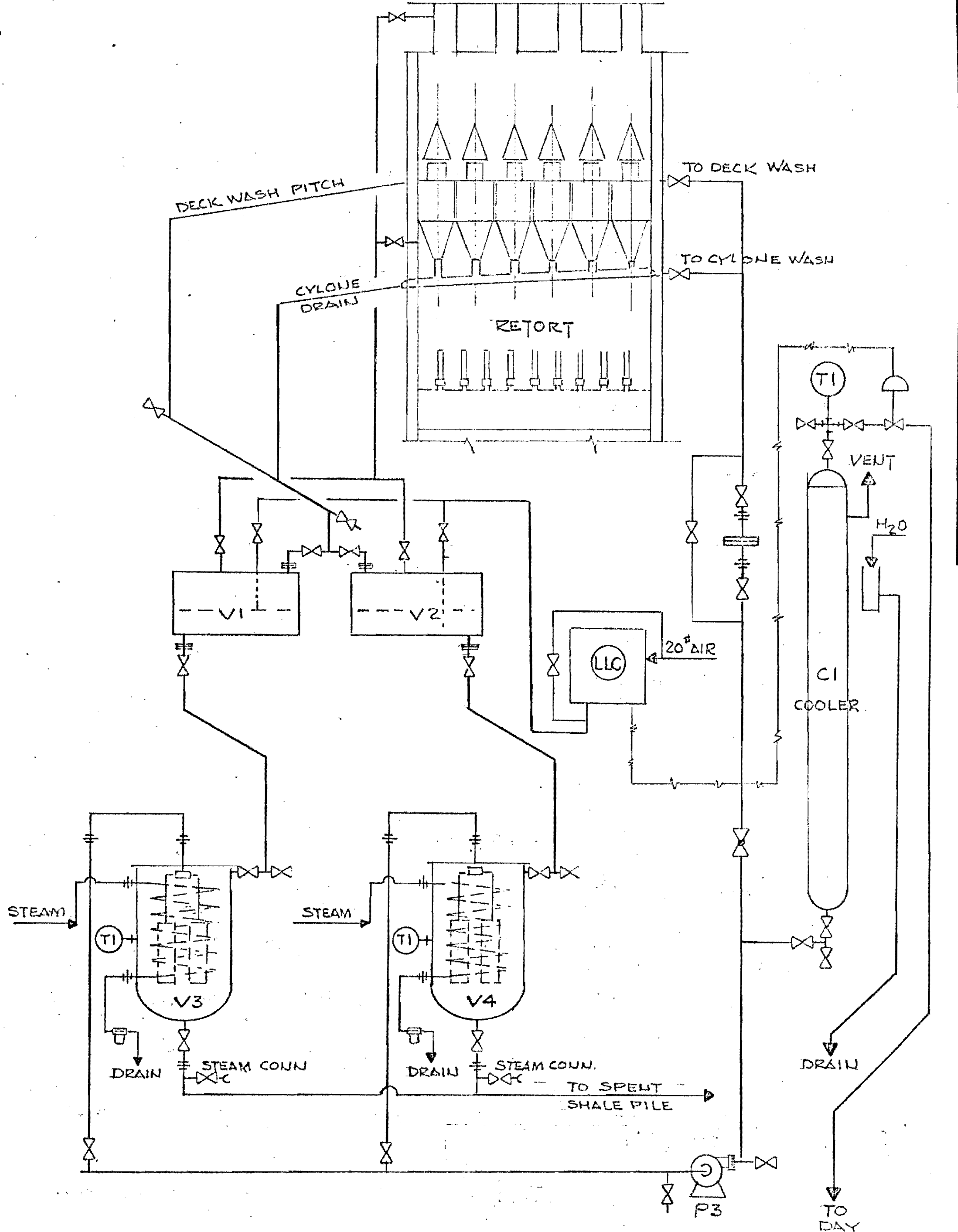
Flush oil will be protected from heat loss, and will be recycled at temperatures as near retort conditions as practical. All of the oil circulating system will be completely balanced and tested prior to the introduction of shale to the unit. While all streams are subject to adjustment based on actual testing, the following values are being used as a design basis:

1.	Amount of product removed by disengager	50%
2.	Flush oil to tray	125 GPM
3.	Flush oil to cyclone drain line	25 GPM
4.	Operating conditions, oil	~600 F

All oil will require constant filtering, and since the amount of solid material to be removed is uncertain, the frequency of filter plugging cannot be estimated. Parallel filter facilities will be provided to allow cleaning and filtration simultaneously.



DECK WASH INLET
CYCLONE WASH INLET
DECK WASH INLET
DECK WASH DRAIN
CYCLONE DRAIN
DECK WASH DRAIN
PLAN
ELEV. 49'-0
ELEV. 46'-0
TOP OF DECK ELEV. 42'-6
DECK WASH DRAIN
TO STEADY-HEAD TANKS
ELEV. 35'-6


TO DECK WASH
DECK WASH PITCH
TO CYLONE WASH
CYLONE
DRAIN
RETORT
TI
VENT
H_2O
V1
V2
LLC
20# AIR
C1
COOLER
STEAM
STEAM
TI
TI
V3
V4
DRAIN
DRAIN
STEAM CONN
STEAM CONN.
TO SPENT
SHALE PILE
DRAIN
P3
TO
DAY

V. RETORTING SECTION (J. E. Lawson)

A. Retort Group (T. C. Lyons, W. M. Broman, R. L. Clampitt, D. P. Cotrupe, P. H. Gifford, J. W. Hasz, R. L. McGalliard, B. L. Reymond and E. E. Turner)

1. Retort No. 3 Operations Summary - Runs C1045 Through C1049 (T. C. Lyons)

The dominant feature of this report period was a continuous 17 1/2 day run with 1/4 to 2 1/2 inch shale which is the longest sustained operation in Retort No. 3 to date. This run was purposely forced down in its eighteenth day when the study was completed. The fraction processed included roughly 94% of the mine run shale. Whereas, the 10 day run made in April with the large, 1 to 2 1/2 inch shale was impressive for its stability at a given set of conditions, the current run was impressive because of the ability of the process to adapt to changing conditions. Throughout the entire run, the primary objective was to increase yield; therefore, the unit was pushed to the brink continuously.

However, prior to the operation with 1/4 to 2 1/2 inch shale, a single run was made with the 1/4 to 1 inch fraction that was too late to be included in the previous Monthly Progress Memorandum. It will be recalled that two unsuccessful attempts were made to run the 1/4 to 1 inch shale at a richness level of 32 gallons per ton (C1043 and C1044). Both runs were conventional cold air operations. Consequently, a third run (C1045) was made with hot dilution gas to test its advantages with this richer shale. Unfortunately, this run failed in a similar fashion. Thus, it was concluded that the richness ceiling for 1/4 to 1 inch shale with the current hardware configuration appears to be about 32 gallons per ton.

Run C1045 concluded the series with 1/4 to 1 inch shale. Operability had been achieved but yields were lower than desired. It will be recalled that the air distributors were spaced wider than normal intentionally in order to emphasize shale flow at the expense of gas distribution. However, the spacing was ideal for the wide range, 1/4 to 2 1/2 inch shale. Therefore, this fraction was evaluated with the same hardware configuration that was used with the small shale.

The unit was started up on June 18 at a mass rate of 300 lbs/(hr)(ft^2) with hot dilution gas. The low temperature startup (700/900 F) used successfully with the small shale worked equally well with the wide range fraction. In the first five days, the yield level was raised from 82% Vol to 85% Vol raw shale Fischer Assay by maneuvering gas rates. Because of surging and coking problems in the line burner internals, the operation was changed to straight hot air at 300 lbs/(hr)(ft^2) for another five days. (The line burner was held at 900 F to insure good air distribution in the headers.) The yield level reached 86% Vol raw shale Fischer Assay with an assay of 29 gallons per ton. It is significant that for several days during this period the assay averaged slightly higher than 30 gallons per ton.

In the tenth day of operation, the mass rate was increased to 400 lbs/(hr)(ft^2) while continuing the hot air operation. The unit was held at this condition for two days - just long enough to establish operability and yield which was about 83% Vol raw shale Fischer Assay at an assay of 29.5 gallons per ton. The mass rate was increased further to 500 lbs/(hr)(ft^2) and was held for five days. The yields were brought up to the 82% Vol raw shale Fischer Assay level (26 to 27 gallons per ton assay).

After completing the seventeenth day of operation, the gas rates were increased to force a shutdown. We had planned to sample the bed for liquid accumulation during the failure period but because of vacuum pump problems, we were unable to do so.

Our conclusions concerning the operation with 1/4 to 2 1/2 inch shale are as follows:

1. Low line burner startup procedure is satisfactory.

2. Operability is entirely satisfactory at mass rates of 300, 400 and 500 lbs/(hr)(ft^2).

3. Dilution gas is not necessary even for insurance. Of course, the hot air operation does give some dilution effect. However, the big unanswered question is whether cold air would not be just as satisfactory.

4. The yields at the 500 mass rate are some 4 Vol % lower than the Retort No. 2 demonstration run. This is because of the lower gas rate limit in Retort No. 3 compared to Retort No. 2. However, at the same gas rate the yields are comparable based on the regression analysis.

In our current operation, we have returned to the 1/4 to 1 inch shale in a further effort to improve the yield by a hardware change. The air distributor under evaluation has 36 bayonets - the same number as before - but they are arranged to give more uniform gas coverage. We expect to improve yield but we may lose operability because of the necessity of putting the bayonets on horizontal yokes. The results of this study will be covered in detail in the next Progress Memorandum.

2. 1/4 to 1 Inch Shale Operations - Run C1045 (J. W. Hasz)

Run C1045 was the only run made with 1/4 to 1 inch shale during this period and was the last of a series of 1/4 to 1 inch shale runs starting with Run C1035. Runs C1035 through C1044 were discussed in the June 15, 1967 Monthly Progress Memorandum.

Run C1045 was made to determine if the use of dilution gas would allow processing of rich shale. Run C1044, a cold air run, shut down with a clinker about 18 hours after fire-off. This failure was attributed to a raw shale Fischer Assay of 32.4 gallons per ton.

The low line burner temperature startup procedure with dilution gas used successfully for Runs C1039 and C1040 was used for C1045. The retort was fired at about 0800 hours, June 15, 1967 and the startup appeared to be successful. The west side of the retort ignited before the center and east side. However at 1300 hours combustion zone temperatures and offgas temperatures were even and at their proper levels. Oxygen concentration in the vent gas was about 0.8 Vol % which was not excessive for a dilution gas operation. Operations remained satisfactory until about 1600 hours when the east side offgas temperature started to split out of the offgas temperature pack. The operation continued to deteriorate with the west side of the retort operating hot and the east side of the retort cooling off. The unit was shut down with a clinker on the west side within 18 hours after fire-off. Average raw shale Fischer Assay was 31.7 gallons per ton. Dilution gas, therefore, does not appear to extend the Retort No. 3 maximum assay limit of about 32 gallons per ton.

3. Discussion of 17 1/2 Day Operation With Wide Range (1/4 to 2 1/2 Inch) Shale - Runs C1046, C1047, C1048 and C1049 (R. L. Clampitt)

Following operations with the 1/4 to 1 inch shale (Run C1045), a decision was made to change to 1/4 to 2 1/2 inch, wide range shale to further test the current retort hardware configuration. It had been discussed previously that the air distributors were spaced wider than desired intentionally in order to emphasize shale flow at the expense of gas distribution for 1/4 to 1 inch shale. However, the spacing was ideal for the 1/4 to 2 1/2 inch wide range shale because of improved penetration. A sustained operation was carried out on 1/4 to 2 1/2 inch shale for 17 1/2 days at 300, 400 and 500 mass rate conditions. All of the conditions exhibited good operability and produced relatively high yields of 86% of raw shale Fischer Assay at the 300 mass rate and 82% at the 500 mass rate.

At the end of Run C1045 on 1/4 to 1 inch shale, it was concluded that Retort No. 3 would not operate at a richness level of 32 gallons per ton with the present hardware configuration while using hot dilution gas (2,000 SCF/T). Four attempts to process 1/4 to 1 inch rich (30 to 32 gallons per ton) shale resulted in shutdowns because of clinker formation.

Various program alternatives were considered before switching to wide range (1/4 to 2 1/2 inch) shale. These were:

1. Attempt to gain operability with the 1/4 to 1 inch shale at the 31 to 32 gallons per ton richness level by removing the center air header thus further minimizing hardware. This was rejected because it was felt that by reducing air distribution that oil yields would be even lower.

2. Revert back to the 25 to 27 gallons per ton richness level and continue efforts to improve yields on 1/4 to 1 inch shale with air distributor hardware variations. This was rejected because of the difficulties of getting lean shale from the current mine benching operations.

3. Change to 1/4 to 2 1/2 inch wide range shale and determine the operability and yields at the 31 to 32 gallons per ton level. <u>This course of action was selected</u>. It was believed that the hardware configuration, which is shown on Figure 12, had a high probability of being successful while charging 28 to 30 gallons per ton shale. From a shale flow standpoint and air distribution adequacy, it was felt that the hardware on Figure 12 would generate high oil yields while charging 1/4 to 2 1/2 inch shale.

Refer to Figure 13, which shows a comparison between the shale size distribution for recent runs in Retort No. 3 with the successful demonstration run in Retort No. 2. Also presented on Figure 13 is a dashed curve which represents the distribution for wide range shale in a commercial operation.

FIGURE 12

RETORT CONFIGURATION - RUNS C1043 - C1049

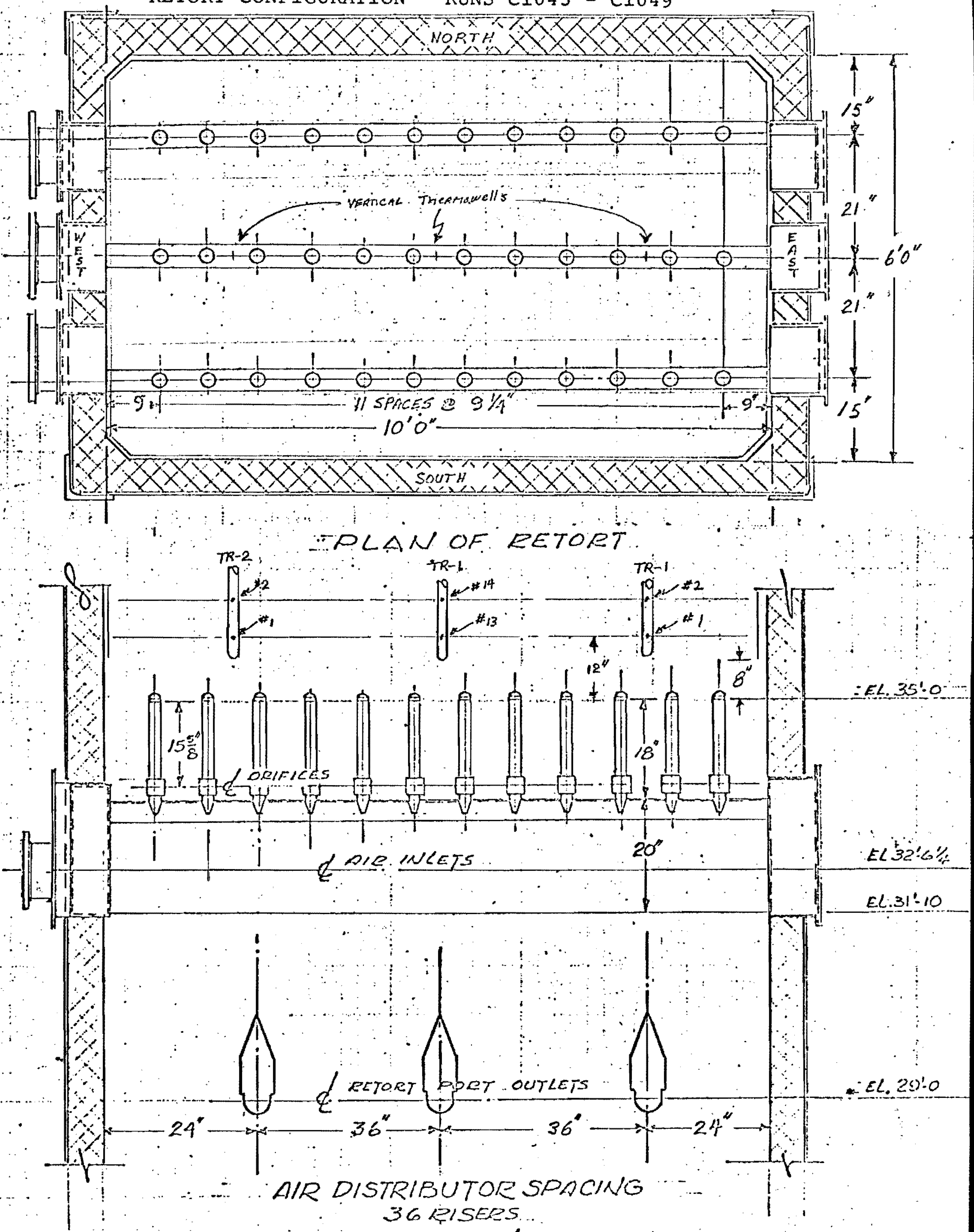
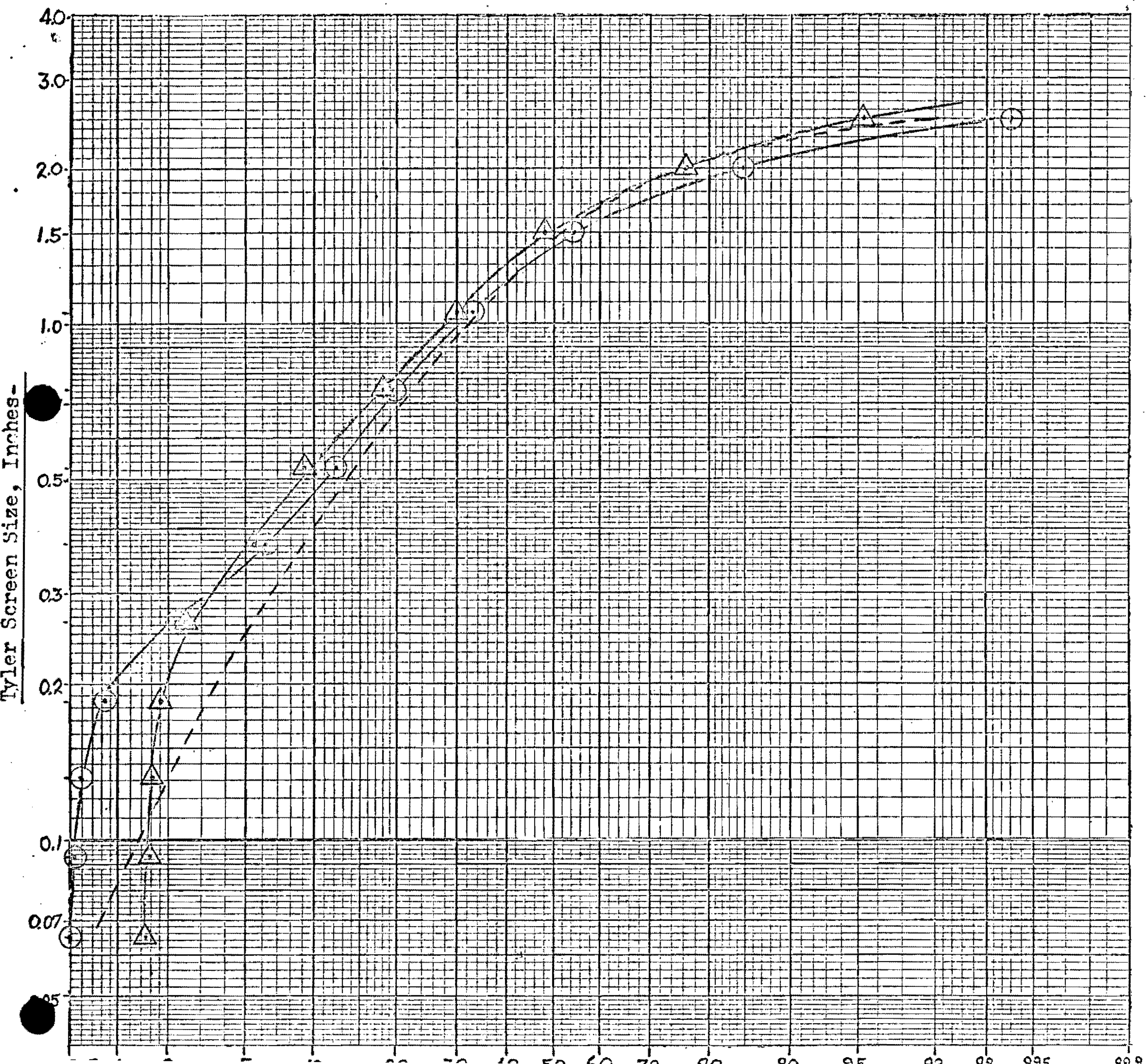


FIGURE 13

SHALE SIZE DISTRIBUTION

Symbol	Retort No.	Run Nos.	Shale Size Range	Da, Inches	Dv, Inches
△—△	3	C1046, C1047	1/4 to 2 1/2 inches	1.10	1.48
⊙—⊙	2	B953	1/4 to 2 1/2 inches	0.98	1.37
– – –	Extimated Commerical Distribution			0.86	1.42



The shale processed in Retort No. 3 is essentially identical to that processed in Retort No. 2. For comparative test purposes, we attempted to make shale for Retort No. 3 similar to that used in Retort No. 2. The only difference in the distributions processed and a commercial distribution is at the 1/4 inch minus level. The size ranges processed were about 2 to 3% short of 1/4 inch minus material. The fraction processed in Retort No. 3 represents an estimated 94% of the mine run shale. The dashed curve represents 96.0% of the mine run.

Before starting up Retort No. 3 on the wide range shale, normal turnaround maintenance was performed. During the turnaround, attention was given several items out of the ordinary classification. These were:

1. Adjusted the spent shale drawoff rolls to a three inch setting for wide range shale.

2. Conducted "quickie" and full drawdowns to check uniformity of shale flow.

3. Checked velocity profiles around all (36) air distributor bayonets while passing cold air.

4. Installed a 3/8 inch bottom screen on the primary screener at the crushing plant. This was done so that the shale size would be comparable to that used in Retort No. 2 demonstration Run B953.

Results of two full drawdowns with 1/4 to 2 1/2 inch shale suggested that shale was flowing slightly faster (5%) in the center third of the retort as opposed to the east-west walls. The flow difference across the long axis of the retort was not considered significant enough to warrant repositioning bottom flow control hardware.

The velometer profiles around the air distributor bayonets indicated passage of equal volumes of cold air through each bayonet.

Retort No. 3 was started up June 18 on 1/4 to 2 1/2 inch shale (Run C1046) which assayed 29 gallons per ton. The startup procedure was the same as that used successfully on 1/4 to 1 inch shale. This procedure was thoroughly discussed on page 30, of the June 23 Monthly Progress Memorandum.

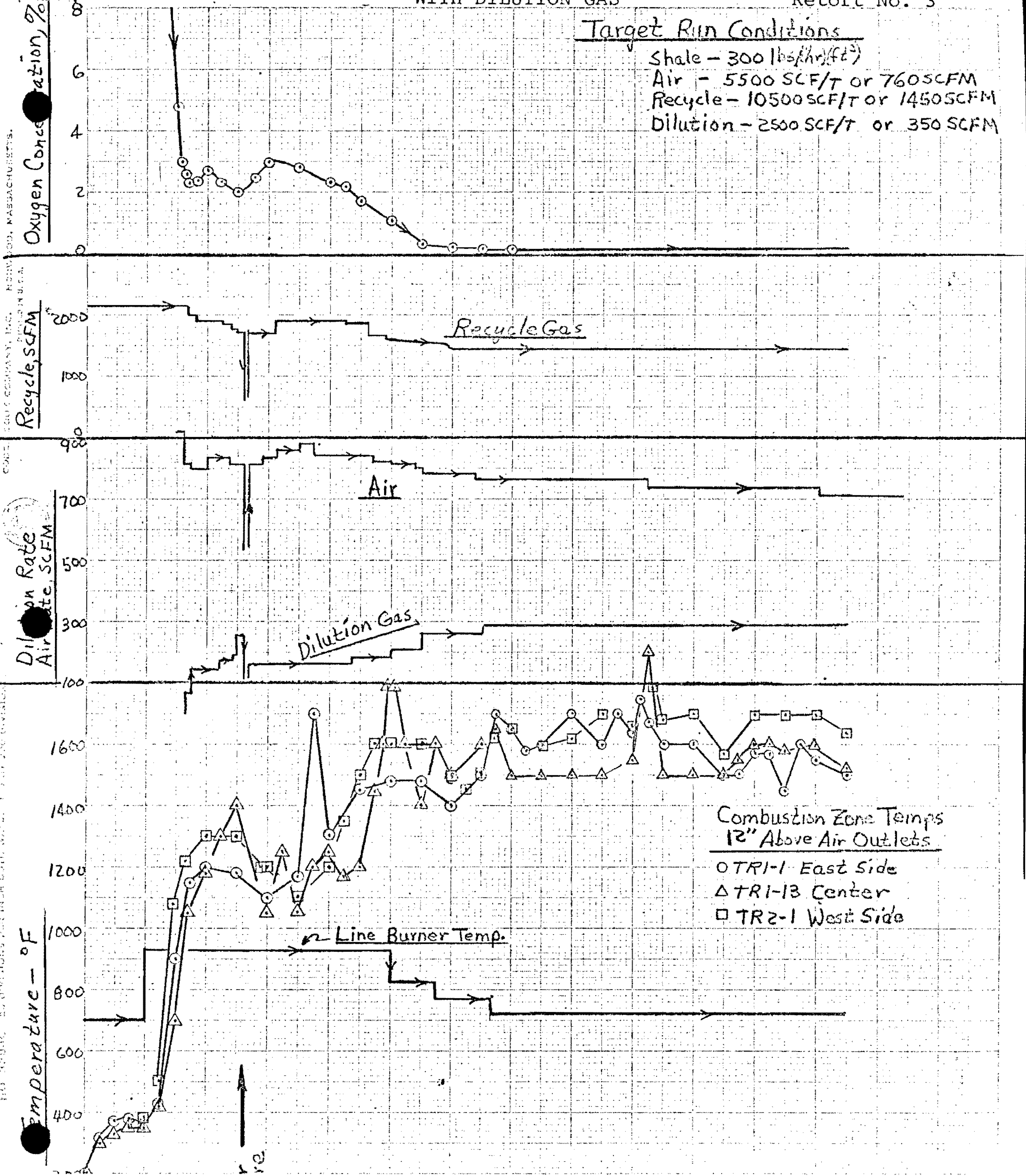
Utilization of the low, line burner temperature startup technique proved successful on the 1/4 to 2 1/2 inch shale. Pertinent startup information (Run C1046) is shown in Figure 14. Startup process conditions used were:

FIGURE 14

STARTUP C1046 - 1/4 To 2 1/2 INCH SHALE

WITH DILUTION GAS

Retort No. 3



Shale Rate - 300 lbs/(hr)(ft^2)
Air Rate - 1,100 SCFM or 7,000 SCF/T
Constant O_2 Consumption Range - 5,000 to 5,500 SCF/T Air Equivalent Rate.
Recycle Rate - 2,150 SCFM or 15,700 SCF/T
Dilution - 350 SCFM or 2,500 SCF/T Began addition of dilution gas when O_2 reached 4% in vent gas. Exchange recycle for dilution added.
Line Burner Temperature - 700 F first two hours and 900 F thereafter.
Bed Height Above Air Distributor - 9.5 feet
Bed Height Below Air Distributor - 6.0 feet

The startup shown on Figure 14 was slowed down because of a 15 minute electric power failure to all electro-pneumatic gas rate control instruments. The air and recycle blowers were shut down. Shale flow was discontinued. Following restoration of power, a proven restart procedure was used in placing the retort back into operation. The recycle blower was started and allowed to operate five minutes. After this period, the spent shale system was started and shale flow re-established at the 300 mass rate level. Approximately 10 minutes after the recycle blower was started, the air blower and line burner was started. The overall procedure was successful in that shale flow was re-established and high localized combustion zone temperatures were avoided. It was necessary to increase the air and recycle gas rates to light or fire all the distributor bayonets following the failure. The startup was extended approximately four hours as a result of the failure.

The first balance (PTC1046) began at 2100 hours on June 18, 1967. This was the first of 19 consecutive balances (9 1/2 days) at 300 mass rate conditions. The initial target process conditions selected were:

Shale Rate - 300 lbs/(hr)(ft^2)
Air Rate - 5,500 SCF/T (Reduce as necessary to avoid high, prolonged, combustion zone temperatures $>$1,600 F)
Recycle Rate - 10,500 SCF/T
Dilution Rate - 2,500 SCF/T
Line Burner Temperature - 700 F

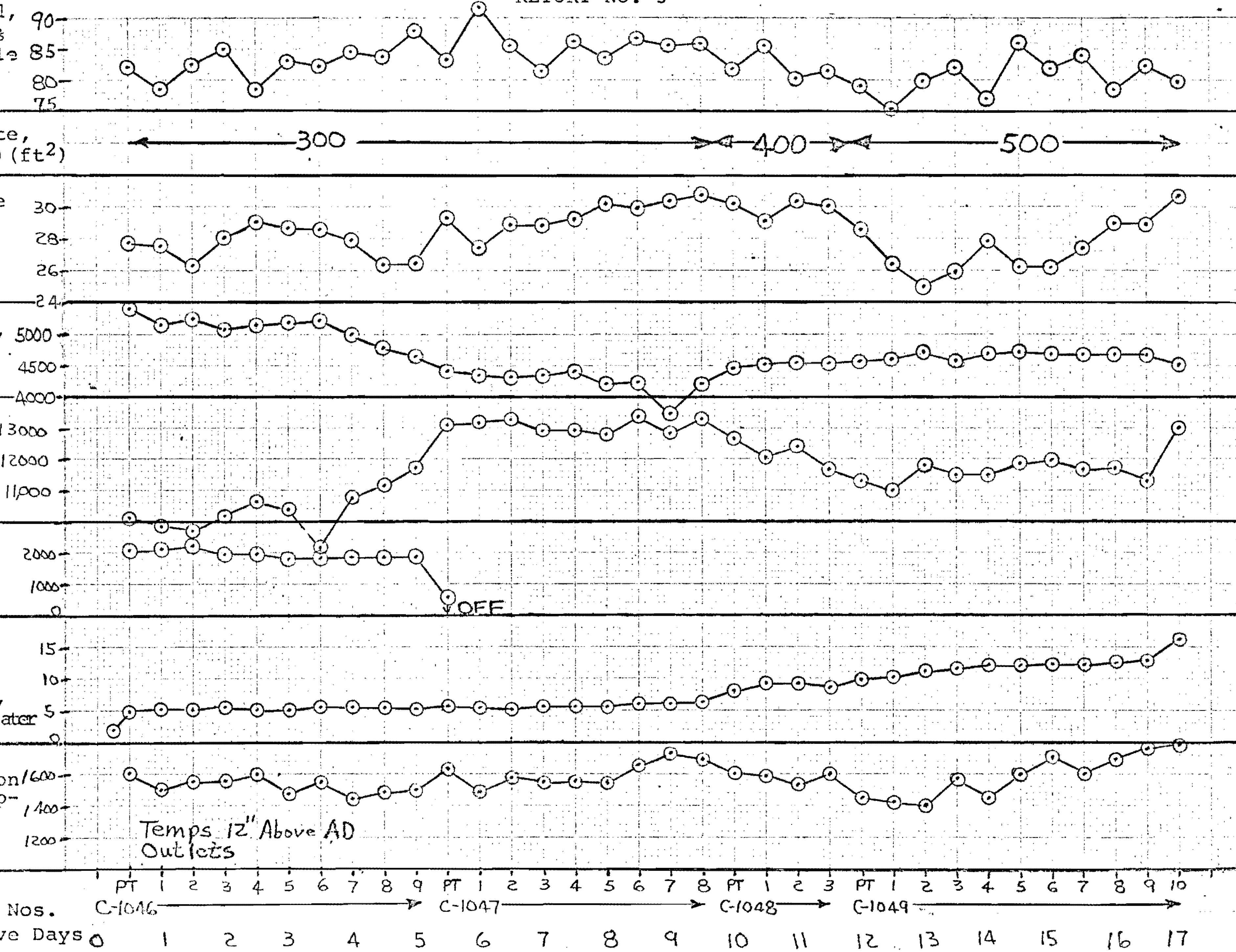
It was recognized that the above conditions would probably produce low oil yields. However, operability should be good. If a stable operation could be obtained, then efforts to raise yields by gas rate optimization would be made.

The first three material balances (C1046 PT, 1 and 2) were made at constant process conditions. Refer to Figure 15 where pertinent data on operations history is shown for

FIGURE 15

OPERATIONS HISTORY - 1/4 TO 2 1/2 INCH SHALE

RETORT NO. 3



RLClampitt
7/12/67

the entire 17 1/2 days. A large portion of the dilution gas in the air stream began to burn and detonate in the horizontal air headers during Run C1046-2. This produced large pressure fluctuations in the headers (30 to 40 inches of water pressure) and tended to make the line burner operation unstable. The explosions (about one per second) were also reflected in the retort bottom pressure. A variation of 3/4 inch of water pressure could be observed in the retort bottom pressure. Header gas temperatures down stream of the line burner were varying between 1,050 to 1,200 F. This contrasts with a gas temperature immediately down stream of the line burner of 700 F.

The dilution gas rate was lowered in Run C1046-3 in order to reduce the burning in the headers. The recycle gas rate was increased at this time. Lowering of the dilution gas rate was effective in minimizing detonation. It also improved the stability of the line burner.

The lower dilution and higher recycle gas rate conditions (Runs C1046-3 through 6) were operated for two days. Operability continued to be good although yields were low averaging 82% of raw shale Fischer Assay for the first seven balances. Good shale flow and relatively low retort bottom pressures ($\approx$ 5 inches H_2O) suggested that yield could be improved by increasing the recycle gas rate.

In Run C1046-7, a transition was made to a higher recycle, lower air operation. The dilution gas rate and total gas rates were held constant. Refer to Figure 15 for conditions. During the last hour of the transition, another power failure was experienced. The air and recycle blowers along with the shale feed systems were shut down. Once again, the restart procedure proved successful in getting the unit back on stream.

An immediate oil yield improvement was observed following the gas rate changes. Oil yields averaged 85.5% during Runs C1046-7, 8 and 9. It was necessary to change process conditions at the end of balance period C1046-9 because of a coking condition in the line burner. The low temperature burning of the dilution gas was producing coke deposits. It appeared that an unstable combustion condition (pulsing flame) was being approached.

Rather than shutting the retort down, a decision was made to continue the operations but without dilution gas. Consideration was given to shutting the line burner off, however, this was rejected. Calculations and temperature data indicated that at cold air operating conditions, non-isothermal flow of air in the horizontal headers existed. This condition, if run very long, could result in skewed east-west combustion zone temperatures and probably an inoperable situation. Even if the retort ran with skewed temperatures, it would likely be at lower oil yields. For these reasons conditions were changed (dilution cut out) to a hot air operation beginning with Run PTC-1047.

The retort had operated 5 1/2 days when the dilution gas was cut out. Efforts were made to increase recycle rates to maintain the same total offgas rates at the top of the retort. Offgas approximated 20,500 SCF/T. Five material balances (C1047-PT through 4) were made at approximately 4,350 SCF/T air and 13,000 SCF/T recycle with the line burner at 900 F and burning propane. Oil yields averaged 85.7% of Fischer Assay. During these runs, operability remained good even though there were times temperatures of 2,000 F were observed 12 inches above the air outlet level. The process was stable as evidenced by the shale rate, temperature data and gas analysis data. The relatively low bottom pressures of 5.4 inches water suggested that total gas rates could be further increased. Hopefully yield improvements could also be realized.

On June 26 (Run C1047-5), a two-step transition was made to higher recycle rate conditions. At the same time, there was a significant increase in shale richness to the 30 gallons per ton level. The targeted conditions were 14,000 SCF/T recycle and 4,200 SCF/T air. Six hours after making the change, the retort experienced an upset condition. Retort bottom pressure increased from 5 to 6.6 inches of water pressure. Shale flow became sticky and there was evidence of bridging. It appeared that a recycle gas rate limitation had been reached with the 30 gallon per ton shale. Actions were taken to lower the combustion zone temperatures below 2,000 F and improve shale flow quality. These consisted of dropping the recycle and air rates 20 to 30% and increasing the shale withdrawal rate by approximately 15% for a period of two hours. The unit responded very well to these actions. Shale flow improved and combustion zone temperatures returned to normal. In three hours the retort was back on conditions but at a lower recycle gas rate - 13,400 SCF/T. The air rate remained at 4,200 SCF/T.

Correcting for known gas leaks at the bottom of the retort, the maximum operable gas rates were observed to be 4,200 SCF/T air and 13,600 SCF/T (corrected) recycle. It should be emphasized that these rates apply to a shale richness level of 30 gallons per ton and the hardware configuration in the retort.

On June 28, a non-eventful transition was made to the 400 mass rate conditions (C1048). The unit was operated two days at the 400 mass rate conditions of 4,500 SCF/T air and 12,200 SCF/T recycle. The retort bottom pressure increased to about eight inches from the six inch level at 300 mass rate conditions. Four material balances which had an average yield of 82% were run while processing 30 gallon per ton shale. No efforts were made to optimize oil yields at the 400 mass rate.

Operability was as good as at 300 mass rate conditions.

At the end of the four balances at the 400 mass rate, a successful transition was made to 500 mass rate conditions on June 30. After one balance at the 500 mass rate conditions, the Fischer Assay of the raw shale dropped from 29 to 30 gallons per ton to the 25 to 26 gallons per ton level. At about the same time, a program was begun to increase gas rates to increase the oil yield.

After six balances or three days, the gas rates were up to about 4,700 SCF/T air and 11,700 SCF/T recycle. Oil yields averaged 82% of raw shale Fischer Assay during the last six balances at the 500 mass rate conditions.

The retort was purposely shut down by using excessive gas rates just prior to the end of material balance period C1048-10. Total gas rates were increased about 1,000 to 1,200 SCF/T. This produced a shale bridge, split in off-gas temperatures, bottom pressures of 20 inches, and a resulting clinker. It was thereby shown that the retort reacts to excessive gas rates in a predictable fashion. The clinker covered about one-third of the retort. It was located over and in the bayonet air distributors in the west half of the retort.

Table 3 shows a comparison of results between Retorts No. 2 and No. 3 for wide range shale.

Note that at the 500 mass rate condition that Retort No. 2 produced oil yields 4% greater than those achieved on Retort No. 3. The reason yields were lower on Retort No. 3 is the result of the gas rate limitation mentioned earlier. This limitation restricted total recycle rates on Retort No. 3 to approximately 12,000 SCF/T at the 500 mass rate conditions.

It can be recalled from earlier reports that the Gas Combustion Retort is gas velocity limited, which limits the amount of recycle which can be employed. For every shale mass rate there is a gas velocity above which the process becomes unstable because excessive dust and oil accumulation in voids between particles results in formation of an agglomerate which causes shale flow stoppage.

TABLE 3

COMPARISON OF RETORT NO. 2 AND RETORT NO. 3
RESULTS WHILE PROCESSING 1/4 TO 2 1/2 INCH WIDE RANGE SHALE

	Retort No. 3			Retort No. 2
Shale Mass Rate, lbs/(hr)(ft^2)	300	400	500	500
Cumulative Days of Continuous Operation	10.0	12.0	17.5	8.5
Results				
Oil Yield, % RSFA	85.9 (1)	82.4 (2)	82.1 (3)	86.4 (4)
Operability Rating	Good	Good	Good	Fair to Good
Estimated Yield by Retort No. 2 Regression Equation				
Oil Yield, % RSFA	83.9	82.1	80.8	85.7
Operating Conditions Which Produced Above Results				
Raw Shale Assay, Gal/Ton	29.5	29.5	27.9	27.7
Air Rate, SCF/T	4,250	4,525	4,690	4,475
Recycle Rate, SCF/T (Corrected)	13,200	12,200	11,700	14,600
Bed Height Above Air Distributor, feet	9.5	9.5	9.5	9.5-10
Bed Height Below Air Distributor, feet	6.0	6.0	6.0	5.5
Material Balance				
Overall Balance, Wt %	99.5	99.5	100.1	99.4
Organic Carbon Balance, Wt %	96.6	95.1	100.3	99.1

(1) Average of Runs C1047 PT through 8
(2) Average of Runs C1048 PT through 3
(3) Average of Runs C1049-5 through 10
(4) Average of Runs B953 A through N

It was not unexpected to find that the operable gas rate limit to be lower than those on Retort No. 2. Channeling of recycle gas up the retort walls was probably more in Retort No. 2 per square foot of cross-sectional area. Ratio of perimeter to retort cross-sectional area was approximately 1.3 in Retort No. 2. In the larger Retort No. 3, this ratio is only 0.5. (These ratios are based on an effect on void fraction up to about four inches from a wall.) Therefore, in Retort No. 3, less gas per square foot of cross-sectional area is channeled up the walls. When the operable gas rate is exceeded in the retort bed, the retort becomes unstable.

Estimated oil yields using the regression equation from Retort No. 2 closely compare to those obtained on Retort No. 3. The effect of recycle on yield in the equation is 1.7% oil yield per thousand SCF/T of recycle gas. If Retort No. 2 had been limited to 12,000 SCF/T recycle the yield would have been 81.9% rather than 86.4%.

The overall and organic carbon balances shown in Table 3 for the 1/4 to 2 1/2 inch operation were greatly improved over those obtained earlier in Retort No. 3. Recent concentrated efforts were responsible for the improvement in balances. These efforts consisted of:

1. Increased technical supervision to improve quality of raw data.

2. The small decanter was reinstalled.

3. We installed a raw shale sampler designed by Warren Broman.

Further efforts to improve the balances on Retort No. 3 will consist of revising the gas sampling system and installing an improved spent shale sampling system.

Conclusions which have been made on the 1/4 to 2 1/2 inch operations are:

1. Operability was good while processing the wide range shale (1/4 to 2 1/2 inch) with the streamlined hardware configuration. The operation was very rugged because of its tolerance to temporary mechanical stoppages and to the many changes made in process conditions.

2. Oil yields were comparable to those on Retort No. 2 at the same gas rate conditions.

3. Dilution gas is not necessary since 300, 400 and 500 mass rate conditions were conducted with only hot air.

4. The hot air probably is not necessary for good operability. It should be emphasized that hot air was used to insure even air distribution along the air headers.

5. The low line burner startup technique used on Retort No. 2 was successful on Retort No. 3 with both 1/4 to 1 and 1/4 to 2 1/2 inch shale.

6. Most of the retort engineers were confident the 1/4 to 2 1/2 inch operation would have operated for an extended period.

4. Analysis of Bayonet Temperature Data (D. P. Cotrupe)

During the turnaround preceding startup C1039, thermocouples were installed in the caps of the air distributor bayonets as shown in Figure 16. The primary objective of the thermocouple installation was to determine whether the temperature data obtained would allow early detection of developing retort operability problems. Data generated during Runs C1040 through C1042 were studied in detail with the specific aim of relating bayonet temperature activity with the overall retort operation.

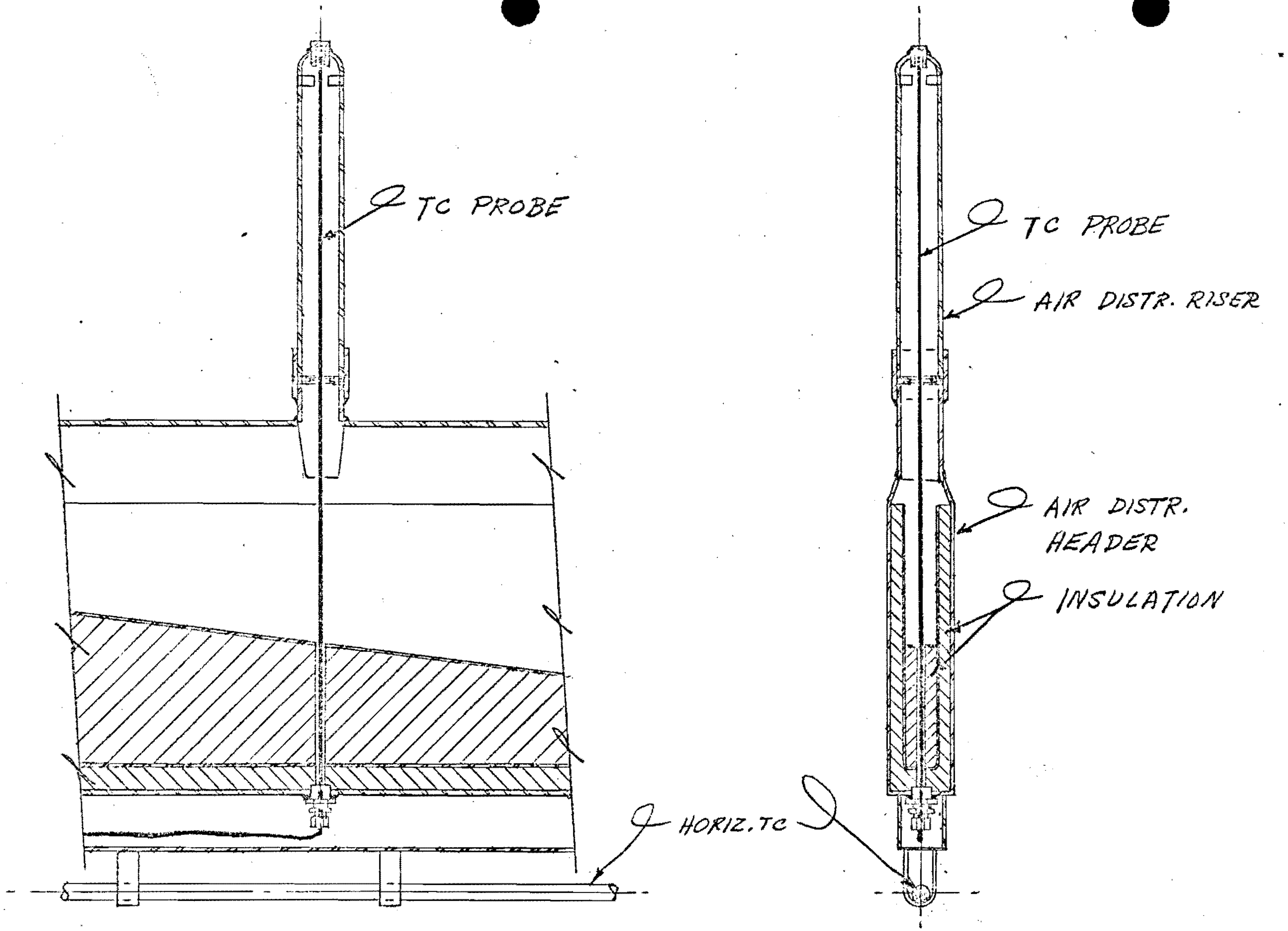
The analysis which was made is based on the theory that if any significant change in shale flow occurs as the shale passes into the bayonets, the resultant change in the ratio of air and recycle gas to shale will be reflected in corresponding temperature changes in the vicinity of the bayonets. Of course, the extreme case is realized when a complete stoppage occurs such as when a shale agglomerate becomes lodged on the bayonets, a situation which is believed to be an intermediate step in the clinker formation process. In the analysis performed, bayonet temperature activity was measured with respect to the following.

1. Frequency of temperature excursion.

2. Amplitude of excursion.

3. Cycle time.

A temperature excursion is defined as either a positive or negative deviation from the normal temperature level. Deviations of less than 100 F were not considered excursions in consideration of the normal temperature cycles and sensitivity of the temperature measurements. The amplitude of an excursion is the peak deviation or maximum ΔT



ATE	PRINT ISSUE TO	ANVIL POINTS OIL SHALE RESEARCH CENTER RIFLE, COLO. PROJECT MANAGER-SOCONY MOBIL OIL CO., INC.	SCALE 1½" = 1'-0"	AIR DISTRIBUTOR THERMOCOUPLES 36 RISER DISTRIBUTOR RETORT NO. 3
		JOB NO. / CHARGE	DRAWN BY [illegible]	FIGURE 16
			STARTED 7/20/67	
		APPROVED / PROCESS / DESIGN / SAFETY	COMPLETED 7/20/69	LOCATION / DRAWING NO. RE 90
			DIMENS.	

reached. Finally, the cycle time is the time interval measured from when an excursion begins until the temperature returns to the normal operating level.

The sketch in Figure 17 is a plan view of the thermocouple locations in the retort for Runs C1040 and C1041. The crossed circles indicate thermocouples which were lost during installation or failed during the operation. Note that the retort has been divided into three sections to facilitate recognition of trends and/or relative activity in the various sections of the retort.

Startup C1040 was very smooth and completely successful. The unit was lined out and operated uneventfully at the following conditions.

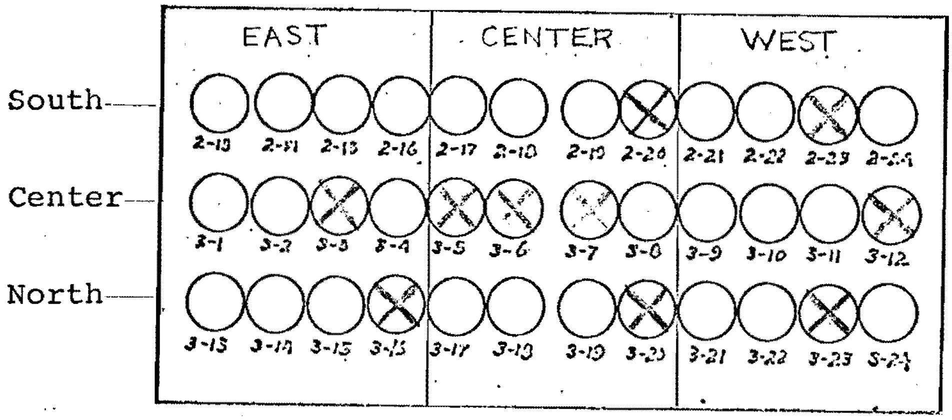
Raw Shale Rate: 300 lbs/(hr)(ft^2)
Air Rate: 5,100 SCF/T
Recycle Gas Rate: 11,000 SCF/T (Ex dilution)
Dilution Gas Rate: 2,500 SCF/T
Line Burner Temperature: 900 F

Runs PTC1040 through C1040-3 were completed during this period and the bayonet temperature data from Runs PTC1040 and C1040-2 were analyzed to establish temperature activity with smooth operations. The data appear in Tables 4 and 5. The bayonet temperature level ranged between 1,100 and 1,300 F in these runs. Referring to Table 4 it can be seen that a total of 38 individual excursions were recorded, equivalent to a frequency of 3.2 per hour. If those which appear to be related to a single event are combined (indicated by brackets in Table 4) the frequency drops to 2.7 per hour. The average cycle time for Run PTC1040 was 39 minutes. Also it is significant to note that the amplitude of 95% of the excursions was less than 200 F. The data from Run C1040-2 (see Table 5) are quite comparable, showing individual and combined frequencies of 3.5 per hour and 2.7 per hour respectively. The average amplitude of excursions in the latter run was slightly higher; but the most significant difference is observed in the cycle times. The average cycle time in Run C1040-2 was 63 minutes compared with 39 minutes for the Pretest.

Subsequently in this operating period, a series of tests were made to help determine the effect of dilution gas on the operation. Dilution gas rate was first reduced by a factor of 2 and an equivalent amount of recycle gas was added. Operations were not as stable as previously and several bridges were experienced. Three balance periods were completed at these conditions, after which the dilution gas and line burner operation were phased out. The following operating conditions were reached after the transition to

FIGURE 17

A. Bayonet Thermocouple Locations For Runs C1040 and C1041



B. Bayonet Thermocouple Locations For Run C1042

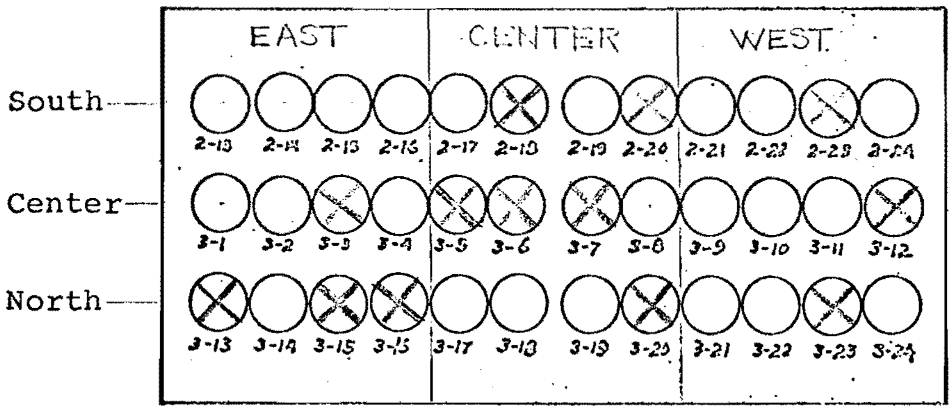


TABLE 4

BAYONET TEMPERATURE DATA - RUN PTC1040

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
1.	2120	North (N)	West (W)	3-24	150	60
2.	2145	Center (C)	W	3-9	-100	30
3.	2250	N	W	3-21	130	50
4.	2320	South (S)	C	2-19	100	20
5.	2340	C	C	3-8	110	35
6.	2355	C	W	3-9	100	10
7.	0045	N	East (E)	3-13	250	45
8.	0055	N	W	3-24	-150	60
9.	0140	N	C	3-17	-100	50
10.	0155	N	W	3-24	140	20
11.	0205	N	E	3-13	200	40
12.	0240	C	E	3-2	-100	20
13.	0245	N	E	3-13	220	60
14.	0255	N	E	3-4	100	40
15.	0255	N	E	3-2	-100	20
16.	0305	C	W	3-9	-140	55
17.	0315	N	W	3-24	-120	30
18.	0320	N	E	3-14	150	35
19.	0330	S	E	2-13	150	50
20.	0405	C	W	3-9	-150	35
21.	0410	N	E	3-15	100	25
22.	0410	N	E	3-14	-100	60
23.	0425	N	E	3-13	100	45
24.	0440	S	W	2-21	100	20
25.	0515	N	E	3-13	180	30
26.	0530	S	C	2-19	100	20
27.	0530	N	C	3-17	140	50
28.	0545	N	E	3-13	-190	75
29.	0550	S	E	2-15	160	20
30.	0620	C	W	3-9	110	25
31.	0630	S	E	2-14	155	50
32.	0630	N	W	3-24	170	20
33.	0640	N	C	3-17	200	50
34.	0650	S	C	2-17	-100	70
35.	0650	N	W	3-24	140	50
36.	0710	C	C	3-8	120	40
37.	0745	N	W	3-24	-120	45
38.	0855	N	W	3-24	140	20

Notes:

A. Run Length = 12 hours

B. Excursion Frequency

1. Individual = 3.2/hr
2. Combined = 2.7/hr

C. Average Cycle Time = 39 minutes

TABLE 5

BAYONET TEMPERATURE DATA - RUN C1040-2

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
1.	1930	Center (C)	East (E)	3-2	150	110
2.	2020	C	West (W)	3-9	170	110
3.	2050	South (S)	E	2-15	150	85
4.	2135	North (N)	W	3-24	230	95
5.	2240	C	C	3-8	-110	115
6.	2300	C	E	3-2	100	30
7.	2320	N	W	3-24	320	50
8.	0015	S	W	2-24	-110	65
9.	0020	N	E	3-15	130	70
10.	0020	N	E	3-14	120	20
11.	0040	N	E	3-14	140	50
12.	0050	S	W	2-21	150	85
13.	0050	C	W	3-9	110	70
14.	0140	N	E	3-14	260	50
15.	0155	N	E	3-13	270	180
16.	0225	S	W	2-21	100	65
17.	0225	S	C	2-19	140	115
18.	0230	N	E	3-14	120	30
19.	0245	N	W	3-24	100	40
20.	0300	N	E	3-14	140	40
21.	0310	C	E	3-1	170	70
22.	0320	C	W	3-9	120	30
23.	0325	N	C	3-17	140	40
24.	0340	S	E	2-13	200	80
25.	0340	C	W	3-10	160	55
26.	0435	C	E	3-2	100	15
27.	0450	C	E	3-2	140	120
28.	0510	S	E	2-13	300	120
29.	0535	C	E	3-1	180	80
30.	0545	N	W	3-24	150	30
31.	0550	N	E	3-13	390	100
32.	0615	N	W	3-14	270	100
33.	0640	C	E	3-2	170	125
34.	0655	N	E	3-15	140	30
35.	0700	C	E	3-1	130	80
36.	0710	S	E	2-13	200	60
37.	0755	N	W	3-24	230	35
38.	0815	N	E	3-13	210	25
39.	0840	S	E	2-16	140	15
40.	0845	S	E	2-17	110	15
41.	0845	N	E	3-13	170	15
42.	0850	C	W	3-9	-100	10

Notes:

A. Run Length = 12 hours

B. Excursion Frequency

1. Individual = 3.5/hr
2. Combined = 2.7/hr

C. Average Cycle Time = 63 minutes

Raw Shale Rate: 300 lbs/(hr)(ft^2)
Air Rate: 4,100 SCF/T
Recycle Gas Rate: 12,500 SCF/T

Runs C1041-1 and C1041-2 were generated at these conditions. The east side was consistently cooler than the center and west side and the operation was not as smooth as the early C1040 runs. Wider temperature fluctuations were observed; however the unit continued to run fairly well. The bayonet temperature data for Run C1041-2 are recorded in Table 6. The most striking feature of these data is the incidence of temperature excursion. The individual and combined frequencies were 8.6 per hour and 6.6 per hour, respectively, attesting to the somewhat erratic nature of the operation. The magnitude of the excursions was significantly larger than that observed in earlier operations; however the average cycle time was only 37 minutes. Reviewing these data, it would appear that this operation was quite unstable despite the fact that it ran reasonably well for about two days. At the end of Run C1041-2, the retort was shut down to install smaller orifices designed for cold air operation. As expected, the unit was found clean after shutdown.

The sketch in Figure 17 is a plan view of the thermocouple locations for Run C1042. As in the earlier sketch, the crossed circles indicate missing or non-functioning couples.

Startup of Run C1042 was made successfully without the use of dilution gas and the unit was lined out at the following conditions.

Raw Shale Rate: 300 lbs/(hr)(ft^2).
Air Rate: 4,600 SCF/T
Recycle Gas Rate: 10,600 SCF/T

The operation appeared to be stable, although the east side of the retort was colder than the center and west side. It was necessary to balance between allowing the fire to go out on the east side and clinkering the west side. Run PTC1042 was started about six hours after fire-off. The bayonet temperature data for this run are shown in Table 7. Examination of the tabulated data shows a preponderance of bayonet activity in the west and center sections of the retort, primarily in the west. At about 0100 hours the chain slipped off the roll feed drive motor and about 25 minutes passed before the trouble was diagnosed properly. Combustion zone temperatures(measured by the vertical thermowells) reached 2,100 F before air and recycle gas rates were cut as the fire was forced up in the bed. This is reflected by the blanket negative temperature excursions observed at the bayonet level. After

TABLE 6

BAYONET TEMPERATURE DATA - RUN C1041-2

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
1.	0900	Center (C)	West (W)	3-9	120	20
2.	0900	C	East (E)	3-2	290	15
3.	0905	North (N)	E	3-14	140	20
4.	0910	N	W	3-22	170	40
5.	0920	N	W	3-24	220	10
6.	0925	C	W	3-10	250	55
7.	0930	C	W	3-9	140	30
8.	0930	N	W	3-24	290	5
9.	0935	N	W	3-24	210	10
10.	0945	C	E	3-2	-110	10
11.	0945	N	W	3-24	-250	20
12.	1000	C	W	3-9	200	15
13.	1000	C	E	3-2	480	30
14.	1005	South (S)	E	2-13	170	30
15.	1010	N	W	3-24	-240	15
16.	1015	N	C	3-17	180	45
17.	1020	C	W	3-9	220	20
18.	1025	N	W	3-24	270	15
19.	1030	S	W	2-21	230	400
20.	1030	C	E	3-2	400	10
21.	1040	C	W	3-10	170	15
22.	1040	N	E	3-14	-140	40
23.	1050	N	W	3-24	-140	10
24.	1055	C	W	3-10	110	5
25.	1100	S	W	2-24	140	70
26.	1100	C	W	3-9	110	15
27.	1100	N	W	3-24	160	10
28.	1105	C	E	3-2	450	25
29.	1115	N	W	3-24	220	10
30.	1125	N	W	3-24	-190	5
31.	1125	N	E	3-14	-130	60
32.	1125	N	W	3-21	220	30
33.	1130	N	W	3-24	120	5
34.	1140	S	W	2-22	100	20
35.	1140	C	W	3-9	580	330
36.	1140	C	E	3-2	220	5
37.	1150	C	E	3-2	540	45
38.	1155	N	W	3-21	-110	45
39.	1200	C	W	3-10	160	35
40.	1200	N	W	3-24	-150	5
41.	1205	C	E	3-1	160	40
42.	1205	N	W	3-24	220	5
43.	1205	N	C	3-19	-120	80
44.	1210	N	W	3-24	-200	5
45.	1210	N	C	3-17	-110	45
46.	1215	N	W	3-24	130	35
47.	1220	N	W	3-21	-140	55
48.	1230	N	E	3-14	-140	50
49.	1240	C	E	3-2	140	35
50.	1250	N	W	3-24	250	5

TABLE 6 (Continued)

BAYONET TEMPERATURE DATA - RUN C1041-2

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
51.	1300	N	W	3-24	220	20
52.	1305	C	W	3-10	-130	125
53.	1315	C	E	3-1	210	65
54.	1315	C	E	3-2	300	65
55.	1325	N	W	3-24	-220	15
56.	1335	N	C	3-19	-100	45
57.	1340	N	W	3-21	-100	85
58.	1345	N	W	3-24	-290	10
59.	1355	N	W	3-24	-180	10
60.	1400	N	E	3-14	200	55
61.	1405	N	W	3-24	-220	15
62.	1420	C	E	3-2	450	40
63.	1425	N	C	3-19	-100	45
64.	1430	N	W	3-24	210	10
65.	1445	N	W	3-24	-260	10
66.	1455	N	W	3-24	300	5
67.	1515	C	E	3-2	450	40
68.	1520	S	W	2-24	140	70
69.	1525	C	W	3-10	-130	125
70.	1525	N	W	3-24	-300	25
71.	1550	N	W	3-24	320	10
72.	1605	N	W	3-24	-300	10
73.	1615	S	E	2-13	130	20
74.	1620	S	E	2-15	130	15
75.	1640	N	W	3-24	270	10
76.	1655	S	W	2-24	120	35
77.	1700	N	W	3-24	-160	20
78.	1705	N	C	3-19	-110	45
79.	1710	C	W	3-10	-140	35
80.	1710	C	W	3-9	290	20
81.	1720	N	W	3-24	180	10
82.	1730	C	W	3-9	300	45
83.	1730	N	W	3-24	-250	10
84.	1740	C	E	3-2	300	45
85.	1750	S	C	2-19	290	45
86.	1800	N	W	3-24	-120	20
87.	1815	N	C	3-19	-110	45
88.	1820	C	E	3-2	240	30
89.	1825	C	W	3-9	490	135
90.	1850	C	E	3-2	380	105
91.	1850	N	W	3-24	-160	10
92.	1910	N	W	3-24	-300	30
93.	1940	S	C	2-19	120	50
94.	1940	C	E	3-1	200	35
95.	1940	N	C	3-19	130	25
96.	1945	N	W	3-24	-270	15
97.	2000	N	W	3-24	-180	15
98.	2020	N	W	3-24	-250	20
99.	2020	N	C	3-19	-130	20
00.	2035	C	E	3-2	290	45

TABLE 6 (Continued)

BAYONET TEMPERATURE DATA - RUN C1041-2

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
101.	2040	C	W	3-9	360	20
102.	2045	N	W	3-24	-150	15
103.	2050	C	E	3-1	120	10

Notes:

A. Run Length = 12 hours

B. Excursion Frequency
   1. Individual = 8.6/hr
   2. Combined = 6.6/hr

C. Average Cycle Time = 38 minutes

TABLE 7

BAYONET TEMPERATURE DATA - RUN PTC1042

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max $\triangle$T), F	Cycle Time, Minutes
1.	2120	South (S)	West (W)	2-21	150	40
2.	2120	Center (C)	W	3-9	180	10
3.	2130	North (N)	C	3-19	100	10
4.	2140	N	C	3-19	-140	15
5.	2140	N	W	3-24	140	15
6.	2145	C	W	3-11	110	15
7.	2150	S	C	2-19	250	65
8.	2150	C	East (E)	3-1	-100	35
9.	2150	C	W	3-9	340	20
10.	2155	N	W	3-24	-150	15
11.	2210	N	W	3-24	230	15
12.	2220	S	W	2-24	-150	65
13.	2220	C	W	3-9	-230	15
14.	2225	N	W	3-21	-110	15
15.	2225	N	W	3-22	-190	50
16.	2230	N	W	3-24	-150	15
17.	2250	C	W	3-9	270	15
18.	2255	S	W	2-21	100	55
19.	2255	N	W	3-21	110	25
20.	2305	C	W	3-9	-150	5
21.	2305	S	C	2-19	-320	160
22.	2310	C	W	3-9	300	25
23.	2320	S	C	2-19	140	30
24.	2330	S	E	2-16	-390	140
25.	0005	N	C	3-19	110	5
26.	0015	N	C	3-19	-170	30
27.	0015	N	W	3-24	170	55
28.	0040	S	E	2-15	-300	70
29.	0050	N	W	3-22	-280	55
30.	0055	S	W	2-22	-310	55
31.	0100	S	W	2-24	-130	40
32.	0100	S	W	2-21	-140	50
33.	0100	N	W	3-21	-300	50
34.	0100	C	W	3-9	-350	45
35.	0100	C	W	3-10	-160	45
36.	0100	C	W	3-11	-320	60
37.	0105	C	C	3-8	-200	40
38.	0110	N	W	3-24	-140	30
39.	0115	S	C	2-19	-160	35
40.	0125	C	E	3-1	-110	75
41.	0140	S	E	2-14	-110	75
42.	0145	C	C	3-8	680	40
43.	0145	C	W	3-9	440	35
44.	0145	C	W	3-10	400	50
45.	0145	N	W	3-22	600	90
46.	0150	S	E	2-15	410	25
47.	0150	S	C	2-19	570	95
48.	0150	S	W	2-21	640	75
49.	0150	S	E	2-13	-110	75
50.	0150	C	E	3-4	-100	65

TABLE 7 (Continued)

BAYONET TEMPERATURE DATA - RUN PTC1042

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
51.	0150	N	C	3-17	-140	80
52.	0150	N	C	3-19	520	10
53.	0150	N	W	3-21	550	70
54.	0155	S	W	2-22	300	85
55.	0200	S	C	2-17	-120	75
56.	0200	N	C	3-19	-140	10
57.	0205	S	E	2-16	-430	120
58.	0210	C	W	3-11	110	40
59.	0235	N	C	3-19	140	40
60.	0240	C	E	3-2	140	15
61.	0240	N	C	3-19	-140	80
62.	0250	S	E	2-15	-310	115
63.	0250	C	W	3-11	-100	25
64.	0300	C	E	3-2	830	365
65.	0320	N	E	3-14	-330	240
66.	0325	S	C	2-17	-220	185
67.	0330	S	E	2-14	-240	240
68.	0340	S	E	2-13	-280	305
69.	0340	C	E	3-4	-240	200
70.	0345	S	W	2-22	530	325
71.	0350	C	W	3-9	600	510
72.	0405	S	W	2-21	580	245
73.	0410	N	C	3-17	-310	170
74.	0455	S	C	2-19	480	220
75.	0455	C	C	3-8	530	250
76.	0530	N	W	3-21	330	120
77.	0540	N	W	3-22	200	100
78.	0620	N	W	3-24	140	110
79.	0750	N	W	3-21	-150	80
80.	0750	N	W	3-22	-240	95

Notes:

A. Run Length = 12 hours

B. Excursion Frequency

1. Individual = 6.7/hr
2. Combined = 4.2/hr

the chain was replaced the unit was restarted. Several hours of rough operation followed as evidenced by the repeated cycles of large temperature excursions on the west side of the retort. Meanwhile, the east side continued to cool and it was necessary to refire the line burner. The large temperature excursions (ΔT_{max} = 400 - 700 F) on the west side persisted for several hours but appeared to be settling down in the early part of Run C1042-1 (see Table 8). At about 1030 hours a second chain failure occurred and the fire level rose in the bed. The attempted restart was unsuccessful. By about 1200 hours all the bayonet temperatures in the west section were hot except for TR3-10 and TR3-11 which were cooling off fairly quickly. Within about 15 minutes all of the west couples began to cool, TR3-8, 9, 10 and 11 ultimately reached the 400 F. The retort continued to limp along until about 1330 hours when it bridged and was shut down. When the unit was opened up, as expected a clinker was found on the west side of the retort as shown in Figure 18. Note that the clinker covers almost all of the bayonet couples in the west section and that it was centered over the couples which cooled off to the 400 F level. Reviewing the data in Table 7, it appears that a large agglomerate became lodged on the bayonets in the west section of the retort between 0330 and 0400 hours. Note the magnitude of the excursions and duration of the cycle times which began at that time. Looking ahead in time, it appears also, that most if not all of this material had cleared before the second chain failure.

It is concluded from this analysis that the bayonet thermocouples do provide a deeper insight into the overall operation of the retort and are more sensitive in detecting developing operability problems. For these reasons they can be extremely useful as an operating tool. It is recommended that new couples be installed as soon as possible.

<u>TABLE 8</u>

BAYONET TEMPERATURE DATA - RUN C1042-1

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
1.	0920	South (S)	East (E)	2-22	130	30
2.	0940	North (N)	West (W)	3-21	-130	20
3.	0950	S	W	2-24	-200	140
4.	0955	S	Center (C)	2-19	110	20
5.	1000	S	W	2-21	150	20
6.	1015	S	C	2-19	110	20
7.	1020	S	W	2-22	360	115
8.	1020	C	C	3-8	360	130
9.	1040	S	E	2-15	370	45
10.	1045	N	C	3-19	230	30
11.	1045	N	W	3-22	190	40
12.	1050	S	W	2-21	240	35
13.	1055	C	W	3-11	110	30
14.	1105	C	W	3-10	110	25
15.	1110	N	W	3-21	140	10
16.	1115	N	C	3-19	-370	50
17.	1120	N	W	3-21	110	10
18.	1120	N	W	3-24	-170	30
19.	1125	S	W	2-21	-160	25
20.	1125	N	W	3-22	-170	30
21.	1130	C	C	3-8	-270	30
22.	1130	C	W	3-10	-330	70
23.	1140	N	W	3-21	-170	15
24.	1145	C	W	3-11	Cooled to 400 F level	
25.	1150	S	W	2-21	450	30
26.	1150	N	W	3-24	250	25
27.	1155	N	W	3-21	310	15
28.	1155	N	W	3-22	220	20
29.	1210	S	C	2-19	-280	25
30.	1210	S	W	2-24	310	10
31.	1210	C	C	3-8	210	35
32.	1210	N	C	3-19	-460	70
33.	1210	N	W	3-21	-190	20
34.	1215	N	W	3-22	-290	60
35.	1215	N	W	3-24	-260	40
36.	1220	S	W	2-21	-210	25
37.	1220	S	W	2-24	-170	20
38.	1220	C	W	3-9	210	15
39.	1230	N	W	3-21	Cooled to 950 F level	
40.	1235	C	W	3-9	210	10
41.	1240	S	C	2-19	280	50
42.	1240	S	W	2-22	110	50
43.	1240	C	W	3-10	Cooled to 400 F level	
44.	1245	C	C	3-8	Cooled to 400 F level	
45.	1245	C	W	3-9	Cooled to 400 F level	
46.	1255	S	W	2-24	-180	30

(continued on next page)

TABLE 8 (Continued)

BAYONET TEMPERATURE DATA - RUN C1042-1

	Time, Hours	Air Header	Retort Section	T.R. No.	Amplitude (Max ΔT), F	Cycle Time, Minutes
47.	1300	S	W	2-21	-120	30
48.	1300	N	W	3-24	250	30

Notes:

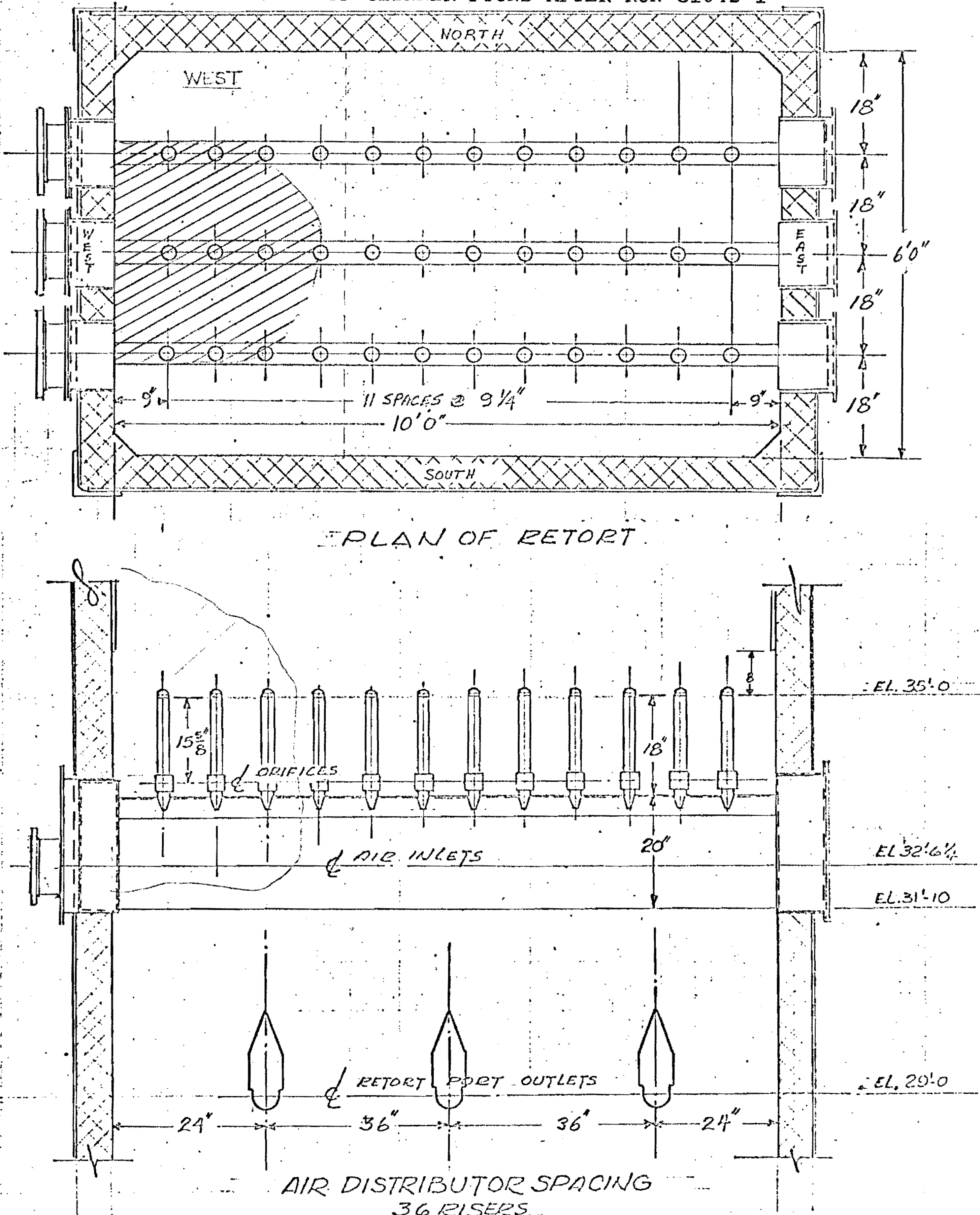
A. Run Length = 4.5 hours

B. Excursion Frequency
   1. Individual = 10.7/hr
   2. Combined = 5.3/hr

C. Average Cycle Time (Run PTC1042 and C1042-1) = 68 minutes

FIGURE 18

LOCATION AND SIZE OF CLINKER FOUND AFTER RUN C1042-1



VI. RETORT OPERABILITY TASK FORCE (K. I. Jagel, Jr. and D. Liederman)

A. 3.6-Inch Retort Operations

In last month's Progress Memorandum, the Task Force reported on the construction and preliminary operation of the 3.6 inch retort. A flow diagram of the system is shown in Figure 19. Operations to be described are for the retort with the sloped liquid disengager section shown in Figure 20, except for two runs where a straight pipe heater section was substituted for it.

All runs were started with ceramic Raschig rings in the retort section. Use of these rings allowed us to achieve our gas and shale flows and temperature patterns before shale entered the retort. The first runs were made at nominal rates of 500 and 1,000 mass, 20,000 SCF/T recycle, 1/4 to 1/2 inch shale, 27 gallons per ton; with and without the disengager. Some later runs were made with combustion in the bed at 500 mass, 25,000 SCF/T recycle, and 5,000 SCF/T air. Table 9 summarizes the data obtained on these runs.

Run 4 was made at 930 mass rate to test the operability of the disengager under the difficult condition of high mass rate. Operation was very good and yield was good at 85.5% Fischer Assay. In this run only, the disengager product was collected in an open bucket. Some of the lighter material flashed off and undoubtedly accounts for some of the deficiency in carbon balance. About 60% of the total oil was collected from the disengager. It was dry and had an API gravity of about 17. The other 40% of the oil, along with most of the water from the process, was collected in a cooled cotton-batting demister. This product contained about 40% water. The gravity of this oil was about 30°API. The gas leaving the demister was about 85 F. The shale was fairly well retorted at this 930 mass rate.

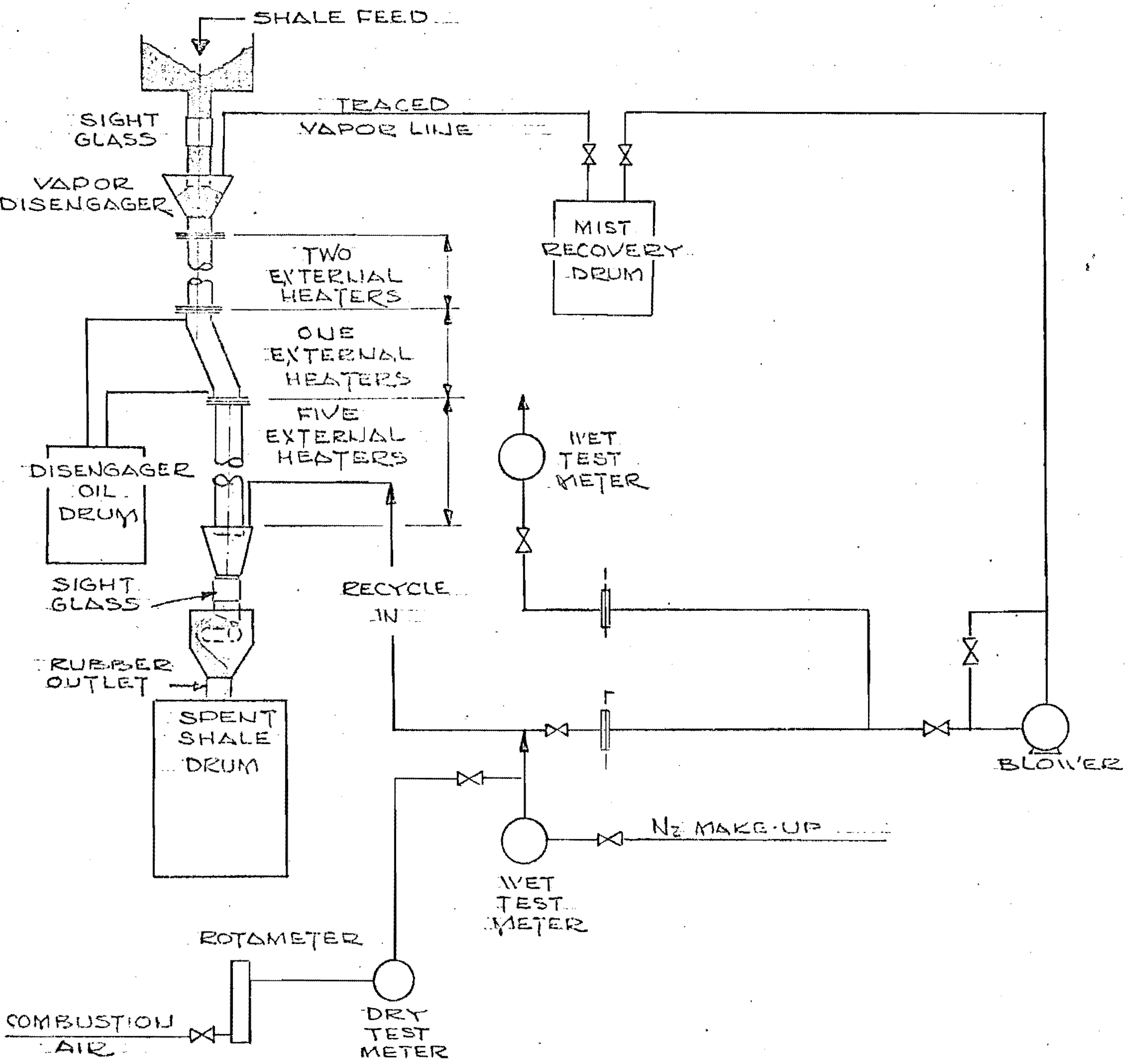
In Run 5, we had difficulty maintaining temperatures high enough in Furnace 4, part of the retorting zone. Consequently our yield fell to 80.5 % Fischer Assay and we left 4.6 gallons per ton in the spent shale. Actually, the 4.6 gallons per ton represents about 15% of the oil, which added to the 80.5 accounts for about 96%.

The gravity of the oil was 18°API for the disengager and 32 $^{\circ}$API for the demister.

Most of the oil was collected in the disengager because of the low temperatures in the furnace directly below it.

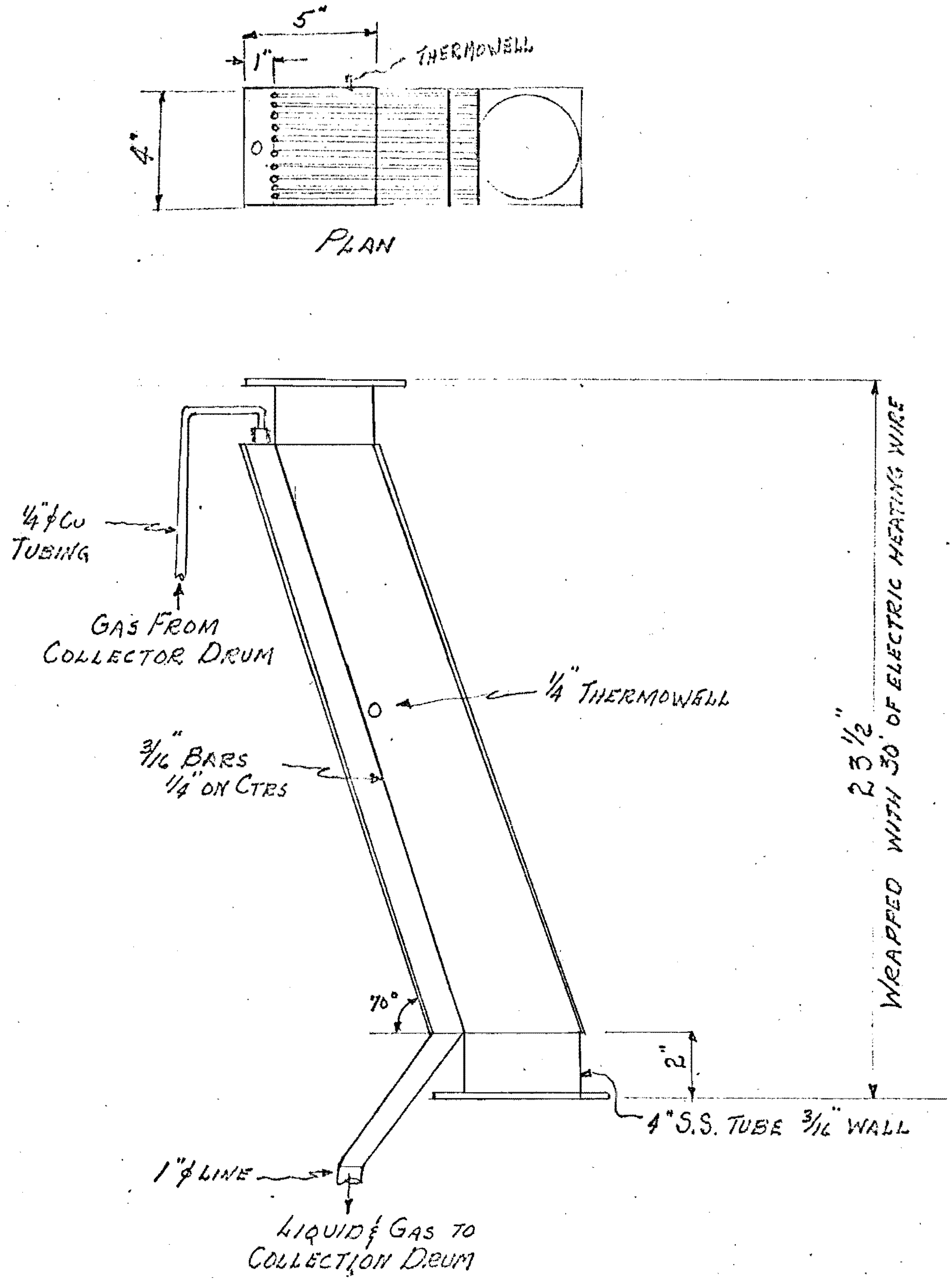
The overall pressure drops in both of these runs show incipient or actual flooding at this high mass rate. In any case, the

FIGURE 19



3.6" RETORT FLOW-DIAGRAM

FIGURE 20



SLOPED LIQUID DISENGAGER

t Disengager

Run 8
500
27.1
0,000
--
--
4.9
3.3
52.2
--
100.0
--
--
--
--
--
24.0
--
24.0
--
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noperable

DLiederman
KIJagel
7/5/67

TABLE 9

EXTERNAL HEATING OPERATION OF 3.6 INCH RETORT WITH 1/4 TO 1/2 INCH SHALE

	Operation With Disengager						Operation Witho	
	Run 4	Run 5	Run 6	Run 9	Run 10	Run 11	Run 7	
ng Conditions								
hale lbs/(hr)(ft^2)	930	930	500	930	500	500	930	
cher Assay (gal/ton)	27.1	27.7	26.9	27.1	25.5	27.9	28.2	
ycle (SCF/T)	20,000	20,000	20,000	20,000	20,000	20,000	20,000	2(
(SCF/T)	--	--	--	--	5,000	--	--	
ng Data								
gager Temperature, F	640	550-650	600-650	600-700	600-700	600	--	
Top ("H_2O/ft)	3.4	3.2	2.0	3.4		--	--	
Overall	3.0	4.0	1.9	3.2		--	4.5	
s Recovered								
ollected (vol % FA)	86.5	80.5	103.3	55.9	Run Aborted - Disengager Line Plugged Agglomerate Formed	95.4	--	
of total oil in Disengager	59.9	86.9	57.7	--		53.0	--	
of total oil in Demister	40.1	13.1	42.3	--		47.0	100.0	
ield (SCF/TRS)	208	387	565	--		--	--	
al CO_2 Dec. (% CO_2 chg'd)	5.4	5.4	6.6	--		--	--	
l Balances (as is)								
Wt %)	95.5	95.0	98.5	96.9		98.3	--	
ll Balance (Wt %)	96.1 (1)	97.3	98.3	103		96.2	--	
ic Carbon Balance (Wt %)	80.5	89.0	88.0	--		--	--	
il Properties:								
(°API) Composite	21.9	20.0	22.7	--		--	--	
Disengager	16.9	18.2	15.9	13.4		12.0	--	
Demister	29.5	32.1	33.1	29.1	23.1	27.3	--	
hale:								
er Assay (gal/ton)	0.9	4.6	0.2	8.4	--	0.0	--	
ic Carbon (Wt %)	2.61	4.12	2.23	5.4	--	2.2	--	
Operational Performance	Very Good	Good	Excellent	Good	Fair	Excellent	Inoperable	Ir

drained into open bucket.

Anvil Points Task Group

Run 6 was run at about 450 mass rate. This was an excellent run which lasted seven hours, until the shale ran out. The yield was 103 vol % Fischer assay. Run 11 was a check on this run and was made at essentially the same conditions (except that the mass rate was 500). Run 11 gave a yield of 95.4 %; the average of the two runs is 99%.

The product split for both of these runs was similar; an average of 55% of the oil into the disengager and 45% into the demister.

Runs 7 and 8 were attempted in the straight pipe retort at about the same conditions as Runs 5 and 6. Both 7 and 8 were aborted because of agglomeration which led to increased pressure drop and gas flow restriction. Some oil collected overhead from Run 8 had an API gravity of 24.0, the same as Fischer Assay oil. The gas from the process also was very similar in composition to the gas from the Fischer Assay.

Temperature profiles for Runs 6 and 8, runs at 500 mass, with and without the disengager, respectively, are shown in Figure 21. The residence-time above 700 F was about 40 minutes, sufficient to retort the shale completely.

Run 9 was an attempt to repeat Run 5, but with higher temperatures for better retorting. Operation was good until temperatures at the bottom got so hot that the bottom rubber seals melted. Retorting was even worse than in Run 5.

Run 10 was the first attempt to operate with combustion in the bed. Air at about 5,000 SCF/T was mixed with recycle at the bottom of the bed. In this run, the disengager was found to be plugged; consequently, no oil was disengaged. An agglomerate formed in Furnaces No. 1 and No. 2.

Run 11 was described above.

A run with combustion in the bed has been completed successfully. Data are being processed currently. When the air is mixed with the recycle at the bottom of the bed, the combustion zone tends to move down the bed at 500 mass and 27,000 SCF/T recycle. Higher recycle rates cause flooding. In future runs with combustion, an air collar will have to be installed to admit air further up the retort.

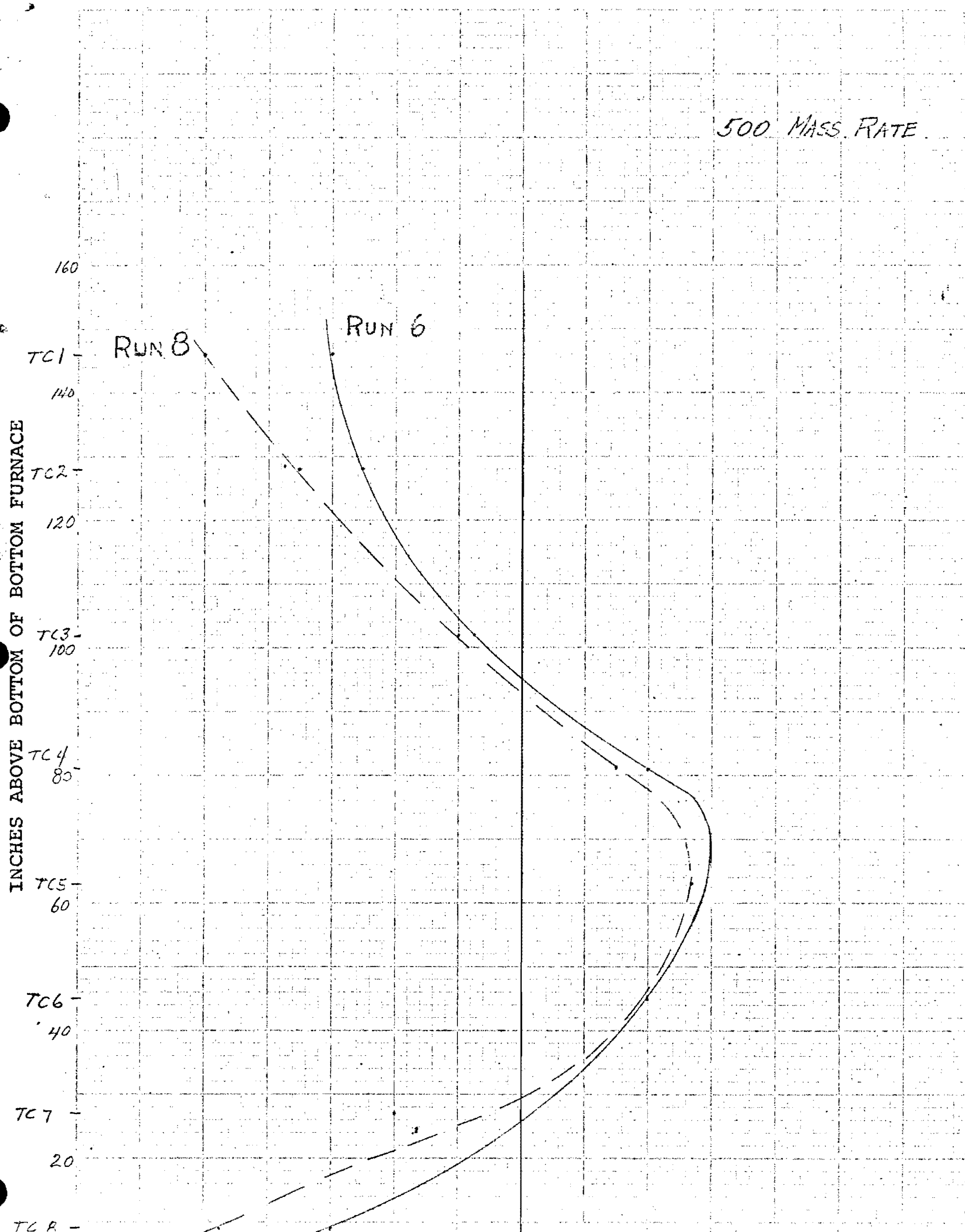
B. Future Plans

We are planning to optimize conditons with and without combustion, with the purpose of demonstrating increase in yields of retorting with liquid and mist disengagement. Optimization includes determining suitable disengaging temperatures.

Experiments at mass rates higher than 500, and at greater

FIGURE 21

TEMPERATURE PROFILES FOR MBR 3.6 RUNS



C. Significance of Two Oil Products

The production of two oil products by this process may be economically significant. The oil disengager separates about 55% of the total oil produced. It is a heavy oil (ca 17°API) and it is dry, therefore needing no dehydration. The other 45% of the product is a light oil (ca 30°API), which comes over with the process water and is easily separated from it. This oil also has a pour point lower than 30 F and, thus, should be readily pumpable.

D. Application of Results to Retort No. 3

Based on the results of the 3.6-inch retort operation and on model work by R. L. McGalliard and L. J. Skowronek, the Task Force has proposed a system of disengaging liquid oil and mist from Retort No. 3.

Mechanical Engineering work on this concept is now in progress and is described in that section.

VII. ENGINEERING AND ECONOMIC ANALYSES (K. I. Jagel, Jr. and R. A. Reitz)

A. Allis-Chalmers Secondary Crushing Tests

Several crushing tests were run on the Allis-Chalmers double roll crusher to partially fulfill our contract obligations to Allis-Chalmers. The tests were run on the 25 inch diameter rolls which have 18 teeth per row around the circumference. Nominal tooth height is one inch. R. L. Clampitt conducted the tests.

Results of the tests are summarized in Table 10, and product size distribution data are given on Figure 22 and Table 11. Although product size distribution data confirmed earlier tests, power and capacity data were obtained for the first time. Power consumption confirmed earlier estimates except for when the roll was choked fed (Test 4), which was higher than expected. This high value of 0.95 Hphr/ton will be reviewed with Allis-Chalmers to try to determine the cause.

The product. size distributions from the closed circuit Tests 6 and 7 are the crusher product including the circulating load. To determine true 1/4 inch minus fines for these tests, the percentage of fines must be divided by the percentage of product. This will give 3.6% passing 1/4 inch for Test 6, and 4.5% passing 1/4 inch for Test 7. These fines percentages are subject to sampling error, handling degradation, etc., but it does appear that closed circuit operation gives slightly less fines than open circuit operation. Economics and design criteria would be used to determine if a closed circuit operation would be used in a commercial installation.

B. Stedman Secondary Crushing Tests

Stedman has completed secondary crushing tests with a Single-Cage Disintegrator to produce minus 2 inch and minus 3 inch shales. A Stedman representitive will visit us in the week of July 17 to give us full details on the tests. However, they did phone us these preliminary results:

100% passing	% < 1/4 inch	% Recycle	Cage RPM
3 inches	6.1	38	low
3 inches	7.5	14	high
2 inches	11.2	30	low
2 inches	12.6	23	high

The percentage passing 1/4 inch minus is about the same as the 1/4 inch minus from a tooth type double roll crusher.

Remarks

ted by primary
throughput.

ted by primary
throughput.

t on product

hoked feed rate
ndary crusher.

heck base point
product distri-

pieces tended to
, also corners
o be rounded or

RLClampitt
RAReitz
7/17/67

TABLE 10

SUMMARY OF RESULTS FROM SECONDARY CRUSHER TESTS
18 TEETH PER ROLL CONFIGURATION

Setting ℄ to ℄	Open or Closed Circuit	Sec. Product 98% Pt.	Sec. Product % < ¼"	Motor Horsepowers(3) West Ave.	West Max.	East(4) Ave.	East Max.	Average Power HpHr/Ton	Throughput TPH	R
27.5"	Open	2.85"	6	5.0	5.4	6.2	6.5	0.28	39.7	Rate limit crusher t
27.0"	Open	2.30"	7.5	8.8	10.2	8.5	12.7	0.45	38.0	Rate limit crusher t
27.0"	Open	2.30"	7.5	9.3	12.6	11.0	15.4	--	--	Bad weight truck.
26.5	Open	2.10"	11.5	12.1	16.3	12.5	17.4	0.95	26.0	Maximum ch for secon
27.5"	Open	3.10"	4	--	--	--	--	--	--	Test to ch setting p bution.
27.5"	Closed(2)	3.0"	3	--	--	--	--	--	--	
28.0"	Closed(2)	3.5"	2.5	--	--	--	--	--	--	Recycled p be slabs, tended to worn.

es:
1) Tests 1 to 4 run on April 4 and 5, tests 5 to 7 run on July 7.
2) Recycled around 2 3/4 inch screen.
3) Idle horsepowers (average of four tests): West motor - 1.7 Hp, East motor - 1.8 Hp
4) East motor drives moveable roll.

cellaneous:
a) Secondary crusher feed was 2 3/4 inch plus primary product.
b) Roll speed is 110 RPM, or 730 fpm surface speed for 25 inch diameter roll.
c) Material through crusher for each test:

Test:	1	2	3	4
Tons:	9.92	10.47	Bad Weight	7.79

FIGURE 22

SHALE SIZE DISTRIBUTION

SECONDARY CRUSHER TESTS

Open Circuit Tests

Symbol	Test	Setting
□—□	4	26.5
▽—▽	3	27.0
○—○	2	27.0
◇—◇	1	27.5
◈—◈	5	27.5

Closed Circuit Tests

Symbol	Test	Setting
△	6	27.5
⊙	7	27.5

Material Recycled Around 2 3/4" Screen
Settings are Shaft ℄ to ℄

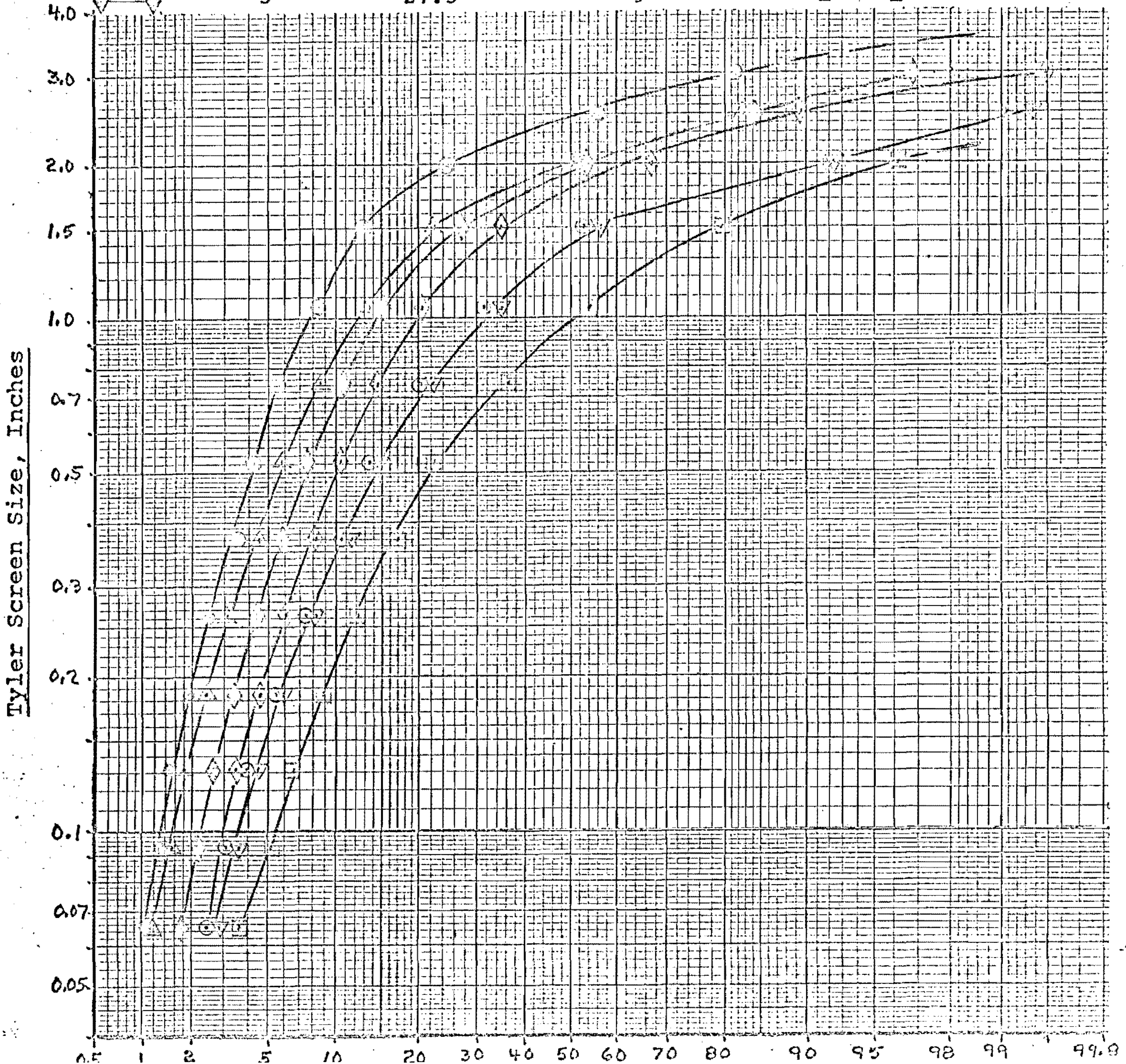


TABLE 11

PRODUCT SIZE DISTRIBUTION DATA

Number	1	2	3	4	5	6	7
ent Passing Screen creen size, inches							
3.0	99.53	100.0	100.0	100.0	96.83	98.02	81.42
2.5	89.39	99.37	99.06	100.0	83.99	82.74	55.98
2.0	66.88	92.46	92.14	96.06	52.91	50.32	24.54
1.5	34.64	56.63	52.82	79.42	26.91	22.31	12.94
1.05	20.29	34.80	31.63	53.96	14.98	13.61	8.30
0.742	14.52	22.17	20.17	36.15	10.72	8.64	5.71
0.525	10.27	14.86	13.51	22.65	7.53	5.78	4.21
0.371	8.23	11.43	10.52	16.98	5.78	4.48	3.46
0.263	6.07	8.06	7.44	12.14	4.34	3.11	2.51
0.185	4.67	5.95	5.47	8.89	3.35	2.36	1.90
0.131	3.62	4.41	3.94	6.58	2.59	1.80	1.56
0.093	3.04	3.61	3.08	5.06	2.21	1.55	1.29
0.065	2.51	2.92	2.40	3.58	1.75	1.12	1.09
Pan	0	0	0	0	0	0	0
l Weight Sampled, lbs.	172	175	117	277	132	161	147

ab testing unit used, 10 minute shaking time

RLClampitt
RAReitz
7/17/67

A Single Cage Disintegrator can be briefly described as a centrifugal impactor where the material is thrown by a revolving cage against breaker plates. The Disintegrator appears to be a simpler machine and to require less maintenance than a double roll crusher. Since the fines levels are about equal between the two machines, the Disintegrator may offer a way to further reduce crushing costs.

C. Heat and Material Balance Computer Program

Work on the heat and material balance computer program is essentially complete. The new version of the computer program is currently being checked out and the Retort Group is reviewing the draft of the Technical Memorandum to insure accuracy. The memorandum should be issued within the next 30 days.

D. Oil Shale Drilling Studies

A joint effort has been carried out with the Mining Section in designing and analyzing a drilling study. The drilling work was done under the direct supervision of the Mining Section. We developed the experimental design, and the computer program for the analysis of variance. This study is described in the Mining Section of this memorandum.